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Research Article
Corn-soybean Double Cropping Yield Potential in Southern of Brazil

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Abstract

Background and Objective: Corn-soybean double cropping is an important tool for farmers as it improve farm's assets (e.g. soil, machinery, fixed labor, etc.) uses and soil/plant agronomical traits due to better crop rotation (avoiding soybean after soybean). This study aimed to study the corn-soybean double cropping system yield potential. **Materials and Methods:** Experiment was laid out as a random block designed in a split-plot scheme with four replications. Corn hybrids (P1680YH and 30F53YH) were established at the main plots and its uses (silage and grains) were assigned to subplots where after it, soybean development and yield potential was evaluated. **Results:** Corn hybrid 30F53 with medium-maturity cycle showed greater biomass and grain yield compared to hybrid P1630 with early-maturity cycle (19481 versus 17066 kg DM ha^{-1} and 11195 versus 8746 kg grain ha^{-1}, respectively), however, soybean yield potential was reduced as sowing is delayed (from 3490-2681 kg ha^{-1} to the sowing data of December, 17 and January, 29). **Conclusion:** Corn-soybean double cropping yields were very interesting showing a great potential to be used by the Brazilian southern farmers. New genetic material with shorter maturity cycle and greater yield potential may increase this system adoption allowing greater yield per area and income to the farmers.

Key words: Agricultural zoning, corn hybrids, biomass dry matter, sowing periods, double cropping, soybean

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Brazilian land use in Corn-Soybean production systems has been undergoing several modifications along the last decades. A long growing season (September to August) associated with good edaphoclimatic conditions allow farmers to grow many crop arrangements at the same growing season, such as corn-beans, corn-soybean, soybean-corn and soybean-soybean, etc[1].

There are many factors to be considered at the time of choosing the crop succession, as market, price, risk of frost, management options, logistic and economic aspects. Due to it, many farmers in the south-west of Parana state have been growing the soybean-soybean succession. However, high disease (Phakopsora pachyrhizi) and insect (Euschistus heros) pressure along growing season resulted in an increased in fungicide and insecticide uses, what has been imposing a high selection pressure resulting in loss of efficiency and also cases of resistance of diseases and insects[2].

Considering these facts, ADAPAR (Agricultural Defense Agency of Paraná)[3] and SEAB-PR (Department of Agriculture and Supply)[4] approved the ordinance No. 193 on October 6, 2015, limiting a soybean sowing deadline at December 31st. This prohibition, sought to give greater amplitude to the sanitary emptiness, as well as to reduce the pressure of selection of stink bugs and diseases in the soybean crop.

Unlike the cultivation of soybeans over soybeans, corn+soybean crop rotation addresses another reality and may bring along some advantages to the productive system at the southern regions of Brazil, such as crop rotation and even the viability of corn cultivation. It is important to emphasize that usually, Brazilian farmers prefer to grow soybean instead of corn, due to its low production risk and investment, associated with higher profit. Although, the possibility to grow soybean as a second summer crop after corn make corn more interesting for farmers that different from the cerrado region, have good rainfall at the beginning of September, allowing this crop sucession[5].

Moreover, corn stands out among summer crops for its productivity and importance to Brazilian agribusiness, since its use occurs in the most diverse forms of processing and is directly linked to the productive chains of poultry and swine, besides being the culture most used for making silage. Data show that in the 2016/2017 crop period, corn first summer crop reached a national production of 30,462.0 thousand tons, 18.3% higher than the 2015/2016 crop season which had been 25,275.5 thousand tons[6].

More than 70% of this corn is used for livestock production (milk, poultry, swine) and therefore, evaluating the productive potential of corn hybrids for silage and grain purposes becomes fundamental for the correct understanding of both quantitative and qualitative aspects of the materials available in the market[7].

Knowing that soybean plays a fundamental role in crop rotation and is an excellent source of income for farmers, the idea is to study the corn-soybean double summer crop sowing corn early on September and harvest it for silage and grain in December/January, allowing the farmers to grow soybean as a second summer crop. Furthermore, when corn is used for silage, it may be harvest before deadline 31st December, allowing soybean to be grow within the established agricultural zoning for the crop in the state of Paraná.

MATERIALS AND METHODS

Experimental site: The experiment was carried out at the Federal Technologic University of Paraná (UTFPR), campus of Dois Vizinhos-Agricultural Research Station, located at 25°48’09” latitude south, 53°06’28” longitude west and at 520 m above sea level. The climate is classified as Cfa-humid subtropical-without a distinct dry season, with an average temperature of 22°C in the hottest month and occasional frosts[8].

Mean rainfall varies between 1800 a 2200 mm well distributed along the year[9]. Data for maximum, minimum and average temperature, as well as precipitation registered during the study, are shown in Fig. 1.

A soil sample was taken with Dutch-type auger at a depth of 0-20 cm for chemical characterization of the area before corn seeding. Soil chemical values found in the soil analyses, were: pH-$CaCl_2$ = 5; P = 11.30 mg dm^3; K = 0.18 $cmol_c$ dm^3; 40.1 g kg^{-1} of organic matter; Ca = 7.28 cmolc dm^3; Mg = 3.38 cmol dm^3; 0.00 cmol dm^3 of Al; Base saturation = 58.8% and 16.5 cmol dm^{-3} of cation exchange capacity.

Experimental design: The experiment was laid out as a random block designed in a split-plot scheme with four replications. Corn hybrids (P1680YH and 30F53YH) were established at the main plots and its uses (silage and grains) were assigned to subplots. After corn harvest (silage or grains), soybean was sowed into these plots. The experiment started on early September, 2015 and finished on May, 2016.

Experimental details: Corn hybrids were sowed with a non-tillage seed-fertilizer planter on September 04, at a seed density of 70,000 plants ha^{-1} and 45 cm between rows with

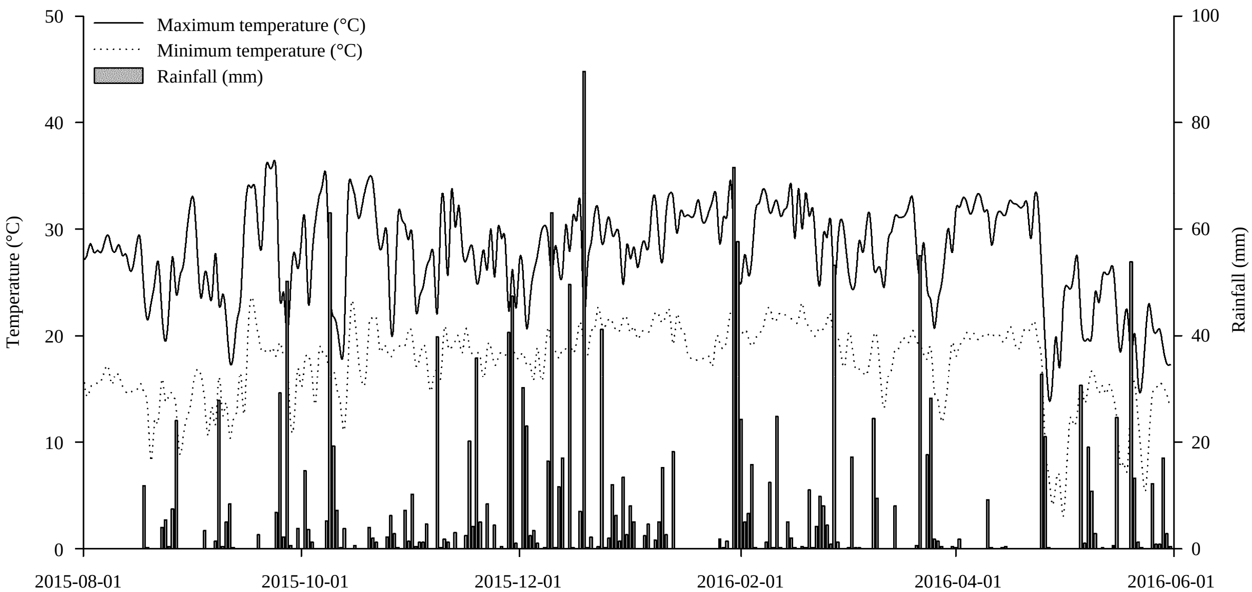

Fig. 1: Rainfall, maximum, minimum and average temperature (°C) recorded in the city of Dois Vizinhos-PR during the corn-soybean growing period, 2017

Source: BIOMET-Meteorological station-Campus of Dois Vizinhos[10]

300 kg ha^{-1} of a fertilizer 13-34-00 (N-P_2O_5-K_2O). Potassium was broadcast applied at sowing, using 200 kg of KCl ha^{-1}. Nitrogen rates (157 kg ha^{-1}) were divided into equidistant values and applied at corn phenological stage of V3 and V8, using urea as a source (46% of N)[11].

Black oat was desiccated with 960 g ha^{-1} of glyphosate 26 days before corn sowing. Weeds were managed by applying atrazine (3.25 kg i.a ha^{-1}) at the corn phenological stage V3.

Corn silage evaluation was done according to the characteristics of grain fraction, in the course of the called "milk line", considering 2/3 of this "line" full of starch, characterizing the beginning of hard grain (R5). Early hybrid P1630YH silage was done on December 17 and Medium-maturity hybrid 30F53YH on January 05.

Corn silage green mass (kg ha^{-1}) was performed by cutting and weighing two rows of 5 m per sampling area (AA), cut at 30 cm above ground level. The sample was weighed and the value extrapolated to hectares. Plants were ground in a forage harvester with a mean particle size of 1.5 cm and a sample was collected and weighed on a precision scale of 1 g and taken to the oven with forced air circulation at 65°C until constant mass. This sample was again weighed, determining the dry matter content of the corn and the value related to the production of green mass, thus obtaining dry mass production (kg ha^{-1}).

The rest of the corn plants present in each subplot were mechanical cut at 30 cm above the soil level and removed from the area, simulating the harvest of the entire area. At the same day, soybean was sowed into the plots.

Grain harvesting was carried out on January 17, (133 days) and January 29, 2016 (146 days) for the P1680YH (20% moisture) and 30F53YH (22% moisture), respectively.

To determine corn yield components, 10 ears per plot were evaluated; the numbers of grains per row (NGR-grain smaller than ½ normal grain was not considered) and the numbers of row (NR) were registered. In addition, the weight of thousand grains was assessed by manual counting 5 samples of 100 grains, weighing and correction for moisture content of 13%, with extrapolation to thousand-grain weight. Number of grain per ear (NGE), was determined considering the NGR and NR. For the statistical analyzes, the mean values observed in each AA were used.

Corn yield was assessed by harvesting the spikes at three central rows of the plot (not considering 0.5 m from each end of the plot and the rows aside) 5 m long and passing the ears through a stationary small-plot corn sheller. Corn grain yields were adjusted to a moisture concentration of 13 g kg^{-1}. Corn populations at grain harvest were determined by counting and recording the number of plants harvested within each plot.

The rest of the corn plants present in each subplot were hand harvest and spikes removed from the area. After it, the area was mechanical rubbed at the soil level, simulating the harvest of the entire area. At the same day, soybean was sowed into the plots.

Soybean (TMG 7062 I PRO) sowing occurred on four different dates: On December 17 over P1680YH corn silage (Silage P1680YH), on January 01 over 30F53YH corn silage (Silage 30F53YH), on January 17 over P1680YH corn grain (Grain P1680YH) and on January 29 over 30F53YH corn grain (grain 30F53YH).

Soybean was sowed with a non-tillage seed-fertilizer planter at a seed density of 270,000 seeds ha^{-1} placed 45 cm between rows with 300 kg ha^{-1} of a fertilizer 02-18-18 ($N-P_2O_5-K_2O$).

Weed management on soybean was carried out between V2 a V4 with glyphosate (1,080 g i.a ha^{-1}). Disease management (mainly Phakopsora pachyrhizi) was carried out at R1, R3 and R5 for all the Soybean sowing data using Trifloxistrobina+Protioconazol (70+60 g ai ha^{-1}) and Azoxistrobina+benzovindiflupir (250 g ha^{-1}) for the first and second and third application respectively. Associated with fungicide, insecticide was applied to control stink bugs (more than 2 adult stink bugs were detected per linear meter of soybean row) using neonicotinoid+pyrethroid (0.50 L ha^{-1}) at the first and third application. Acephate (0.7 kg ha^{-1}) was used at the second application. A fourth application of insecticide (neonicotinoid+pyrethroid-0.50 L ha^{-1}) was performed on March 08, due to the high pressure of stink bugs in the crop. Pesticides were applied with a manual backpack sprayer, with a spray bar of four nozzles (11002) spaced at 45 cm, in order to apply a volume of 160 L ha^{-1}.

Soybean final stand was determined in the physiological maturation of the culture by counting the plants at 5 m in each of the three central sowing lines to every experimental unit. The result was extrapolated to the number of plants per hectare. Yield components were determined in 10 plants per plot.

Final height of the plants was measured by the distance between the soil and the apex of the main stem. Height of first pod insertion was determinated considering de distance from de soil to the first pod. The total number of pods per plant (NPP) was determined by counting all of the pods inserted in the plant including those deemed empty. These pods were hand opened and grains counted to determinate de number of grain per plant. The mean number of grains per pod was obtained by the relation between the number of pods per plant and the number of grains per plant. Number of nodes per plant (NNP) and reproductive nodes (RN) were also determinated. The weight of thousand grains was assessed by manual counting 5 samples of 100 grains, weighing and correction for moisture content of 13%, with extrapolation to thousand-grain weight.

The harvest was done manually and the threshing by a stationary combine harvester. To calculate the yield, the humidity of the grains was corrected to 13%. The productivity in kg ha^{-1} was calculated through the total mass of grains produced per plot.

Statistical analysis: All of the data were submitted to the Shapiro-Wilk test ($p \leq 0.05$) to verify the homogeneity of the variances and once attended the normality were tabulated and underwent a variance analysis to verify the level of significance of the factor tested using the t-test ($p > 0.05$). When significant differences occurred ($p \leq 0.05$), means were compared to the Tukey test ($p \leq 0.05$). For the analysis of the data, Assistat 7.7beta software was used[12].

RESULTS AND DISCUSSION

For the 2015/2016 crop season in the Southwest of Paraná, no problems related to precipitation were observed. According to Fig. 1, it is possible to observe that during the whole productive cycle of corn and soybean there was good water supply, which allowed good productive indexes.

Thus, when analyzing the green mass (GM) and dry mass (DM) yield, it is observed that there were statistical differences for these variables in which the hybrid P30F53YH presented higher rates of silage production (Table 1).

It is important to consider that there was a difference of 18 days of harvest between the early hybrid P1680YH and Medium-maturity hybrid 30F53YH. Both hybrids were cut for silage with 103 and 121 after its emergence with dry matter content of 35.9 and 28.9%, respectively.

Corn silage yield differences between hybrids may be explained by the cycle difference. Hybrid P30F53YH showed longer cycle, which consequently obtained a greater vegetative development and thus could accumulate more

Table 1: Corn silage green and dry mass from two hybrids with different maturity cycles in the 2015/2016 crop season. Dois Vizinhos-PR

Hybrids/variables	Green mass (kg ha^{-1})	Dry mass (kg ha^{-1})
30F53YH	67.290^{a}	19.481^{a}
P1680YH	47.407^{b}	17.066^{b}
Mean	57.248	18.273
DMS	5.910	1.816
CV (%)	2.930	2.830

In each column, to each factor, averages followed by different lowercase letter differ by the tukey test in 5% of probability, CV: Coefficient of variation

Table 2: Corn yield components as number of rows (NR), number of grain per row (NGR), number of grain per corn ear (NGE), thousand-grain weight (g) and grain yield (kg ha^{-1}) of hybrids with different cycles in the 2015/2016 crop season. Dois Vizinhos-PR

Hybrids/variables	NR	NGR	NGE	TGW	Yield
30F53YH	16.80[NS]	34.20[a]	576.40[a]	325.80[a]	11.195[a]
P1680YH	16.70	28.10[b]	473.00[b]	280.70[b]	8.746[b]
Mean	16.80	31.10	524.70	303.20	795.600
DMS	1.10	2.58	9.51	27.97	9.971
CV (%)	2.03	2.36	0.52	2.62	2.270

[NS]Not significant. In each column, to each factor, averages followed by different lowercase letter differ by the tukey test in 5% of probability, CV: Coefficient of variation

biomass. Thus, beyond silage quantitative yield, it is very important to consider qualitative yield, which is very dependent on grain yield.

Usually, at the time to choose a corn hybrid, farmers look for its yield potential, short cycle and resistance to bugs and disease that it is very difficult to find all these traits together in a corn hybrid. As the case of P1680YH, which shows precocity and high yield potential, but is very susceptible to bugs and diseases.

Corn silage evaluation was done according to the characteristics of grain fraction and P1630YH at this point, showed most of its leaves dead by diseases. It is also emphasized that in the definition of the cut-off time, the sanity of the plant is considered beyond the phenological stage of the plant, since it interferes directly with the dry mass content of the material to be silage.

A difference in the green mass of 30% between the materials was observed, however, this difference drops to 12.4% when compared to the dry mass yield, which is the most important variable. According to Nussio *et al.*[13] dry matter contents varying between 30 and 35%, are ideal for the formation of good silage, where it will have adequate fermentation and soon good quality.

Regarding to the corn yield components, it was noticed that only the number of rows per ear did not differ and for the other yield components, hybrid P30F53YH showed higher values (Table 2). This response is possibly due to the divergent cycle between the hybrids, with the early cycle (P1630YH) having a shorter field time when compared to the Medium-maturity cycle hybrid (P30F53YH), allowing a high development and filling of grains, thus expressing greater productive potential. Furthermore, no fungicide was used at the experiment, factor that could have beneficiate the earlier material.

Flesch and Vieira[14] evaluated Pioneer 3099 (early cycle) and Agroceres 1051 (normal cycle) hybrids in different plant populations and observed higher yields for the longer cycle hybrid in all the evaluated populations, collaborating with the results found in this experiment.

When comparing grain yield average obtained for each hybrid, P30F53 (11,195 kg ha^{-1}) and P1680 (8,746 kg ha^{-1}) (Table 2), with the Brazilian corn average (4,867 kg ha^{-1}) and Paraná corn average (7,953 kg ha^{-1}) in the 2015/2016 crop season[6], it is noticed that grain yield was above averages, even in the early cycle hybrid, but this yield could be better. Higher plant population (mean final population between hybrids reported at the experiment: 66.233 plants ha^{-1}), better Bt technology as offered today (YH versus LYH) and higher nitrogen rates might allow higher yield.

Similar as reported before to silage production, grain yield difference observed between hybrids may be associated with a greater susceptibility of P1680YH to diseases such as *Phaeosphaeria maydis* and *Helminthosporium turcicum*. Loss of leaf area due to leaf disease damage affect photosynthetic efficiency what resulted in lower number of grain per row (grains not formed at the point or the spike) and thousand-grain weight at the P1630YH in relation to P30F53.

Our results are beneficial once it shows that even producing less, early corn material allow earlier harvest and consequently anticipate second summer crop sowing, reducing frost risk and allowing higher yield. Moreover, this material used for silage was the only one harvest before December 31st allowing so farmers to grow soybean as a second summer crop within the zoning established for the crop in the State. Thus, it important to emphasize that this may vary along years once corn development is directly affect by thermal some. Thus, early soybean sowing results in lower disease pressure.

Corn yield in relation to its cycle must consider their effect over the next crop, which is this case, was soybean. According to it, Table 3 and 4 shows soybean development characteristics, yield components and grain yield.

Parameters such as plant height in soybean are of relevant importance, since they have a direct relationship with productivity, because they provide more or less numbers of pods depending on the size of the stem. According to Taiz and Zeiger[15], times of sowing, soil fertility, as well as temperature directly affect the final height of the plant.

According to the data observe in Table 3, it is possible to infer that the delay in soybean sowing directly interfere its development and plant height, reducing it as sowing is delayed. According to Zanon *et al.*[16], when the sowing period

Table 3: Plant population (POP) (plants ha^{-1}), plant height (PH) (cm), first pod height (FPH) (cm), number of nodes per plant (NNP), number of reproductive nodes (NRN) and number of soybean shoots (NS) grown over corn of different cycles used for silage and grain. Dois Vizinhos-PR

Treatments	POP	PH	FPH	NNP	NRN	NS
Sil. P1680[1]	259.750[NS]	90.80[a]	20.30[a]	29.10[NS]	20.10[bc]	2.70[NS]
Sil. 30F53[2]	253.641	78.60[b]	17.20[ab]	24.80	17.60[c]	3.70
Grain P1680[3]	228.888	61.70[c]	11.20[c]	32.50	26.70[a]	3.70
Grain 30F53[4]	218.764	58.90[c]	13.00[bc]	31.60	25.30[ab]	3.10
Mean	240.261	72.50	15.40	29.51	22.45	3.30
DMS	88.437	7.13	5.64	7.82	5.57	2.63
CV (%)	13.01	3.47	12.89	9.37	8.77	27.84

[NS]Not significant. In each column, to each factor, averages followed by different lowercase letter differ by the tukey test in 5% of probability, CV: Coefficient of variation. [1]Soybean sown on 12/17/2015 after corn P1680YH for silage, [2]Soybean sown on 04/01/2016 after corn 30F53YH for silage, [3]Soybean sown on 01/17/2016 after corn P1680YH for grain, [4]Soybean sown on 01/29/2016 after corn 30F53YH for grain

Table 4: Number of pods per plant (NPP), number of grain per pod (NGP), number of grain per plant (GP), weight of thousand-grain (WTG) (g) and soybean yield (kg ha^{-1}) grown over corn of different cycles used for silage and grain. Dois Vizinhos-PR

Treatments	NPP	NGP	GP	WTG	Yield
Sil. P1680[1]	54.9[a]	1.95[NS]	103.60[ab]	189.30[NS]	3.490[a]
Sil. 30F53[2]	42.9[b]	2.03	86.90[b]	174.40	3.438[a]
Grão P1680[3]	55.3[a]	2.16	118.80[a]	164.70	2.992[ab]
Grão 30F53[4]	52.6[a]	2.23	116.90[a]	165.10	2.681[b]
Mean	51.4	2.09	106.59	173.40	3.150,56
DMS	8.83	0.29	18.79	35.30	594.50
CV (%)	6.07	4.85	6.23	7.20	6.67

[NS]Not significant. In each column, to each factor, averages followed by different lowercase letter differ by the tukey test in 5% of probability, CV: Coefficient of variation. [1]Soybean sown on 12/17/2015 after corn P1680YH for silage, [2]Soybean sown on 04/01/2016 after corn 30F53YH for silage, [3]Soybean sown on 01/17/2016 after corn P1680YH for grain, [4]Soybean sown on 01/29/2016 after corn 30F53YH for grain

of soybean is delayed (from November/December to January/February), there is a decrease in its vegetative and reproductive periods, resulting in smaller plants, a factor directly related to the shorter photoperiod. Sowings of September, January and February promote a reduction in vegetative stage in most cultivars when compared with the recommended period (November and December).

The effect of day length directly affects soybean development and final height, what affect the yield components as number of nods and grain per plant. This fact is so important, that first sowing period (after P1630YH corn silage), sown on 12/17/2015, was the one that obtained the highest height (90.86 cm), which is 35.17% higher than the last date of sowing (01/29/2016), after corn 30F53YH grain.

Shigihara and Hamawaki[17], a final plant height satisfactory for both yield and operational yield at harvest, plants should be between 60 and 110 cm in height, values observed in this work (Table 3).

According to Taiz and Zeiger[15], day of sowing, soil fertility, as well as temperature directly affects the final height of the plant. Plant height and first pod height insertion also suffer variations with the established plant stand (plants per linear meter), both as a function of competing for natural resources. According to Ribeiro *et al.*[18], higher plant populations cause the plant to have higher height and insertion of the first pod.

As days go by from December to June, day length gets shorter and shorter photoperiodic results in a reduced height and legumes formation very close to the ground[19]. Therefore, it is considered, plant heights between 12-15 cm as suitable for mechanized harvesting[20].

Regarding to the number of pods per plant, a tendency to have fewer pods per plant as sowing time advance to fall was expect, once at latter sowing period, final height is lower as explained before, resulting in lower reproductive nodes. However, this tendency was not observed as the second sowing period data showed the lowest average (42.97 pods per plant) among the other different sowing dates, which did not differ from each other (Table 4). Different pressure of stink bugs and its damage may result in pods abortion, what helps to explain these differences. Worse climatic conditions with a shorter water stress reported for the second sowing data may also explain the lower number of pods.

It is important to highlight that all the yield components are influenced by the number of plants per hectare. Thus, as higher the number of plants per area, lower is the number of pods per plant. In the other hand, as lower the number of plants per area, higher the number of branches. These data demonstrate the enormous plasticity of the evaluated soybean cultivar, that is, in the density of smaller plants, the legume compensating the yield increasing the number of branches and pods per plant.

According to Dalchiavon and Carvalho[21], the weight of thousand-grain, together with the number of pods per plant and grains per pod, are the main yield components of soybean and are directly related to the soybean yield factor. There was no difference on the weight of thousand-grain in relation to the sowing data, however, there is (Table 4) a tendency to have lower WTG as sowing is delayed once values drops from 189.33-165.13 g from the first to the last sowing data. These values are below those provided by the holding company of the cultivar, which suggest WTG around 185 and 196 g[22].

It is worth to highlight that the difference in days from the soybean sowing data at the early-cycle to the medium-cycle corn was of 12 days and this resulted in a difference of 311 kg ha^{-1}. However, as mentioned before, medium-cycle corn yielded 2.249 kg ha^{-1} more than the early-cycle what suggest that it is better to use P30F53.

Thus, it is important to mention that the literature shows better yield results to the P1630YH, when the material is submitted to a different management[23]. P1630YH with higher plant population (final population of 83.200 plants ha^{-1}), good fungicide management (3 applications: V8, pré and post anthesis) and higher nitrogen levels (209 kg N ha^{-1}) reported yield of 19.6 t ha^{-1}. This value shows that P1630YH has a better yield potential than showed in this experiment, but it depends on edaphoclimatic conditions and fungicide management.

Observed differences on soybean yield are higher when corn crop is used for silage in relation to harvest for grain. There is a difference of 757 kg ha^{-1} of soybean between sowing it after P30F53 for silage or grain.

Soybean yielded 757 kg ha^{-1} more when grown after P30F53 for silage in relation to its use for grain. This difference brings along other advantages, as low risk of frost, low disease and bugs pressure and also better potential profit from corn, once it is transformed into meat or milk, aggregating value to the farmer.

Soybean yield was reduced as sowing period was delayed. From the first sowing (17/12/18) to the last (01/29/16) one there was a difference of 810 kg ha^{-1}. The first two sowing periods were cultivated after corn for silage, which naturally has a higher rate of nutrients export, however, even though, these treatments presented higher productive potential due to the anticipated sowing season, demonstrating that in the second crop, each day of delay in sowing, represents a great potential of loss of income for the producer.

Furthermore, it is important to highlight that beyond grain yield potential, soybean as a second summer crop may result in superior seed quality. Bornhofen *et al.*[24] reported better climatic conditions (cooler temperatures) to the soybean cultivated as a double crop after corn, finding better seed viability, germination and vigor in relation to the normal crop. Moreover, this seed are harvested in late May, period which is closer to the next crop season, which begins in September, different from soybean from the first summer crop, which is harvest in January/February, submitted to hotter conditions which increases the seed respiration process, reducing so its quality. Even if this seeds are stored under refrigerator, there is the energy cost to maintain this seed, turning it more expansive.

Thus, it can be stated that the double summer crop system (corn silage/grain-soybean) has great potential to be used by the farmers at the Southwest of Paraná, as long as farmers follow the defensive modes of action rotation and period of sowing.

SIGNIFICANCE STATEMENT

It was discovered by this work and its data shows that corn+soybean double summer crop rotation has a great yield potential, although, the actual sowing data deadline established for the crop in the Paraná State unfeasible its uses by farmers. This result may help researchers to support this crop rotation and prove that it is possible to grown soybean after corn cultivation with low inputs and great yield potential. Thus, researches may direct studies to develop corn cultivars with shorter cycle and soybean cultivars adopted to be grown in the second summer crop season.

CONCLUSION

Corn hybrid 30F53 with medium-maturity cycle showed greater biomass and grain yield compared to hybrid P1630 with early-maturity cycle, although, soybeans yield in the double summer crop season reduces as it's sowing is delayed. Early-maturity corn cycle when used for silage allows farmers to grow soybean as a second summer crop within the zoning established for the crop in the Paraná State.

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