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Soybean and maize in agrosilvipastoral system after thinning of eucalyptus at seven years of implantation

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***Abstract*— *This work was carried out with the objective of investigating the effect of thinning eucalyptus at seven years of implantation on the components of production and productivity of soybean and maize crops, cultivated in the renewal of pasture in an agrosilvipastoral system. The experimental design used was a randomized block, with four replications, using as treatments three sampling positions of the components of production and grain productivity of soybean and maize crops in relation to the eucalyptus line: 2, 4 and 6 m away from the eucalyptus lines, under two thinning of the eucalyptus: thinning of 0% and 50% of trees, compared to a treatment with thinning of 100% of trees (standard). The different sampling positions in relation to the planting line, under the two thinning of the eucalyptus, provided differences in relation to the mass of one hundred grains and grain productivity of the soybean crop and in relation to the height of plants, number of ears and mass of one hundred grains of maize crop. The standard treatment provided greater plant height in the soybean crop and greater insertion height of the first ear and higher grain productivity in the maize crop, and the sampling position at 2 m from the eucalyptus planting line under 0% thinning provided a lower mass of one hundred grains for soybean and maize crops and a lower number of ears ha^{-1} for the maize crop.*

Keywords*— *Cropping systems, Glycine max, integrated systems, sustainable agriculture, Zea mays.

I. INTRODUCTION

Integrated agricultural production systems are interesting options for approaching global issues such as food security, climate change and sustainable farming besides improving social conditions in the rural environment [1].

The agrosilvipastoral system is among these systems. It consists of the implantation of different productive systems of grains, fibers, meat, milk, agro-energy, among others, in the same area, in intercropped, sequential or rotational planting [2].

In this exploration model, the interest is based on the benefits that can be obtained by the synergism between pastures and annual crops, such as: improvement of the physical, chemical and biological properties of the soil; breaking of the cycle of diseases and reduction of insect-pests and weeds; reduction of economic risks through diversification of activities; and cost reduction in the recovery and renovation of pastures in the process of degradation [3].

However, the success of an intercropping system depends on the correct management of the species and the factors of production that affect the species, aiming to guarantee satisfactory economic and environmental returns [4].

Unlike eucalyptus monoculture systems, in the agrosilvipastoral systems it is necessary to manage the forestry component through pruning and thinning, so to promote light input between the hills and reduce competition for water and nutrients with agricultural crops and pasture.

There is too much information about the cultivation of soybean and maize in the initial phase of implantation of agroforestry systems. However, there are many doubts about the cultivation of a new cycle of these crops, for the renewal of pastures, with the forest component well developed.

This work was carried out with the objective of investigating the effect of thinning eucalyptus at seven years of implantation on the components of production and grain productivity of soybean and maize crops, cultivated in the renewal of pasture in an agrosilvipastoral system.

II. METHOD

The experiment was carried out over 2016/17 and 2017/18 harvests, in an experimental area with an agrosilvipastoral system, at the Advanced Research Center for Rubber and Agroforestry Systems, of the Agronomic Institute (IAC in Portuguese) owned by São Paulo Agribusiness Technology Agency (APTA), located in the municipality of Votuporanga, State of São Paulo, (20º20'S, 49º58'W and 510m of altitude), in a dystrophic Red Yellow Latosol with sandy texture, according to SiBCS [5].

The climate in the region is tropical with dry winters (Aw in the Köppen's classification) with an average annual temperature of 24°C, an average maximum temperature of 31.2°C and an average minimum temperature of 17.4°C. The average annual rainfall is 1328.6 mm.

The experimental design used was a randomized block, with four replications, using as treatments three sampling positions of the components of production and grain productivity of soybean and maize crops in relation to the eucalyptus line: 2 m away from the eucalyptus lines (2 m); 4 m away from the eucalyptus lines (4 m); 6 m away from the eucalyptus lines (6 m), under two thinning of the eucalyptus: thinning of 0% of the trees (0%); thinning of 50% of trees (50%), compared to a treatment with thinning of 100% of trees (standard), totaling seven treatments: T1 - 0% and 2 m; T2 - 0% and 4 m; T3 - 0% and 6 m; T4 - 50% and 2 m; T5 - 50% and 4 m; T6 - 50% and 6 m; T7 - standard.

The agrosilvipastoral system was implemented in an area with degraded pasture with ten years of cultivation. The area was prepared in a conventional manner, through plowing and harrowing. After tillage, in September 2009, millet (*Pennisetum glaucum*) was sown between the terraces for soil conservation (terraces).

In October 2009, Urograndis H-13 eucalyptus hybrid (*Eucalyptus urophila* x *E. grandis*) was planted on terraces, in a simple line system, with a spacing of 2 m between plants and 13.5 m between lines, totaling 370 plants ha^{-1}.

On November 30 2009, millet was desiccated and soybean sowing was carried out, between the terraces, in no-tillage system over the millet straw. The soybean harvest was carried out on April 8 2010.

After the soybean harvest, *Crotalaria juncea* was sown, used as a cover plant. *C. juncea* was desiccated on November 29 2010.

On December 15 2010, maize was sown, between the terraces, in no-tillage system on *C. juncea* straw.

The sowing of *Urochloa brizantha* cv. Marandu (pasture) was held on December 16 2010, with two lines sown between the lines of the maize.

In September 2011, the area was divided into 1.0-ha plots (paddocks) and four newly weaned beef cattle were introduced per plot, which remained in the area on continuous grazing for twenty-four months, when they were sent to the slaughter. After the slaughter of the first batch, new batches of beef cattle were introduced into the area, using a rotational grazing system, which remained in the area until slaughter. The stocking rate of cattle varied according to the forage supply.

In July 2016, animals were removed from the area for pasture regeneration, which was used as straw for sowing soybean, and thinning of the eucalyptus was carried out.

The crops used in the system are shown in Table 1 and the amount of nutrients used is shown in Table 2.

Soil samples for chemical characterization [6] were collected in the 0-0.20 depth layer, in October 2016 and 2017, and the results are shown in Table 3.

Soil samples for physical [7], particle size [8] and structural [9] characterization were collected in the 0-0.20 and 0.20-0.40 m depth layers, in October 2016, and the results are shown in Table 4.

On October 19 2016, the amount of straw in the area was sampled. Two 0.5 x 0.5-m samples were taken per plot, which were packed in paper bags and taken for drying in a forced ventilation oven, set at 65-70ºC for 72 hours. The average amount of dry matter in the area was 8404 kg ha^{-1}.

Table.1: Crops used in the September (Sep)/2009-August/2016 period

Sept/March	April/August	Sept/March	April/August	Sept/March	April/August
2009/10		2010/11		2011/12	
Millet/Soybean	*C. juncea*	Maize + *U. brizantha*	*U. brizantha*	*U. brizantha*	*U. brizantha*
2012/13		2013/14		2014/15	
U. brizantha	*U. brizantha*	*U. brizantha*	*U. brizantha*	*U. brizantha*	*U. brizantha*
2015/16					
U. brizantha	*U. brizantha*				

Table 2. Nutrient amount used in the September-August period 2016

N	P	K	N	P	K	N	P	K
				kg ha^{-1}				
	2009/10			2010/11			2011/12	
15.0	124.0	60.0	116.4	91.0	86.4	45.0		
	2012/13			2013/14			2014/15	
33.0			100.0			50.0		
	2015/16							
25.0								

Table 3. Soil chemical characterization in the 0-0.20 m depth layer, 2016 and 2017

Year	P	OM	pH	K	Ca	Mg	H+Al	Al	V
	mg dm^{-3}	g dm^{-3}		-----------------mmol$_c$ dm^{-3}------------------					%
2016	7	18	5.8	3.7	26	21	15	0	77
2017	10	17	5.2	2.0	18	12	18	0	64

Table 4. Particle size, physical and structure characterization of soil in the 0-0.20 and 0.20-0.40 m layers, 2016

	Sand	Silt	Clay
	----------------------------------g kg^{-1}------------------------------------		
0-0.20	815	104	81
0.20-0.40	783	142	75

	M$^{(1)}$	µ$^{(2)}$	TP$^{(3)}$	BS$^{(4)}$	> 2 mm$^{(5)}$	AWD$^{(6)}$
	-------------- m^3 m^{-3} ---------------			kg dm^{-3}	%	mm
0-0.20	0.03	0.34	0.38	1.59	57.88	2.76
0.20-0.40	0.03	0.34	0.37	1.58	52.26	2.61

$^{(1)}$macroporosity; $^{(2)}$microporosity; $^{(3)}$total porosity; $^{(4)}$bulk density; $^{(5)}$percentage of aggregates larger than 2 mm; $^{(6)}$average weighted diameter.

The area was desiccated on October 20 2016. The sowing of soybean was carried out mechanically on November 17 2016, between the terraces, in no-tillage system on the straw of *U. brizantha* cultivar Marandu. The cultivar used was Brasmax Potencia RR, at the spacing of 0.5 m and a population of 320000 plants ha^{-1}. For sowing fertilization, the 04-20-20 formulated fertilizer was used, in the dosage of 400 kg ha^{-1}.

The parameters evaluated in the soybean crop were: insertion height of the first pod, plant height, final stand ha^{-1}, mass of one hundred grains and grain productivity ha^{-1}. The evaluations were carried out at soybean harvest, performed on March 9 2017. The weight of one hundred grains and grain productivity were obtained by standardizing the grain moisture to 13%.

Sampling of the insertion height of the first pod and plant height was carried out in ten plants in each plot, and sampling of the final stand ha^{-1}, mass of one hundred grains and grain productivity was carried out in 10 m of each plot.

The pods were threshed in a mechanical thresher. After threshing, the grains were weighed and their moisture measured to calculate grain productivity. Next, one hundred grains were separated to calculate the mass of one hundred grains.

After the soybean harvest, *C. juncea* was sown, between the terraces, for seed production and also to be used as a cover plant.

On November 3 2017, a new sampling of the amount of straw in the area was carried out, using the same methodology as the previous year. The average amount of dry matter in the area was 12805 kg ha^{-1}.

The area was desiccated again on November 7 2017. Maize sowing was mechanically performed, between the terraces, in the no-tillage system on the straw of *C. juncea*, on November 24 2017, using the cultivar Dow AgroSciences 2B587 PowerCore™ at the spacing of 0.8 m and the population of 72500 plants ha^{-1}, with seeding fertilization at a dose of 315 kg ha^{-1} of the formulation 08-28-16.

On December 11, 2018, the first topdressing fertilization was carried out, using the fertilizer formulated 20-00-20, at a dose of 270 kg ha^{-1}.

Sowing of *U. brizantha* cultivar Marandu was carried out on December 14 2017, using 10 kg ha^{-1} of forage seeds, with a cultural value of 50%, mixed with simple super phosphate fertilizer, at a dose of 60 kg ha^{-1}, with two rows sown between the lines of the maize crop.

On December 18, 2017, the second topdressing fertilization was performed, using ammonium sulfate, at a dose of 250 kg ha^{-1}.

The parameters evaluated in the corn crop were the insertion height of the first ear, plant height, final stand ha^{-1}, number of ears ha^{-1}, mass of one hundred grains and grain productivity ha^{-1}.

The evaluations were performed at maize harvesting, which was carried out on March 27 2018. The mass of one hundred grains and the grain productivity were obtained by standardizing the grain moisture to 13% (wet basis).

Sampling of the insertion height of the first ear and plant height was carried out in ten plants in each plot, and the sampling of the final stand ha^{-1}, mass of one hundred grains and grain productivity was carried out in 10 m of each plot.

The ears were threshed in a mechanical thresher. After threshing, the grains were weighed and their moisture measured to calculate grain yield. Then one hundred grains were separated to calculate the mass of one hundred grains.

The data were submitted to the F test and the means were compared using the Dunnett test ($p < 0.05$), using the computer program Assistat [10].

III. RESULTS

The different sampling positions in relation to the planting line, under the two thinning of the eucalyptus, provided differences ($p < 0.05$) in relation to the mass of one hundred grains and grain productivity of the soybean crop and in relation to the height of plants, number of ears and mass of one hundred grains of maize crop (Tables 5 and 6).

No differences were observed regarding the insertion height of the first pod and final stand ha^{-1} of the soybean crop and, in relation to the final stand ha^{-1} of the maize crop (Tables 5 and 6).

The standard treatment, with 100% thinning of the eucalyptus, provided greater plant height in the soybean crop and greater insertion height of the first ear and higher grain productivity in the maize crop.

The sampling position at 2 m from the eucalyptus planting line under 0% thinning provided a lower mass of one hundred grains for soybean and maize crops and a lower number of ears ha^{-1} for the maize crop.

IV. DISCUSSION

The sampling position of 6 m from the eucalyptus planting line under 50% thinning provided height for maize plants and it was similar to the standard treatment, with 100% thinning. [11] also found higher height of maize plants as the distance from *Cordia oncocalyx* trees increased, in which the tallest plants were found in the treatment 4 m away from the trees, which were completely out of the canopy. They authors also mentioned that this result can be attributed to the fact that maize is a species that does not support shading [12],[13].

On the other hand, [14] found a difference in the height of the maize only at 1 m away from the stem of *Grevillea robusta* trees, where maize, in an agrosilvipastoril system, was smaller than in single cultivation.

On average, there was a reduction in grain productivity in the soybean crop by 48.4 and 37.7% with 0 and 50% thinning of the eucalyptus, respectively, in which the sampling position 2 m from the planting line, under 0% of thinning, provided a reduction of 59.0%, corroborating with [15], who also found a reduction in the productivity of soybean in agrosilvipastoral system in relation to soybean cultivation under full sun and claimed that productivity was possible related to the value of solar radiation that reached the strata formed by the soybean plants. According to [16], the intensity of shading decreases with the distance from the row of trees.

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Table 5. Soybean crop production components and grain productivity, Votuporanga, SP, 2017

Treatment	IH	PH	Stand	One hundred grains	GP
	m		ha^{-1}	g	kg ha^{-1}
0% - 2 m	0.09 |	0.65 ‖	196667 |	11.53 ‖	972 ‖
0% - 4 m	0.09 |	0.72 ‖	243333 |	12.55 |	1388 ‖
0% - 6 m	0.10 |	0.69 ‖	248333 |	12.34 |	1306 ‖
50% - 2 m	0.10 |	0.74 ‖	216667 |	12.70 |	1187 ‖
50% - 4 m	0.09 |	0.71 ‖	268333 |	12.69 |	1673 |
50% - 6 m	0.08 |	0.71 ‖	196667 |	13.50 |	1569 ‖
Standard	0.08 |	0.86 |	218519 |	13.98 |	2368 |
F test	2.1584^{ns}	11.1679^{**}	2.8446^{*}	2.0843^{ns}	5.8723^{**}
SMD	0.03	0.08	64619	2.20	743
CV	15.07	5.45	14.23	8.62	24.85

| - Not different from the standard treatment by the test of Dunnett at 5%; ‖ - Different from the standard treatment by the test of Dunnett at 5%; SMD - significant minimum difference; CV - Coefficient of variation (%); IH - Insertion height of the first pod; PH - Plant height; Stand - Final stand ha^{-1}; One hundred grains: mass of one hundred grains; GP - Grain productivity; ns - not significant; * - significant at 5% by the F test; ** - significant at 1% by the F test.

A reduction was also found in grain productivity in the maize crop of 86.3 and 57.1% with 0 and 50% thinning of the eucalyptus, respectively. The sampling position of 2 m from the planting line under 0% thinning provided a 92.3% reduction in productivity. According to [17], there is influence of the tree component, according to its distance from the row of trees in an agrosilvipastoral system, and the effect is consistent with the importance of radiation in the photosynthetic processes of the plants, especially those of the C4 cycle, such as maize.

[18] also found that the agrosilvipastoral systems used provided lower grain productivity than the agropastoral system and no-tillage system with maize cultivation in monoculture under full sun, and the maize was sown after fourteen months of planting the forest component, which had a height greater than 4.5 m.

[19] also observed higher grain productivity of maize in the central planting lines of systems intercropped with eucalyptus clones, and [20] found a drop in the yield of shaded corn plants, in comparison to those completely exposed to the sun, and mentioned that this fall was related to changes in incident photosynthetically active radiation, air temperature and CO_2 concentration, and [21], observed some reductions in photosynthetically active radiation, when the maize plants were closer to the trees, especially at sixty days after sowing, which, according to the authors, resulted in a drop in maize yield.

This highlights the need for thinning eucalyptus, with the removal of over 50% of the plants, when the intention is to carry out a new cycle of soybean and maize crops, in the renewal of pasture in an agrosilvipastoral system, with seven-year-old eucalyptus as there was a clear competition for water, light and nutrients between eucalyptus and soybean and maize crops, mainly in the sampling position at 2 m from the eucalyptus planting line.

[22] mentioned that shading and competition for nutrients and water for the tree component is likely to affect grain productivity, considering the spacing used, a fact observed in this study, where eucalyptus was 26.7 m in height, in October 2017, and according to [23], the solar radiation incident under the canopy becomes a highly determining factor for the insertion of agricultural and / or forage crops in wooded production systems.

Table 6. Production components and grain productivity of maize crop, Votuporanga, SP, 2018

Treatment	IH	PH	Stand	Ears	One hundred grains	GP
	m		ha^{-1}		g	kg ha^{-1}
0% - 2 m	0.74 ǁ	1.61 ǁ	59375 |	54167 ǁ	29.01 ǁ	705 ǁ
0% - 4 m	0.97 ǁ	1.84 ǁ	65625 |	58333 |	30.71 |	1014 ǁ
0% - 6 m	1.02 ǁ	2.03 ǁ	67708 |	55208 |	29.94 |	2018 ǁ
50% - 2 m	0.77 ǁ	1.71 ǁ	64583 |	60417 |	30.46 |	3352 ǁ
50% - 4 m	0.98 ǁ	2.01 ǁ	68750 |	62500 |	31.30 |	4086 ǁ
50% - 6 m	1.07 ǁ	2.12 |	67708 |	60417 |	31.07 |	4296 ǁ
Standard	1.13 |	2.23 |	63021 |	61458 |	30.83 |	9106 |
F Test	92.4604**	59.6764**	5.1830**	3.9933*	6.5109**	127.6661**
SMD	0.06	0.12	5760	6357	1.23	1008
CV	3.16	3.00	4.41	5.39	2.01	14.35

| - Not different from the standard treatment by the test of Dunnett at 5%; ǁ - Different from the standard treatment by the test of Dunnett at 5%; SMD - significant minimum difference; CV - Coefficient of variation (%); IH - Insertion height of the first pod; PH - Plant height; Stand - Final stand ha^{-1}; Ears - Number of ears ha^{-1}; One hundred grains: mass of one hundred grains; GP - grain productivity; ns - not significant; * - significant at 5% by the F test; ** - significant at 1% by the F test.

Since the highest grain productivity of soybean and maize crops were obtained with 100% thinning, an alternative would be to let the eucalyptus plants sprout and conduct the regrowth to carry out a new cycle with the soybean crops and of maize for pasture renewal in an agrosilvipastoral system, as [22] did not find negative effects on maize productivity intercropped with *E. grandis* x *E. urophylla* and *Acacia mangium*, in the spacing of 12 m between rows and 2 m between plants, in an agrosilvipastoral system in the first year of cultivation, possibly due to the small size of tree species until maize harvesting.

[24] also found that the total production of maize biomass intercropped with monospecific and mixed plantations of forest species did not differ between the treatments tested and mentioned that the same production between treatments can be attributed to the fact that there was no competition of forest species with maize, as maize sowing was carried out one month after planting the trees.

Another alternative for a new cycle with soybean and maize crops for pasture renewal in an agrosilvipastoral system, which should be studied, would be the thinning of alternating rows by increasing the spacing between the eucalyptus rows because [25] did not find competition with the corn crop for the Xaraés grass (*U. brizantha* cultivar Xaraés) and the mulateiro forest species (*Calycophyllum spruceanum*) in an agrosilvipastoral system. They also mentioned that maize grain productivity was not affected by the intercropping with the trees due to extensive spacing between the lines in the system (20 m), which did not promote excessive shading in the area, and also due to the characteristics of the species, which has a high crown, with elliptical vertical and a fine shape [26].

V. CONCLUSION

The thinning of up to 50% of the trees was not sufficient to reduce the influence of eucalyptus on the components of production and grain productivity of soybean and maize crops in relation to the renewal of pasture in an agrosilvipastoral system, with eucalyptus at seven years of implantation.

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