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What are the effects of irrigation rates and cropping systems on the soybean agronomic traits?

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ABSTRACT

The irregularity and uneven distribution of rainfall may restrict the potential productive development of soybeans, causing numerous losses to farmers. The use of irrigation systems in hydrically heterogeneous areas are important measures that should be adopted during the crop cycle. Furthermore, the implementation of conservationist strategies, such as crop rotation or intercropping and no-till (NT) farming systems, can minimize the damage caused by water deficit. Therefore, the present study aimed to evaluate the soybean yield under different irrigation sheets and cropping systems in the extreme west of São Paulo. A completely randomized design was used, with 10 repetitions, in a subdivided plot scheme. The treatments were composed of different cropping systems in the plots, with four levels (conventional system; NT, using *Urochloa brizantha* cv Paiaguás; *U. brizantha* cv Piatã; and *U. ruziziensis* cv Ruziziensis), and different irrigation scheduling in the subplots, with three levels of irrigation scheduling (0%, 70% and 100%) based on reference evapotranspiration (ETo). Irrigation rates of 70% and 100% ETo in the conventional system provided higher grain yields under the climatic conditions in which the experiment was conducted. However, the continuity of long-term research is necessary, since NT is incipient, and have been implemented only two years ago. This is a relatively short period to observe the advantages of this cultivation system and for its consolidation process. Thus, the *Brachiaria* residual dry mass showed similar behavior in NT at the irrigation levels evaluated.

KEYWORDS: No tillage system, water deficiency, soil conservation.

INTRODUCTION

The cultivation of soybeans [*Glycine max* (L.) Merril], considered an important worldwide commodity, has grown significantly in recent years. According to FAO data (2020), world soybean production in 2019 reached 333.6 million tons in a planted area of 120.5 million hectares, a different scenario from ten years ago, where production was established at 223.3 million tons with an area of 99.3 million hectares. Despite the substantial growth in soybean cultivation, some climatic factors, such as irregularity and the uneven distribution of the rainfall regime, can intensely restrict its potential productive development, causing numerous losses to farmers (MORANDO et al., 2014). According to Mantovani, Bernardo and Palaretti (2009), the use of irrigation systems in hydrically heterogeneous areas are important measures that should be adopted during the crop cycle. Furthermore, through these practices, it is possible to prevent grain yields from decreasing.

However, the maximization of soybean yield through irrigation is only possible with the proper management of hydraulic systems. Applying water uniformly, efficiently and timely are important principles that should be taken into account to minimize laminar erosion caused by hydraulic kinetics, fertilizer waste, phytosanitary problems (excessive irrigation) and frequent labor need (FIOREZE et al., 2011; BRYANT et al. 2017). According to Viçosi et al. (2017), the water deficit at the beginning of the soybean cycle powerfully reduces the emission of new branches, which makes it substantially difficult to establish the crop in the short term. During soybean development, the need for water increases, reaching the maximum point (7 to 8 mm day^{-1}) between the phenological stages of flowering and crop filling, followed by a decrease (OLIVEIRA et al., 2007). During these stages, the water deficit can considerably alter the morphophysiological health of the plant, promoting stomatic closure and leaf winding and, as a consequence, the premature fall of leaves, flowers and pods (EMBRAPA, 2011).

The use of edapho-conservationist strategies associated with crops irrigation management, enhance the productivity of agronomic crops and improve simultaneously all the physical, chemical and biological attributes of the soil (CASALI et al., 2016; MORAES et al., 2016).

Conservation strategies, such as crop-livestock-forest integration; green fertilization; cultivation in plots; succession, rotation or intercropping; and mainly no-tillage system, can minimize the damage caused by water deficit.

The no-tillage system is based on the cultivation of agronomic crops in soils with vegetation cover. This type of system has as main characteristic the reduction of the negative impact of agricultural operations on soil and plant, mainly of machinery and phytotoxic substances in the environment (REICHARDT et al., 2009; LEITE et al., 2010).

The no-tillage system has multiple benefits when compared to conventional cultivation, such as long periods of soil water retention and storage; good penetration and development of the root system of the plant; improvement of edafo chemical biological physical quality and; diversification of crops through intercropping or crop rotation (DERPSCH et al., 2010; MENDONÇA, 2012).

According to Richart et al. (2010), crop rotation consists of alternating, in an orderly manner, different plant species in the same productive area, thus avoiding the development of pests and diseases. These species can be: white oat (*Avena sativa*), black oat (*Avena strigose*), millet (*Pennisetum glaucum*), lupin (*Lupinus albus* L), sunflower (*Helianthus annuus*) and mainly forage of the *Urochloa* genus. Forages have vigorous and deep roots, allowing them to absorb nutrients from the deepest layers of the soil. In addition, they have tolerance to water deficit and are adapted to unfavorable environments for most grain-producing crops (CORREIA et al., 2013).

Thus, the consortium of forages in sustainable cultivation systems, such as the no-tillage system, beyond providing the maintenance of the adequate amount of straw on the soil surface throughout the year, alters the dynamics and cycling of nutrients, providing great yield of substitute crops (CORREIA and DURIGAN, 2008; CRUSCIOL et al., 2009). The greatest limitation for the sustainability of the NT in most of the State of São Paulo and Central Brazil is the low straw production in the autumn/winter and winter/spring period, due to the low water availability, characterized by dry winter (CRUSCIOL et al., 2009). Thus, many areas in these regions are idle for seven months of the year and with low vegetation cover, compromising the viability and sustainability of the NT (BARDUCCI et al., 2009).

Furthermore, the soil of the Far West region of São Paulo is very sandy and of low fertility. It presents limitations for the cultivation of plants due to the low content of organic matter and clay present, which are essential factors for its structure and physical, chemical and biological organization (ALMEIDA et al., 2014). Thus, this study aimed to evaluate the yield of soybean grain under different irrigation sheets and cultivation systems in the Far West of São Paulo.

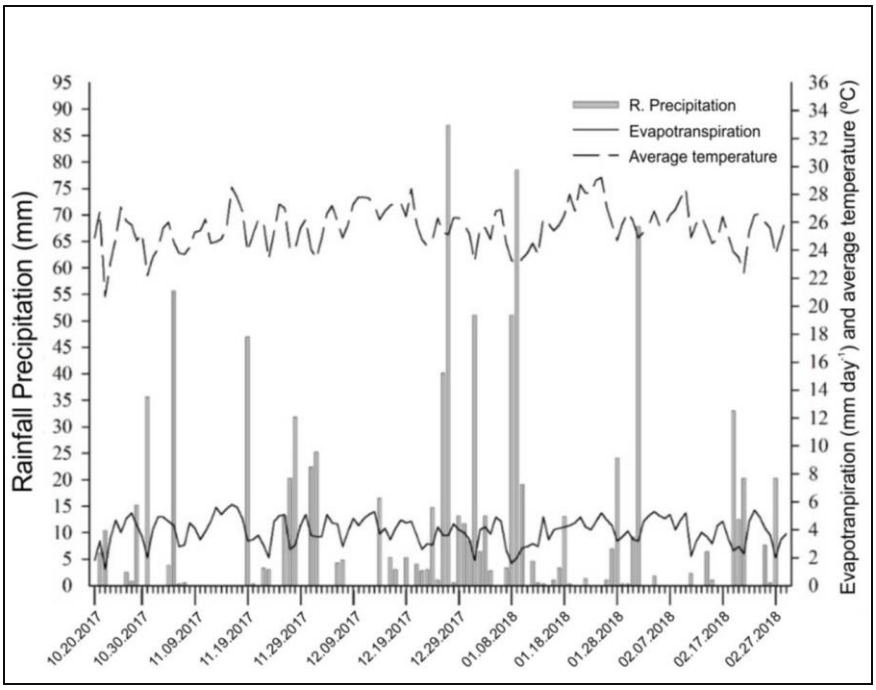
MATERIAL AND METHODS

Experimental Methodology

The experiment was conducted in the 2017/2018 summer harvest in the Irrigated Experimental Area of São Paulo State University (Unesp), College of Agricultural and Technological Sciences, located in the municipality of Dracena - SP, with geographic coordinates: Latitude 21°27' S and Longitude 51°33' W and average altitude of 400 m. According to the

Köppen classification, the predominant weather of the region is AW type, categorized as subtropical humid, with hot and rainy summer from October to March, dry winter and mild rainfall from April to September. The average annual climatic data are based on: 23.97°C of temperature, 64.23% relative humidity and 1261 mm year^{-1}rainfall. Details related to climatic events during the experimental period are presented in Figure 1.

Figure 1: Climatic behavior: rainfall (mm), reference evapotranspiration (mm) and average air temperature (°C).



Source: Author data (2018).

The soil of the experimental area was classified as Dystrophic Red-Yellow Argisol (SANTOS et al., 2018). A chemical analysis of the soil was performed in September/2018, at a depth of 0.0 to 0.20 m (Table 1), in order to indicate the necessary amount of fertilizers used during sowing. The fertilizations were defined according to the expected productivity of the soybean crop.

Table 1. Chemical characterization of the soil of the layer 0.00 - 0.20 m performed using a composite sampling of the experimental area.

pH	MO	P	K	Ca	Mg	Al	H+Al	SB	CTC	V
$CaCl_2$	(g dm^{-3})	(mg dm^{-3})	------------------ (mmol$_c$ dm^{-3}) -------------------							(%)
4.9	14	8	5.0	14	9	2	22	28.0	50.0	56

Source: Author Data (2018)

The experiment began with the forage desiccation. Then, *Urochloa ruziziensis cv Paiaguás, U. brizantha cv Piatã* and *U. brizantha cv Ruziziensis* intercropped with off-season corn from the previous harvest (in 2017) were dried. The straw intake from previous harvest aimed at sustainability and viability of the no-tillage system. The sowing was performed by applying 2 kg ha^{-1} of Glyphosate Ammonium Salt (792.5 g kg^{-1}). After desiccation, soybean was sowed using the 3730 Agroeste variety under the residual straw of corn and forage. Furthermore, sowing was performed in a conventional system (soil without the straw presence).

The experimental unit was composed of 5 lines of 5 m in length spaced at 0.45 m. The 3 central lines were evaluated with 2 meters in length, obtaining a useful area of 2.7 m^2.

The pests control, such as soybean caterpillar (*Anticarsia gemmatalis*); small green bedbug (*Piezodorus guildinii*); brown bedbug (*Euschistus heros*), was performed by applying the Engeo-pleno S (tiametoxan 141 g L^{-1} 14,1% m v^{-1}) at a dose of 200 mL ha^{-1} between phenological stages V3 and R2, and also by applying the Connect SC (imidacloprid, 100 g L^{-1} to 10.0% m v^{-1} active ingredient – a.i) at a dose of 800 mL ha^{-1} at phenological stages R5 and R7. Preventive control of Asian rust *(Phakopsora pachyrhizi)* was performed with two applications of the Elatus WG (azoxistrobin, 300 g kg^{-1} to 30% m.m^{-1}), at a dose of 800 mL ha^{-1} between the phenological stages V5 and R3. The applications were performed with spray tank coupled to the tractor, calibrated to the volume of 240 L ha^{-1}. The application of 1.2 kg ha^{-1} of Glyphosate Ammonium Salt (792.5 g kg-1) was performed in the V4 phenological stage in order to control weed infestation. The recommendation regarding the need of irrigation was defined based on the methodology proposed by Allen et al. (1998). According to the authors, the reference evapotranspiration (ETo) can be calculated from the meteorological data of air temperature (ºC), relative humidity (%), wind speed (m s^{-1}) and solar radiation (MJ m^{-2}) obtained from the Campbell Scientific CR10X Meteorological Station, installed at FCAT - School of Agrarian and Technological Sciences of the São Paulo State University - UNESP. Irrigation management was based on reference evapotranspiration (ETo). The irrigation system used was the conventional sprinkler, composed of 3 lines with 6 sprinklers, spaced at 12 x 12 m between the lines, with a sheet of 4.0 mm h^{-1} and service pressure of 2.0 bar, with irrigation time variable as a function of crop evapotranspiration (Etc), being performed in a fixed irrigation shift of 4 days. Crop evapotranspiration was obtained from the multiplication of daily ETo and crop coefficient (Kc) in their respective phenological stages.

Experimental design

A completely randomized design was used in a split plot scheme with 10 repetitions. The treatments were composed of different cultivation systems, in the plots, with four levels (conventional system; NT using *Urochloa brizantha cv Paiaguás; U. brizantha cv Piatã;* and *U. ruziziensis cv Ruziziensis),* and different irrigation sheets, in the subplots, with three levels [0% (dryland), 70% and 100%].

Analyzed traits

There acquired by manual harvesting were randomly taken from the experimental units. Thereafter, they were dried at room temperature and then the mechanical threshing was performed using a 150 HP threshing machine (Vencedora MaqTron). The following agronomic parameters were evaluated: plant height (cm), insertion height of the first pod (cm), total pod numbers (plant $pods^{-1}$), grain yield estimate (kg ha^{-1}), final stand (plant number m^{-1}), dry mass of soybean straw (kg ha^{-1}), residual dry mass of forage straw (kg ha^{-1}) and dry mass of total residual straw (kg ha^{-1}).

The plant height and insertion height of the first pod was performed using a measuring tape. Then, the numbers of total pods in each plant were quantified.

The estimated grain yield was performed according to the methodology described by Brazil (2009), in which the natural wet mass of the plots was corrected for the wet basis of 13%. The final stand estimate was determined by the amount of plants in the area during harvest.

The same plants used to estimate grain yield were used to determine the soybean straw residual dry mass (kg ha^{-1}). Three plants were randomly selected, which were dried in a forced air ventilation oven for 72 h at 65°C to determine the moisture content.

The residual dry mass of forage straw (kg ha^{-1}) was estimated on the same day of soybean harvest. For this determination, an square structure of known area (0.5 m^2), made of iron was randomly positioned within the plots, in order to obtain a sub sample. The forages were carefully collected using a sieve; then, they were sifted and placed in paper bags. Subsequently, a sample of 100 g of forages was taken and placed in the forced air ventilation oven for 72 h at 65°C to determine the moisture content. From this result, it was possible to estimate the dry mass of *Brachiaria* residual straw. The dry mass of total residual straw was obtained by the sum of the dry mass of soybean residual straw and dry mass of *Brachiaria* residual straw.

Statistical analysis

The data were submitted to variance analysis and Tukey test ($p \leq 0.05$), using the R software, version 4.1.0 (R CORE TEAM, 2021).

RESULTS AND DISCUSSION

The results of the variance analysis for the evaluated traits are presented in Table 2. A significant effect of the interaction between the factors (cultivation system × irrigation sheets) was observed for all variables analyzed, except for insertion height of the first pod.

Table 2. Analysis of variance of grain yield (GY), number of pods (NP), plant stand (PS), plant height (PH), first pod insertion height (FPIH), soybean residual dry mass (SRDM), *Brachiaria* residual dry mass (BRDM) and total residual straw (TRS).

		MS			
SV	**DF**	**GY**	**NP**	**PS**	**PH**
Cultivation systems	3	3554314^{***}	579.39^{**}	1.4302^{ns}	8912409^{***}
Error (a)	36	190979	70,57	3,0159	986258
Irrigation sheets	2	3694836^{***}	79.77^{ns}	4.9136^{ns}	49811736^{***}
Interaction	6	985228^{*}	311.53^{*}	6.7928^{**}	3338687^{***}
Error (b)	92	483372	112.95	2.2097	506179
CV 1 (%)	-	9.88	14.91	17.11	21.94
CV 2 (%)	-	15.72	18.86	14.65	15.72

		MS			
SV	DF	FPIH	SRDM	BRDM	TRS
Cultivation systems	3	97.187***	494476**	29325072***	188.14*
Error (a)	36	10.666	899475	160752	57.98
Irrigation sheets	2	4.853ns	1390129ns	18711627***	2046.59***
Interaction	6	17.316 ns	234267ns	2233706***	288.96***
Error (b)	92	11.101	651195	146618	61.01
CV 1 (%)	-	16.40	28.7	27.07797	7.114084
CV 2 (%)	-	16.40	24.40	27.08	7.30

Source of variation (SV); coefficient of variation (CV); mean square (MS); degree of freedom (DF). ns - not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Source: Author data (2018).

According to the data in Table 3, the irrigation sheet of 0% ETo showed no statistical difference between the cultivation systems. The irrigation sheet of 70% ETo presented the highest grain yield value with the conventional system, providing increases of 24% in relation to the average of the values observed with the treatment levels in PS, for this characteristic. On the other hand, the irrigation sheet of 100% ETo performed in the conventional system provided higher values when compared to the NT *with U. brizantha* cv Paiaguás, but did not differ statistically from the NT with *Urochloa brizantha* cv Piatã and *U. ruziziensis* cv Ruziziensis.

Table 3. Results of the Tukey test for pairwise mean comparisons regarding the traits of grain yield (RG), total number of pods (NV), final stand (EF) and plant height (PA).

Irrigation sheet	Cultivation systems			
	Conventional	Paiguás	Piatã	Ruziziensis
		RG (Kg ha^{-1})		
0%ETo	4213 b	4084	3889 b	4286
70%ETo	5511 Aa	4083 B	4278 Bab	4159 B
100%ETo	5553 Aa	4138 B	4897 ABa	4516 AB
		NV (plant pods^{-1})		
0%ETo	58.6	51.0	57.9	54.2
70%ETo	49.6	61.0	61.2	50.8
100%ETo	60.9 AB	50.6 B	68.4 A	52.0 B
		EF (plants m^{-1})		
0%ETo	10.6	8.9 b	10.2	10.4 ab
70%ETo	9.7	10.9 a	9.7	9.0 b
100%ETo	10.9	10.7 a	9.6	11.0 a
		PA (cm)		
0%ETo	99.8 Ab	101.4 Ab	104.8 A	89.3 Bb
70%ETo	103.6 Bab	114.9 Aa	112.7 A	110.3 ABa
100%ETo	110.3 a	111.3 a	110.3	116.1 a

The mean values followed by the same letter do not differ by the Tukey test ($p<0.05$). Uppercase letters were used for means compared in rows, while lowercase letters were used for means compared in columns.

The results observed in the conventional cultivation system with irrigation sheets of 70% and 100% ETo may be associated with intermediate grading performed to uncompact the soil surface, since this practice allows better development of the root system of the crop.

According to Moraes et al. (2020), soils with compacted surface layer reduce soybean yield by 15%, due to the difficulty of crop rooting. Similar results were verified by other authors. Carvalho et al. (2004) verified that the conventional system provided higher soybean grain yield compared to the no-tillage system in the year in which normal precipitation occurred in succession to green fertilizers in Cerrado soil for two consecutive years. Santos et al. (2015) also found that conventional systems were better than the no-tillage for the soybean yield. Calonego et al. (2017) concluded that the conventional cultivation system provides better immediate results in soil structure and soybean yield, but such benefits do not last until the second year. Furthermore, the beneficial effect of cover crops was observed in the medium and long term, leading to soybean yield equal to or greater than conventional cultivation. Also, in the long term, the use of cover crops improves soil structure in deeper layers compared to conventional cultivation.

It is noteworthy that although the highest grain yield was verified with the conventional system using the irrigation sheets of 70% and 100% ETo, the no-tillage system becomes consolidated approximately between the 9th and 10th year of its implantation (NETO et al., 2007); and then provide all the benefits inherent to this cultivation system (BRANCALIÃO; MORAES, 2008; CALONEGO et al. 2017; DEIMLING et al. 2019).

In the cultivation systems, it was observed that the irrigation sheets of 70% and 100% ETo were the ones that provided the highest grain yield for the conventional system. On the other hand, a different response was verified in the no-tillage, and the irrigation sheet of 100% ETo with the *Urochloa brizantha* cv Piatã, provided the highest value for the grain yield when compared to the irrigation sheet of 0% ETo (seed); however, it did not differ from the irrigation sheet of 70% ETo. *U. brizantha* cv Paiaguás and *U. ruziziensis* cv Ruziziensis showed no statistical difference for the different irrigation sheets.

The lowest grain yield observed in the irrigation sheet of 0% ETo (dryland) may have been caused by the low availability of moisture in the soil, comprised by two periods of water deficit, referring to the vegetative and reproductive phenological stages, considered critical for soybean.

The water supply is important for soybeans, even during the rainy season, because the occurrence of hot summers can compromise the physiological activities of the vegetable and, consequently, reduce grain yield (SANTOS et al. 2015; MORAES et al., 2016).

For the total number of pods, the conventional system and the no-tillage system showed no statistical difference in the irrigation sheets of 0% and 70% ETo. In the irrigation sheets of 100% ETo, the conventional system and the no-tillage with *Urochloa brizantha* cv Piatã did not differ statistically for total number of pods. However, the *Urochloa brizantha* cv Piatã showed higher values for this trait when compared to *U. brizantha* cv Paiaguás and *U. ruziziensis* cv Ruziziensis. Neves et al. (2018) verified that higher yields of *U. ruziziensis* in the no-tillage system offer exceptional persistence of dry mass on the surface in tropical climate regions, besides providing greater nutrient cycling for subsequent crops in the no-tillage. Gazola et al. (2017) observed that there was no significant difference in the cultivation systems in relation to plant height, first pod insertion height, number of pods per plant and mass of one hundred soybean grains.

The plant final stand showed no statistical difference between the cultivation systems. The irrigation sheets did not influence the conventional system and NT with *Urochloa brizantha* cv Piatã. However, a significant effect of irrigation sheets was detected among the other cultivation systems. The NT with *U. brizantha* cv Paiaguás using the irrigation sheet of 70% and 100% ETo presented higher values in relation to the irrigation sheet of 0% ETo (sizo) and did not differ from each other. On the other hand, *U. ruziziensis* cv Ruziziensis with the irrigation sheet of 100% ETo presented higher value in relation to the irrigation sheet of 70% ETo and did not differ from the irrigation sheet of 0% ETo. These results are different from those obtained by Gazola et al. (2017), evaluating the soybean crop implanted on straw from the autumnal corn intercropping with brachiaria at different sowing depths. In their study, the authors found that the total straw obtained at the lowest sowing depths of forage in intercropping with corn provided, in the soybean crop, higher straw production and plant population, but did not influence the productivity of soybean grains.

According to Souza et al. (2019) the uniformity of seed distribution is one of the factors that most contributes to obtain satisfactory plant stands and good crop yield, which corroborates with the results obtained in this study for cultivation systems.

It is important to note that the final stand presented low values when considering the desired density (377,000 plants ha^{-1}). Even so, soybeans showed high grain yields for the Far West region of São Paulo, due to its ability to compensate failures. Thus, there is a greater development of lateral branches associated with less competition for interception of light, water, nutrients. Consequently, there is a stimulus of the emission of reproductive nodes, followed by an increase of the number of pods and grain yield, as reported by Tourino et al. (2002) and Basso et al. (2016).

Considering the plant height, in the irrigation sheet of 0% ETo, the no-tillage with *Urochloa ruziziensis* cv Ruziziensis presented lower values in relation to the other cultivation systems. On the other hand, in the irrigation sheet of 70% ETo, the NT with *U. brizantha* cv Paiaguás and *U. brizantha* cv Piatã presented higher values for the plant height when compared to the conventional system, but did not differ statistically from the no-tillage with *U. ruziziensis* cv Ruziziensis. In the irrigation sheet of 100% ETo, no statistical difference was verified between the cultivation systems.

The no-tillage system with *U. brizantha* cv Paiaguás and *U. ruziziensis* cv Ruziziensis presented higher height with irrigation sheet of 70% and 100% ETo when compared to the irrigation sheet of 0% ETo. On the other hand, this behavior was not observed for the no-tillage with *U. brizantha* cv Piatã, and no statistical difference was detected. The conventional system with the irrigation sheet of 100% ETo presented higher value for plant height in relation to the irrigation sheet of 0% ETo (land) and did not differ from the irrigation sheet of 70% ETo (Table 3).

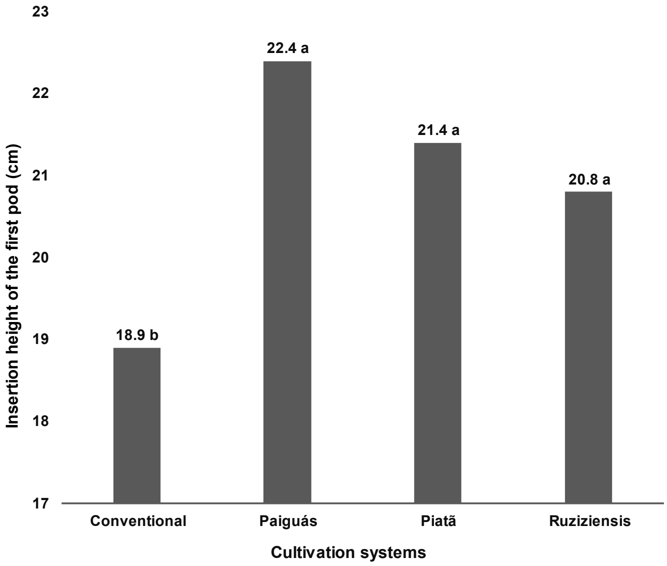
According to the results obtained for plant height, the irrigation sheet 70% and 100% ETo statistically stood out from the irrigation sheet of 0% ETo (dryland), since conditions of lower water availability in the soil can directly affect the physiological homeotase of the plant, such as transpiration, photosynthesis, leaf temperature, stomatic opening, accumulation of solutes and antioxidant metabolism. Thus, cultures grow and develop under this abiotic condition (CHAVES et al., 2016).

The height of the soybean plant desirable for an efficient harvest range from 70 cm to 80 cm (MENDES et al., 2018), values that were lower than those found in this study. Friedrich and Tavares (2015), evaluating the performance of 36 soybean cultivars in the municipality of

Luis Eduardo Magalhães (BA), found that plant height values ranged from 66.5 cm to 108.0 cm, which are similar to those observed in this study.

The first pod insertion height was influenced by the cultivation systems, where the crops in no-tillage were the ones that provided the highest values (Figure 2). This result may be related to the effect of the forages residual straw that provided higher soil moisture and mineralization, providing more nutrients for the plants (MACHADO et al. 2017).

Figure 2. Results of the Tukey test for pairwise mean comparisons regarding the first pod insertion height (FPIH).



Source: Author data (2018).
Means followed by the same letter do not differ between them by the Tukey test (p>0.05).

The values of first pod insertion height are above the limit of 13 cm. Then, losses can occur in mechanical harvesting (PEREIRA JÚNIOR et al., 2010; ORMOND et al., 2016; HOLTZ et al., 2019). In the study performed by Friedrich and Tavares (2015) the values of insertion height of the first pod ranged from 8 cm to 19 cm.

The conventional cultivation system presented zero value of *Brachiaria* residual dry mass, since in this system there was no intercropping with forages. The irrigation sheet of 0% ETo (seed) and 100% ETo in no-tillage showed no statistical difference. On the other hand, the irrigation sheet of 70% ETo had a different behavior in the no-tillage, in which *Urochloa ruziziensis* cv Ruziziensis and *U. brizantha* cv Paiaguás showed no statistical difference, but *U. ruziziensis* cv Ruziziensis presented higher *Brachiaria* residual dry mass when compared to *U. brizantha* cv Piatã (Table 4).

In the cultivation systems, the irrigation sheets of 70% and 100% ETo presented lower values of *Brachiaria* residual dry mass in relation to the irrigation sheet of 0%, and did not differ from each other, except for *U. ruziziensis* cv Ruziziensis, which showed the lowest value when compared to the other irrigation sheets (Table 4). This result demonstrates that the *U. ruziziensis* cv Ruziziensis is more susceptible to decomposition in the presence of water. According to SOUZA et al. (2010), considering identical soil conditions for a material with the same chemical composition, the decomposition speed is directly influenced by climatic conditions, mainly by the amount of water present in the plant residue, either by rainfall or supplementary irrigation.

Furthermore, the same authors reported that higher rates of irrigation sheets presented higher rates of decomposition. These results were corroborated by Souza et al. (2014), who reported that the increase in the volume of water applied by supplementary irrigation accelerated the process of decomposition of plant residues.

Table 4. Results of the Tukey test for mean pairwise comparisons regarding *Brachiaria* residual dry mass (BRDM) and total residual straw (TRS).

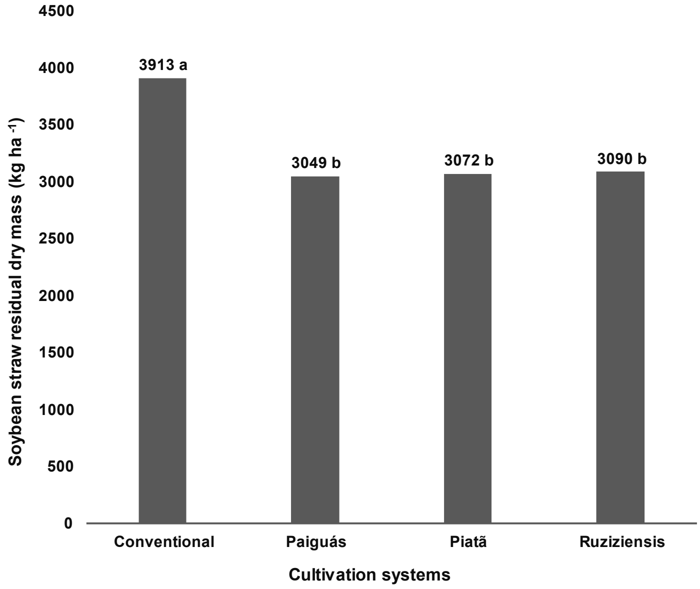
Irrigation Sheets	Sowing systems			
	Conventional	Paiguás	Piatã	Ruziziensis
	BRDM (Kg ha^{-1})			
0%ETo	0 B	3099 Aa	3011 Aa	2952 Aa
70%ETo	0 C	1500 ABb	1349 Bb	1809 Ab
100%ETo	0 B	1344 Ab	1349 Ab	1355 Ac
	TRS (Kg ha^{-1})			
0%ETo	3533 B	5974 Aa	5954 Aa	5962 Aa
70%ETo	4183	4674 b	4767 b	4859 b
100%ETo	4024	4512 b	4437 b	4537 b

The mean values followed by the same letter do not differ by the Tukey test ($p<0.05$). Uppercase letters were used for means compared in rows, while lowercase letters were used for means compared in columns.

Source: Author data (2018).

For the soybean residual dry mass (SRDM), the conventional system presented the highest value (Figure 3). This result is probably related to the best soil physical conditions inherent to this soil preparation modality, since the no-tillage is incipient, being only the 2nd year of implantation. Similar results were observed by Narimatsu (2008), who found that at the two years of implementation, the conventional system and minimum cultivation provided higher yields of residual dry mass of soybean straw in relation to the no-tillage. However, different results were found by Bertollo et al. (2020), in which the evaluation for 2 years after the implementation of a cultivation system with soil cover partially improved some physicochemical attributes of the soil, and in addition, the root growth and soybean grain yield had a positive balance.

Figure 3. Results of the Tukey test for mean pairwise comparison test of the soybean residual dry mass (SRDM).



Source: Author data (2018).
Means followed by the same letter do not differ between them by the Tukey test ($p<0.05$).

The irrigation sheet of 0% ETo provided the highest values for dry mass of total residual straw in the no-tiilage when compared to the conventional system (Table 4), since there was no forages straw intake. In the irrigation sheets of 70% and 100% ETo, no statistical differences were verified, indicating that the irrigation provided higher accumulation of soybean residual dry mass (Figure 3), which was compensated by the increase of dry mass of total residual straw. According to Torres et al. (2015) and Silva et al. (2017), the amount of straw residual dry mass added on the surface and the amount of organic matter accumulated in the soil are dependent on the crop system adopted and its respective management.

The amount of dry mass of total residual straw verified in this study was similar to the values obtained by Costa et al. (2012), who working with no-tillage with corn/soybean intercropped with *Brachiaria*, and verified an amount above 5000 kg ha^{-1}. This value is similar to that obtained in this study and close to the value recommended for the sustainability of the NT, estimated at 6000 kg ha^{-1}.

CONCLUSION

The irrigation sheets of 70% and 100% ETo in the conventional system provided higher grain yield in the climatic conditions in which the experiment was conducted. However, it is necessary to continue with the study for more years, since the no-tillage is incipient, being implemented only two years ago, a relatively short period for the process of consolidation of this system. Therefore, it did not provide all the benefits inherent to this cultivation system installed in the region of the extreme West of the State of São Paulo. In general, the *Brachiaria* residual dry mass showed similar behavior in the no-tillage system in the irrigation sheets evaluated.

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