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Evaluation of Multiple-Use Cover Crops under Rainfed during Two Seasons in Yucatan, Mexico

Castillo-Caamal José Bernardino*, Caamal-Maldonado Jesús Arturo,
Belmar-Casso Roberto, Trejo Lizama Wilberth

Campus de Ciencias Biológicas y Agropecuarias—Universidad Autónoma de Yucatán, Mérida, México
Email: *jose.castillo@uady.mx

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Abstract

The aim of the study was assessing seven legumes as cover crops during cropping seasons of the years 2000 and 2001 in the central region of the Yucatan. An experimental design of randomized blocks with arrangement of split plots was used; where treatment was the legume, and sub-treatment, was the management of defoliation, 90 days after sowing (DAS) or after harvesting the grain (AHG). Treatments were: short-cycle seed white lima bean (*Phaseolus lunatus*), long-cycle seed white lima bean (*Phaseolus lunatus*), cowpea (*Vigna unguiculata*), dwarf velvet bean (*Mucuna pruriens* var. *utilis*), ash velvet bean (*Mucuna pruriens* var. *utilis*), sword bean (*Canavalia ensiformis*) and red rice bean (*Vigna umbellata*). It was collected data on coverage and biomass production, grain, leaf litter and stubble yields, biomass and relative frequency of weeds, pH, total nitrogen, organic matter (OM), potential anaerobic mineralization of nitrogen (MPAN) and soil CO_2 evolution. Coverage varied from 70% to 90%; and biomass from 1900 to 2500 kg·DM·ha^{-1} at 90 DAS in ash velvet bean (AVB) and sword bean (SB). Stubble yielded from 800 to 2200 kg·DM·ha^{-1}. The SB reached ~3200 kg·DM·ha^{-1} of grain yield in the first cropping season and it was reduced in the second cropping season. AVB and SB reduced the biomass of weeds from 890 to 780 kg·DM·ha^{-1}. The OM of soil reached 14.9% in AVB. NH_4, pH, and soil CO_2 evolution remained without significant changes by effect of legumes.

Keywords

Legumes; Biomass; Weeds; Soil Properties

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[*] Corresponding author.

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1. Introduction

Agriculture based on slash and burn system, is carried out by nearly 300 million farm peasants on the 30% of worldwide agricultural soils. In Mexico, agriculture based on slash and burn system is carried out on 10% out of the 5 million of hectares on which this agriculture takes place, and all the rest remain on fallow. At the Peninsula of the Yucatan in Mexico, corn produced under slash and burn provides of food to over one million of farm peasants cropping maize under that system. Besides, low maize production and its declining production from one year to the next one, is attributed to crop competition with weeds [1] as well as to dropping soil fertility [2]. Therefore, integration of legumes as cover crops into the farm systems is an option to improve soil fertility as well as weed competition due to their capacity to capacity to fix atmospheric nitrogen as well as to improve physical and chemical soil properties. The characteristics of those crops allow an erosion reduction and a biological activity increase on soils, besides controlling weeds and soil pests, as well as to be used as feed or forage. Legumes as cover crops should be assessed in terms of biomass production due to its importance on nutrients recycling and on soil quality. However, distribution of seasonal availability of water as well as its annual accumulation must be taken into account in order for maize to be sown. Such water availability determines if coverings management would be under rotation, intercropping or relaying [3]. It is suggested that one ideal plant used as cover crop must yield a minimum of 2000 kg·DM·ha^{-1} of aboveground biomass or 40 kg of N·ha^{-1} to be incorporated into the soil before sowing the main crop [4].

On that sense, sword bean (*Canavalia ensiformis*) and velvet bean (*Mucuna pruriens var. utilis*) yield between 10,000 and 12,000 kg·DM·ha^{-1} [5] [6] and they have been used on cover crops systems with positives results [5]-[8]. However in spite of such results the interdisciplinary and interinstitutional assessments of several cover crops in Mexico shown a low adoption of velvet bean due to excessive competition of it over maize crop, as well as its displacement by other crops and peoples low knowledge of its grain uses. As result of all the above, due to the foreseen opportunity to be used as livestock feeding there has been an increase on researching chemical composition and nutritional attributes of velvet bean and sword bean [9]-[12].

2. Materials and Methods

2.1. General Conditions

This experiment was carried out in the municipality of Maní, Yucatán on lands under the property of the agricultural ecological school named Uyit's Ka'an in Mayan language. It was carried out during two farming seasons, one between the years of 1999 and 2000 and the second between the years of 2000 and 2001. The climate in the municipality of Maní is sub humid warm, in according with climatic Köppen classification is AX (wo) (i) g W", which is considered as the driest of sub humid climates (with rains of 1047 mm/year). This climate has a drought season amidst summer; the average temperature is of 25.8˚C, showing thermal oscillation that varies from 5˚C to 7˚C. The landscape shows an alternated relief of hills and multiple depressions, and an altitude not higher than 100 meters over the sea level. The soils are classified as Leptsolrendzico (LPrz) or Lithic Haplustolls and Luvisolrodic (Lvro) or TypicRhodustalfs accordingly with FAO typology.

2.2. Experimental Plots

Experimental land surface was prepared through slash and burn of secondary vegetation under fallow. Once the vegetation was burnt, four sections of that land showing similar characteristics of rockiness and soil color were selected to establish blocks plots. Inside each block were traced seven plots measuring 4 m × 6 m where large plots were randomized (corresponding to legume specie), and within these the smaller plots corresponding to split plots (corresponding to accumulated biomass during the length from sowing to harvesting), which dimensions were of 3 m × 4 m. Inside the useful area of the plot measuring 2 m × 2 m, samples of soil, weed biomass, litter production and biomass yield (including foliage and grain) were taken.

Experimental area was cropped under slash and burn as it is done on the Mayan traditional way. Sowing, weeding and harvesting were all made by hand. After the first maize cropping period its harvest residues are being always burnt however for the objectives of this study they were not burnt, and they were instead slashed, together with the grown leaves of stumps and weeds grown on that period. Legumes were planted then, after having the mentioned slash done.

Legumes were sown on June 12, 1999, for the first crop season, at the start of the rainy season, and on June

10, 2000, for the second crop season. Planting arrangement had a rectangular pattern with a distribution of 1.0 m between rows and 0.50 m within rows, and a number of two seeds sown on each sowing hole, obtaining in that way a planting density of 20,000 planted seeds per hectare.

First weeding was made at the 35 day after sowing (DAS), and second one was made at the 75 day after the first weeding, both by hand. The whole cropping of the experiment was rain fed, and, with no external inputs being used.

2.3. Measuring Variables: Soils and Plants

Three subsamples of soil were taken on the first crop period at a depth of 0 to 10 cm within the useful area on each experimental unit. They were mixed to obtain a mixed sample and then each one was dried under shadow and then sieved with a sieve of 0.417 mm in diameter.

Soil samples were subjected to the next analysis: pH in water at a 1:2.5 ratio measured using the potentiometric method [13], organic C measured by the Walkey and Black method [14] [15], CO_2 evolution [16] [17]; and the potential anaerobic mineralization of nitrogen with an incubation period of seven days [13] [18]. Nitrogen content was determined through the Kjeldahl method as well as the available phosphorous (Olsen), respectively [15]. Soil and plant samples were analyzed at the soils laboratory of the Facultad de MedicinaVeterinaria y Zootecnia (FMVZ) of the Universidad Autonoma de Yucatan (UADY).

Plants variables measured were: aboveground biomass of the legume plant was weighted at the 90 day after sowing (90 DAS) as well as when grain harvesting was at its end (AGH), and when litter was yielded. In order to estimate the legumes biomass yield at 90 DDS as well as the AGH, plants were harvested from the useful area of the plot cutting them to the ground, then weighted at the field with a clock weight scale, and taking a sub sample of 300 to 400 g of it, to be subjected to dehydration at 60˚C for 48 hours. The percentage of DM was used to estimate the yield of biomass at dry basis

Cover of legumes was estimated at 90 DAS through a visual estimate of the percentage of area covered by the legume. Biomass of weeds and their relative frequency were estimated using the method of sampling frames of 50 × 50 cm, taking three samples with those frames within the useful area of the experimental unit. Identification of weeds species was made before sampling their biomass. Once the above was made, weeds and tree stumps were counted on each sampling frame, taking individual samples of certain species when it was not possible to identify them on the field, to be identified later on the Herbarium of the Facultad de Medicina Veterinaria y Zootecnia of the Universidad Autónoma de Yucatán. The samples were dehydrated in a drying oven with forced air at a temperature of 60˚C during a period of 48 hours.

Samples of legume biomass obtained from the growth at 90 DAS and grain harvested in the sub treatments harvested after the 90 days DAS, were measured on their nitrogen content (Kjeldahl) and on their total phosphorus through digestion and subsequent titration colorimetric [15].

2.4. Experimental Design and Treatments

Treatments were: short-cycle seed white lima bean SCSWLB (*Phaseolus lunatus*), long-cycle seed white lima bean LCSWLB (*Phaseolus lunatus*), cowpea CWP (*Vigna unguiculata*), dwarf velvetbean DVB (*Mucuna pruriens var. utilis*), Ash velvetbean AVB (*Mucuna pruriens var. utilis*), sword bean SB (*Canavalia ensiformis*) and red rice bean RRB (*Vigna umbellata*), all of them planted under monoculture.

It was used an experimental design of randomized blocks with four replicates under an arrangement of split plots, the large main plots were occupied by the legume types (treatments), while the small plots were occupied for the management of biomass (sub-treatments), it means for instance, the harvested biomass at 90 DAS or at AGH.

It was used a randomized block design, to analyze the variables of legume coverage at 90 DAS, including, biomass yielding at 90 DAS, concentrations of N and P of harvested biomass at 90 DAS, and the amount of litter, all produced during the crop season between 1999 and 2000. It was used a variance analysis accordingly to an arrangement under a split plot in randomized blocks design for the variables of contents of pH, organic matter (OM), total nitrogen, potential anaerobic mineralization of N (MPAN), evolution of CO_2 from the soil, weeds biomass and litter amounts during the crop season between 2000 and 2001 were subjected to analysis of variance according to an arrangement of split-plot in randomized block design. The coverage of legumes was transformed into arcsine $\sqrt{n+1}$; while weeds biomass, legumes stubble and litter were transformed into logarithm base 10 + 1.

3. Results

3.1. Biomass and Cover at 90 DAS

Seedlings emergence was homogeneous on treatments and plants shown excellent vigorous growth at the beginning of the crop season. AVB, LCSWLB and RRB were found in vegetative stage at 90 DAS of the first crop season, plants of DVB and of SCSWLB were found in flowering stage, whereas the DVB and CWP were both flowering and fructification. At 90 DAS the AVB developed 90% coverage making it superior ($P < 0.01$) to all other legumes, followed by SB, DVB and SCSWLB on this order respectively from high to less high percentage of coverage (**Table 1**), and finally by RRB, LCSWLB, and CWP reaching the lower development of coverage with 20%, 21% and 42%, respectively (**Table 1**).

Coverage measured at 90 DAS in the second cropping season (the second year of the experiment), SB and AVB reached the highest percentages of coverage ($P < 0.01$) of 75% and 92%, respectively, whereas DVB and, SCSWLB shown an intermediate coverage of 51% and 52% respectively, and LCSWLB and CWP developed a lower coverage, making them the lowest of all other legumes (**Table 1**). In the same second cropping season there were observed damages on emerged plants of RRB and CWP most probably caused by hares, therefore, in the statistical analysis coverage and biomass were omitted on RRB because its plants could not recover at the time of data collection (**Table 1**). In the first cropping season (the first year of the experiment), the accumulated biomass at 90 DAS in AVB was higher ($P < 0.001$) than that of all t other legumes, yielding almost 2500 kg·DM·ha^{-1} (**Table 1**).

In the second cropping season (the second year of the experiment), the biomass at 90 DAS decreased in all treatments, within a range of yield from 264 to 1528 kg·DM·ha^{-1} (**Table 1**). Significance ($P < 0.001$) between leguminous plants was detected on this second cropping season when AVB and SB were outstanding, while LCSWLB and CWP accumulated the lowest amount of biomass. RRB was omitted of the analysis, due to the severe damages caused on it by hares.

3.2. Stubble and Litter Production: First Cropping Season

In the first cropping season (the first year of the experiment), residual biomass derived from stubbles left after grain harvest shown yields within a range of 309 to 2196 kg·DM·ha^{-1}, corresponding both to DVB and SCWLB, respectively. There was significance ($P < 0.001$) on stubbles yields among treatments, however in spite that SB and LSWLB accumulated big amounts of residual biomass at the end of the grain harvest, even higher than DVB and AVB (**Table 2**), SCWLB shown an outstanding higher amount of stubbles when compared to all other legumes. The amount of litter recovered of soil was within the range of 1054 to 3708 kg·DM·ha^{-1} (**Table 2**). A significant response was detected ($P < 0.05$) between treatments, being AVB, SB and SCSWLB outstanding with higher DM.

3.3. Stubble and Litter Production: Second Cropping Season

In the second cropping season (the second year of the experiment) stubble yields showed a decrease, detecting significance ($P < 0.001$) among treatments. SB, SCSWLB and LCSWLB were outstanding on stubble yields (**Table 2**). The amount of litter ranged from 1340 to 4182 kg·DM·ha^{-1}, being detected a significant effect ($P < 0.001$). SB treatment shown the greatest amount of litter, even do, it was equal to AVB and the SCSWLB. It was recovered the lowest amount of litter in CP. Sub treatment effect on litter production shown significance ($P < 0.001$) on CPF, with an amount of 3521 kg·DM·ha^{-1} in CPF contrasting with 1863 kg·DM·ha^{-1} obtained at 90 DAS.

3.4. Grain Yield of Legumes

In the first cropping season (the first year of the experiment) the values of grain yield ranged from 511 to 3189 kg·DM·ha^{-1} both corresponding to RRB and SB, respectively. The highest grain yield ($P < 0.001$) was reached by SB, while the second better legume was AVB (**Table 3**). Intermediate grain yields were obtained in the DVB and LCSWLB (**Table 3**). The lowest grain yields were obtained from RRB and SCSWLB, whereas CWP did not produce grain at all (**Table 3**).

Table 1. Plant cover and biomass yield in monoculture legumes at 90 DAS.

Treatments	Plant cover (%)		Biomass (kg·DM·ha^{-1})	
	1999-2000	2000-2001	1999-2000	2000-2001
AVB	1.95 a (90)	1.96 a (92)	2496 a	1528 a
SB	1.83 ab (70)	1.86 a (75)	1912 ab	1469 a
DVB	1.90 ab (81)	1.70 ab (52)	1400 b	782 b
SCSWLB	1.97 abc (67)	1.68 ab (51)	438 c	705 b
LCSWLB	1.56 bcd (21)	1.48 b (26)	422 c	264 b
CWP	1.64 cd (42)	NE	639 c	456 b
RRB	1.41 d (29)	NE	301 c	-
SE (±)	0.083	0.139	427	274

Values in parentheses indicate means of the original data (%); NE: no estimated, because plants were damage. Different letters within columns are different to ($P < 0.01$) and ($P < 0.001$). SE: Standard error of the difference between two means.

Table 2. Yield of residual biomass (kg·DM·ha^{-1}) of legumes under monoculture.

Treatment	1999-2000		2000-2001	
	Stubble	Litter	Stubble	Litter
AVB	3.830 cd (736)	4.432 a (3009)	3.437 bc (243)	4.504 ab (4116)
SB	4.247 ab (1862)	4.563 a (3708)	4.176 a (1752)	4.551 a (4182)
DVB	3.434 e (309)	4.207 ab (1905)	3.394 c (166)	4.242 cd (1998)
SCSWLB	4.335 a (2196)	4.322 a (3045)	3.627 ab (454)	4.396 abc (2744)
LCSWLB	3.983 bc (1268)	4.247 ab (2406)	3.773 ab (898)	4.353 bc (2474)
CWP	-	-	-	4.084 d (1340)
RRB	3.637 de (511)	3.961 b (1054)	3.469 b (281)	4.259 c (1989)
SE (±)	0.150	0.156	0.265	0.080

SE: Standard error of the difference between two means; Values in parentheses indicate means of the original data (log10^{-1}).

Table 3. Grain yields of cover crop legumes (kg·DM·ha^{-1}) assessed on two cropping seasons.

Legume	Cropping season	
	1999-2000	2000-2001
AVB	1153 b	908 a
SB	3189 a	360 c
DVB	803 bc	166 d
SCSWLB	559 c	Notproduced
LCSWLB	872 bc	600 b
CWP	Notproduced	Notproduced
RRB	511 c	281 d
SE (±)	202	102

AVB and LCSWLB produced the highest grain yield ($P < 0.001$) in the second cropping season (the second year of the experiment) as compared with lower SB and the DVB grain yields in the same season (**Table 3**). In-the same second cropping season (the second year of the experiment), LCSWLB and CWP accumulated a significant amount of biomass at 90 DAS whereas grain yield in both was null (**Table 3**).

3.5. Weed Biomass

It is reported [16] the absence of effect on the accumulation of weeds biomass with all of the seven legumes for three sampling dates in a first cropping season of cultivation (the first year of the experiment) (**Table 4**).

In the first sampling date of the second cropping season (the second year of the experiment) taking place in August, the accumulated weeds biomass was similar ($P > 0.05$) over the seven legumes. Likewise it was found and absence ($P > 0.05$) of effect over the accumulation of weeds biomass raised from sub treatment (**Table 5**).

Table 4. Effect of legumes on weeds biomass ($g \cdot DM \cdot m^{-2}$) on first cropping season (the first year of the experiment).

First sample		Second sample		Third sample	
Treatment	Log10 + 1	Treatment	Log10 + 1	Treatment	Log10 + 1
SB	2.778	RRB	2.419	LCSWLB	2.544
DVB	2.765	LCSWLB	2.378	CP	2.476
LCSWLB	2.657	SB	2.279	XCOLB	2.466
SCSWLB	2.524	CP	2.235	SCSWLB	2.459
AVB	2.513	DVB	2.164	AVB	2.456
XCOLB	2.507	SCSWLB	2.059	RRB	2.416
CP	2.489	AVB	2.016	DVB	2.340
RRB	2.347	XCOLB	1.996	SB	2.241

Source: [16].

Table 5. Effect of legume species and their management on weeds biomass accumulation in the second cropping season (the second year of the experiment).

Main plot Treatment (Legume)	Sample 1 (August)	Sample 2 (October)
AVB	2.5271	2.8340 c
SB	2.8845	2.7184 bc
DVB	2.9095	3.0505 ab
SCSWLB	2.8997	2.9424 ab
LSCWLB	2.9503	2.9405 ab
CWP	2.9549	2.9254 ab
RRB	2.9825	2.9450 ab
SE (±)	0.51	0.099
Prob.	NS	($P < 0.01$)
Sub-plot Sub-treatment (Biomass harvest)		
90 DAS	2.29 a	2.45 a
AGH	2.26 a	2.26 b
SE (±)	0.074	0.048
Prob.	NS	($P < 0.0001$)

SE: Standard error of the difference between two means.

However, in the second sampling period taking place in October, significant differences ($P < 0.01$) were found among the treatments, showing a reduction of weeds biomass caused by AVB and SB legumes (**Table 5**). Similar amounts of weeds biomass were accumulated ranging from 94 to 129 $g \cdot m^{-2} \cdot DM$. AGH sub-treatment inhibited the growth of weeds and reduced significantly ($P < 0.0001$) weeds biomass accumulation. Sac-itsaa or Tsaitsa (*Neomillspaughia emarginata*) was outstanding amongst the 45 weeds species found, in terms of relative frequencies showing percentages ranging from 30% to 85% in the AVB treatment, whereas relative frequencies of the same weeds species ranged from 21% to 100% in the SB treatment.

3.6. Soil Properties

After the first cropping season cycle (the second year of the experiment), the effect of treatments was null regarding soil pH of soil with values ranging from 7.92 to 8.04 (**Table 6**). On the other side, OM indicated differences ($P < 0.01$) among treatments, such as the OM contents of 14.9% shown on AVB treatment which was higher than soil OM found from all other treatments (**Table 6**). Likewise contents of soil OM indicated differences ($P < 0.001$) between the sub-treatments, because it was found an 11.5% at 90 DAS as compared with a 13.5% at AGH.

There was a null effect among treatments ($P > 0.05$) regarding evolution of soil CO_2 with amounts ranging from 720 to 816 $mg \cdot kg^{-1}$. However, it was not found for the mentioned variable any significant effect amongst sub-treatments (**Table 6**).

There were not found differences ($P > 0.05$) among treatments regarding the MPAN. However it was detected a significant effect ($P < 0.001$) among sub-treatments, registering 19.5 mg NH_4 kg^{-1} in AGH, as compared with 17.1 mg NH_4 kg^{-1} at 90 DAS (**Table 6**). Nitrogen concentration in the foliage of plants at 90 DAS ranged from 23 to 29 $g \cdot N \cdot kg^{-1}$ DM, with no differences ($P > 0.05$) among treatments. However, concentrations of phosphorus of the foliage indicated significance ($P < 0.01$) among treatments (**Table 7**).

On the other hand, nitrogen yield of aboveground biomass, shown effects from different treatments, where AVB was outstanding with 58 $kg \cdot N \cdot ha^{-1}$ accumulated on aboveground biomass over a period of 90 DAS as compared with the 9 and 12 $kg \cdot N \cdot ha^{-1}$ obtained in RRB and LCSWLB, respectively (**Table 7**).

Table 6. Effect of legumes on monoculture and biomass management over several soil proprieties.

Main Plot Treatment (Legume)	pH	OM (%)	CO_2 ($mg \cdot kg^{-1}$soil)	MPAN mg NH_4^+ kg^{-1} soil
LCSWLB	8.04	12.8 b	776	18.3
CP	8.01	12.2 b	753	17.7
DVB	7.99	12.8 b	781	18.8
SCSWLB	7.98	11.0 b	815	20.0
SB	7.96	11.6 b	782	17.6
RRB	7.94	12.4 b	720	17.4
AVB	7.92	14.9 a	765	18.0
SE (±)	0.07	0.94	64	1.2
Prob.	NS	($P < 0.01$)	NS	NS
Sub-plot Sub-treatment (Biomass harvest)				
90 DAS	7.97	11.5	756	17.1
AGH	7.98	13.5	787	19.5
SE (±)	0.033	0.51	31.4	0.55
Prob.	NS	($P < 0.001$)	NS	($P < 0.001$)

Different letters in the columns indicate differences at ($P < 0.05$). SE: Standard error of the difference between two means.

Table 7. Concentration and yielding of nitrogen and phosphorous estimated from legumes biomass when harvested at 90 DAS.

Treatment	Nitrogen (%)	N yield (kg·ha^{-1})	Treatment	Phosphorous mg·kg^{-1}·DM
LSCWLB	2.92	12.0	LSCWLB	1447 a
RRB	2.75	8.9	RRB	1257 ab
SB	2.49	47.6	SCSWLB	927 bc
CWP	2.40	14.3	SB	920 bc
SCSWLB	2.36	28.7	CWP	822 c
DVB	2.33	32.3	DVB	808 c
AVB	2.30	58.5	AVB	794 c

4. Discussion

4.1. Development of Legume Cover and Its Effect on Weeds

Maximum coverage of 90% achieved by AVB at 90 DAS in the first and second cropping season, coincides when legumes were assessed in the East of Yucatan. Similar results were also found assessing velvet bean and sword bean as a cover crop in Northern Yucatan and assessing three genotypes of velvet bean under monoculture in the region of Los Tuxtlas, Veracruz [19].

The fast of crop to cover the soil is a useful indicator for cover crops management [19] [20]. AVB producing the highest cover of all legumes reduced the weeds biomass in the same way than results found by other the authors [19] [20]. It is attributed to some chemical compounds in the Mucuna foliage, as responsible of weeds control due to their allelopathic effects [21] regarding their soil coverage. Meanwhile LSCWLB and RRB developed little coverage at 90 DAS.

4.2. Biomass Yield

The amount of biomass accumulated by legumes to at 90 DAS in the first cropping season, ranged from 1400 to 2500 kg·DM·ha^{-1}. Such low yield however was even more reduced at the second cropping season with a maximum of 1500 kg·DM·ha^{-1}. The minimum amount of biomass produced by legumes should be of at least 2000 kg·DM·ha^{-1} in order to function as cover crops and thus be able to effect on a favorable way on crops [4]. SB and AVB were the only species that reached in the first cropping season at least the above mentioned yield mount, failing on this in the second cropping season.

When stubble biomass was added, there were found biomass amounts of 2196, 1862, 1268 and 735 kg·DM·ha^{-1}, on SCSWLB, el SB, LCSWLB and AVB, respectively. Moreover, the litter recovered from soil was of 2091, 2058, 1372 and 1268 kg·DM·ha^{-1}, on SB, AVB, SCSWLB and LCSWLB, respectively. With such amounts of biomass on those treatments it was achieved to produce from 2793 to 3953 kg·DM·ha^{-1}, indicating that with those amounts it would be enough to promote a significant impact on main crop [4].

Besides the quality of biomass in terms of C/N ratio, recalcitrant compounds, rate of decomposition and mineralization, influence its utilization by main crop [7] [22]-[25].

In the first cropping season, high yields of stubble were outstanding on assessed legumes, mainly on LCSWLB, SB and SCSWLB. This feature has great relevance on cropping systems based on the utilization of crop residues, as grain legumes (e.g. the two lima beans), could increase total nitrogen of soil only if the amount of fixed and left nitrogen and left in the site is greater than the amount of N in the soil removed through the exportation of grain or removed with the residues of the cropping system [22] [26]. At the end of seeds harvesting, it was also found a significant yield of biomass derived from stubble on SB and LCSWLB from the second cropping season, although it was shown in all treatments a general diminishment of biomass on the first 90 DAS and on AGH in all treatments.

4.3. Grain Yield

The values obtained in the variable of legumes grain yield are consistent with those obtained from several studies developed in the areas, where it was reported values ranging from 300 to 3100 kg·DM·ha^{-1}, on sword beans [4]. The amount of rain in the second cropping season ranging from 2000 to 2001 was close to usual rain amounts, where rain falls were of more than 93% of what commonly rains in the area, even do in the month of October 2000 the rainfall decreased as compared to that one from the year of 1999. Therefore, due to a lower rainfall amount on October the grain yield of SB decreased in the second cropping season. It was also noted plants defoliation due to an intense crop infestation with the beetle, *Platiprosapus* sp. [4] accentuating the yield decrease.

On the other hand, the null grain yield of cowpea, is attributed to damages caused by bugs of fruits (*Nezara* sp., *Acanthomia* sp. and *Anoplocnemis* sp.), feeding from sucking the green pods, therefore inhibiting seeds development and premature drying of pods [27] [28]. Damages on pods of cowpea due to the attack of this complex of sucking bugs were estimated in an area with a less intensive cropping of cowpea under monoculture for the north area of the Yucatan within a level of 50%, as compared with an area where experiment was carried out, where concomitantly higher levels of damages and a null fruits production was found. Area with low intensity of the monoculture of the cowpea, in contrast to the area where it was developed this experiment, which would explain the high damage and no fruit production.

The rainfall precipitation on September of the year of 2000, at the flowering stage of LSCWLB and DVB treatments was similar to that one at the same stage of the year of 1999, therefore it is unexplainable the null grain yield on LSCWLB and the lower grain yield on DVB in the year of 2000, because humidity would not be a limiting factor for fruits mooring. On the other hand, the grain yield of AVB showed little variation on both, the first and the second cropping seasons, the same way as it has been reported on previous studies [29].

4.4. Concentration of N in Foliage

The concentration of nitrogen in the foliage of defoliated legumes at 90 DAS ranging from 23 to 29 g·N·kg^{-1} DM coincides with that of the reported [30]. They indicated concentrations of nitrogen in the foliage of trees ranging from 2.0% to 3.46% on the other hand [24] found a concentration of nitrogen in the foliage of *Leucaena* and *Senna*, ranging from 3.22% to 5.33% on regrowth at 6, 14 and 29 weeks.

Reported values of N concentration on leaves of peanut (*Arachis hypogea*), dolicos (*Lablab purpureus*), alfalfa (*Medicago sativa*) and lima bean (*Phaseolus lunatus*) have been superior to values found in this study for the same variable [31] [32]. It is usual to find yields of nitrogen between 100 and 600 kg·ha^{-1} in legumes of vigorous growth, such as AVB, when concentrations of N are from 0.5% to 1% in the foliage of legumes [31].

However, maximum values of total nitrogen coming from biomass at 90 DAS were respectively of 48 and 58 kg·ha^{-1}, for sword bean and ash velvet bean. Those values are lower to those indicated [31] as well as a value of 300 kg·N·ha^{-1} per cropping season was reported in a rotation system of maize and velvet bean [27].

In this study, AVB and SB reached the minimum amounts of biomass yield (2000 kg·DM·ha^{-1} or 40 kg·N·ha^{-1}) enough to have a positive effect over the next crop [3]. Likewise, the effect of AGH sub-treatment allowed the accumulation of a higher amount of biomass in the stubble and litter, contributing in this way at least on quantitative terms to the system performance [22]. It is due to the regulation of biomass utilization by means of the chemical quality, the rate of decomposition and mineralization of it [33].

4.5. Soil Properties

The AVB led to an increase on soil organic matter as compared to all other legumes, and such increase corresponded to a higher biomass yield at 90 DAS. In addition, the AGH sub-treatment, promoted in average an increase of soil OM. In this sense, it is reported up to 10 t·DM·ha^{-1} of biomass and favorable changes on soil properties [5].

On the other hand, the MPAN of soil indicated no significant effect caused by the cultivation of legumes. In contrast, the AGH sub-treatment increased the values of ammonium. This response corresponds to a higher accumulation of organic material of rapid mineralization, composed of leaf litter, with a low C/N ratio on labile consequences [7] [22].

5. Conclusions

Biomass accumulation and coverage shown at 90 DAS was higher in AVB and SB in the first and second year of cropping. It was accumulated a considerable amount of biomass derived from senescent material coming from litter recovered from soil surface, particularly on AVB, SB and LSCWLB, contributing to organic material in cover crop systems. The development of the coverage in the second year of cropping, during the first ~60 DAS was insufficient to reduce the weeds biomass; although AVB and SB diminished weeds biomass at 120 DAS.

Grain yield in SB was the highest in the first year of cropping, and higher than AVB, while AVB was outstandingly higher on grain yield in the second year of cropping as compared to all of the other legumes, occupying grain yield of LSCWLB the second place. The concentration of nitrogen in the legumes biomass when harvested at 90 DAS was similar between all genotypes. Values of N yield harvested at 90 DAS were different among treatments, and AVB and SB were outstanding on the values of this variable, however, the found amounts would be enough to supply and cover the needs of nitrogen for a subsequent crop season. Regarding the effects of assessed soil variables none of them had any effect on legumes after one cropping season.

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Abbreviations

DAS: Day after sowing;
AHG: after harvesting the grain;
SCSLB: short-cycle seed white lima bean (*Phaseolus lunatus*);
LCSLB: long-cycle seed white lima bean (*Phaseolus lunatus*);
CWP: cowpea (*Vigna unguiculata*);
DVB: dwarf velvet bean (*Mucuna pruriens var. utilis*);
AVB: ash velvet bean (*Mucuna pruriens var. utilis*);
SB: sword bean (*Canavalia ensiformis*);
RRB: red rice bean (*Vigna umbellata*);
XCOLB: common bean or frijol de milpa (*Phaseolus vulgaris*);
OM: organic matter;
MPAN: potential anaerobic mineralization of nitrogen;
DM: dry matter;
NH_4: ammonia;
N: nitrogen.