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Energy demand in soybean seeding on maize straw intercropped with forage

Carlos A. Chioderoli[1], Vicente F. A. Silva[2], Carlos E. A. Furlani[3], Rafael S. Bertonha[4] & Fabio A. Cavichioli[5]

[1] DENA/UFC. Fortaleza, CE. E-mail: ca.chioderoli@ufc.br (Autor correspondente)
[2] UFRA. Parauapebas, PA. E-mail: vicentedelta@yahoo.com.br
[3] DER/UNESP. Jaboticabal, SP. Bolsista de Produtividade do CNPq. E-mail: furlani@fcav.unesp.br
[4] DER/UNESP. Jaboticabal, SP. E-mail: rafabertonha@hotmail.com
[5] DER/UNESP. Jaboticabal, SP. E-mail: cavichioli2003@hotmail.com

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slippage of wheels
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ABSTRACT

The sustainability of no-tillage system is fully linked to the soil use and management, in order to use technologies that promote the accumulation of dry vegetation in the soil, but it may affect the performance of agricultural machinery. Therefore, the objective of this study was to evaluate in soybean seeding the operational performance of tractor-seeder on maize straws intercropped with *Urochloas* in different treatments. The study was conducted in a randomized block design in factorial scheme 2 x 4 + 1, with four replications, formed by two intercropped forage species and five cropping systems. The dry maize straw, *Urochloas* dry mass and total straw dry mass were determined in treatments to verify the operational performance of the machines. The results showed that the amount of straw produced by maize and *Urochloas* interferes with the slippage of the tractor's front wheels, i.e., areas with higher amount of straw promotes lower adherence of the wheel. Energy demand was not affected by amount of straw produced by the treatments, as well as fuel consumption and operational field capacity.

Palavras-chave:
sistema plantio direto
patinagem dos rodados
integração lavoura-pecuária

Demanda energética na semeadura de soja sobre palha de milho consorciado com forrageiras

RESUMO

A sustentabilidade do sistema plantio direto está ligada ao uso e ao manejo do solo com o propósito de utilizar tecnologias que promovam o acúmulo de massa seca vegetal no solo porém podem afetar o desempenho das máquinas agrícolas. O objetivo deste trabalho foi avaliar, na semeadura da soja, o desempenho operacional do conjunto trator-semeadora sobre palhadas de milho consorciado com *Urochloas* em diferentes tratamentos. A pesquisa foi instalada em blocos casualizados em esquema fatorial 2 x 4 + 1, com quatro repetições, formados pelo consórcio de duas espécies forrageiras em cinco sistemas de cultivo. A massa seca de palha do milho, massa seca de *Urochloas* e massa seca total de palha foi determinada nos tratamentos para verificar o desempenho operacional das máquinas. Os resultados demonstraram que a quantidade de palha produzida pelo consórcio de milho com *Urochloas* interfere na patinagem dos rodados dianteiros do trator, ou seja, áreas com maior quantidade de palha promovem menor aderência dos rodados. A demanda energética não é afetada pela quantidade de palha produzida pelos tratamentos tal como o consumo de combustível e a capacidade de campo operacional.

Introduction

The practice of intercropping of grain crops with tropical forages, in the summer crop, is being used by several farmers to anticipate the introduction of forage, particularly in regions where winter is dry and does not allow good development of crops in late summer, allowing the utilization of forage, for the production of straw and for installing the pasture. The no-tillage system - NTS and crop-livestock integration are management alternatives which combine maintenance and even increase production with greater rationality of inputs used (Santos et al., 2008), besides to produce large amounts of straw to the system, however it is of fundamental importance to evaluate the performance of the machines on the supply of straw.

The operational performance of the tractor on straw depends on numerous factors, related to the tractor configuration, or to the soil surface modifications arising under each production system. According to the recommendation of ASABE (2006), to obtain maximum traction efficiency, the slippage between 8 and 10% in not mobilized soils, and between 11 and 13% in mobilized soils, is considered ideal; and the mean force required per line of 1.1 kN and 2.0 kN (ASABE, 1996).

Performance evaluation of agricultural machinery is very important, especially the seeders, since one of the major barriers to full adoption of direct seeding is the difficulty in obtaining versatile and resistant seeding machines (Vale et al., 2010), and are used for different crops and soils, with the function of opening the groove, removing not much soil and straw, with good penetration and acceptable depth control, adequately covering the seeds, factors that guarantee the success of the exploration (Vale et al., 2008). Therefore, for the success of no tillage system, tractor-seeder should work synergistically because the different quantities of straw on the surface provided by the system of crop-livestock integration can cause the straw accumulation and harm other mechanisms that affect the soil, that can directly affect the operating performance of the tractor, which is the proposal of this research.

This amount of crop residue on the soil surface produced by the Santa Fé system may affect the operational performance of the agricultural machines, which should be researched more thoroughly, which is also mentioned by Maughan et al. (2009), in which there is a need for funding for further research in order to better address the consequences of crop-livestock integration in the socio-economic-environmental complex. The objective of this study was to evaluate the soybean crop, the performance of tractor-seeder on maize straws intercropped with *Urochloas* in the NTS in different types of seeding.

Material and Methods

The experiment was conducted in Jaboticabal, São Paulo state, Brazil (21° 14' S, 48° 16' W; 560 m above sea level) in crop year 2011/12. The soil is classified locally as a typical Eutropheric Red Latosol (EMBRAPA, 2006), at the time of soybean seeding, the soil had a water content of 0.36 and 0.35 kg kg^{-1}, with soil mechanical resistance to penetration (SMRP) of 1.97 and 3.16 MPa for layers of 0 - 0.10 m and 0.11 - 0.20 m, respectively. The soil bulk density and total porosity presented values of 1.48 kg dm^{-3} and 0.46 m^3 m^{-3}, respectively, in the layer of 0 - 0.20 m.

The experimental area was under NTS for 11 years, and in the last three years it was utilized for the consortium of maize with forages and soybeans in succession. The experimental design was randomized block with nine treatments in factorial scheme 2 x 4 + 1, with four replications. The treatments consisted of two species of *Urochloas* (*Urochloa brizantha* and *Urochloa ruzizienses*) in four different ways of consortium of *Urochloas* with maize + control treatment. The treatments were: maize with *Urochloa* in the seeding row, with *Urochloa* mixed with manure based on maize and deposited at 0.10 m on the side of the maize seed (MBL); maize with *Urochloa* between the rows, sown between the rows on the same day of maize seeding, with the presence of an intermediate seeding line (MBE); maize with *Urochloa* sown between the rows at the time of fertilization of maize (topdressing) in the V_4 stage (MBC); maize with *Urochloa* in the haul at the time of topdressing fertilization (MBLA); single maize (control).

The experimental plot was of 180 m^2, consisting of eight rows of maize 25 m long and 0.90 m apart, with carriers of 15 m for maneuvering of machinery and implements, and a carrier for separation of the experimental blocks. The floor area evaluated for determination of maize straw dry mass and of forage were the two central rows, with 5 m each.

In the summer harvest, the soybean crop was sown on the straw of treatments obtained in a previous experiment. The tractor 4 x 2 TDA, with maximum power of 91.9 kW (125 hp) engine, the rotation of 2300 rpm and working in the march L2, was used for soybean seeding. It presented a mass of 7000 kg (40% front and 60% rear), front tires of 14.9-24 R1, with inflation pressure of 18 psi (124 kPa), rear tires of 18.4-34 R1 with inflation pressure of 22 psi (152 kPa) and drawbar height of 0.415 m. The precision seeding tractor had seven spaced rows of 0.45 m, set to no till with straw cutting disc of 18", chisel plow operating at a depth of 0.14 m, tip of 0.027 m thick, stem of 0.01 m thick, distance from the cutting disc to stem of 0.12 m, and attack angle of 20.

The determination of the maize straw mass was obtained by weighing each plant of the floor area of the plot, discounting, after the track, the weight of the grains, resulting in a green mass of straw. For forage dry mass, the iron frame was used with an area of 0.25 m^2, collecting four sub-samples per plot in the treatments, with the forage between the rows and haul, and for seeded forages in line, 2 m of two rows of floor area of the plot was collected being the drying procedure the same as described previously, highlighting that the total straw dry mass was obtained by means of the sum of maize straw and forage, which represented the initial condition for seeding.

The values of operating parameters for the tractor-seeder were stored for a "CR23X micrologger, Campbell Scientific Company." The speed values were obtained by seeding the radar unit located on the right side of the tractor, an angle of 45° with the ground, RVS type II. The slippage of the wheel was obtained by pulse generators of S&E Ibrand; model GIDP-60-U-12V, which made converting rotary motion into electrical pulses. According to Schlosser et al. (2004) is essential to mention that if the connection between the axles is rigid, there will necessarily invariant relationships between the angular velocities of axles, however in this configuration, there may be a discrepancy kinematic between the axes, causing the theoretical variation of speed between front and rear wheels, even though the actual speeds of advancement in the front and rear axles need to be equal.

The traction force average was measured by a load cell connected to the data acquisition system. The parameter drawbar power is a function of the force in the drawbar and the operating speed (Salvador et al., 2009).

The operational field capacity was calculated according to width working of the seeding tractor and displacement speed, as Mialhe (1996). The volumetric consumption was determined by flow meter on all the experimental plots, i.e the difference between the measured amount of fuel in the input and return fuel injection pump.

The data were submitted to the F test in the Assistat Version 7.6 beta program and when necessary was performed the Tukey test ($p < 0.05$) for comparison of mean consortium, and the factorial comparison with the control (maize without intercropping) using the Dunnet test ($p < 0.05$).

Results and Discussion

The assessment of the productivity of dry straw obtained by intercropping maize with the forage was essential in order to interpret the results of operational performance on these straws, since the total dry mass of straw is the most important variable to be analyzed, because represents the initial condition for soybean planting.

According to Table 1, the maize showed higher production of dry matter on the straw of *U. ruzizienses*, which demonstrates the high adaptability of maize in this forage straw.

For treatment modality of seeding, the highest mass production of forage straw occurred in the treatment of MBE, differing significantly from the other treatments ($p < 0.05$), except for MBL, that showed similar results.

The highest MBE forage production occurs due to less competition provided by the maize when compared to other treatments, allowing fast initial development of forage and higher photosynthetic efficiency, becoming the fastest final growing, i.e., dry matter accumulation.

Data from this study agree with Jakelaitis et al. (2005) who observed in *U. brizantha* seeding systems of single or in lines and broadcast intercropped with maize, strongly influenced the forage production.

The results of Machado & Assis (2010) corroborate with that of the present study, it was concluded that the *Urochloa ruziziensis* and *Urochloa decumbens* forages, for staying in growth throughout the dry season and easily dried, might be better exploited in order to cover the soil. For mode of seeding, the increased production of forage straw occurs in the treatment of MBE, differing from the other treatments ($p < 0.05$), except for the MBL ($p > 0.05$). The highest yield of forage between the row occurs because of less competition provided by the maize when compared to other treatments, thus allowing rapid development of the initial forage and higher photosynthetic efficiency, becoming the fastest final growing, i.e., dry matter accumulation.

For the values of total dry mass of straw, it appears that there was no significant difference between treatments. These results show the condition before seeding soybean, serving as explanatory variables for the operational performance of the tractor-seeder. Mean yields of 12 Mg ha^{-1} are frequently obtained and provide full coverage of the soil, with good thickness of straw, especially when the consortium is made with maize (Crusciol et al., 2009), which can be considered sufficient for the NTS in tropical regions.

The cumulative amount of straw dry mass, regardless of the forage species and the type of consortium, was enough to supply the amount of straw that must be added annually to the soil surface. These conditions are essential to direct seeding to have full conditions to express its potential.

The results of dry matter comparing the maize without intercropping (control) with the consortium treatments are shown in Table 2. For dry matter forage the values differ from the control of all other treatments ($p < 0.05$), except *U. ruzizienses* broadcasted in V_4. As for total dry straw, the control differs only from *U. brizantha* in the inter row and *U. ruzizienses* on the line, having both treatments with higher straw on the surface.

The values of displacement speed and wheel slippage showed no significant differences ($p > 0.05$) between the evaluated treatments (Table 3), that can be explained by using the same work march and the engine rotation. However, it is observed that the highest values of wheel slippage were found on the front wheels, being a possible explanation for these results is the dynamic distribution of weight of the tractor (40% FW and 60% RW), which is determined by the static load on the axle, drawbar height, distance between axle and maximum force on the bar. This configuration, associated with the type of tyre, may change the advance of the front wheels, supporting the increase of slippage.

Table 1. Mean values obtained for the maize straw dry mass, dry mass of *Urochloa*, and total straw dry mass in intercropped system of *Urochloas* with maize in different modalities of seeding

Variation factors		Maize straw	*Urochloa*	Total straw
		Dry mass (kg ha^{-1})		
Forages (F)	*U. brizantha*	7222 b	3954	11177
	U. ruzizienses	8015 a	3856	11871
Seeding Modalities (M)	MBL	7941	3919 ab	11860
	MBE	6912	5408 a	12320
	MBC	7870	3525 b	11395
	MBLA	7751	2769 b	10519
F Value	F	5.82*	0.05^{NS}	0.99^{NS}
	M	2.11^{NS}	5.57*	1.22^{NS}
	F*M	1.90^{NS}	0.80^{NS}	0.60^{NS}
DMS	F	678	965	1430
	M	1280	1818	2693
CV (%)		12.05	38.31	17.62

Means followed by the same letter do not differ from each other by Tukey test at probability level of 0.05 of significance. MBL - Maize intercropped with *urochloas* on row; MBE - Maize intercropped with *urochloas* in between rows; MBC - Maize intercropped with *urochloas* on coverage on V4 stage; MBLA - Maize intercropped with *Urochloas* in haut on V_4; C – Control; NS - Non-significant; CV - Coefficient of variation (%)

Table 2. Mean values obtained for the maize straw dry mass – MSM, forage straw dry mass – MSF and straw total dry mass – MST in intercropped system of *Urochloas* with maize in different modalities of seeding

Treatments		MSM	MSF	MST
Forages	Modalities		kg ha^{-1}	
U. brizantha	Line	7209	3553 a	10732 b
U. brizantha	Interline	6713	5669 a	12382 a
U. brizantha	Cover	8020	3330 a	11349 b
U. brizantha	Broadcast in V_4	6948	3296 a	10244 b
U. ruzizienses	Line	8673	4315 a	12988 a
U. ruzizienses	Interline	7112	5147 a	12559 b
U. ruzizienses	Cover	7721	3720 a	11441 b
U. ruzizienses	Broadcast in V_4	8554	2240 b	10794 b
Maize without intercropping		8408	0.0 b	8408 b
F Value - Factorial x Control		2.57^{NS}	30.67*	8.90*
DMS		1878	2668	3953
CV (%)		12.05	38.31	17.62

^{NS} Non-significant; Means followed by the same letter of maize without intercropping (control) do not differ from each other by Dunnett test ($p < 0.05$)

Table 3. Mean values obtained for seeding speed, slippage of front (SFW) and rear wheels (SRW), mean traction force (Fm) and mean power on drawbar (PD) while operating the soybean seeding on maize straw intercropped with *Urochloas*

Variation causes		Speed (km h^{-1})	Slippage (%) SFW	Slippage (%) SRW	Fm (kN)	PD (kW)
Forages (F)	*U. brizantha*	3.52	11.67	7.40	23.92	23.38
	U. ruzizienses	3.53	11.33	7.94	22.03	21.59
Seeding Modalities (M)	MBL	3.57	12.11	7.81	21.24 b	21.02
	MBE	3.54	11.01	7.00	20.97 b	20.52
	MBC	3.48	11.33	8.27	25.42 a	24.55
	MBLA	3.52	11.55	7.61	24.26 b	23.85
F Values	F	0.06^{NS}	0.15^{NS}	2.26^{NS}	2.35^{NS}	22.23^{NS}
	M	0.54^{NS}	0.29^{NS}	2.16^{NS}	3.23*	2.81^{NS}
	F*M	1.20^{NS}	2.65^{NS}	0.95^{NS}	0.91^{NS}	1.22^{NS}
DMS	F	0.10	1.77	0.74	2.54	2.48
	M	0.19	3.40	1.40	4.44	4.68
CV (%)		4.07	21.16	13.23	15.22	15.19

Means followed by the same letter do not differ from each other by Tukey test at level of 0.05 of significance. MBL - Maize intercropped with *urochloas* on row; MBE - Maize intercropped with *urochloas* in between rows; MBC - Maize intercropped with *Urochloas* on coverage on V4 stage; MBLA - Maize intercropped with *Urochloas* in haut on V_4; C – Control; NS - Non-significant; CV - Coefficient of variation (%)

For the power values in the drawbar (Table 4) did not differ for the studied treatments, however for traction force there was no difference between treatments ($p < 0.05$) demonstrating that the MBC provided higher energy demand of the tractor-seeder, i.e., in the greatest effort of all elements to make the cut of straw, seed and fertilizer distribution (Table 3). These results are attributed to the straw that not anchored when subject to etiolation due to the MBC mode, ie, the forage do not promote uniform coverage of the soil directly affecting the active parts of the seeder, reflecting the increase in energy demand.

The results for mean traction force on the drawbar were 3.28 kN per line for the forage treatment and modalities of seeding, above the mean of the values proposed by the ASABE (1996), ranging from 1.1 kN to 2.0 kN, as those found by Silveira et al. (2011), who found values of 2.42 kN to 2.61 kN, depending on the displacement speed. Cepik et al. (2010), working with doses of residues of 0-6 Mg ha^{-1}, obtained no difference in the values of force demanded on the stems in different doses in the operation with five planting rows, in which case it may be mentioned that the amount of waste do not affect the demand for power by the plow. Similar results were found by Kamimura et al. (2009), working with performance of the seeder fertilizer with manure at two depths (0.06 and 0.12 m), observed that the traction force was not influenced by the levels of plant residues (0-6 Mg ha^{-1}) used in the treatments. However, the margins of these authors are well below those found in this study.

Table 4. Mean values obtained for seeding speed – V (km h^{-1}), slippage in percentage of front (PRD) and rear wheels (PRT), mean traction force – FT (KN) and mean power on drawbar – PB (kW) in the consociation system of *Urochloas* with maize in different modalities of seeding

Treatments Forages	Treatments Modalities	V	PRD	PRT	FT	PB
U. brizantha	Line	3.63	10.35	7.23	21.61	21.79
U. brizantha	Interline	3.54	12.59	7.23	23.13	22.66
U. brizantha	Cover	3.47	11.69	7.92	27.08	26.13
U. brizantha	Broadcast in V_4	3.45	12.03	7.22	23.85	22.94
U. ruzizienses	Line	3.50	13.87	8.39	20.87	20.26
U. ruzizienses	Interline	3.55	9.44	6.76	18.81	18.38
U. ruzizienses	Cover	3.48	10.97	8.61	23.77	22.97
U. ruzizienses	Broadcast in V_4	3.60	11.07	8.00	24.67	24.75
Maize without consociation		3.42	10.97	7.92	22.23	21.20
F Value - Factorial x Control		1.92^{NS}	0.17^{NS}	0.22^{NS}	0.16^{NS}	0.51^{NS}
DMS		0.29	4.90	2.06	7.04	6.86
CV (%)		4.07	21.16	13.23	15.22	15.19

^{NS} Non-significant

The effective field ability showed and power consumption no difference ($p > 0.05$) for the studied treatments, as well as the values of volumetric and operational consumption, which requires that the different conditions of straw on the soil surface at seeding, does not affect these variables (Table 5).

Table 5. Mean values obtained for volumetric consumption, effective field capacity (EFC) and specific consumption in soybean seeding operation on maize straw intercropped with *Urochloas*

Variation factors		Consumption (L h^{-1})	EFC (ha h^{-1})	Specific consumption (kW h ha^{-1})
Forages (F)	*U. brizantha*	15.2	1.10	28.12
	U. ruzizienses	15.0	1.11	25.90
Seeding Modalities (M)	MBL	15.1	1.12	24.97
	MBE	15.2	1.11	24.65
	MBC	15.0	1.10	29.89
	MBLA	15.1	1.11	28.52
F Values	F	0.38^{NS}	0.06^{NS}	0.90^{NS}
	M	0.07^{NS}	0.61^{NS}	1.25^{NS}
	F*M	0.06^{NS}	1.35^{NS}	0.35^{NS}
DMS	F	0.58	0.03	4.78
	M	1.09	0.06	9.00
C.V. (%)		5.28	3.83	24.49

MBL - Maize intercropped with *Urochloas* on row; MBE - Maize intercropped with *Urochloas* on between rows; MBC - Maize intercropped with *Urochloas* on coverage on V_4 stage; MBLA - Maize intercropped with *Urochloas* in haut on V_4; C – Control; NS - Non-significant; CV - Coefficient of variation (%)

Comparing the control with the other treatments, the results show that (Tables 4 and 6) there was no significant difference ($p > 0.05$) among the studied treatments. These results are due to even distribution of straw from the tractor and the straw anchored to the forage, which increases the traction coefficient without affecting operational performance and energy. They are considered positive results, because it is possible to make the consortium for straw production without affecting the operational parameters of the machines. The volumetric consumption confirms the results presented by Gabriel Filho et al. (2010), who found values of 14.3 L h^{-1} working at speed of 4 km h^{-1} with set force of 25 kN provided by the Mobile Drawbar Test Unit (UMEB). The operational field capacity (Table 6) is close to values found by Santos et al. (2008), who worked in clay Oxisol with tractor seeder of four lines at a speed of 4.9 km h^{-1}, but the consumption found in this study was higher.

According to Franzluebbers (2007), the results of this system reflect on advances in aspects of technology, management, productivity and profitability increase. The lower

Table 6. Mean values obtained for volumetric consumption - CH (L h^{-1}), effective field capacity - CCE (ha h^{-1}) and specific consumption - CE (kW h ha^{-1}) evaluated from the treatments of maize intercropping with forage and maize without intercropping

Treatments		CH	CCE	CE
Forages	Modalities			
U. brizantha	Line	15.21	1.14	25.41
U. brizantha	Interline	15.22	1.11	27.19
U. brizantha	Cover	15.10	1.10	31.84
U. brizantha	Broadcast in V_4	15.30	1.08	28.04
U. ruzizienses	Line	15.10	1.10	24.53
U. ruzizienses	Interline	15.16	1.12	22.11
U. ruzizienses	Cover	14.94	1.10	27.94
U. ruzizienses	Broadcast in V_4	14.92	1.13	29.00
Maize without intercropping		14.89	1.08	26.14
F Value - Factorial x Control		0.28 NS	2.17 NS	0.06 NS
DMS		1.60	0.08	13.22
CV (%)		5.28	3.83	24.49

NS Non-Significant

adhesion of the wheels on the soil surface with increasing amount of straw did not affect the other operating and energy parameters, which concludes that it is possible to use the technology of crop-livestock integration because it provides through the system of succession/rotation an increase of vegetal straw on soil, with function of making it vertical and making sustainable the agricultural productivity.

Conclusions

1. The cumulative amount of straw dry mass, regardless of the forage species and the type of consortium, was enough to supply the amount of straw that must be added annually to the soil surface.

2. Despite the higher traction force required in maize intercropped with Urochloas on coverage on V_4 stage, did not affect the effective field capacity and volumetric consumption, operational characteristics important in the planning of agricultural activities and costs.

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