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Research paper

Effect of enset leaf pruning on legume growth and yield under intercropping in bensa, southeast Ethiopia

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Abstract

As a result of declining farmland and increasing food security needs, intercropping is necessary for small-scale farmers in Ethiopia. An enset–legume intercropping study was conducted for two consecutive cropping seasons during 2020-2021 in the Bensa district to investigate the effect of enset leaf pruning on the growth and grain yield of legumes. The treatments in the experiment involved two levels of enset leaf pruning (retaining eight and all leaves) with three legume crops (bush bean, climbing bean, and soybean). The sole leguminous plants were also included, resulting in a factorial arrangement with 12 treatments laid out in a randomized complete block design with three replications. The results of this study revealed that there were significant differences due to the main effects of legume cultivar on the number of branches, the number of pod per plants, the biomass, and the grain yield with climbing beans during both seasons. On the one hand, significant variances were observed due to the main effects of leaf pruning on the number of branches and grain yield during the first season, while their interaction had no significant variations except for 50% of the days of flowering, in which the shortest day was obtained from bush beans during both cropping cycles. Enset leaf pruning improved grain yield during the first cropping cycle. Significantly, the highest legume yield was recorded for climbing beans during the short season due to the main effect of enset leaf pruning, which decreased in the later growing season. In general, the trends in the data for almost all the parameters showed a drastic decline during the second cropping season, particularly for bush beans and soybeans. These findings indicated that more enset leaf pruning is needed for bush beans, particularly soybeans, in the later enset growth stage. Thus, it can be concluded that with wider spacing, climbing beans are promising cultivars for obtaining a reasonable legume yield under enset intercropping. However, the performance of all the leguminous crops was nevertheless impaired at the 1.5 × 1.5 m-spaced mature enset plant intercropping growth stage.

Keywords: *Enset; Cultivar; Intercrop; Legume.*

1. Introduction

Enset [Ensete ventricosum (Welw.) Cheesman] is closely related to bananas and belongs to the order Zingiberales and the family Musaceae. It is an important component of cropping systems and contributes to food security and livelihoods for more than 20 million people in the highlands of southern and southwestern Ethiopia (Azerefegne et al., 2009). Enset-based agriculture is considered the most sustainable of the indigenous farming systems in Ethiopia and is able to support dense populations in this country. Nevertheless, with increasing population numbers and shrinking farm sizes, traditional farming practices are under pressure to maintain the same levels of productivity. In addition, the abundance of topsoil in the region has deteriorated due to various factors, such as erosion and soil acidity, resulting in delayed maturity (Tsegaye and Struik, 2002). In Ethiopia, various enset cropping systems exist (Abebe, 2005). For example, young enset plants are often intercropped with annual crops, while mature enset is either grown solely or often intercropped with coffee and multipurpose trees on smallholder farms. However, the use of mature enset intercropped with annual crops is rare, indicating that agronomic practices for optimum growth and yield of enset and component crops are lacking.

Enset is a starchy staple crop that is high in carbohydrates but low in vitamins and protein, and it contains low levels of essential amino acids such as methionine and isoleucine (Nurfeta et al., 2008a). Therefore, sustainable intensification and diversification efforts are needed to improve farm productivity and dietary diversity in enset-based regions. As a result of declining farmland and increasing food security needs, intercropping is necessary for the majority of small-scale farmers in Ethiopia. Due to the high population density, banana-legume intercropping is widely practiced in eastern and central Africa (CIALCA, 2010). The land use efficiency of smallholder banana farms in East and Central Africa can be enhanced through the incorporation of food and/or fodder legumes (Sileshi et al., 2007). Likewise, an approach using shade-tolerant food legumes could be conceived for intercropping with mature enset plants. Enset intercropping, which includes Gurage, Hadiya, and Wolaita, is widespread across the southwestern parts of Ethiopia (Belachew et al., 2017). However, only a limited amount of data supporting best management practices for optimum yields of ensets and components are found in the literature. Farmers acknowledge that intercropping prolongs the growth cycle of ensets. However, no research data are available to quantify the effects of such cropping strategies on the performance of enset or other crops in the system (Brandt et al., 1997).

Crop production is primarily the conversion of solar energy to stored food energy (Pimentel and Pementel, 2008), and a reduction in intercepted sunlight reduces crop production (Nyambo et al., 1982). Light competition is an important factor influencing the yield of relatively small plants grown under partial shade in an intercropping system. It is clear that large plants such as ensets provide substantial levels of shade and influence the growth and yield of smaller intercrops (Davis et al., 1987). In Ethiopia, it is evident that enset leaf pruning is practiced when plants are intercropped with annual crops. However, it varies between the southern and southwestern regions of Ethiopia. In the study area, farmers plant enset with dense plantations, without a definite row of plants, and with rare pruning practices. As a result, some plants may not develop fully and have a stunted appearance. Leaf pruning enhances light penetration to ground level and thus positively influences legume growth and yield through an increase in the interception of light (Ntawira et al., 2013). However, there are no quantitative data available on the effect of enset leaf pruning during intercropping on the growth and yield of legumes. Therefore, the objectives of the present study were to investigate the effect of enset leaf pruning on the growth and grain yield of legumes under intercropping and to identify shade-tolerant legume varieties for intercropping with enset plants.

2. Materials and methods

2.1. Description of the study site

The study was conducted in Bensa District, which is located in the Sidama National Regional State, for two consecutive cropping seasons (short and long) during 2021. It is located at 38° 27’44’’E longitude and 06° 26’59’’, N latitude approximately 420 km from Addis Ababa. The altitude of the experimental area is 1894 meters above sea level. The climate of the study area is subhumid with a bimodal rainfall pattern characterized by a short rainy season and main rainy season. The short rainy season starts in February and ends in May. The main rainy season starts in late June and extends to early October. The average annual rainfall in the area is 1208.5 mm, and the mean annual temperature is 19°C. The potential crops grown in the area are enset, coffee, potatoes, cabbage, wheat, barley, maize, and grain legumes such as Haricot beans for local consumption. The daily rainfall, minimum temperature, and maximum temperature during the legume growing seasons are presented below (Figure 1).

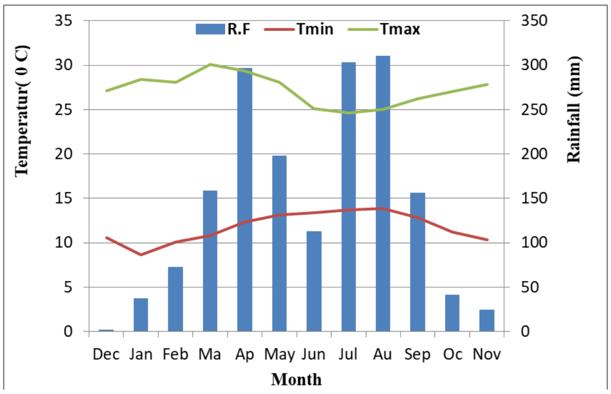

Fig. 1: Monthly Rainfall and Mean Minimum and Maximum Temperatures During the 2020–2021 Growing Season at the Bensa Site.

2.2. Experimental materials

The experiment was conducted using three legume cultivars, namely, Hawassa dume, Haramaya, and Awassa-95, and one enset clone (Genticho) as the test plant. The local enset clone was obtained from Shanta Golba Kebele depending on the agro ecological conditions, while leguminous cultivars were collected from the Hawassa Agricultural Research Center.

2.3. Treatments and experimental design

The treatments consisted of three legume cultivars, namely, bush bean (Hawassa dume), climbing bean (Haramaya variety), and soybean (Awassa 95), and two levels of enset leaf pruning (without leaf pruning and with leaf pruning). The sole leguminous plants were also included, resulting in a factorial arrangement with 12 treatments laid out in a randomized complete block design with three replications.

2.4. Experimental procedures and crop management

The experimental field was prepared manually. In accordance with the specifications of the design, a field layout was prepared. The size of each experimental unit was 6 m × 6 m, accommodating 4 rows with 16 enset plants per plot. The main crop plant spacing between rows and plants was 1.5 by 1.5 m, and the plants were 2 years old. The component crops were sown in rows after they had attained the desired number of leaves, and the planting densities for the common bean and soybean varieties were 10 cm × 30 cm and 5 cm × 50 cm, respectively. In the pruning treatments, the old enset plant was pruned to a maximum of eight leaves at a frequency of every three weeks, starting at the sowing of the legumes. A distance of 1.5 m was left between both the plots and the blocks. The sole legumes were planted as controls at 40 cm × 10 cm, 40 cm × 10 cm, and 50 cm × 5 cm for bush bean, climbing bean, and soybean, respectively, for comparison with the intercropping system. One hundred kg/ha NPS fertilizer was applied uniformly to the legumes just before sowing. One row was used for destructive sampling from all plots for legumes. Agronomic management practices other than treatment variations will be uniformly applied to all the experimental plots as recommended and adopted for the crop.

2.5. Data collection

In each plot with legume crops, 5 plants were collected from the center of a (1 m^2) net plot for phenology, growth, yield components, and yield parameters. The number of days to 50% flowering (DF) was recorded as the number of days from sowing to the time when 50% of the plants in the net plot area showed their first flower. Similarly, the number of days to 90% physiological maturity was recorded for each plot as the number of days from planting to when 90% of the plant leaves and pods started turning yellow in color. The number of total nodule $plant^{-1}$ (NTNP) plants was recorded from the bulk of the roots of 5 randomly selected plants from the destructive rows in each plot after the plants were carefully exposed at 50% flowering and uprooted for the nodulation study. Plant height was recorded from 5 randomly selected plants per plot before harvest, from the base of the plant to the tip of the main stem. The number of primary branches plant^{-1} was counted by taking 5 plants randomly per net plot area at harvest. The number of pods per plant was counted by taking 5 plants randomly per net plot area at harvest. The number of seeds per pod was counted by taking 10 randomly selected pods from each net plot area at harvest. The aboveground dry biomass yield (kg ha^{-1}) was measured at physiological maturity after 5 randomly sampled plants were cut at ground level and sun-dried. The dry biomass per plant was multiplied by the number of plants in the net plot area to calculate the total dry biomass yield, which was subsequently converted into kg ha^{-1}. Grain yield (kg ha^{-1}): This was recorded as the total seed weight obtained from the net plot area adjusted to 10.5% moisture content at maturity and then converted to kg ha^{-1}.

2.6. Data analysis

All the data were subjected to analysis of variance (GLM procedure) using the SAS software program version 9.4 (SAS Institute, 2013). The homogeneity of variance was evaluated using the F test as described by Gomez and Gomez (1984), and the Tukey range test was subsequently used to determine significant differences at the 5% probability level.

3. Results and discussion

3.1. Before sowing soil sampling and analysis

The key soil properties analyses of the experimental area are summarized below (Table 1).

Table 1: Physio-Chemical Properties of the Soil

Physical properties					Chemical properties	
Particle distribution (%)			Textural class	P^{H} OC (%)	Total N (%)	CEC(Meq/100 g)
Sand 24	Silt 22	Clay 54	Clay	5.02 2.93	0.23	32.59

3.2. Effect of enset leaf pruning on legume phenology and growth

3.2.1. Days to 50% flowering and 90% physiological maturity

The analysis of variance indicated that the number of days to 50% flowering and 90% physiological maturity in legume crops were significantly (P<0.05) influenced by the interaction effect of legume cultivar and enset leaf pruning during both cropping seasons (Table 2). There was no significant variation in the number of days of 50% flowering on legume crops in either crop cycle except for bush bean, for which the shortest day was obtained during the first cropping cycle. On the other hand, the days from planting to attaining 50% flowering in the legumes intercropped with no leaf pruning were significantly different from those in the sole crop treatment during the first cropping season, except for the climbing bean variety, which was significantly associated with parity with the sole crop during the first cropping season. However, the two levels of pruning were significantly different from those of the monocropping crop during the second cropping cycle. Hawassa Dume flowered significantly earlier during both seasons than did the other cultivars when they were grown under non enset leaf pruning, while the longest days to reach 50% flowering were taken up by the soybeans when they were grown under mono crop conditions (Table 2). Similarly, there were no significant differences observed on the day 90% physiological maturity was achieved for all legumes grown under either of the two emset pruning types during the two consecutive cropping seasons. The earlier days to reach 90% germination were observed for bush bean during the former and consecutive seasons, while the longest days were taken by soybean plants. The duration of 50% flowering was significantly shorter in the intercropping without enset leaf pruning treatment than in the pruning treatment for all the legume crops. However, there was a slight delay in the 50% flowering day under leaf pruning, except for climbing beans. The reduced days to flowering and maturity of legume varieties under no pruning may be related to high competition for nutrients, light, and moisture by the well-established enset plant, which results in forced flowering and maturity of legume crops. Similarly, Tamiru (2014) reported a significant difference among intercropped soybean varieties in terms of days to flowering and maturity and attributed this difference to resource competition and the inherent genetic character of the varieties. In contrast, Murthazar et al. (2020) reported that flowering days in winged beans could be delayed by low light intensity.

Table 2: Interaction Effect of Cultivars and Enset Leaf Pruning on Legume Phenology and Growth

Legumes type	Level of Pruning	DF		DPM	
		Short rainSeason	Long rain Season	Short rain Season	Long rain Season
	Sole	48.0b	47.3c	89.3c	92.3c
Bush bean	Pruning	47.0c	40.3d	79.7d	76.7d
	No pruning	43.3d	39.3d	77.3d	73.0d
	Sole	48.7c	48.3c	92.0c	93.0c
Climbing bean	Pruning	48.5c	42.3 d	93.3c	83.0cd
	No pruning	48.3c	41.7d	89.3c	81.3cd
	Sole	87.1a	86.0a	153.3a	149.0a
Soybean	Pruning	84.0ab	82.3b	136.7b	132.7b
	No pruning	82.7b	80.0b	132.7b	131.3b
LSD (5%)		2.374	2.156	8.417	5.237
CV (%)		2.3 2.2		4.6	4.2

The means in columns followed by the same letter (s) are not significantly different at the 5% level of significance; LSD= least significant difference; CV= coefficient of variation; DF = days of flowering; and DPM =days of physiological maturity.

On the other hand, slightly delayed flowering (50%) and physiological maturity (90%) were recorded when the plants were grown under enset leaf pruning. However, the effect was more marked for soybean plants than for the other crops, in which an approximately 4-day delay with pruned leaves was observed in the former cropping season when the enset canopy was not covered. This 50% reduction in flowering and 90% reduction in physiological maturity might also be due to the reduced incident PAR resulting from enset shading, which led to slowed leaf photosynthetic activity in intercropped legumes under nonpruning. These results are in agreement with the findings of Ntamwira et al. (2014) who reported the least variation in the phonological data for bean crops intercropped with bananas. Similarly, Shiferaw et al. (2013) reported that maize leaf shade forced common bean varieties to complete their life cycle earlier (mechanism of escaping resource insufficiency) when they were intercropped with maize. In addition, Muhammad et al. (2019) reported that the defoliation of maize leaves resulted in a later onset and termination of flowering in soybean plants than in intercropped plants without defoliation.

3.2.2. Plant height

The main effect of variety had a highly significant ($P<0.01$) effect on plant height, total nodule plant^{-1} and the number of primary branches, while the main effect of pruning had a significant ($P<0.05$) influence. However, the interaction effect was not significant (Table 3). The highest plant height was recorded for climbing bean (Haramaya), and the lowest height was obtained for bush bean (Hawassa Dume) during the two cropping seasons. The climbing bean plants significantly differed in height from the two remaining legume cultivars in both growing cycles. This variation might be attributed to varietal differences and resource competition between legume crops, which determine their growth and development. In agreement with this result, El-Aref Kh (2019) reported an increase in the plant height of cowpea plants compared with peanut plants under intercropping with sorghum due to the density of plants in a unit area, which led to elongation as a result of shading thereafter decreasing with increasing growth period due to increased competitiveness of both plants.

Table 3: The Main Effects of Legume Cultivar and Enset Leaf Pruning on Legume Growth

Varieties	PH (cm)		NTN		NPB	
	Short rain Season	Long rain Season	Short rain Season	Long rain Season	Short rain Season	Long rain Season
Bush bean	49.7 b	34.4 b	38.9b	27.6b	4.8a	3.0a
Climbing bean	121.2a	114.5a	50.9a	41.9a	4.1a	3.1a
Soybean	67.9 b	43.7b	12.3c	7.9c	2.3b	1.4b
LSD (5%)	20.38	22.84	7.98	9.6	0.865	1.12
Pruning levels						
Sole	63.2b	65.2a	43.2a	41.7a	5.1a	5.0a
Pruning	84.4ab	59.2a	32.6b	19.4b	3.6b	1.7b
No pruning	91.2a	70.3a	26.1 b	16.2b	2.5c	0.8b
LSD (5%)	20.38	22.84	7.98	9.6	0.865	1.12
CV%	25.6	29.2	23.2	30.5	23.2	26.5

Means in columns followed by the same letter (s) are not significantly different at the 5% level of significance; LSD= least significant difference; CV= coefficient of variation, PH =plant height, NTN = number of total nodules and NPB = number of primary branches.

Similarly, compared with mono-cropping, enset leaf pruning significantly influenced the height of legume crops. In this regard, the tallest height was recorded from nonenset leaf pruning in both legume cropping seasons, but it was greater during the first than during the second season due to partial leaf canopy cover. However, enset leaf pruning and nonpruning had statistically similar effects on the first growing cycle, whereas in the second cropping cycle, the two pruning levels were significantly similar to those of monocropping. This increase in plant height in the absence of leaf pruning might be due to competition for light resources when the enset canopy is not fully covered ground. In line with this result, Nyombi et al. (2009) reported that 55% of the solar radiation is intercepted when the banana LAI is 1.1. This agrees with the significant decrease in light resources, but even so had slight consequences for the legumes during the first season. Similarly, Undies et al. (2012) reported that soybean plant height increased above that of its sole crop under different intercrop row arrangements. In contrast to the present findings, Zama and Malik (2000) and Getahun and Abady (2016) reported that the height of rice bean plants intercropped with maize was significantly lower than that of plants monocropped with maize.

3.2.3. Number of total nodules per plant

The analysis of variance indicated that the number of total nodules plant^{-1} in legume crops was strongly significantly ($P<0.01$) influenced by the main effect of variety and pruning level in the first cropping cycle, where both variables highly significantly influenced the number of total nodules in the second season, while their interaction had no significant effect (Table 3). The three leguminous crop species significantly differed due to cultivar differences in both cropping cycles. . Accordingly, climbing bean (haramaya) was the most common nodule bearing legume among the two remaining legumes, while the lowest nodule number was recorded for soybean during the two seasons. This variation may be due to the genetic makeup of the legume cultivars. In agreement with these findings, Guy (2022) reported that mucuna produced the lowest number of nodules among the three legumes in banana-based intercropping systems during both the dry and wet seasons. On the other hand, there were no significant differences in the numbers of total nodules due to enset leaf pruning or non-pruning during the two growing cycles. However, significantly greater numbers of total nodules were obtained from legume mono cropping than from the two pruning levels. The number of effective root nodules formed in legumes strongly correlates with the effect of shading. In this regard, compared with those of non-pruning plants, more nodules were observed when the enset leaf was pruned when the photosynthetic active radiation reached the legume plants through the opened enset canopy. This difference may be due to the shading effect of enset plants under corresponding nitrogen fixation conditions. These findings are in agreement with the findings of Ntamwira et al. (2021), Yemataw et al. (2018) and Lemlem (2013), who also reported a decreased number of nodules that formed in legumes due to an increase in the shading effects of banana and maize under intercropping compared to mono-cropping. In addition, Guy (2022) reported an increase in the average number of nodules plant^{-1} with increased PAR. In contrast to these findings, Mandal et al. (2014) reported that nodule formation in soybean plants was unaffected by intercropping with maize.

3.2.4. Number of primary branches plant-1

The main effects of pruning highly significantly ($P<0.01$) influenced the number of primary branches plant^{-1} during both cropping seasons, and the main effects of variety were highly significantly influenced during the first cropping cycle but significantly influenced during the second cropping cycle. However, the interaction effect was not significant during either consecutive season (Table 3). A significantly lower number of primary branches was observed for soybean than for the other two legume cultivars, which were significantly different during both seasons. Among the three legumes, the number of primary branches was greater for the Bush bean than for the other plants, but only during the first growing season did it decrease below the climbing bean in the second season with increased enset leaf shading. The differences in the number of primary branches between legume cultivars might be due to the genetic makeup of the crops used to withstand shading effects. Inconformity, Adem (2006) reported the presence of a significant difference in cowpea branch number in sorghum–cowpea intercropping due to interspecific competition between the components. Similarly, enset leaf pruning had significant effects on the number of primary branches plant^{-1} during the first growing cycle, but leaf pruning and no pruning did not significantly differ during the second cropping season (Table 3). A significantly large number of branches were produced when legumes were grown alone or on pruned leaves. Notably, in the field, reducing the number of enset leaves to eight enhanced the branching ability of the legumes, while nonleaf pruning reduced the number of branches by 44% and 88% during the first and second seasons, respectively, compared to pruning. The increased number of branches when the enset canopy is opened through pruning could be due to enhanced resource availability conditions for legume plants to grow vigorously. These findings agreed with those of Morgado and Willey (2003), who reported that the number of branches and dry matter plant^{-1} of beans decreased significantly as the bean population increased in combination with maize due to shading. In addition, Wondimkun and Nibret (2021) obtained the highest and lowest numbers of branches from sole and intercropped common bean, respectively.

3.3. Effect of enset leaf pruning on the yield component and yield of legume crops

3.3.1. Number of pods plant-1

Analysis of variance revealed a highly significant (P<0.01) main effect of legume cultivar on the number of pods plant$^{-1,}$ and the main effect of pruning was significant (P<0.05) during the first cropping season, while the main effect of pruning was highly significant (P<0.01) on the number of pod plant^{-1} plants, and the main effect of legume cultivar was significant (P<0.05) during the second cropping cycle (Table 4). However, their interaction was not significant. Climbing bean produced a significantly greater number of pod plant^{-1} than the two other legume species during both cropping cycles. The results revealed that soybean was the lowest pod producer among the legume species, although the difference was statistically significant. The difference might be due to genetic differences associated with the formation of a number of branches and other sinks that determine the yield of a variety. In agreement with this result, Zewde (2016) obtained a greater mean number of pods per plant for the 'Hawassa Dume' variety than for the Red Wolaita and 'Omo-95 varieties when intercropped with defoliated maize and maize leaves. In addition, Muhammad et al. (2019) reported that maize leaf defoliation increased flower production in soybean plants, resulting in a greater number of pods.

Table 4: The Main Effects of Legume and Enset Leaf Pruning on Yield Components and Yield

Varieties	NPP Short rain Season	Long rain Season	NSPP Short rain Season	Long rain Season	BY Short rain Season	Long rain Season	GY Short rain Season	Long rain Season
Bush bean	29.7b	14.8b	5.7a	3.7a	3607.3a	1075.2b	2196.6a	632.9 b
Climbing bean	39.3a	21.8a	5.1a	4.1a	4065.4a	2774.3a	2482.2a	1041.2a
Soybean	23.6 b	9.9b	2.2b	1.7b	1022.4b	825.1b	935.6b	437.6b
LSD (5%)	5.121	5.7	0.593		855.2	512.3	479.2	298.7
Pruning levels								
Sole	36.0a	35.4a	4.7a	4.2a	3561.3a	3137.0a	2148.3a	1999.6a
Pruning	30.7ab	6.0 b	4.5ab	2.9b	2673.3b	966.7b	2042.8a	243.0b
No pruning	25.9a	5.0 b	3.9b	2.3b	2460.5b	571.0b	1423.3b	169.1b
LSD (5%)	5.121	5.7	0.60	0.99	855.2	512.3	479.23	298.7
CV%	16.6	30.0	3.7	25.9	24.3	27.0	21.1	34.8

Means in columns followed by the same letter (s) are not significantly different at the 5% level of Significance: LSD= least significant difference; CV= coefficient of variation; NPP = number of pods per plant; NSPP = number of seeds per pod; BY = biomass yield; and GY = grain yield.

With regard to leaf pruning levels, there were no significant differences between enset leaf pruned and not pruned leaf numbers plant^{-1} during either season. However, legume mono cropping resulted in significantly greater pod numbers than did the two pruning methods during the second cropping season. The average number of pods plant^{-1} increased with decreasing enset leaf canopy length and increasing PAR in both sowing seasons on all three legume crops. The progress in the decrease in the number of pod plant^{-1s} might be due to the competition and shading effect of enset plants. In line with these findings, Stephen (2012) reported that the shade of legume crops intercropped with coffee significantly decreased the number of pods plant^{-1} in butter bean and soybean food legumes.

3.3.2. Number of seeds per pod

Analysis of variance revealed a highly significant (P<0.01) effect of legume cultivar on the number of seeds per pod, while the main effect of pruning was a significant (P<0.05) effect on the number of seeds per pod during the two sowing seasons. However, their interaction effect was not significant. There was a significant difference among the legume crops in terms of the number of seed per pods. Accordingly, soybean produced significantly lower numbers of seed pod^{-1} plants during the two planting seasons, while bush bean produced greater numbers of seed pod^{-1} plants in the first growing season and thereafter decreased during the consecutive season with an increased enset leaf canopy. However, no significant difference was detected in the number of seed pod^{-1s} produced by bushes or climbing beans between the two seasons.

These results agree with those of Demissie et al. (2018) and Saban (2007), who reported that delaying the introduction of legumes to already established maize stands resulted in a decrease in the number of seeds per pod. In other words, the number of seed pod^{-1s} did not differ significantly between the pruned and non-pruned plants. However, the number of seed pod^{-1s} increased as the canopy in the intercropping system opened by reducing the number of enset leaves to eight. During the supervision, when the canopy of the enset fully covered the ground, unfilled and empty seeds were observed in the field, especially on the soybean plants. This difference might be because plants under partial shading experienced less competition for light than plants under full shading and thus exhibited greater growth, which contributed to a greater number of seed pod^{-1s}. In accordance with the present results, Stephen (2012) reported the absence of significant effects on the number of seeds pod^{-1} due to coffee shade under intercropping with legumes in Kenya. In addition, Eskandarnejada et al. (2013) reported that inter row spacing of 30 cm of maize intercropped with soybean produced more kernels per ear than did 20 cm of plant spacing.

3.3.3. Biomass yield (kg ha-1)

Analysis of variance revealed a highly significant (P<0.01) effect of variety on biomass yield, while the main effect of pruning was significant (P<0.05) during the first sowing season, while the two main effects were highly significantly influenced during the second season. However, their interaction was not significant in both cycles. The legume species exhibited variation in biomass yield between the two cropping seasons. The highest biomass yield was obtained from climbing bean, while the lowest was obtained from soybean (Table 4). However, the climbing bean production was not significantly different from the bush bean production during the first legume species cropping season. The differences in biomass yield accumulation among legumes may be attributed mainly to variations in the amount and duration of PAR intercepted by legumes and in the crops that grew quickly and those that had spreading growth habits, such as climbing and bush bean, which attained fast ground cover and hence high PAR interception. This difference could also be attributed to the differences in the performance genotypes of the different legume species. In line with these findings, Stephen (2012) and Birteeb et al. [33, 37] reported significant differences among legume species intercropped with cereal crops. With regard to leaf pruning levels, legume biomass was greater under mono cropping than under intercropping during both legume growing seasons. Similarly, compared with the sole crop, the no pruned leaf reduced the legume biomass yield by 8.6% and 69.1% during the first and consecutive seasons, respectively. However, there were no significant differences between enset leaf pruned and no pruned plants during either cropping season. This difference could be due to reduced incident PAR resulting from enset shading, which led to slowed leaf photosynthetic activity in intercropped legumes with no leaf pruning and hence decreased biomass accumulation in these legumes compared to that in sole legumes. In agreement with this result, Stephen (2012) reported that intercropping reduced the dry matter accumulated by Vicia and Neontonia by 83% and 78%, respectively. On the other hand, keeping enset leaves to eight increased the biomass yield of legumes, although the difference was statistically at par with that of nonpruning plants. This increase in biomass yield with enset leaf pruning might be due to the adequate supply of light possibly increasing the number of branches plant^{-1} and leaf area, which in turn increased the photosynthetic area and number of pods per plant, thereby increasing biomass accumulation. In agreement with these findings, Ocimatia et al. (2019) reported that the increase in legume biomass yield was associated with leaf pruning levels and the amount of PAR received by legume crops.

3.3.4. Grain yield (kg ha-1)

Analysis of variance revealed a highly significant (P<0.01) effect of legume cultivar on grain yield, while the main effect of pruning was significant (P<0.05) during the first legume cropping season, while the main effect of pruning highly significantly influenced grain yield, and the main effect of cultivar was significantly influenced during the second legume cropping season. However, their interaction was not significant in both seasons. The grain yield significantly varied among legume cultivars. A greater grain yield was obtained from climbing bean during the former and consecutive seasons, although not significantly different from that of bush bean during the former legume cropping seasons; however, the lowest yield was recorded from the soybean cultivar, although it was not significantly different from that of bush bean in the second cropping season (Table 4). In general, the yields of all legume species drastically decreased during the second cropping season. However, the effect on climbing bean yield was greater than that on bush and soybean bean yields. In contrast, for bush bean and particularly for soybean, more intense enset leaf pruning with wider spacing is required to obtain a reasonable legume grain yield. The differences in grain yield among the legume cultivars might be related to the genotypic differences in shade tolerance among the cultivars. This result was similar to that of CILCA (2007), who reported that the overall grain yields of different legume species evaluated in monocultures were greater than those of local cultivars. The legume grain yield was greater under mono cropping than under intercropping during both legume cropping seasons. However, the grain yield obtained from the mono crop was not significantly different from that obtained from the pruned during the first cropping cycle. On the other hand, no leaf pruning significantly decreased the grain yield during both cropping seasons, although the difference was not significant compared with that of pruned plants during the second growing cycle. This study revealed that enset leaf pruning enhanced grain yields, although the yields in the eight leaf pruning treatments were not significantly greater than those in the mono cultured crop. However, enset leaf shading resulted in drastic decreases in the grain yields of legumes, particularly during the second cropping season. The differences in grain yield among leaf pruning levels might be due to improved light availability. In accordance with these results, Demissie et al. (2018) and Ocimatia et al. (2019) obtained significantly lower legume grain yields in delayed common bean intercrops than in legume monocrops and increased yields with simultaneous maize and common bean planting and with leaf pruning than with nonpruning. In addition, Muhammad et al. (2019) reported that, compared with single-crop removal, maize leaf removal increased the grain yield of soybean plants.

4. Conclusion

Enset leaf pruning improved grain yield, especially during the first legume cropping season. Among the legume species, the climbing bean cultivar was superior to the other cultivar when intercropped with pruned ense leaf in terms of the number of pod per plant, biomass and grain yield. However, almost all legume crop parameters exhibited drastic decreases, particularly during the second cropping season, especially for bush bean and soybean both in the pruned and non-pruned treatments. Legume yields were lower under intercropping with enset than under mono cropping during the two cropping seasons. However, the yield obtained from mono cropped legumes did not significantly differ from that of enset leaves pruned during the first cropping cycle, but during the second legume cropping season, pruned leaves did not result in a yield advantage compared to no pruned leaves. This result revealed that more enset leaf pruning is needed for bush bean plants, particularly for soybean plants, in the later enset growth stage. Thus, it can be concluded that growing climbing bean under the eight retained enset leaves is promising for obtaining a reasonable yield to meet food security and nutritional needs for up to eight to nine months of enset plant establishment after two fertile soil cycles. However, the performance of all the leguminous crops was nevertheless embarrassed by the 1.5 × 1.5 m spaced enset plants intercropped during the mature growth stage, signifying that more benefits from the legumes will be achieved only for wider spaced mature enset plants. Hence, wider spacing and genotypes of ensets with erect leaves and greater soil fertility status need to be included.

Conflicts of interest

The authors declare that they have no competing interests.

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