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Agronomic traits and seed yield produced in the soybean-corn crop in succession cropping

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ABSTRACT. Competition experiments were installed at the COODETEC unit in Palotina, Paraná State, with the objective of evaluating the influence of the cultivation of soybean in succession to a second crop season on different sowing dates on the agronomic traits and seed yield in both cultures. The experiment consisted of four field replicates, arranged in a completely randomized block design and carried out in two agricultural years (2003/2004 and 2004/2005). The individual blocks were comprised of three early-maturing soybean cultivars (CD 202, CD 215 and CD 216) sowed on five different dates (9/15, 9/30, 10/15, 10/30 and 11/15) and also three corn hybrids (CD 305, CD 306 and CD 308) that were sowed on different dates (1/30, 2/15, 3/1, 3/15 and 3/30). Data were submitted to a joint analysis, and the interaction decompositions were made when verified significance. Based on the results obtained, it can be concluded that early season second crop growing is a valid strategy for obtaining a good agronomical performance and better productivity in off-season corn sowing. The succession of early soybean/early corn in the off-season is a potentially viable alternative for the west region of Paraná State, as long as the soybean sowing is done by the first half of October and the second crop season corn is sown in the first half of February.

Key words: off-season corn sowing, climate adverse conditions, cultivars, hybrids.

RESUMO. Desempenho agronômico e produtividade na sucessão soja – milho safrinha. O objetivo do presente trabalho foi avaliar a influência do cultivo em sucessão da soja com o milho safrinha, em diferentes épocas de semeadura, no desempenho agronômico das plantas e na produtividade de soja e milho. Utilizou-se o delineamento em blocos casualizados, com quatro repetições. O experimento foi realizado em dois anos agrícolas, 2003/2004 e 2004/2005, utilizando as cultivares de soja CD 202, CD 215 e CD 216, semeadas em 15/9, 30/9, 15/10, 30/10 e 15/11. Em sucessão utilizou-se três híbridos de milho (CD 305, CD 306 e CD 308) semeados em 30/01, 15/2, 1/3, 15/3, 30/3. Os dados coletados foram submetidos à análise de variância conjunta realizando desdobramentos das interações, quando constatado significância. Com base nos resultados encontrados, constatou-se que a antecipação da semeadura da safrinha é uma estratégia válida para obtenção de bom desempenho agronômico e de produtividade em semeaduras extemporâneas de milho. A sucessão soja-milho em safrinha é uma alternativa viável para a região oeste do Estado do Paraná, desde que a semeadura da soja seja realizada na primeira quinzena de outubro e a do milho safrinha na primeira quinzena de fevereiro.

Palavras-chave: semeadura antecipada do milho, adversidade climática, cultivares, híbridos.

Introduction

Off-season corn crop sowing right after the soybean harvest in a conventional season has been a practice conducted by most farmers who make use of these crop rotation systems. Nevertheless, knowledge about the most appropriate sowing period for this off-season summer crop has been quite limited.

Due to its wide adaptability, corn cropping has presented no restrictions in the State of Paraná; ranging from highest to lowest yield scale, as well as in all edaphic-climatic parameters that are present in the territory. Off-season corn crop sowing occurs from January to April, normally after early-maturing soybeans have been harvested.

However, when this cropping occurs late in the recommended period, growth yields can be greatly reduced due to the rain regime and also by limited solar radiation and temperature in the final phase of the cycle, and even by frosts (GONÇALVES et al., 2002). Since sowing is possible only after summer crop clearance, the off-season sowing of corn crops will depend mainly on the sowing time of the previously grown crop, which normally is the soybean (CARDOSO et al., 2004; DURÃES et al., 1995; FARINELLI et al., 2003; GONÇALVES et al., 2002; MATZENAUER et al., 2005).

In order to have a successful soybean-corn crop succession establishment, a study on the climatic factors related to each crop's physiological characteristic and an examination of the varieties and hybrids that are best adapted to the climatic adversities encountered in off-season corn sowing are required.

The objective of this present study is to evaluate the agronomic traits and seed yields produced from different sowing dates in the soybean-corn crop succession.

Material and methods

The present study was carried out in the agricultural years of 2003/2004 and 2004/2005 at an experimental area located in the city of Palotina belonging to the Central Cooperative of Agriculture Research (COODETEC), in the western region of the Paraná State, Brazil (Altitude: 310 m; Latitude: 24°18´S; Longitude: 53°55´W). The soil in which the experiment was carried out was classified as Rodhic Haplorthox. The predominant climate in the region is the Cfa-type according to Köppen (IAPAR, 1987): wet mesothermic; abundant rain in summer; a dry winter and a hot summer. Data on the pluvial precipitation and the high and low daily temperatures for the duration of the experiment were collected daily and displayed in decennial periods for the studied agricultural years (Figure 1A, B, C and D).

The experimental design consisted of random blocks with four field replicates, and each sowing season consisted of an individual cultivar competition assay of three soybean cultivars and corn hybrids. Parcels were comprised of 8 lines measuring 5 m in length that were spaced by 0.5 m for the soybean cultivars and of 4 lines measuring 5 m in length spaced at 0.90 m for corn hybrids.

Three early-maturing soybean cultivars CD 202 (determinate growth habit), CD 215 (determinate growth habit) and CD 216 (indeterminate growth habit) and three corn hybrids CD 305 (early maturing triple hybrid); CD 306 (triple super early maturing hybrid); and CD 308 (double early maturing hybrid) where grown. Soybean sowing was conducted on 9/15, 9/30, 10/15, 10/30 and 11/15, while the corn hybrids were sowed on 1/30, 2/15, 3/1, 3/15 and 3/30 in both of the agricultural years.

Soil preparation, fertilization and other cultural practices were the same as those utilized by the production systems common in this region (EMBRAPA, 2002). During harvest one outer line of corn and two outer lines of soybean crops were eliminated. A 0.5 m portion at the extremity of each central line was also removed, as were all of the border plants. The subsequent useful area of the experimental units was 7.2 m^2 for both crops.

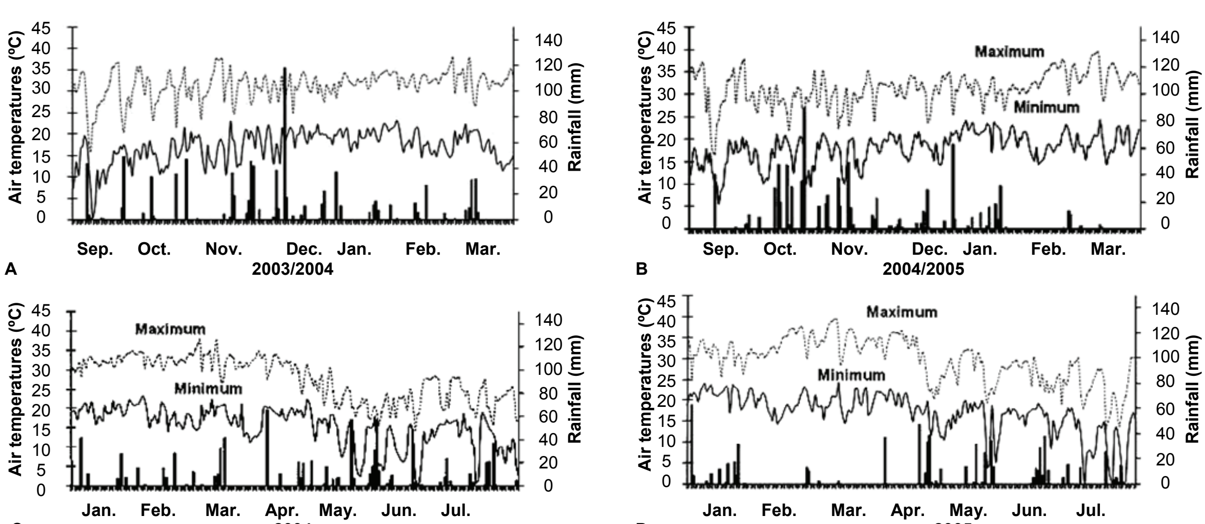

Figure 1. Maximum and minimum (high and low) temperatures and rainfall in Palotina, Paraná State, from September through March in the agricultural year of 2003/2004 (A) and 2004/2005 (B); as well as from January through July of 2004 (C) and 2005 (D).

Average plant height, height of the first pod insertion, the number of pods per plant and yield were determined for the soybean crop. Plant height and height of first pod insertion were evaluated by measuring ten plants at random in the useful parcel area using a millimeter ruler and were expressed in centimeters. The number of pods per plant was evaluated on the full maturation stage R_8 (EMBRAPA, 2002) by counting the number of pods on the same ten plants chosen randomly used for height measures.

For the corn crop, plant heights, prolificity index and yield were evaluated. Plant height was determined by measuring the plant from the base to the point of tassel insertion. The prolificity index was calculated using the ratio of the number of ears to the number of plants on the parcel area.

Plants were hand harvested when seeds displayed 16% moisture for the soybean and 22% moisture for the corn grains. After harvesting, the seeds of the soybean and the corn grains were threshed from the pods in a stationary threshing machine and where then cleaned with the use of sieves followed by shade-drying and placement into paper bags.

Productivity in kg ha^{-1} was calculated from the seed yield on the parcels. The data on seed yield were corrected to 13 and 14% moisture for both the soybean and corn, respectively. The degree of seed moisture was evaluated via the oven method at 105ºC for 24 hours (BRASIL, 1992).

Data were submitted to a joint analysis of variance, which verified similar quadratic means by using the Hartley test (RAMALHO et al., 2000). This analysis was accomplished for different sowing dates when the ratio between the highest and the lowest residual quadratic mean was up to 7 (BANZATTO; KRONKA, 2008).

In this experiment fixed effects were adopted (cultivar, period and year). The expected quadratic means were calculated according to the biometrical model adopted as well as that of Cruz et al. (2004). Apart from using the significance of the F test ($p < 0.05$) on the second order interaction, necessary partitioning was performed (year x cultivar x period) in order to identify possible interaction effects.

Results and discussion

The evaluation of cultivar plant height for each sowing time for the two agricultural years showed that sowing accomplished on 9/15 in 2003/2004 promoted superior plant height when compared to the CD 202 and CD 215 cultivars that were sown on 2004/2005, but there was no significant difference between crops of the CD 216 cultivar (Table 1). On the second sowing date (9/30), plants did not present height variations between the two agricultural years. On the third sowing date (10/15), the CD 215 cultivar did not present any variation between years. The CD 202 cultivar was the one that grew better for the 2004/2005 year crops, while the CD 216 cultivar (2004/2005 year crops) was the best on first three sowing dates. On the forth sowing date (10/30), there was statistical difference between the years being the 2003/2004 year crops more favorable the taller plants; whereas on the fifth sowing date (11/15), the first year (2003/2004) was the best for the CD 202 and CD 215 cultivars but the second year (2004/2005) was most favorable for the CD 216 cultivar.

Evaluating cultivar performance throughout each year, it was possible to observe that in the first agricultural year (2003/2004) the CD 215 cultivar was superior on the first sowing date (9/15); while with the following second (9/30) and third (10/15) sowing dates, the CD 216 cultivar presented superior plant height. On the forth sowing date (10/30) there was no difference between the cultivars. On the fifth sowing date (11/15), CD 216 presented a taller plant height. On the forth sowing date (10/30) there was no difference among the cultivars, while on the fifth sowing date (11/15) CD 216 presented the worst performance when compared to the other cultivars. In the second year (2004/2005) the CD 216 cultivar presented the better result on both the first (9/15) and fifth (11/15) sowing dates; whereas on the second sowing date (9/30) the CD 215 cultivar presented the lowest height. On the third sowing date (10/15), the CD 202 cultivar exhibited the best performance. Nevertheless, cultivars did not present significant differences on the forth sowing date (10/30).

The lowest plant height for most of cultivars across the years studied was verified on the first (9/15) and fifth (11/15) sowing dates. Higher plant heights have been obtained when sowing was carried out between late October and late November in the State of Paraná (EMBRAPA, 2006), which are in accordance with the results obtained in this experiment that show that the forth sowing date (10/30), in general, presented the tallest plant height across all cultivars studied.

The tallest plant height obtained by the CD 216 cultivar at some of the sowing dates within both agricultural years is in accordance with its undetermined growing habits, which account for some of its peculiar characteristics (COODETEC, 2005).

In the agricultural year of 2004, there was no variation among the hybrids between the sowing dates. This demonstrated a high stability in height across the hybrids studied in that particular agricultural year (Table 1). Nevertheless, in 2005, hybrid CD 305 reached a taller plant height for almost all sowing dates, with the exception of 2/15 when there was no significant difference among the hybrids. Tassel insertion height was higher on all four of the first sowing dates, except for hybrid CD 305, which in 2005 had lower height.

On the first sowing date (2004), no significant difference was observed in ear insertion height among the hybrids evaluated (Table 1). The same occurred in the following agricultural year (2005), in which hybrid CD 308 presented a lower insertion height on the first sowing date (1/30) compared to the CD 305. There was a significant difference only between hybrids CD 305 (higher insertion height) and CD 306 (lower insertion height) on the sowing date 3/1, 3/15 and 3/30 in 2005.

Regarding the number of pods per plants (Table 2), the cultivars evaluated did not present any significant difference between the agricultural years on the first sowing date (9/15). On the second (9/30) and forth (10/30) sowing dates, only cultivar CD 216 did not display any difference in the number of pods per plant. For the other cultivars, the number of pods per plant obtained was always superior in the second sowing year. On the third (10/15) and fifth (11/15) sowing dates differences were observed between the two agricultural years; sowing in 2004/2005 presented the highest number of pods for the three cultivars evaluated.

No difference was seen in the cultivars in the first year of evaluation with one exception; CD 215 was significantly differed from CD 216 for the last sowing date (11/15). However, in the second year, cultivar CD 216 presented the worst result on this variable for all sowing dates except for the first sowing date (9/15), in which there was no difference in the number of pods among the cultivars experimented. On the other hand, CD 202 exhibited the best performance in the number of pods per plant on both the second (9/30) and forth (10/30) sowing dates, but was not significantly differing from the other cultivars.

The prolificity index (Table 2) on the first sowing date (1/30) did not vary among hybrids in the agricultural years of 2004 and 2005. On the second sowing date (2/15) the first agricultural year was not favored the prolificity index, obtaining indexes similar in corn plants for the three hybrids studied, except in (3/15) third sowing date where the hybrids CD 306 and CD 308 had higher showed prolificity index in 2005. There was no variation for hybrids CD 305 and CD 306 in first, third and fifth sowing date of 2004 off-season. However, on the last sowing date (3/30), the hybrid CD 308 presented a better prolificity index in 2005. The hybrids CD 305 and CD 306 did not present variation through the years in the same period.

Table 1. Plant height of soybean cultivars and corn hybrids for each sowing year.

	Soybean			Corn	
	Plant height			Plant height	
	Agricultural year[2]			Agricultural year[2]	
	2003/2004	2004/2005		2004	2005
Cultivar[1]	Sowing days		Hybrid	Sowing days	
	9/15			1/30	
CD 202	56.75 Ba	45.00 Bb	CD 305	164.25 Aa	145.50 Ab
CD 215	73.50 Aa	35.25 Bb	CD 306	149.00 Aa	120.50 Bb
CD 216	64.00 Aba	60.25 Aa	CD 308	151.25 Aa	116.00 Bb
Mean	64.75	46.83	Mean	154.83	127.33
	9/30			2/15	
CD 202	65.50 Ba	72.00 Aa	CD 305	184.75 Aa	139.75 Ab
CD 215	61.75 Ba	57.00 Ba	CD 306	179.50 Aa	130.25 Ab
CD 216	75.75 Aa	66.00 ABa	CD 308	175.75 Aa	134.75 Ab
Mean	67.67	65.00	Mean	180.00	134.92
	10/15			3/1	
CD 202	74.25 Bb	89.25 Aa	CD 305	178.25 Aa	153.00 Ab
CD 215	69.25 Ba	70.50 Ba	CD 306	175.75 Aa	135.75 Bb
CD 216	99.50 Aa	74.50 Bb	CD 308	180.00 Aa	130.50 Bb
Mean	81.00	78.08	Mean	178.00	139.75
	10/30			3/15	
CD 202	105.50 Aa	78.75 Ab	CD 305	164.75 Aa	150.25 Ab
CD 215	101.75 Aa	70.00 Ab	CD 306	167.70 Aa	121.25 Bb
CD 216	109.50 Aa	79.75 Ab	CD 308	171.75 Aa	127.50 Bb
Mean	105.58	76.16	Mean	168.06	133.00
	11/15			3/30	
CD 202	102.25 Aa	62.75 Bb	CD 305	146.00 Ab	172.50 Aa
CD 215	100.50 Aa	57.00 Bb	CD 306	149.75 Aa	151.25 Ba
CD 216	65.50 Bb	90.75 Aa	CD 308	151.25 Aa	154.75 Ba
Mean	89.41	70.16	Mean	149.00	159.5
C.V.(%)	9.58		C.V.(%)	6.07	

[1]Means followed by the same capital letter in each column do not differ between each other according to Newman-Keuls test, using 5% of probability. [2]Means followed by the same non-capital letter in each line do not differ between each other according to F test, using 5% of probability.

The prolificity index (Table 2) of the three hybrids from the five sowing dates from 2004 and 2005 sowed on 1/30 did not show variation across the years. On the sowing date of 2/15 only hybrid CD 305 presented a significant difference, in which the 2005 off-season crop the index was favored, obtaining the highest number of ears per plant. On the third sowing date (3/1) again there was not again variation in the prolificity index between 2004 and 2005. Hybrids CD 306 and CD 308 from the sown on 3/15 presented the highest number of ears per plant, and thus had the highest prolificity index in the 2005 off-season crop. There was no difference within the years for hybrid CD 305, except in second sowing date. On the fifth sowing date (3/30), only CD 308 showed significant difference in the prolificity index between 2004 and 2005, with the second year having an increased index.

A more regular water supply provided hydric intake during the crop's reproductive phase, enhancing the generation, fecundation and the maintenance of a superior number of ears in 2005.

By comparing hybrid performance within each sowing date in 2004, it was observed that there was no significant difference among the hybrids evaluated for prolificity index from any sowing date. In 2005, there was not also difference among the hybrids on the first, second and third sowing dates. Nevertheless, CD 305 presented the worst performance on the sowing date of 3/15, being significantly different from the other hybrids. Hybrid CD 308 presented the highest prolificity index on the sowing date of 3/30, which was significantly differing from the others. From these results, it can be inferred that CD 308 is more prolific, mainly in lower water availability conditions.

The yield of all three soybean cultivars on the five sowing dates for the two agricultural years is presented in Table 3. By comparing soybean crop yield on the first sowing date (9/15), it was observed that cultivars CD 202 and CD 215 sown in 2003 had better yield in relation to the year 2004/2005. However, for CD 216, there was no significant difference in seed yield for this same sowing date in the two agricultural years evaluated.

Sowing accomplished on 9/30 showed no statistical difference in seed yield in year 2003/2004 for the three cultivars evaluated, being the cultivar CD202 showed better yield in the year 2004/2005. On the third sowing date (10/15), the first sowing year was inferior when compared to the second year only for cultivar CD 202. This result was likely obtained due to the water deficit that this cultivar had been through in the second decennial period on December, 2004 (Figure 1A), which coincides with the initial phase of pod filling.

Table 2. Number of pods per plant and prolificity index of cultivars and hybrids for each period and year of sowing as well as in between years for each cultivar and hybrid.

	Soybean			Corn	
	Number of pods per plant			Prolificity index	
	Agricultural year[2]			Agricultural year[2]	
	2003/2004	2004/2005		2004	2005
Cultivar[1]	Sowing days		Hybrid[1]	Sowing days	
	9/15			1/30	
CD 202	33.00 Aa	41.75 Aa	CD 305	1.00 Aa	0.99 Aa
CD 215	36.25 Aa	36.25 Aa	CD 306	1.01 Aa	1.02 Aa
CD 216	30.25 Aa	36.25 Aa	CD 308	1.02 Aa	0.96 Aa
Mean	33.17	34.75	Mean	1.01	0.99
	9/30			2/15	
CD 202	44.25 Ab	71.25 Aa	CD 305	0.99 Ab	1.09 Aa
CD 215	39.50 Ab	56.00 Ba	CD 306	1.00 Aa	1.01 Aa
CD 216	34.25 Aa	36.75 Ca	CD 308	1.02 Aa	1.05 Aa
Mean	39.33	54.67	Mean	1.00	1.05
	10/15			3/1	
CD 202	39.00 Ab	74.00 Aa	CD 305	1.04 Aa	1.01 Aa
CD 215	29.00 Ab	67.25 Aa	CD 306	1.00 Aa	1.06 Aa
CD 216	29.25 Ab	50.25 Ba	CD 308	1.01 Aa	1.06 Aa
Mean	32.42	63.83	Mean	1.02	1.04
	10/30			3/15	
CD 202	53.50 Ab	67.50 Aa	CD 305	1.00 Aa	0.96 Ba
CD 215	43.25 Ab	54.25 Ba	CD 306	1.00 Ab	1.10 Aa
CD 216	43.50 Aa	50.25 Ba	CD 308	1.00 Ab	1.09 Aa
Mean	46.75	57.33	Mean	1.00	1.05
	11/15			3/30	
CD 202	26.25 ABb	91.50 Aa	CD 305	1.00 Aa	0.96 Ba
CD 215	33.75 Ab	95.00 Aa	CD 306	1.00 Aa	1.02 Ba
CD 216	21.00 Bb	76.50 Ba	CD 308	1.01 Ab	1.14 Aa
Mean	27.00	87.67	Mean	1.00	1.04
C.V.(%)	15.53		C.V.(%)	5.25	

[1]Means followed by the same capital letter in each column do not differ between each other according to Newman-Keuls test, using 5% of probability. [2]Means followed by the same non-capital letter in each line do not differ between each other according to F test, using 5% of probability.

Table 3. Cultivar and hybrid yields for each period and year of sowing and in between years for each cultivar and hybrid.

	Soybean			Corn	
	Yield			Yield	
	Agricultural year[2]			Agricultural year[2]	
Cultivar[1]	2003/2004	2004/2005	Hybrid	2004	2005
	Sowing days			Sowing days	
	9/15			1/30	
CD 202	3,507.11 Aa	2,410.29 Ab	CD 305	5,318.66 Aa	4,636.06 Aa
CD 215	3,587.77 Aa	2,121.24 Ab	CD 306	5,664.45 Aa	5,516.36 Aa
CD 216	2,620.12 Ba	2,082.14 Aa	CD 308	6,076.36 Aa	5,220.02 Aa
Mean	3,238.33	2,204.56	Mean	5,685.82	5,124.15
	9/30			2/15	
CD 202	3,792.63 Aa	4,076.11 Aa	CD 305	5,078.55 Aa	6,086.58 Aa
CD 215	3,742.81 Aa	3,791.93 ABa	CD 306	5,773.05 Aa	6,071.18 Aa
CD 216	3,692.82 Aa	3,251.49 Ba	CD 308	5,831.95 Aa	6,770.35 Aa
Mean	3,742.75	3,706.51	Mean	5,561.18	6,309.37
	10/15			3/1	
CD 202	1,858.78 Bb	2,711.38 Aa	CD 305	2,253.34 Ab	5,717.51 Aa
CD 215	2,524.06 Aa	3,109.26 Aa	CD 306	3,327.10 Ab	5,513.16 Ba
CD 216	2,999.50 Aa	2,756.53 Aa	CD 308	3,613.88 Ab	6,000.86 Aa
Mean	2,460.78	2,859.06	Mean	3,064.77	5,743.84
	10/30			3/15	
CD 202	836.05 Ab	3,283.29 Aa	CD 305	1,933.97 Ab	6,776.41 Aa
CD 215	1,336.43 Ab	2,627.88 Aa	CD 306	2,496.25 Ab	5,019.15 Ba
CD 216	1,232.56 Ab	2,706.24 Aa	CD 308	2,759.25 Ab	5,586.96 ABa
Mean	1,135.01	2,872.47	Mean	2,396.49	5,794.17
	11/15			3/30	
CD 202	303.19 Ab	1,356.65 Aa	CD 305	2,656.60 Ab	4,561.44 Ba
CD 215	583.65 Ab	1,286.80 Aa	CD 306	3,914.56 Ab	5,934.33 ABa
CD 216	610.62 Ab	1,920.89 Aa	CD 308	3,807.44 Ab	7,128.93 Aa
C.V.(%)	18.39		C.V.(%)	21.13	

[1]Means followed by the same capital letter in each column do not differ between each other according to Newman-Keuls test, using 5% of probability. [2]Means followed by the same non-capital letter in each line do not differ between each other according to F test, using 5% of probability.

For cultivars CD 215 and CD 216 there was no significant difference through the years for sowing on 10/15. This is due to the fact that these last two cultivars are known to mature earlier than CD 202 (COODETEC, 2005), and they might have "escaped" from this water stress period (ALBRECHT et al., 2008, 2009).

The forth (10/30) and fifth (11/15) sowing dates in 2004 were superior with respect to seed yield when compared to the previous year (2003) for all cultivars under study (Table 3).

In the first agricultural year, there was difference in yield among the cultivars only for CD 216 on the first sowing date (9/15) where it was inferior to all other cultivars. The cultivar CD 202 presented a yield that was unsatisfactory and was statistically differing from cultivars CD 215 and CD 216 on the third sowing date (10/15). The other sowing dates did not produce a significant difference in seed yield among the soybean cultivars across the years. In the second agricultural year, the only difference among the cultivars was observed on the second sowing date (9/30), in which CD 202 presented a mean yield superior to CD 216. This last cultivar, despite being classified as early maturing with a much faster cycle than the other cultivars studied, exhibited a lower yield due to the fact that it must have suffered more under the water deficit that occurred at the flowering phase and at the beginning of grain filling, thus, decreasing its yield.

The water restriction period associated was high temperatures occurred in the period between January and February in 2004 (Figure 1C) and between February and March in 2005 (Figure 1D). These periods coincided with the crop's reproductive stages and were probably the causes of the low yields observed from the sowing dates of 10/30 and 11/15.

Flowering is severely affected by water deficiency in the period from two to four weeks prior to floral differentiation (SANTOS, 2008). The period of dry matter transference is the most critical for soybean crops because it restricts the duration of the leaf area, induces the abortion of vegetative parts, speeds leaf senescence, and, consequently, the weight and number of grains is reduced. Lower water availability promotes a decrease in photosynthesis and reduces the period of seed filling, impairing the yield (FRANÇA NETO et al., 1993).

Results on the yield of the three corn hybrids for the five sowing dates over the two years are presented in Table 3. Analyzing the effect of sowing year on each hybrid for each sowing date, no statistical differences were observed throughout for the first and second sowing date. However, on the third, forth and fifth sowing dates, the year 2005 was superior when compared to the mean yield for all hybrids evaluated in that year.

The resultant yield of the hybrids from each sowing date and in each growing year showed a great diversity of performance among the hybrids evaluated. The results obtained from corn sown in 2004 did not present any difference in yields evaluated at any sowing dates (Table 3).

The sowing dates of 1/30 and 2/15 in 2005 did not present significant difference in the yield of the three hybrids. For sowing carried out on 3/1 and 3/15, the best yields were seen with hybrid CD 306 and CD 308, and the worst performance was seen in hybrid CD 305. On the last sowing date (3/30), only a statistical difference between hybrids CD 308 and CD 305 was observed (Table 3).

Analyzing the Table 4, it was observed that for the first agricultural year, cultivar CD 202 presented a crescent linear effect, in which the plants grew 0.87 cm a day, reaching a height of 107 cm at 60 days after sowing (9/15). Cultivar CD 215 presented a cubic behavior, maximum plant height reached 106 cm at 54 days after sowing (9/15), and the minimum plant height was 58 cm 13 days after sowing (09/15).

In the same year, Cultivar CD 216 presented a quadratic tendency, in which the highest plant height was obtained 33 days (maximum point) after sowing (9/15), reaching 101 cm (maximum of the function) of plant height.

In the second growing season (2004/2005) the behavior of the cultivars CD 202 and CD 215 was quadratic with maximum points (maximum function) obtained for 34 (86.36 cm) and 37 (71.23 cm) after 9/15, respectively. Cultivar CD 216, in turn, showed a linear increase, reaching a maximum height of 89.20 cm to 60 days after 9/15, and the daily increment in plant height of 0.4983 cm per day (Table 4).

In Table 4, there is it is observed that there was no significant difference ($p > 0.05$) was seen in the number of pods per plant in the first agricultural year for any of the cultivars due to the variation of soybean crop sowing dates. Nevertheless, in the second agricultural year, all of the cultivars presented a increasing linear effect due to sowing date variation. Cultivar CD 202 had an increase of pods by up to 0.64 per plant per day, reaching a minimum number around 50 pods per plant under early sowing on 9/15. Cultivar CD 215 had its pods increased to 0.77 per day and per plant (minimum number around 39 pods per plant) and cultivar CD 216 had its pods increased to 0.64 pods per day per plant (minimum 31 pods) with later sowing dates.

Table 4. Average plant height, number of pods per plant and yield of three soybean cultivars during two agricultural years and five sowing days.

		Sowing years – 2003/2004		
		Plant height (cm)		
Cultivar	Equation	R^2	Maximum/Minimum Point (days after 9/15)[1]	Maximum of the Function[4]/Angle Coefficient[5]
CD 202	$\hat{Y}=54.65 + 0.873^{*}X$	0,89	-	0,873
CD 215	$\hat{Y} = 74.42 - 2.78^{*}X + 0.13^{*}X^2 + 0.0013^{*}X^3$	0,96	54/13	105.60/58
CD 216	$\hat{Y} = 57.61 + 2.63^{*}X - 0.039^{*}X^2$	0,74	33.89	101.10
		Number of pods per plant		
Cultivar	Equation	R^2		
CD 202	$\hat{Y} = \bar{Y} = 39.20$	-----	-----	-----
CD 215	$\hat{Y} = \bar{Y} = 36.35$	-----	-----	-----
CD 216	$\hat{Y} = \bar{Y} = 31.65$	-----	-----	-----
		Yield (kg ha^{-1})		
Cultivar	Equation	R^2	Maximum Point (days after 9/15)[3]	Maximum of the Function[4]/Angle Coefficient[5]
CD 202	$\hat{Y} =3,932.4 - 62.429^{*}X$	0,90	-	62,429
CD 215	$\hat{Y} =4,037.9 - 56.097^{*}X$	0,93	-	56,097
CD 216	$\hat{Y} = 2,889.4 + 41.813^{*}X - 1.4168^{*}X^2$	0,86	14.75	3,185.4
		Sowing years – 2004/2005		
		Plant height (cm)		
Cultivar	Equation	R^2	Maximum Point (days after 9/15)[3]	Maximum of the Function[4]/Angle Coefficient[5]
CD 202	$\hat{Y} = 44.85 + 2.4483^{*}X - 0.0361^{*}X^2$	0.98	33.9	86.36
CD 215	$\hat{Y} = 34.721 + 1.9671^{*}X - 0.0265^{*}X^2$	1.00	37.12	71.23
CD 216	$\hat{Y} = 59.3 +0.4983^{*}X$	0.90	-	0.49
		Number of pods per plant		
Cultivar	Equation	R^2	-	Angle Coefficient[5]
CD 202	$\hat{Y} = 50.05 + 0.638^{*}X$	0.72	-	0.638
CD 215	$\hat{Y} = 38.6 + 0.7717^{*}X$	0.72	-	0.771
CD 216	$\hat{Y} = 31.2 + 0.6417^{*}X$	0.86	-	0.641
		Yield (kg ha^{-1})		
Cultivar	Equation	R^2	Maximum Point (days after 9/15)[3]	Maximum of the Function[4]
CD 202	$\hat{Y} = 1,013.4 + 1,959.3^{*}X - 374.88^{*}X^2$	0.69	2.61	3,573.50
CD 215	$\hat{Y} = 526.18 + 2,212^{*}X - 415.87^{*}X^2$	0.89	2.65	3,467.50
CD 216	$\hat{Y} = 1,071.4 + 1,398.1^{*}X - 247.48^{*}X^2$	0.79	2.82	3,046.00

[1]It comprises the days after 9/15 in which there was no response. [2]Maximum plant height, number of pods per plant and yield according to the maximum point in days after 9/15. [3]It comprises the days after 9/15 in which there was a maximum and minimum response. [4]Maximum plant height, number of pods per plant and yield according to the maximum and minimum point in days, after 9/15. [5]Angle Coefficient.

The performance of seed yield presented a decreasing linear tendency for cultivars CD 202 and CD 215. By using the adjusted linear equation, it is possible to infer that for each day in which sowing is delayed after 9/15 there is a decrease of 62 kg ha^{-1} for cultivar CD 202 and a decrease of 56 kg ha^{-1} for cultivar CD 215 on the sowing year 2003/2004.

There was a quadratic tendency for cultivar CD 216, probably due to its higher precocity, suffering even more with sowing delay. It had a shorter cycle and a shorter time to recover from initial adverse conditions; such as low air and soil temperatures, low rainfall and lack of photoperiod insufficient. The maximum point for cultivar CD 216 in the first year was 14 days along with a 3,197 kg ha^{-1} yield.

The same situation was observed in the second year for all of the cultivars regarding yield. The maximum points provided by the equations were 23 days for CD 202; 24 days for CD 215 and 26 days for CD 216 after 9/15.

Therefore, the preferential time period was not the most favorable for seed production in any of the two years of study for any cultivar due to the severe water stress and high temperatures. These were more evident in the first agricultural year. By evaluating the second agricultural year it can be inferred that advancing the sowing date may cause a risk for yield in early-matured cultivars considering the edaphoclimatic conditions in the western region of Paraná State.

Plant height from the three corn hybrids across the five sowing dates in the off-season period in each agricultural year is shown in Table 5. Sowing accomplished in 2004 showed that all hybrids presented a quadratic tendency for the plant height variable, where the maximum height obtained on sowing carried out 23, 29 and 39 days after 1/30 was 181 cm, 179 cm and 181 cm for hybrids CD 305; CD 306 and CD 305, respectively. In 2005, there was no difference ($p > 0.05$) in plant height for hybrid CD 305. However, the plant height for hybrid CD 306 exhibited a cubic behavior, whose maximum point after 15 days after 1/30 reached a maximum plant height of 134 cm. The lowest plant height was reached 52 days after 1/30 (109 cm).

Table 5. Average plant height, prolificity index and yield of three corn hybrids sowed during two agricultural years and five sowing days in off-spring time.

Sowing year – 2004				
Plant height (cm)				
Hybrid	Equation	R^2	Maximum Point (days after 1/30)[1]	Maximum of the Function[2]
CD 305	$\hat{Y} = 166.69 + 1.252*X - 0.0271*X^2$	0.94	23	181
CD 306	$\hat{Y} = 151.94 + 1.859*X - 0.0321*X^2$	0.91	29	179
CD 308	$\hat{Y} = 152.16 + 1.925*X - 0.0325*X^2$	0.99	30	181
Prolificity index				
Hybrid	Equation	R^2	-	-
CD 305	$\hat{Y} = \overline{Y} = 1.01$	-	-	-
CD 306	$\hat{Y} = \overline{Y} = 1.00$	-	-	-
CD 308	$\hat{Y} = \overline{Y} = 1.01$	-	-	-
Yield (kg ha^{-1})				
Hybrid	Equation	R^2	Maximum/Minimum Point (days after 1/30)[3]	Maximum/Minimum of the Function[4]
CD 305	$\hat{Y} = 5,410 + 33.4*X - 6.7*X^2 + 0.09*X^3$	0.94	2.63/47.00	5,453.14/1,523.40
CD 306	$\hat{Y} = 5,715 + 104*X - 9.3*X^2 + 0.13*X^3$	0.98	7.18/40.51	6,030.40/3,080.13
CD 308	$\hat{Y} = 6,116 + 59.3*X - 7.4*X^2 + 0.10*X^3$	0.99	4.43/44.90	6,242.17/2,911.98
Sowing year – 2005				
Plant height (cm)				
Hybrid	Equation	R^2	Maximum/Minimum Point (days after 1/30)[3]	Maximum/Minimum of the Function[4]
CD 305	$\hat{Y} = \overline{Y} = 152$	-	-	-
CD 306	$\hat{Y} = 119 + 2.3*X - 0.1*X^2 + 0.001*X^3$	0.86	15.00/51.67	134.73/109.16
CD 308	$\hat{Y} = 116 + 2.7*X - 0.1*X^2 + 0.001*X^3$	1.00	18.13/48.53	137.41/124.26
Prolificity index				
Hybrid	Equation	R^2	-	Angle Coefficient[5]
CD 305	$\hat{Y} = \overline{Y} = 1.00$	-	-	-
CD 306	$\hat{Y} = \overline{Y} = 1.04$	-	-	-
CD 308	$\hat{Y} = 0.98 + 0.0027*X$	0.92	60	0.0027
Yield (kg ha^{-1})				
Hybrid	Equation	R^2	Maximum/Minimum Point (days after 1/30)[3]	Maximum/Minimum of the Function[4]
CD 305	$\hat{Y} = \overline{Y} = 5,555$	-	-	-
CD 306	$\hat{Y} = \overline{Y} = 5,611$	-	-	-
CD 308	$\hat{Y} = 5,235 + 215*X - 9.4*X^2 + 0.11*X^3$	0.99	16/44	6,710/5,521

[1]It comprises the days after 1/30 in which there was no response. [2]Maximum plant height, number of pods per plant and yield according to the maximum point in days after 1/30. [3]It comprises the days after 1/30 in which there was a maximum and minimum response. [4]Maximum plant height, number of pods per plant and yield according to the maximum and minimum point in days after 1/30. [5]Angle Coefficient.

The same tendency occurred for hybrid CD 308, which presented a maximum plant height of 137 cm 18 days after 1/30 and the lowest one after 48 days after 1/30 whose plant height was 124 cm.

Regression analysis for the prolificity index of corn plants revealed a non-significant effect for the three corn grain hybrids evaluated in 2004. Nevertheless, in 2005, only hybrid CD 308 presented a significant effect in the analysis, permitting for adjustments in the system of the linear rising trajectory equation (Table 5).

Yield performance for all three hybrids of corn for each growing year in different off-season sowing dates can be observed in Table 5. Regression analysis on the data revealed that the hybrids presented a cubic performance corresponding to an increase in sowing dates in 2004. It was observed that maximum and minimum yield for hybrid CD 305 was reached at three and forty-seven days after 1/30, respectively, having a maximum yield of 5,453.14 kg ha^{-1} and minimum yield of 1,523.40 kg ha^{-1}. Maximum and minimum points for hybrids CD 306 were obtained at seven and forty days after 1/30, respectively, having a maximum yield of 6,030.40 kg ha^{-1} and a minimum yield of 3,080.13 kg ha^{-1}. Hybrid CD 308, in turn, obtained maximum yield (6,242.17 kg ha^{-1}) four days after the first sowing date and a minimum yield (2,911.98 kg ha^{-1}) forty-five days after the first sowing date. The cubic tendency, having minimum points between 46 and 49 days, indicates a yield drop for corn grain sown near 3/14 and 3/30. Such occurrence is mainly due to climatic influence on physiology and consequently on the agronomic yield of the crop. It is important to point out that the hybrids of corn grains sown on the forth (3/14) and fifth (3/30) sowing dates entered the reproductive phase in late May, and that the consecutive months had not only low temperatures, but also low pluvial precipitation. The drop in yield for corn grains is due to these thermal and hydric restrictions, in addition to the solar radiation decreased in winter (June 21st, was winter solstice and was the shortest day of the year).

Corn crop yield is limited, mainly by solar radiation and temperatures, and these limitations are important for certain regions, especially for non-conventional sowing dates, such as the off-season period in the southern region in Brazil (CHANG, 1981; FANCELLI; DOURADO-NETO, 2008; FARINELLI et al., 2003).

Concerning water requirements, the plant demands at least 350 to 500 mm of rainfall, and its daily input seldom exceeds 3 mm until the seven-leaf stage. However, during its reproductive stages, it can reach 10 mm. Fancelli and Dourado-Neto (2008) show evidenced that water deficit throughout a week during flowering may reduce yield grain to 50%, while, after the pollination period it can be reduced to 30%.

There was no significant difference in yield for hybrids CD 305 and CD 306 in 2005, indicating a higher yield stability for these two hybrids on different sowing dates in the off-season period. This was probably due to a more constant water input when compared to 2004 (Table 5). However, the performance of hybrid CD 308 with respect to the yield (having a maximum point of 6,710 kg ha^{-1} and a minimum point of 5,521 kg ha^{-1} at 16 and 44 days after 1/30, respectively) permitted that adjustment on the equation of cubic regression could be made.

According to the results previously discussed in Tables 1, 2 and 3, hybrids CD 305, CD 306 and CD 308 presented a satisfactory agronomic performance for off-season growing. It is important to highlight that the best sowing date is until February, especially in the first agricultural year. This timing avoids the diminution of solar radiation, drought and low temperatures at the crop's reproductive phase; a period when these factors are harmful to the development of the plant (BERGAMASCHI et al., 2004; CARDOSO et al., 2004; JONG et al., 1982; LOZADA; ANGELOCCI, 1999; MATZENAUER, 2002; MOTTA et al., 2002). For late sowings, a good suggestion would be the use of hybrids CD 308 and CD 306, which are double and triple hybrids, respectively, that demonstrated more adaptation to the adverse climatic conditions as diagnosed in this experiment.

For the selection of a sowing date for early soybean cultivars that precede off-season corn crop succession, the preferable date within the recommended range (EMBRAPA, 2006) is not indicated by the results obtained throughout the two years studied.

Moreover, regarding the second year of growth, the data presented here suggest that the first period of sowing would not be the most convenient. Sowing on 9/30 produced a soybean crop with a better agronomic performance and a more satisfactory yield. This occurred once water supply was more favorable according to the soybean physiological demanding (CÂMARA et al., 1998; MATZENAUER et al., 2003).

Some farmers have experimented with different early soybean varieties with the objective to accomplish off-season corn crop sowing at the earliest possible date, at least in some part of their property. The ideal cultivar to precede the off-season corn crop would be cultivar CD 215 because it did not present any inferior yield compared to the others tested. Anticipated soybean sowing, concerning the soybean cycle, makes it possible for the off-season corn crop sowing to occur as son as possible and climatic limitations can possibly be minimized. A more accurate strategy may be suggested from the data obtained in this study. By analyzing the characteristics of cultivars within the periods and the years, the second soybean sowing date (9/30) and the second off-season corn (2/15) in succession were the ones that presented the best performance in all cultivars and for all hybrids; favoring succession growing in the western region of Paraná State. It is assumed that for the off-season crop, growing dates later in March account for more natural drops in yield. The best growth was experienced with sowing dates up until February, and this is the recommended period if a grower intends to use these practices.

Conclusion

In the second agricultural year, a higher seed yield was obtained for the three soybean cultivars sowed in October. The anticipation of off-season growth is a valid strategy for obtaining a good agronomic performance and the best yields in corn for off-season sowings. The hybrids CD 308 and CD 306 were the ones that demonstrated a better performance in adverse climatic conditions in the off-season.

The succession of early soybean-early corn in the off-season is a viable alternative for the western region of Paraná State, unless both the soybean and corn sowings are anticipated for the first fifteen days in (early) October and February, respectively.

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