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Selected Mung Bean (*Vigna radiata* L. Wilczek) Genotypes' Agronomic Performance in Sole and Intercropping Systems in Ghana's Sudan Ecology

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Abstract

Ghanaians place a high value on agriculture, but crop cultivation is threatened by increase in extreme weather events. Diversified and intensive cropping system, such as intercropping major cereals with orphan or neglected legumes can increase total productivity. To determine which mung bean (*Vigna radiata* L. Wilczek) genotype is promising for maize-mung bean intercropping, a two-year experiment was carried out at Manga (11˚01N, 0˚16W). The findings indicated that every genotype examined (IC-39368, IC-39288, IC-39399, MUM-2, GOGG-912, IC-39427, RMG-492, IC-39375, IC-39298, and IC-39333) confirmed suitable for intercropping with maize without any damaging effect. Although the intercropping decreased the number of grain per pod, plant height, pod length, one thousand grain weight, pod load, grain, and biomass yields of mung bean genotypes, it had no detrimental effect on the agronomic parameters of maize. On the contrary, it boosted total productivity per intercropped unit area. The land equivalent ratios of 1.00 to 1.90 confirmed that intercropping maize and mung beans have high agronomic benefits. Thus, for small-scale farmers in Ghana's Sudan and Guinea savannah ecologies, mung bean intercropping provides a climate-smart approach to increase their resilience to climate change and household food insecurity.

Subject Areas

Agricultural Science

Keywords

Pulses, Crop Intensification, Sustainable Cropping, Small Scale Farmers

1. Introduction

Intercropping is becoming more popular as a means of making effective use of limited resources due to growing awareness in ecological issues and sustainable crop production. The goal of intercropping is to alleviate the global food crisis by increasing production per unit area and optimizing resource use efficiency [1]. Intercropping augments total productivity per unit area, besides judicious and equitable utilization of land resources and farming inputs including labors [2]. Intercropping is most extensively practiced in subsistence Africa and food production in countries where arable land is scarce and contributes to biodiversity and food security [3] [4].

The challenge that small farmers face, particularly in Africa, is lack of land. Therefore, it is imperative to utilize the limited land areas more effectively [5]. Small-scale farmers are the primary practitioners of intercropping, which is known to generate consistent yields from a variety of crops while requiring less input for fertilizer provision [6]. An effective tactic with favourable results in the current climate change scenario is intercropping [7]. Compared to sole maize planting, Kumar *et al*. [8] found that during a 6 to 8 day dry spell, the soil surface stayed moist in an intercrop system. The best intercrops for systems based on maize are those that have a suitable plant type, growth pattern, and mature well before the peak growth period of maize.

With a rapid maturity period of 75 - 90 days, mung beans are a valuable crop in arid regions with a significant potential for crop rotation, relay cropping, and intercropping with cereals [9] [10]. Mung beans are environmentally beneficial and a great source of vitamins, minerals, and proteins [11]. The grain is mostly used for food, and because it is a rich source of protein and lysine, it can supplement a diet centred on cereal for humans. On the other hand, the stalks, leaves, and husk make up a sizable amount of animal feed [12]. It develops faster than maize; therefore, intercropping maize and mung beans can lower the risk of crop failure that could arise from a terminal moisture deficit [10].

2. Materials and Methods

This experiment was carried out at the Sudan Savannah agroecology of Ghana on the research fields of the Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI), at Manga (11˚01N, 0˚16W). Rainfall is typically unimodal, with an average yearly total of approximately 1200 mm, starting in mid-May and ending in early October. The average yearly temperature is measured around 27.3˚C, with March through May being the hottest months. FAO has designated the well-drained soil as ferric lucvisol. It is brown, fine sandy soil, with low organic matter. Ten (10) mung bean genotypes (IC-39368, IC-39288, IC-39399, MUM-2, GOGG-912, IC-39427, RMG-492, IC-39375, IC-39298, and IC-39333) (**Table 1**) available at the research station were evaluated in sole and intercropping systems.

Table 1. Mung bean genotypes.

IC-39368	IC-39288	IC-39399	MUM-2	GOGG-912
IC-39427	RMG-492	IC-39375	IC-39298	IC-39333

A bullock tracked ridger was used in land preparation to make ridges for planting. On July 10th, maize was planted, and the ten mung bean genotypes were intercropped and also sole planted two weeks later in a Randomized Complete Block Design (RCBD) with four replications each. In both the sole and intercropped systems, five seeds were planted per hill, and the plants were subsequently thinned to two per stand after germination. The intercropping arrangement was 2 plants of mug beans in-between 2 hills of maize plants. The spacing was 75 × 40 cm, for maize-cowpea intercropping and 75 × 20 cm for sole mung bean cropping. An N.P.K. fertilizer of 90 kg N ha^{-1}, was applied as top dressing to the maize in the maize-mung bean intercropping system. Basal fertilizer of 40% urea was also applied to the maize. Muriate of potash was applied to the sole mung bean at a rate of 40 kg K ha^{-1}. Weeds were controlled manually as and when necessary using the local hand hoe. Ridges reshaping was done and ridges tied to prevent water runoff. The pesticide K-Optimal (Cyhalothrin 15 g/l + Acetamiprid 20; EC) at 500 ml ha^{-1} was used to spray two times to control insect pests at the flowering and podding stages of the mung-bean. Days to 50% flowering, days to 90% pod maturity, average pod load per plant, grain yield per genotype (t/ha), biomass yields per genotype (t/ha), one thousand grain/seed weight (g), average pod length (cm), average plant height (cm), and land equivalent ratio (LER) were recorded during the experiment. Chicago, IL, USA's GenStat 12th Edition was used to analyse the data. Fisher's protected LSD at 5 percent was used to separate the means. Using the formula developed by Mead and Willey [13], the land equivalent ratio (LER) was computed to compare the productivity of the intercrops to that of the sole crops [13].

$$\text{LER} = \frac{\text{Yield of maize intercrop}}{\text{Yield maize sole crop}} + \frac{\text{Yield legume intercrop}}{\text{Yield legume sole crops}}$$

3. Results

Genotypes IC-39368, IC-39288, IC-39399, IC-39427, IC-39375, IC-39298 (**Figure 1**) were the first to reach 50% flowering in both the sole cropping and intercropping systems at 45 - 50 days after planting. The other four genotypes (MUM-2, GOGG-912, RMG-492, and IC-39333) took 51 and 52 days to reach 50% flowering in both the sole cropping and intercropping systems in 2021 and 2022 cropping seasons.

The genotypes IC-39368, IC-39288, IC-39399, IC-39427, and IC-39375 reached 90% pod maturity at 60 - 65 days after planting in sole and intercropping systems (**Figure 2**). It was also observed in IC-39298, IC-39333, MUM-2, GOGG-912, and RMG-492 at 60 - 65 days after planting in the sole cropping but 66 - 70 days in intercropping systems in 2021 and 2022.

The average number of pods carried by a plant was observed to range between 130 - 150 and 100 - 110 pods in the genotypes IC-39368, IC-39288, IC-39399, GOGG-912, and RMG-492 in sole cropping and intercropping systems (**Figure 3**). The other mung bean genotypes IC-39427, IC-39333, IC-39375, IC-39298, and MUM-2 had 100 - 125 pods in sole cropping and 85 - 95 pods in intercropping systems.

Seed number per pod was also considered in this evaluation research. The genotype IC-39399, GOGG-912, RMG-492, MUM-2, IC-39333, IC-39427, and IC-39375 had 15 - 21 seeds per pod in both the sole cropping and intercropping systems. On the other hand, the genotype IC-39368, IC-39288, and 39298 also had 10 - 14 seed per pod in the sole and intercropping systems.

The grain yields of genotypes MUM-2, IC-39333, IC-39427, IC-39375, and IC-39298 were recorded as 0.30 - 0.80 t/ha and 0.35 - 0.79 t/ha in 2021 and 2022 sole cropping and intercropping systems (**Table 2**). The rest of the genotypes IC-39368, IC-39288, IC-39399, GOGG-912, and RMG-492 had 0.15 - 0.29 t/ha in both sole and intercrop systems.

Genotypes IC-39368, IC-39288, IC-39399, IC-39333, IC-39427, and IC-39375 recorded biomass yields of between 1.15 - 2.0 t/ha in the sole cropping and 1.10 - 1.14 t/ha in the intercrop system (**Table 3**). Genotypes GOGG-912, RMG-492, MUM-2, and IC-39298 had biomass yields of 1.00 - 1.09 t/ha in the sole and intercrops systems.

One thousand (1000) seed weight (g) of both the sole crop and intercrop systems were considered. In the sole and intercropping systems, the genotypes GOGG-912, RMG-492, MUM-2, IC-39333, IC-39427, IC-39375, and IC-39298 had 1000 seed weight of 30 - 35 g (**Figure 4**). The rest of the genotypes IC-39368, IC-39288, and IC-39399 had 1000 seed weight (g) of 25, 28, and 29 g respectively in both the cropping systems in both years.

The pod lengths of the genotypes were measured. The pod length of the genotypes IC-39368, IC-39288, IC-39399, GOGG-912, RMG-492, and MUM-2 had pod length of 5 - 8 cm in the sole cropping system, but between 4 - 6 cm by the same genotypes in the intercrop systems (**Figure 5**). The genotypes, IC-39333, IC-39427, IC-39375, and IC-39298 had pod length of 3 - 4 in both the sole cropping and intercropping systems.

Plant height (cm) 35 - 45 cm was recorded in the mung bean genotypes IC-39368, IC-39288, IC-39399, GOGG-912, RMG-492, and MUM-2 in sole cropping and 30 - 40 cm in intercropping system (**Figure 6**). However, the genotypes, IC-39333, IC-39427, IC-39375, and IC-39298 recorded 30 - 34 cm and 25 - 29 cm plant height in the sole and intercropping systems respectively.

Land equivalent ratio of the genotypes IC-39368, IC-39288, IC-393999, GOGG-912, RMG-492, MUM-2, IC-39333, IC-39427, IC-39375, and IC-39298 were 1.00 (**Figure 7**), signifying efficient use of resources. The yield and yield components of maize were not significantly affected by intercropping in either year. There were no significant differences in number of cobs per square meter, number of seeds per cob, 100 weight, and grain yield.

4. Discussions

Flowering reached 50% in the genotypes IC-39368, IC-39288, and IC-39399 without significant differences ($p > 0.05$) in sole cropping systems in 2021 and 2022 cropping seasons (**Figure 1**), but was significantly different to genotypes IC-39427, IC-39375, and IC-39298 as well as MUM-2, GOGG-912, RMG-492, and IC-39333 in same cropping system and years. In the 2021 and 2022 intercropping system, the genotypes IC-39333, RMG-492, GOGG-912, and MUM-2 were not significantly different ($p > 0.05$) but had significant difference in days to 50% flowering to the genotypes IC-39298, IC-39375, IC-39427, IC-39399, IC-39288 ($p < 0.05$) and as well IC-39368. Though significant differences were not observed between the same genotypes in the same year in the sole and intercropping systems, it was however evident at ($p < 0.05$) in the genotypes IC-39288 and 39399 in the intercropping and sole cropping systems. Additive and dominance gene action are responsible to days to first flower [14], therefore the quantitative trait - days to 50% flowering in both the sole and intercropping systems by the genotypes could be attributed to genetic diversity, seasonal, and environmental factors as described in [15].

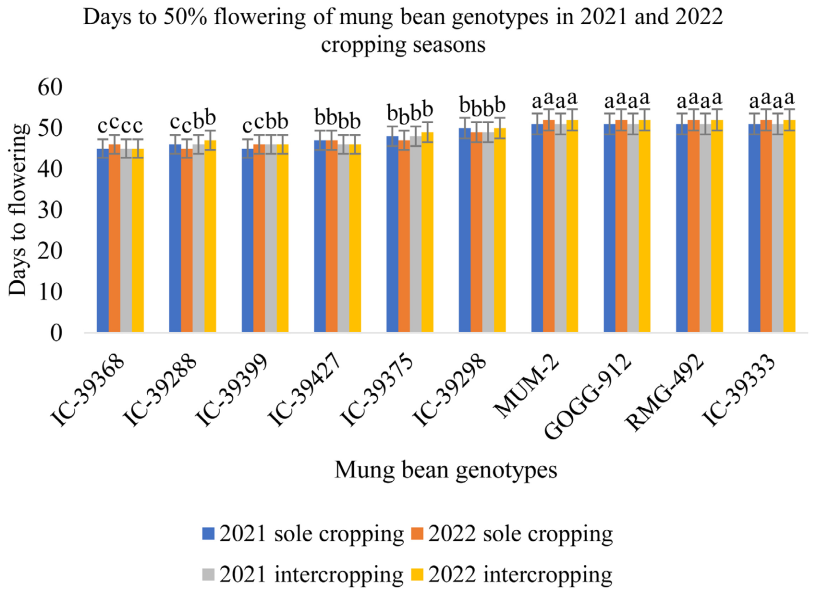

Figure 1. Days to 50% flowering of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

In 2021 and 2022 sole cropping seasons, the genotypes IC-39368, IC-39288 did not show any significant difference ($p > 0.05$) in their days to 90% pod maturity, likewise the genotypes IC-39427, IC-39298, IC-39333, GOGG-912, RMG-492, and MUM-2 (**Figure 2**). These genotypes however had significant differences ($p < 0.05$) between themselves in same year, different year's and cropping systems. The genotypes IC-39399 and IC39375 did not also have any significant difference ($p > 0.05$) in their days to 90% pod maturity in 2022 and 2021 sole cropping systems, but significantly differed ($p < 0.05$) in the sole and intercrop systems and to the rest of the other genotypes in 2021 and 2022 seasons. In the 2021 and 2022 intercropping season's, the genotypes IC-39288, IC-39399, IC-39427, IC-39375, and RMG-492 had no significant difference ($p > 0.05$), but differed ($p < 0.05$) in 2021 and 2022 in the intercropping system. Moreover, the genotypes IC-39368, IC-39298, IC-39333, GOGG-912, and MUM-2 had significant differences ($p < 0.05$) in days to 90% pod maturity in 2021 and 2022 sole and intercrop systems. Generally significant differences ($p < 0.05$) existed among genotypes in the same season, the same and different years, and the cropping systems. The duration for flowering, length of reproductive phase and maturity duration dynamics are accountable for the differences in days to 90% pod maturity as explained in [14] [16].

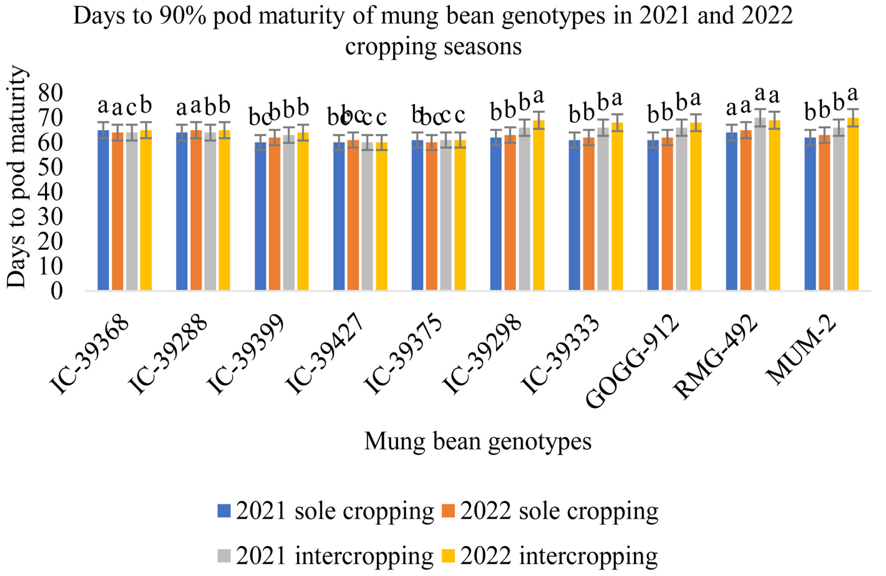

Figure 2. Days to 90% pod maturity of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

In the 2021 and 2022 sole cropping seasons, only the genotypes IC-39298 showed significant difference ($p < 0.05$) in pod load (**Figure 3**). The rest of the genotypes showed no significant difference in pod, but showed significant differences ($p < 0.05$) to the intercropping system in same years. Moreover, in the intercropping system in 2021 and 2022, only the genotypes IC-39368, GOGG-912, IC-39427, and IC-39333 showed significant difference ($p < 0.05$) in pod load ranging from 85 - 95 and 100 - 110 average pods per plant. Pod load differences existed among genotypes and the cropping systems, and in the years. Likely reason for the higher pod load per plant in sole mung bean plots might be attributed to no inter specific competition which is explained [12] and the better utilization of the potash fertilizer applied. The reduction in pod load among some genotypes in the intercropping system could be attributed to resource competition in the mixed cropped system. This finding is in tandem with [17] [18] which states that heat stress can reduce pollen viability, pollen load, stigma receptivity and hence pod set in mung bean.

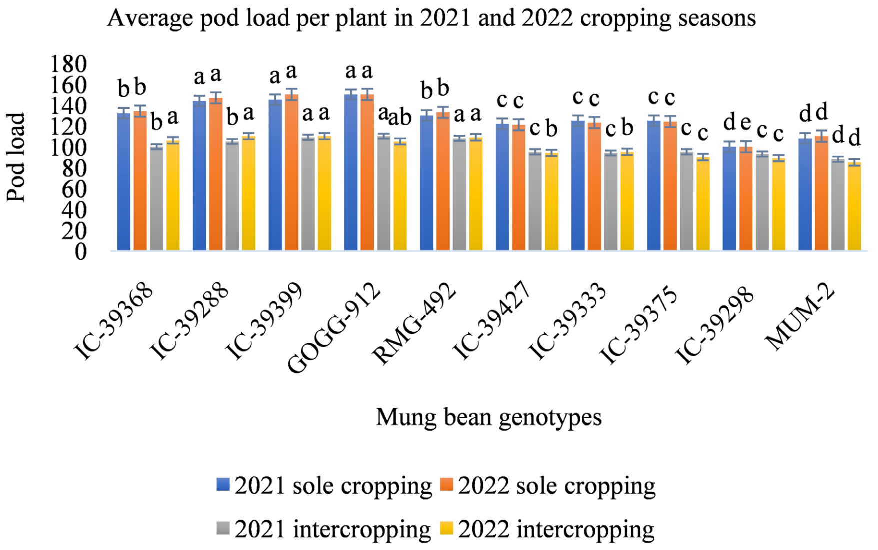

Figure 3. Average pod load per plant of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

In the year 2021 and 2022 sole cropping seasons, only the genotypes GOGG-912 and RMG-492 showed significant difference ($p < 0.05$) in grain yields, likewise the genotypes IC-39368 in 2021 and 2022 intercropping system (**Table 2**). All other genotypes remained the same in 2021 and 2022 sole and intercrop systems without significant difference ($p > 0.05$). However, only the genotypes, IC-39368, IC-39399, GOGG-912, and RMG-492 showed significant difference ($p < 0.05$) between 2021 sole and intercrop systems, and 2022 sole and intercrop systems.

The highest grain yield was obtained in the genotypes MUM-2 and IC-39289 in 2021 sole cropping system with 0.80 and 0.79 t/ha. The least grain yield was obtained in IC-39288 at 0.15 t/ha and 0.16 t/ha from the genotype IC-39368 in 2021 sole cropping system. In 2021 and 2022 intercropping system, the genotypes MUM-2 and IC-39298 obtained the highest grain yields of 0.80 and 0.79 t/ha. The least grain yield was recorded in the genotype IC-39368 in both the sole and intercrop systems in all years. This was significantly different ($p < 0.05$) to many of the genotypes in the various cropping system. The genotypic variance and photosynthetic loss among the genotypes in the various cropping systems might have being the cause for the differences in grain yields as described in [19] [20]. However, in this experiment the grain yield of maize was not influenced by intercropping with mung bean. This findings is in tandem with [21] who reported that maize grain yield was unaffected by legume intercrops involving mung bean, peanut (*Arachis hypogaea*) and soybean (*Glycine max*) though reduced legume intercrop density partly contributed.

Table 2. Grain yield per genotype.

Genotypes	Cropping Systems				Average Mean	CV
	2021	2022	2021	2022		
	Sole cropping (t/ha)		Intercropping (t/ha)			
IC-39375	0.42c	0.45c	0.45c	0.44c	0.44	0.11
IC-39427	0.30d	0.35d	0.30d	0.35d	0.33	0.10
IC-39333	0.56b	0.54b	0.55b	0.55b	0.55	0.14
IC-39298	0.77a	0.79a	0.80a	0.79a	0.79	0.20
MUM-2	0.80a	0.78a	0.80a	0.79a	0.79	0.20
IC-39368	0.16e	0.16e	0.15e	0.17ef	0.16	0.04
IC-39288	0.15e	0.22e	0.17e	0.20e	0.22	0.05
IC-39399	0.20de	0.22e	0.25e	0.25e	0.23	0.06
GOGG-912	0.25d	0.27e	0.29e	0.29e	0.28	0.07
RMG-492	0.29d	0.29de	0.29e	0.28e	0.29	0.07

Grain yield of genotypes in sole and intercropping systems. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

Biomass yield was very important in this evaluation research. All the genotypes were assessed in both the sole and intercropping systems. The results showed that only the genotypes RMG-492 and IC-39298 demonstrated significant difference ($p < 0.05$) in their biomass yields in 2021 and 2022 sole cropping seasons (**Table 3**). In the intercropping system, in 2021 and 2022, all the genotypes had no significant difference ($p > 0.05$) in biomass yields. The genotypes however had significant differences ($p < 0.05$) between genotypes in the same and different years, and between cropping systems in the same and different years. It can be assessed generally that, intercropping mung bean with maize can reduce biomass yields of mung bean up to 50%.

Table 3. Biomass yield per genotype.

Genotypes	Cropping Systems				Average Mean	CV
	2021	2022	2021	2022		
	Sole cropping (t/ha)		Intercropping (t/ha)			
IC-39368	1.17a	1.15a	1.13a	1.12a	1.14	0.29

Continued

IC-39288	1.18a	1.19a	1.14a	1.14a	1.16	0.29
IC-39399	1.19a	2.00a	1.10a	1.11a	1.35	0.34
IC-39333	2.00a	2.00a	1.11a	1.10a	1.55	0.39
IC-39427	1.15a	1.16a	1.12a	1.11a	1.14	0.28
IC-39375	1.16a	1.15a	1.10a	1.10a	1.13	0.28
GOGG-912	1.09b	1.08b	1.09ab	1.08ab	1.10	0.27
RMG-492	1.00c	1.08b	1.05b	1.04b	1.04	0.26
MUM-2	1.07b	1.09b	1.06b	1.06b	1.07	0.27
IC-39298	1.04b	1.00c	1.00c	1.02c	1.02	0.25

Biomass yield of genotypes in sole and intercropping systems. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

One thousand (1000) grain weights (g) of all the genotypes were taken into consideration. The genotypes GOGG-912, IC-39375, IC-39298 were the only genotypes that showed significant difference in 1000 grain weight in 2021 and 2022 sole cropping season (**Figure 4**). In the 2021 and 2022 intercropping seasons, the genotypes GOGG-912, RMG-492, IC-39333, IC-39375, IC-39298, IC-39368, IC-39288, and IC-39399 showed significant difference in the intercropping system. The only genotypes that did not show any significant difference were IC-39427 and MUM-2. Generally, only the genotypes MUM-2 and IC-39427 had no significant difference in 1000 seed weight in all the years and the cropping systems.

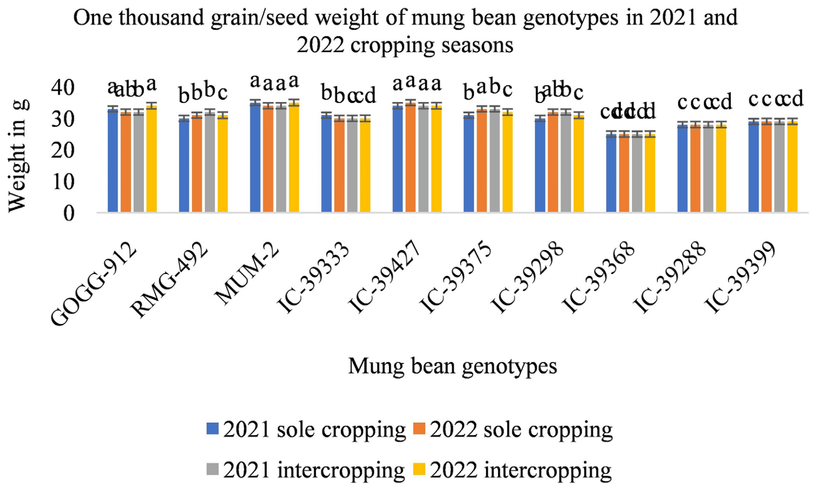

Figure 4. One thousand grain/seed weight of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

In the sole and intercropping system in 2021 and 2022 season, only the genotypes IC-39288, MUM-2 and IC-39427 had significant differences in pod length

(**Figure 5**). However, only the genotypes, IC-39288 and MUM-2 significantly had differences in the sole cropping systems in 2021 and 2022 cropping seasons. In the intercropping systems, the genotypes IC-39288 and IC-39427 had significant differences in pod length. Significant differences occurred across, among, and between the genotypes in all the cropping systems and years.

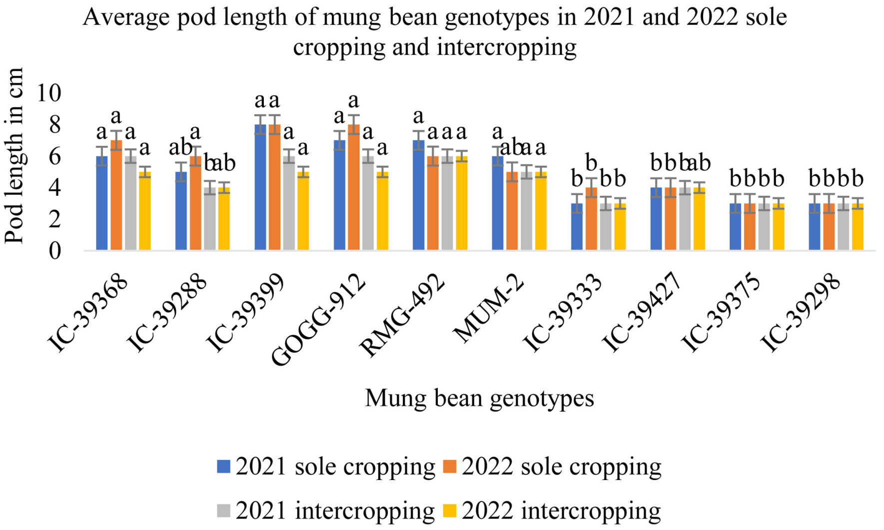

Figure 5. Average pod length of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

Plant height of the genotypes, IC-39333, RMG-492, and MUM-2 had no significant difference in the sole cropping system (**Figure 6**). Plant height in the sole cropping system ranged from 35 - 45 cm in both the 2021 and 2022 cropping seasons with significant differences. The highest plant height was recorded in the genotypes RMG-492 and MUM-2 at 45 cm in the sole cropping system, while the least plant height was recorded in the genotypes IC-39375 and 39298 at 30 cm. The genotypes, IC-39288, IC-39399, GOGG-912, IC-39333, IC-39427, IC-39375, and IC-39298 had no significant difference in plant height in the 2021 and 2022 sole cropping season. The differences however, existed in the genotypes, IC-39288, IC-39399, GOGG-912, IC-39333, IC-39427, IC-39375, and IC-39298 at ($p < 0.05$).

In the intercropping system of 2021 and 2022 cropping seasons, the genotypes IC-39333, IC-39399, GOGG-912, RMG-492, and MUM-2 had no significant difference in plant height. Plant height had significant differences in the genotypes IC-39288, IC-39333, IC-39427, IC-39375, and IC-39298 in the intercropping system in 2021 and 2022 cropping season. The genotypes IC-39399 and RMG-492 recorded the highest plant height in the intercropping system in both the 2021 and 2022 cropping seasons. The least plant height was recorded in the genotypes IC-39427. Significant differences existed among the genotypes in the same cropping system, the same year and different years.

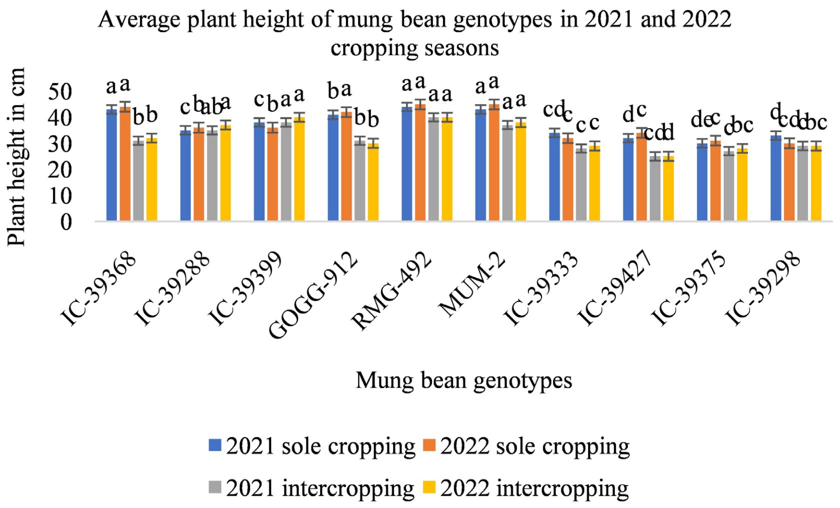

Figure 6. Average plant height of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

In the 2021 and 2022 cropping seasons, land equivalent ratios were calculated to estimate the intercropping advantage (**Figure 7**). All the calculated LER were between 1.00 - 1.90 indicating advantages and benefits of intercropping mung bean with maize as described in [22] Sija *et al.*, which states that when LER of mung bean and maize is above 1, it indicates an intercropping over mono-cropping advantages. In the 2021 and 2022 cropping seasons, the highest land equivalent ratio was recorded in the genotypes RMG-492 at 1.80 and MUM-2 at 1.90 with significant difference ($p < 0.05$) among them. The least land equivalent ratio was recorded in the genotypes IC-39427 and IC-39399 at 1.00 in the 2021. Significant differences ($p < 0.05$) existed among the genotypes in their LER in 2021 and 2022, such as IC-39333, IC-39427, IC-39375, IC-39298, IC-39288, IC-39399, while the genotypes IC-39368, GOGG-912, RMG-492, and MUM-2 had significant difference ($p > 0.05$) in 2021 and 2022. The differences in the LER might be attributed to the genotypes greater sensitivity to competition as explained in [23].

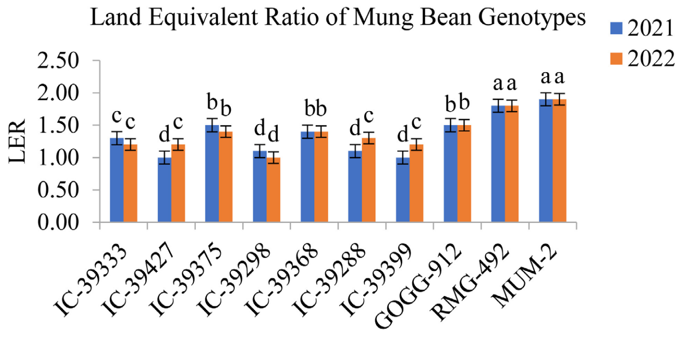

Figure 7. Land equivalent ratios of mung bean genotypes. Values represent the standard deviation (SD) of the mean over four replicates. Means preceded by the same lowercase letter do not differ between genotypes according to Duncan's Multiple Range's Test.

5. Conclusion

Mung bean intercropping had no detrimental impact on the intercropped maize productivity. Intercropping mung bean with maize is a sustainable system to maximize total grain harvest by small scale farmers. Breeders should combine genotypes of early flowering, higher pod load, early pod maturity, grain, and biomass yields traits to enhance effective mung bean intercropping with maize and other cereals.

Conflicts of Interest

The authors declare no conflict of interest.

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