Economic analysis of sorghum consortia with forages or with dwarf pigeon pea succeeded by soybean or corn

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Abstract – The objective of this work was to determine the most economically viable integrated no-tillage crop-livestock system by intercropping sorghum with tropical forages or dwarf pigeon pea, succeeded by soybean or corn, over a two-year period. The experiment was carried out in a randomized complete block design with four replicates. The treatments consisted of forage sorghum intercropped with: 'Marandu' grass; 'Marandu' grass and dwarf pigeon pea; 'Mombaça' grass; 'Mombaça' grass and dwarf pigeon pea; and dwarf pigeon pea and single sorghum, harvested for silage in the first cut and regrowth, succeeded by soybean or corn. The following calculations were made: effective operational cost, total operational costs, gross revenues, operational income, profitability index, equilibrium price, and equilibrium productivity. These variables were determined for individual crops, as well as for the sum of the crops occupying the same area over time. The sorghum consortia with 'Mombaça' grass, with or without dwarf pigeon pea, had 18 and 14% lower productivity and profitability, respectively, than the sorghum consortia with 'Marandu' grass, with or without dwarf pigeon pea. Soybean in succession requires less chemical control of the 'Mombaça' grass than corn in succession.

Index terms: *Cajanus cajan*, *Megathyrsus maximus*, *Urochloa brizantha*, integrated crop-livestock system, no-tillage, profitability.

Análise econômica de consórcios de sorgo com forrageiras ou guandu-anão sucedidos por soja ou milho

Resumo – O objetivo deste trabalho foi determinar a opção economicamente mais viável do sistema de integração lavoura-pecuária em plantio direto, com sorgo consorciado com forrageiras tropicais ou guandu-anão, sucedido por soja ou milho, pelo período de dois anos. O experimento foi realizado em delineamento de blocos ao acaso, com quatro repetições. Os tratamentos consistiram de sorgo-forrageiro consorciado com: capim 'Marandu'; capim 'Marandu' e guandu-anão; capim 'Mombaça'; capim 'Mombaça' e guandu-anão; e guandu-anão e sorgo solteiro, colhidos para silagem no primeiro corte e na rebrota, sucedidos por soja ou milho. Os seguintes cálculos foram feitos: custo operacional efetivo, custo operacional total, receita bruta, lucro operacional, índice de lucratividade, preço de equilíbrio e produtividade de equilíbrio. Estas variáveis foram determinadas para as culturas individuais e para a soma das culturas que ocuparam a mesma área ao longo do tempo. Os consórcios de sorgo com capim 'Mombaça', com ou sem guandu-anão, apresentaram produtividade e lucratividade, respectivamente, 18 e 44% menores do que os consórcios de sorgo com capim 'Marandu', com ou sem guandu-anão. A soja em sucessão demanda menor controle químico do cultivo antecedente de capim 'Mombaça' que o milho em sucessão.

Termos para indexação: *Cajanus cajan*, *Megathyrsus maximus*, *Urochloa brizantha*, integração lavoura-pecuária, plantio direto, rentabilidade.

Introduction

Intensified monoculture systems have increased with food demand and the evolution of agricultural technology. Consequently, sustainability has decreased, and the dependence on agrochemicals has accrued (Balbino et al., 2011). Integrated no-tillage crop-livestock may break this cycle, and bring conservation benefits to agricultural production.

When there is a consortium of two grass species in an integrated crop-livestock system, forage can serve both as a food source for livestock in the winter and as

DOI: 10.1590/S0100-204X2017001000002

a producer of no-tillage straw, at the onset of the wet season. This way, weeds can be suppressed before the next grain crop is sown (Borghi & Crusciol, 2007).

Many reports have already shown the technical efficiency of grain-fodder crop consortia, a key feature of integrated crop-livestock systems (ICL), and their impact on succeeding crops. Nevertheless, few studies investigated their profitability, although ICL occupy a prominent position in agriculture (Braz et al., 2012). Martha Júnior et al. (2011) reported that the economic advantages of ICL, namely lower-production costs and price risk, can be negated by the high investment required. Therefore, the economic returns for this system depend on high-crop-livestock yield. The adoption of this system increases profitability by raising yield and lowering production costs (Balbinot Junior et al., 2009), provided only when technical, productive, and economic aspects of the crops are well understood. Crusciol et al. (2012) showed the superior efficiency and viability of ICL, when 'Marandu' grass was intercropped with early soybean, in tandem, with a late soybean consortium, because grazing time in this configuration was prolonged after harvest.

Therefore, the agricultural system planning should be based on financial analyses and simulated production scenarios because the farmer will always expect profitability, irrespective of which production system is used (Araújo et al., 2012).

The objective of this work was to determine the most economically viable integrated no-tillage crop-livestock system, by intercropping sorghum with tropical forages or dwarf pigeon pea, succeeded by soybean or corn, over a two-year period.

Materials and methods

The experiment was conducted during the 2013/2014, 2014/2015, and 2015/2016 crop seasons, in a dry farming area within the plant production sector of Fazenda de Ensino, Pesquisa e Extensão (FEPE), at Faculdade de Engenharia de Ilha Solteira, Unesp, Selvíria, MS, Brazil. The center of the plot is located at 20°20'35"S and 51°24'04"W, at 358 m altitude. The region’s climate is Aw, according to the Köppen-Geiger′s classification system, with rainy summers and dry winters. For the three years of the experiment – 2013/2014, 2014/2015, and 2015/2016 –, the annual daily averages were respectively as follows: relative humidity, 72.0, 73.5, and 78.4%; precipitation, 3.68, 3.85, and 5.84 mm; minimum temperatures at 19.8, 20.2, and 22.0°C; and maximum temperatures at 31.9, 32.4, and 33.6°C.

The soil in the experimental area is a Typic Haplorthox [Latossolo Vermelho distroférrico, according to the Brazilian Soil Classification System (Santos et al., 2013)]. Before the experiment started, the area was cultivated with cotton under conventional cultivation, in 2011/2012 and 2012/2013. In October 2013, undeformed soil samples were collected for soil physical characterization (Claessen, 1997), and deformed soil samples were collected for chemical characterization (Raij et al., 2001). Twenty random sample points were used at 0–0.20 m soil depth.

The following values were determined from the soil samples: pH ($CaCl_2$), 4.6; organic matter, 19 g dm^{-3}; H+Al, 43 mmol dm^{-3}; P (resin), 40 mg dm^{-3}; K^+, Ca^{2+}, and Mg^{2+}, 1.3, 10, and 8 $mmol_c$ dm^{-3}, respectively; base saturation (BS), 31%; macroporosity and microporosity, 0.03 and 0.38 m^3 m^{-3}, respectively; and soil density, 1.59 kg dm^{-3}.

In 2013/2014 and 2014/2015, sorghum consortia with tropical forages, with or without dwarf pigeon pea, for silage production were installed in a randomized complete block design with four replicates. Treatments consisted of forage sorghum intercropped with: 'Marandu' grass (SU); 'Marandu' grass and dwarf pigeon pea (SUG); 'Mombaça' grass (SG); 'Mombaça' grass and dwarf pigeon pea (SMG); dwarf pigeon pea (SG); and single sorghum (SS), harvested for first cut silage and regrowth. Each plot was 58.4 m^2 with seven sorghum lines, 20-m long and 0.40 m apart from each other.

Before the consortia sowing, in 2013/2014 and 2014/2015 crop seasons, weeds in the area were desiccated with glyphosate (1.56 kg ha^{-1} i.a.). Soil analysis results indicated that liming should be performed by casting 2 Mg ha^{-1} dolomitic limestone (PRNT = 85%) without incorporation.

Forage sorghum (cultivar Volumax) sowing was performed using a seeding machine with a shank-like mechanism for no-tillage, in 0.45 m spacing between rows, at the rate of 15 seed m^{-1}, and at 0.05 m depth.

Fertilizer (N-P_2O_5-K_2O 08-28-16) at 300 kg ha^{-1} was added to the sorghum seeding system. For the cover fertilization, 600 kg ha^{-1} ammonium sulfate, and 80 kg ha^{-1} potassium chloride were applied. In November

2013 and November 2014, the forage species were sown together in the same line as sorghum. Seed were deposited together with the fertilizer, so they were placed under the sorghum seed. 'Marandu' grass (*Urochloa brizantha* 'Marandu') was planted in the first and second crop seasons at 13.3 and 9.6 kg ha^{-1}, with cultural values (CV) of 36 and 50%, respectively. For 'Mombaça' grass (*Megathyrsus maximus* 'Mombaça'), seed were sown at 14.4 and 10.3 kg ha^{-1}, and the CV was of 25 and 35%, respectively.

Dwarf pigeon pea (*Cajanus cajan* 'IAPAR 43') was sown between lines immediately after sorghum and forage sowing. Planting was done together with fertilizer using a double-disc type mechanism for no-tillage at 0.45 m between rows, at 0.05 m depth, and 20 seed m^{-1}.

In both years, silages of the first cut and of 95 days after the regrowth were mechanically harvested using a JF C-120 forage harvester (twelve knives), at the physiological maturity plant stage, when grain dry matter (DM) content was 70%.

After the regrowth harvest, 'Marandu' and 'Mombaça' grasses were left in place for 90 days for straw production. Two desiccations were carried out after that period, using glyphosate (1.56 kg ha^{-1} i.a.) to resume the consortia for the next year, and to plant soybean and corn the year after that.

In 2015/2016, experimental plots previously cultivated with the consortia were divided into two equal areas and sown with either soybean or corn. Soybean ('RR Potência BM') was sown with the same seeding-fertilizer machine used in sorghum seeding, at 0.45 m intervals, with 19.6 m^{-1} seeding rate. Before sowing, seed were treated with Vitavax-thiram, and were inoculated with *Bradyrhizobium* spp. Fertilization consisted of $N\text{-}P_2O_5\text{-}K_2O$ 04-20-20 formulation applied at 300 kg ha^{-1}.

Corn ('DKB 350PRO') was sown with the same seeding-fertilizer machine used in sorghum planting at 0.45 m intervals, and at 3.3 seed m^{-1}. Seed were treated with Cropstar. Fertilization consisted of $N\text{-}P_2O_5\text{-}K_2O$ 04-20-20 application at 400 kg ha^{-1}. Cover fertilization consisted of 600 kg ha^{-1} ammonium sulfate. All fertilizations were carried out based on the recommendations of Raij et al. (1996). During crop development, weeds, pests, and diseases were controlled as necessary. Data obtained from intercropping corn, soybean, and sorghum with *U. brizantha*, *M. maximus*, and dwarf pigeon pea were subjected to the analysis of variance using the F-test, at 5% probability. Means were compared by the Scott-Knott's test, at 5% probability.

The production costs were calculated according to the methodology proposed by Matsunaga et al. (1976). Profitability indices were determined with the technique used by Martin et al. (1998). The total operational cost (TOC) was obtained from the sum of the effective operational costs (EOC), the cost of interest, other expenses, and depreciation. The EOC calculation considered expenses incurred from mechanized operations, manual operations, and inputs. The costing interest was taken as 5.5% over 50% of the EOC, while the other expenses accounted for 5% of the EOC. Linear depreciation was determined by dividing the difference between the initial and final values over the useful life of the equipment relative to the crop cycle. Gross revenues (GR) were determined by multiplying the yield and the unit sales price. The operating profit (OP) was calculated as the difference between the GR and the TOC. The profitability index (PI) represents the percentage by which the OP exceeds the GR. The equilibrium price is the quotient of the TOC and the productivity. The equilibrium productivity is the quotient of the TOC and the price. Values were obtained by consultations with rural producers in the region, local marketing establishments of agricultural products, and Agrianual… (2016). Product prices were set as R$200.00 (2013/2014) and R$210.00 (2014/2015) per megagram of sorghum silage, R$70.00 per 60 kg bag soybeans, and R$37.00 per 60 kg bag corn. Prices were based on sale season quotations for each product in its respective harvest year.

As the research was developed in an area belonging to the university, the fixed costs of the activity, such as land remuneration, pro-labor of the producer and interest of facilities, improvements, machinery, and equipment were disregarded.

Results and Discussion

The economic analysis of 1 ha sorghum consortia with tropical forages, with or without dwarf pigeon pea, in 2014/2015, is presented in Table 1. Data for the consortia installed in 2013/2014 were not tabulated because the same analytical methodology was applied to them. In 2014/2015, inputs accounted for the largest production cost (57.2% of the total operating cost). Fertilizers constituted 66% of all inputs. Rodrigues et al. (2015) also found higher inputs accounting for 85% of all expenses associated with the sorghum-'Marandu' grass consortium. Operations accounted for only 33.6% of the total operational cost. The largest amount was invested in the harvest, a sum of the first cut and regrowth (57%). Since the consortia were planted in no-tillage, there were no expenses associated with soil preparation; and silage production costs were reduced.

'Mombaça' grass seed costed 21% more to acquire than the 'Marandu' grass seed. Therefore, production costs increased for areas consorted with 'Mombaça' grass. Garcia et al. (2012) also found that the purchase price of 'Mombaça' seed was 20% higher than that of *Urochloa brizantha* seed.

Table 1. Total operational cost for one hectare of first-cut and regrowth silages, consisting of sorghum in consortium with 'Marandu' and 'Mombaça' grasses with or without dwarf pigeon pea, in the 2014/2015 growing season.

Description	Unit	Coefficient	Unit value (R$)	Amount (R$)
A-Operations				
Desiccation	HM	0.5	59.10	29.55
Scouring (Triton)	HM	1.0	53.73	53.73
Seeding				
Sorghum/forage	HM	0.7	150.43	105.30
Dwarf pigeon pea	HM	0.7	150.43	105.30
Cover fertilizer	HM	0.6	59.10	35.46
Silage harvest	HM	6.0	128.94	773.64
Silage transportation	HM	1.5	85.96	128.94
Silage compaction	HM	1.5	60.00	90.00
Subtotal A				1,321.92
Subtotal A (%)(1)				33.6
B-Inputs				
N-P-K fertilizer (08-28-16)	(kg ha^{-1})	300.0	3.37	1,011.00
Ammonium sulfate	(kg ha^{-1})	600.0	0.60	360.00
Potassium chloride	(kg ha^{-1})	80.0	1.50	120.00
Seed, sorghum	(sc ha^{-1})	18.9	18.00	340.20
Seed, 'Marandu' grass	(kg ha^{-1})	9.6	12.36	118.66
Seed, 'Mombaça' grass	(kg ha^{-1})	10.3	13.97	143.89
Seed, dwarf pigeon pea	(kg ha^{-1})	14.4	6.98	100.51
Glyphosate herbicide	(L ha^{-1})	4.0	13.97	55.88
Subtotal B				2,250.14
Subtotal B (%)(1)				57.2
Effective operational cost				3,572.06
Other expenses				178.60
Costing interest				98.23
Linear depreciation				87.33
Total operational costs				3,936.23

(1)(%) In relation to total operational costs.

Pests and diseases can compromise soybean yield and final quality. Therefore, four sprays were applied where and when needed to control rust, caterpillars, and bedbugs (Table 2). These operations increased production costs. Nevertheless, the cost of pest control for grain harvest is lower than that for seed harvest. Oliveira et al. (2015) reported an expenditure 140% higher on spraying than the harvest because seed had to be free of pathogens, and pest control should be preventive rather than curative.

To produce 1 ha corn (Table 3), 19.4 and 67.7% of the total operational costs incurred the operations and inputs, respectively. Fifty-three percent of the operational costs were invested in the harvest, and 74% of the input costs were invested in pest control products, soil-acidity amelioration, and fertilizers. Since corn is highly dependent on soil fertility for maximum yield (Costa et al., 2012), and it does not fix nitrogen, it demanded the highest fertilizer costs of the three crops studied.

Table 2. Total operational cost of the operations and inputs used in the production of one hectare of soybean, in the 2015/2016 growing season.

Description	Unit	Coefficient	Unit value (R$)	Amount (R$)
A-Operations				
Desiccation (×4)	HM	2.0	84.92	169.84
Distribution of limestone	HM	0.5	122.23	61.115
Seeding	HM	0.5	144.88	72.44
Pulverization (×4)	HM	2.0	84.92	169.84
Harvest	HM	1.0	330.95	330.95
Subtotal A				804.19
Subtotal A (%)(1)				29.5
B-Inputs				
Dolomitic limestone	(kg ha^{-1})	2.0	145.00	290.00
N-P-K fertilizer (04-20-20)	(kg ha^{-1})	300.0	1.66	498.00
Seed, soybean	(kg ha^{-1})	55.0	3.20	176.00
Glyphosate herbicide	(L ha^{-1})	7.5	6.75	50.63
Gramoxone herbicide	(L ha^{-1})	2.0	20.00	40.00
Inoculant	(L ha^{-1})	0.1	35.00	3.50
Lannate insecticide	(L ha^{-1})	2.4	19.00	45.60
Premium insecticide	(L ha^{-1})	0.16	660.00	105.60
Vitavax-thiran fungicide	(L ha^{-1})	0.2	58.00	11.60
Subtotal B				1,544.93
Subtotal B(%)(1)				56.6
Effective operational cost				2,349.11
Other expenses				117.46
Costing interest				64.60
Linear depreciation				196.74
Total operational costs				2,727.91

(1)(%) In relation to total operational costs.

The profitability indicator data are presented in Table 4. The data presented for the sorghum consortia is a sum of the 2013/2014 and 2014/2015 crop seasons. Consortia with 'Mombaça' grass had the lowest yields, whether or not dwarf pigeon pea was present. This finding may be explained by the fact that 'Mombaça' grass grows more vigorously, and competes more for resources than does 'Marandu' grass.

Although a higher-dry matter yield of fodder provides a greater amount of first cut silage, the more vigorous growth of forage may inhibit sorghum regrowth. In the present study, sorghum regrowth was suppressed by the competition with 'Mombaça' grass. In this treatment, sorghum yield was 15% lower than the mean yield of the 'Marandu' grass treatments, considering the first cut and regrowth silages.

The lower yield of the treatments with 'Mombaça' grass reduced the gross revenues and operating profits. Nevertheless, the equilibrium productivity (26.8–28.4 Mg ha^{-1}) was surpassed, and both the operating profit and the profitability index were positive (25.0–28.7%) for these treatments. For the other treatments, profits exceeded 30%. Single sorghum had the highest profitability index (41.7%), as this treatment had the lowest total operating cost because there was no expense with forage or dwarf pigeon pea involved.

Table 3. Total operational cost of the operations and inputs used in the production of 1 ha corn in 2015/2016.

Description	Unit	Coefficient	Unit value (R$)	Amount (R$)
A-Operations				
Desiccation (×3)	HM	1.5	84.92	127.38
Distribution of limestone	HM	0.5	122.23	61.12
Seeding	HM	0.7	144.88	101.42
Harvest	DH	1.0	330.95	330.95
Subtotal A				620.86
Subtotal A(%)[(1)]				19.4
B-Inputs				
Dolomitic limestone	(kg ha^{-1})	2.0	145.00	290.00
N-P-K fertilizer (04-20-20)	(kg ha^{-1})	400.0	1.66	664.00
Ammonium sulfate	(kg ha^{-1})	600.0	1.10	660.00
Seed, corn	(sc ha^{-1})	1.2	360.00	432.00
Cropstar insecticide	(L ha^{-1})	0.3	270.00	81.00
Subtotal b				2,168.50
Subtotal B (%)[(1)]				67.7
Effective operational cost				2,789.36
Other expenses				139.47
Costing interest				76.71
Linear depreciation				196.74
Total operational costs				3,202.28

[(1)](%) In relation to total operational costs.

The average yield for all soybean treatments (Table 4) exceeded the national average, of 48 bags ha^{-1} (Acompanhamento…, 2016), and their equilibrium productivity, which resulted in operating profits greater than R$1,000.00, and mean profitability indices were higher than 25%. Soybean preceded by sorghum intercropped with *U. brizantha* and dwarf pigeon pea was the most productive treatment. It showed 39.9% profitability, as opposed to 27.7% for soybean preceded by sorghum intercropped with dwarf pigeon pea.

Plots sown with forage (in the year antecedent to those without forage) had higher yields and profitability indices in their consortia. Forage has added straw, which conserved soil moisture and decomposed to provide nutrients for the succeeding crop.

In all treatments, corn yield exceeded the national mean of 70 bags ha^{-1} estimated by Acompanhamento… (2016) (Table 4). Corn plots preceded by sorghum intercropped with dwarf pigeon pea had the lowest yield and profitability of all treatments, as dwarf pigeon pea rapidly released nitrogen and stimulated weed growth during the corn cycle. The relatively low-population and foliage densities of corn canopies allowed sunlight to infiltrate between rows throughout the crop cycle. As a result, weed growth and grasses from the previous culture regenerated faster than they do between rows in the soybean crop. Strieder et al. (2008) studied the canopy characteristic of various corn hybrids, and found that the amount of photosynthetically active radiation reaching the soil was inversely proportional to the plant density.

Similarly, treatments preceded by sorghum intercropped with 'Mombaça' grass, with or without dwarf pigeon pea, also had lower yields, although with positive profitability. Even after two glyphosate desiccations, grass regenerated and formed clumps competing with corn in the reproductive phase, when workers could not enter the area to apply chemical control.

Oliveira et al. (2011) obtained relatively high-corn yields in succession in areas with total forage control, and low-corn yields in areas with uncontrolled grass clumps. Therefore, corn and forage were competing with each other for resources.

Borghi & Crusciol (2007) studied the interaction between corn and forage in the same area. They observed that chemical control of forage using suboptimal herbicide doses was required, so that their growth and competition with corn could be reduced.

The highest yields were obtained from the previous consortium with 'Marandu' grass with or without dwarf pigeon pea. Operating profits surpassed R$1,000.00 ha^{-1} per year (Table 4). This grass species does not regenerate as fast as 'Mombaça' grass, and it produces straw that inhibits weed development. Costa et al. (2012) also observed that the yield of beans increased when they grew on straw from forages of the genus *Urochloa*.

The three-year sum of all profitability components of the crops that occupied the same area is reflected in the profitability indices presented in Figure 1. Since the species interact with each other and their environment, their economic metrics should be interpreted together to determine whether the system is profitable as a whole.

Whether the succeeding crop was soybean or corn, the least profitable areas were those with 'Mombaça' grass consortia with or without dwarf pigeon pea. Since the grasses regenerated during the corn cultivation, competition occurred between species, and these areas were less profitable than those with the same treatments preceding soybean, whose canopies inhibited grass regrowth by excluding light. In addition, herbicides could be used during soybean development because the planted cultivar, RR, is tolerant to glyphosate.

The highest profitabilities were obtained for soybean and corn preceded by sorghum intercropped with

Table 4. Sum of dry matter yield (DMY) of the first cut, regrowth, and grain yield, gross revenues (GR), total operating cost (TOC), operating profit (OP), profitability indices (PI), and balancing points of productivity (ProE) and price (PriE) of the consortia for the silage production (sum of the 2013/14 and 2014/15 crop seasons), succeeded by soybean or corn[1].

Treatment[2]	DMY (Mg ha^{-1})	Grain yield[3] (bags ha^{-1})	GR	TOC	OP	PI (%)	ProE (Mg ha^{-1})	PriE (R$)
				(R$ ha^{-1})				
SUG	48.6	-	9,938.00	5,891.87	4,046.13	40.7	28.1	121.23
SU	42.8	-	8,797.00	5,569.26	3,227.74	36.7	26.5	130.12
SMG	38.9	-	7,950.00	5,959.92	1,990.08	25.0	28.4	153.21
SM	38.7	-	7,904.00	5,637.31	2,266.69	28.7	26.8	145.67
SG	40.3	-	8,270.00	5,645.07	2,624.93	31.7	26.9	140.08
SS	44.4	-	9,124.00	5,322.45	3,801.55	41.7	25.3	119.87
Mean	42.3	-	-	-	-	-	-	-
CV (%)	13.3	-	-	-	-	-	-	-
				Soybean as the last crop				
SUG	-	64.9	4,542.48	2,727.91	1,814.57	39.9	39.0	42.04
SU	-	60.2	4,211.08	2,727.91	1,483.17	35.2	39.0	45.35
SMG	-	59.9	4,190.46	2,727.91	1,462.55	34.9	39.0	45.57
SM	-	63.4	4,436.08	2,727.91	1,708.17	38.5	39.0	43.05
SG	-	53.9	3,774.00	2,727.91	1,046.09	27.7	39.0	50.60
SS	-	54.8	3,834.25	2,727.91	1,106.34	28.9	39.0	49.80
Mean	-	59.5	-	-	-	-	-	-
CV (%)	-	9.7	-	-	-	-	-	-
				Corn as the last crop				
SUG	-	125.5a	4,643.50	3,202.28	1,441.22	31.0	86.5	25.52
SU	-	120.6a	4,462.50	3,202.28	1,259.92	28.2	86.5	26.55
SMG	-	95.2b	3,522.40	3,202.28	320.12	9.1	86.5	33.31
SM	-	90.7b	3,355.90	3,202.28	153.62	4.6	86.5	35.31
SG	-	83.3b	3,082.10	3,202.28	-120.18	-3.9	86.5	38.44
SS	-	101.4b	3,751.80	3,202.28	549.52	14.6	86.5	31.58
Mean	-	102.8	-	-	-	-	-	-
CV (%)	-	16.5	-	-	-	-	-	-

[1]Values followed by different letters differ significantly, by the Scott-Knott´s test, at 5% probability. [2]Sorghum consortia: SUG, with *Urochloa brizantha* and *Cajanus cajan*; SU, with *U. brizantha*; SMG, with *Megathyrsus maximus* and *Cajanus cajan*; SM, with *M. maximus*; SG, with *Cajanus cajan*. SS, single sorghum. [3]Bags of 60 kg. **and*Significant at 1 and 5% probability, respectively.

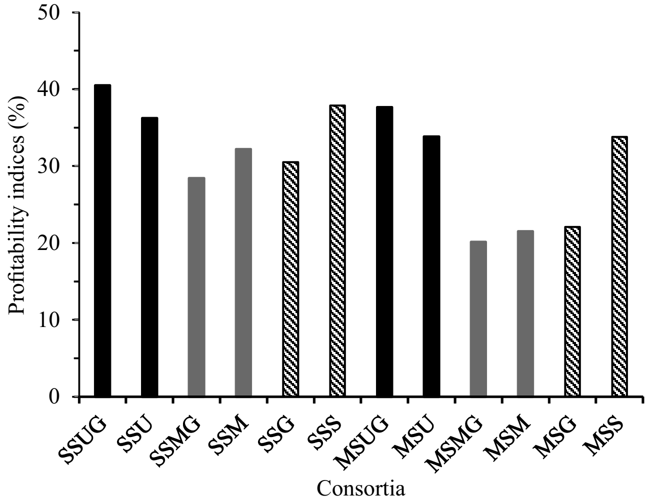

Figure 1. Sum of the profitability indices of all crops that occupied the same area in the 2013/2014, 2014/2015, and 2015/2016 crop seasons. Sorghum consortia: SUG, with *Urochloa brizantha* and *Cajanus cajan*; SU, with *U. brizantha*; SMG, with *Megathyrsus maximus* and *Cajanus cajan*; SM, with *M. maximus*; SG, with *Cajanus cajan*. SS, single sorghum. When preceded by: S, soybean as last crop; M, corn as last crop.

'Marandu' grass and dwarf pigeon pea because grass produced straw, and legume increased the nitrogen supply.

Conclusions

1. In integrated crop under no-tillage cultivation and livestock system, the establishment of sorghum consortia with 'Marandu' grass or 'Mombaça' grass, with or without dwarf pigeon pea, are economically viable for the production of first-cut silage and regrowth in a dry farming area of Cerrado.
2. 'Marandu' grass in consortium with sorghum for first-cut and regrowth silages has economic advantages over 'Mombaça' grass in dry farming areas of Cerrado.
3. Corn in succession requires a greater chemical control of forage sown in the previous cropping than soybean in succession, in order to reduce economic losses from interspecific competition.

Acknowledgments

To Fundação de Amparo à Pesquisa do Estado de São Paulo (Fapesp, process No. 2015/06685-0), for scholarship granted.

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Received on November 28, 2016 and accepted on March 27, 2017