Revista Ciência Agronômica, v. 50, n. 1, p. 114-122, jan-mar, 2019
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Yield loss in sunflower cultivars due to bird attack [1]

Perda no rendimento de cultivares de girassol devidas ao ataque de pássaros

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ABSTRACT - Bird attacks on the sunflower may hinder its exploitation in the Brazilian semi-arid region. The aim of this study was to evaluate the effects of different levels of protection (0, 33, 66 and 100%) of the capitula of eight sunflower cultivars, evaluated in randomized blocks with sub-divided plots and four replications. The cultivars were allocated in the plots and the levels of protection in the sub-plots, by covering the capitula with caps of non-woven fabric after physiological maturity. The most frequent bird species was the *Paroaria dominicana*. The Aguará 06 cultivar was the most productive and most tolerant to bird attack, followed by the Helio 250, CF 101 and Charrua cultivars. There was a positive correlation between yield loss (YL) due to birds and the flowering period, YL and the period for physiological maturity, YL and capitulum diameter, YL and stem diameter, YL and plant height, YL and the angle of the capitulum with the stem, and between YL and the distance of the capitulum from the ground. A negative correlation and the absence of correlation were seen between YL and the number of leaves, and between YL and distance of the capitulum to the stem respectively. The effects of protecting the capitula were similar for grain yield in the cultivars under test. Use of the caps was efficient, since an increase in the proportion of protected capitula determined an increase in grain yield, number of grains per capitulum and 1000-grain weight. These increases continued up to a certain proportion, after which there was a decrease in the three characteristics.

Key words: *Helianthus annuus. Paroaria dominicana*. Protection of capitula. Phenotypic correlation. Genetic improvement.

RESUMO - O ataque de pássaros ao girassol pode dificultar a exploração do girassol no semiárido brasileiro. O objetivo deste trabalho foi avaliar os efeitos de níveis (0, 33, 66 e 100%) de proteção dos capítulos de oito cultivares de girassol, avaliadas em blocos casualizados com parcelas subdivididas e quatro repetições. As cultivares foram aplicadas nas parcelas e, nas subparcelas, foram aplicados os níveis de proteção, cobrindo-se os capítulos com toucas de tecido não tecido, após a maturação fisiológica. A espécie de pássaro mais frequente foi a *Paroaria dominicana*. A cultivar Aguará 06 foi a mais produtiva e mais tolerante ao ataque de pássaros, seguida pelas cultivares Helio 250, CF 101 e Charrua. Foi positiva a correlação entre: perda de rendimento (PR), devida aos pássaros, e o período para a floração; PR e o período para a maturação fisiológica; PR e o diâmetro do capítulo; PR e o diâmetro do caule; PR e a altura da planta; PR e o ângulo do capítulo com o caule; e entre PR e a distância do capítulo ao solo. Correlação negativa e ausência de correlação foram observadas entre PR e o número de folhas e entre PR e distância do capítulo ao caule, respectivamente. Os efeitos da proteção dos capítulos foram similares no rendimento de grãos das cultivares testadas. O uso das toucas foi eficiente, pois o aumento da proporção de capítulos protegidos determinou aumentos no rendimento de grãos, no número de grãos por capítulo e na massa de 1000 grãos. Esses aumentos ocorreram até determinadas proporções, a partir das quais ocorreram decréscimos nas três características.

Palavras-chave: *Helianthus annuus. Paroaria dominicana*. Proteção dos capítulos. Correlação fenotípica. Melhoramento genético.

DOI: 10.5935/1806-6690.20190014
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Received for publication in 31/08/2017; approved in 18/03/2018
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INTRODUCTION

Biodiesel is a substitute for diesel oil, obtained from vegetable or animal oils. The National Program for the Production and Use of Biodiesel (PNPB) was created by the Brazilian government with the aim of encouraging the production of biodiesel, and promoting social inclusion through the strengthening of family farming in the semi-arid region (GARCIA; ROMEIRO, 2010). There is therefore interest in crops that are able to meet the aims of the PNPB in the Brazilian semi-arid region. The sunflower (*Helianthus annuus* L.) is one of the crops that can meet these goals.

The result of the above was a program to evaluate sunflower cultivars, which was started in 2011 in Mossoró in the State of Rio Grande do Norte. In that year, there were no bird attacks on sunflower plots. However, in 2012, grain losses due to bird attack were estimated at 25% to 70%, depending on the cultivar. Alizadeh (2009) estimated losses in grain yield of between 75% and 84%, which again depended on the cultivar.

Damage to the sunflower caused by birds occurs in the major producing regions of the world (LINZ *et al*., 2011). Several researchers have been concerned with the problem and several control measures have been suggested, including firecrackers, decoy crops, traps, chemical repellents, cropping practices and resistant cultivars (LINZ; HANZEL, 2015). Most of these methods are economically unviable or harmful to the environment.

The development of sunflower cultivars resistant to bird attack is an economical and environmentally safe method of minimizing the problem, and several researchers have attempted to obtain such crops (KHALEGHIZADEH; ALIZADEH, 2009; YASUMOTO *et al*., 2012). There is a need therefore, to identify the characteristics that condition resistance to bird attack.

The most frequently identified characteristics of sunflower cultivars that make them less vulnerable to bird attack include concavity of the capitulum (KHALEGHIZADEH *et al*., 2009), ground-facing capitula, a distance of greater than 15 cm between the capitulum and stem, seeds firmly attached to the capitulum, long bracts facing the front of the capitulum, lower plants, less tilt of the capitulum (PRAKASH; GULED; BHOSALE, 2008), a capitulum angle of 16 to 25° (KHALEGHIZADEH *et al*., 2009), and late cultivars (KHALEGHIZADEH; ALIZADEH, 2009).

Identifying these characteristics has generally been done by estimating correlations between the characteristics and yield, with or without protection for the capitula against bird attack. Experimentally, protection has been by plastic mesh (SILVA *et al*., 2009), non-woven fabric bags (SANTOS *et al*., 2012) or cloth bags (COELHO; GERALD, 2013). No studies were found in the literature on the relationship between the proportion of protected capitula and grain yield in the sunflower.

The aim of the present work was to evaluate the effects of different levels of protection of the capitula of sunflower cultivars, in order to identify the most tolerant to bird attack and the most productive.

MATERIAL AND METHODS

The experiment was carried out on the Rafael Fernandes Experimental Farm of the Federal Rural University of the Semi-Arid Region (UFERSA), located 20 km from the district of Mossoró (5°3'38'' S, 37°23'46'' W) at an altitude of 18 m. According to the Gaussen Bioclimatic Classification, the climate in the region is type 4ath, strongly thermoxeroquimenic, meaning hot tropical with a long season of marked drought (seven to eight months) and a xerothermic index between 150 and 200 (CARMO FILHO; OLIVEIRA, 1989).

The soil is classified as a Red-Yellow Argissol according to the Brazilian System of Soil Classification (EMBRAPA, 2013), and was prepared by harrowing twice and then fertilized with 75 kg of N, 115 kg of P_2O_5 and 85 kg of K_2O per hectare. Ammonium sulfate, single superphosphate and potassium chloride were used as the source of N, P_2O_5 and K_2O respectively. A third of the nitrogen, all the phosphorus and all the potassium was used as fertilizer when sowing, which was applied next to and below the sowing grooves. The rest of the nitrogen was applied as cover, at 20 and 40 days after sowing.

Sowing was done with four seeds per pit on June 25, 2015, at a spacing of 0.7 m x 0.3 m. Weeds were controlled by hoeing, 20 and 40 days after sowing. After the first weeding, the plants were thinned to leave the most vigorous plant. After thinning, the planned planting density of the experiment was 47,619 plants ha^{-1}.

Eight cultivars (Aguará 05, Aguará 06, CF 101, Charrua, Hélio 250, Paraíso 55, Paraíso 65 and Paraíso 104 CL) were evaluated in randomized complete blocks, with sub-divided plots and four replications. Each plot consisted of six rows, 6.0 m in length. The four central rows were considered the working area, from all of which one plant at each end was discarded when harvesting. The cultivars were allocated in the plots and the protection against bird attack in the subplots. This protection was by placing caps of the type used by medical workers and made from non-woven fabric (NWF, No. 13370), over the capitula after the physiological maturity of the sunflower. In each of the working rows, one of the following

proportions was tested: 0% protection = no caps on the capitula of any of the 18 plants; 33.3% protection = a cap on the capitula of six plants and no caps on the capitula of 12 plants; 66.6% protection = a cap on the capitula of 12 plants and no caps on the capitula of six plants; 100% protection = caps on the capitula of all 18 plants.

The following characteristics were only evaluated in the row where all the capitula were protected: period to start of flowering - number of days from sowing (DS) to the appearance of the first flower at stage R4[5] (CONNOR; HALL, 1997); full flowering - DS until 50% of the plants in the working area were at phenological stage R4; physiological maturity - DS until 90% of the plants in the useful area presented capitula with bracts of a yellow to chestnut coloration (30% moisture in the achenes); number of leaves - in ten competitive plants, when 50% of the plants in the working area were at phenological stage R4; plant height - from ground level to the point of insertion of the capitulum, in ten competitive plants; stem diameter - 5.0 cm from ground level, measured with digital calipers; and capitulum diameter - measured with a rule. The following characteristics were estimated in each of the four rows of each plot: number of grains per capitulum (in five capitula); 1000-grain weight (estimated from the grain of the same five capitula); grain yield (estimated from the grain produced by the plants in the working area of each experimental unit, corrected for 11% moisture). Monitoring of the birds in the experiment began shortly before physiological maturity, by means of visual observation and photographs.

The experimental data were submitted to analysis of variance (GOMES, 2009). The data for grain yield, number of grains per capitulum and 1000-grain weight were analyzed as data in an experiment in sub-divided plots. For these characteristics, the effects from the proportion of plants protected against bird attack were evaluated using regression analysis. The other characteristics under evaluation were analyzed as an experiment in randomized blocks. The analysis of variance was carried out in the SIRVAR software developed by the Federal University of Lavras (RIBEIRO JÚNIOR, 2001) and the mean values of the treatments were compared by the Scott-Knott test (1974) at 5% probability. The regression analysis was performed with the Tablecurve 2D software developed by Jandel (1992). The linear correlation coefficient between grain-yield loss and the other evaluated characteristics was also estimated. Yield loss was expressed as a percentage, where the yields obtained with the protection of all the capitula in the plot were equal to 100%. The estimated correlation coefficients were tested at 5% probability by t-test (GOMES, 2009).

RESULTS AND DISCUSSION

There were differences between cultivars regarding the periods to the start of flowering and to full flowering, capitulum diameter and plant height (Table 1). In terms of flowering (start and full flowering), three groups of cultivars were identified (Table 2). For the start of flowering, the earliest cultivars were Aguará 05 and Paraíso 55, and the latest were Aguará 06, CF 101, Charrua and Paraíso 65. The other cultivars displayed an intermediate cycle. With full flowering, classification of the cultivars was similar to their classification for the start of flowering, except for cultivar CF 101, that became a member of the intermediate full-flowering group. There were no differences between cultivars regarding the period to physiological maturity (Tables 1 and 2).

Some researchers defend precocity as a desirable characteristic in crops that are exploited in the northeast of Brazil, arguing that this characteristic enables the crops to avoid the hot-dry periods that are common during the rainy season in the region. This argument must be considered with caution, since these periods occur randomly. This means that a hot-dry period can damage an early cultivar but cause no damage to a late cultivar and vice versa. Differences between cultivars regarding phenological characteristics, as seen in the present study, were found by other authors (ALI *et al*., 2012).

Two groups of cultivars were identified in relation to plant height and stem diameter (Table 2). The cultivars that displayed the greatest plant height (Aguará 06, Helio 250 and Paraíso 65) were also those with the greatest stem diameter (except for the Charrua cultivar, which was included among the cultivars with the greatest stem diameter). The two characteristics, especially plant height, are associated with lodging (KOUTROUBAS; VASSILIOU; DAMALAS, 2014; PIVETTA *et al.*, 2012).

Lodging in the sunflower often occurs when the plants begin to mature, and is a major problem in regions subject to strong winds or torrential rains. In the experiment that served as the basis for the present study, lodging, when it occurred, was reduced. It should be noted that not only plant height and stem diameter influence lodging; susceptibility to lodging depends on complex interactions between the mechanical properties of the stem and the roots, and the environmental conditions (SPOSARO *et al*., 2010). For example, sunflower lodging depends on the force exerted by the wind on the upper part of the plant (SPOSARO *et al*., 2010). Hall, Sposaro and Chimenti (2010) drew attention to the thickness of the stem wall as an important characteristic associated with lodging in the sunflower, as in other crops.

Table 1 - Summary of the analysis of variance for the period to the start of flowering, to full flowering and to physiological maturity, for the capitulum and stem diameter and plant height, in sunflower cultivars

Source of variation	Degrees of freedom	Period (days after sowing)			Capitulum diameter (cm)	Stem diameter (mm)	Plant height (cm)
		Start of flowering	Full flowering	Physiological maturity			
		---------- Mean squares ----------					
Blocks	3	1.13	2.53	5.88	1.36	5.88	102.44
Cultivars	7	51.13*	49.03*	23.69*	9.00*	23.69*	694.48*
Residual	21	4.79	1.84	2.92	0.96	2.92	90.03

ns, * Corresponding non-significant and significant values at 5% probability by F-test respectively

Table 2 - Mean values for the period to the start of flowering, to full flowering and to physiological maturity, for the stem and capitulum diameter and plant height, in sunflower cultivars[1]

Cultivar	Start of flowering	Full flowering	Physiological maturity	Plant height (cm)	Stem diameter (mm)	Capitulum diameter (cm)
	---------- Days after sowing ----------					
Aguará 05	49.3 c	53.5 c	86.3 a	109.3 b	14.8 b	13.5 b
Aguará 06	57.5 a	62.0 a	89.0 a	142.8 a	19.5 a	16.8 a
CF 101	54.8 a	56.8 b	86.5 a	110.3 b	15.0 b	12.8 b
Charrua	58.0 a	61.5 a	86.5 a	116.3 b	17.0 a	14.3 b
Hélio 250	52.3 b	57.3 b	87.5 a	130.3 a	17.8 a	14.8 b
Paraíso 55	48.5 c	53.5 c	85.8 a	106.0 b	14.5 b	13.8 b
Paraíso 65	55.5 a	61.5 a	90.3 a	129.3 a	19.3 a	16.3 a
Paraíso 104CL	51.8 b	56.3 b	88.0 a	110.5 b	12.8 b	12.8 b
CV, %	3.8	2.2	3.6	8.0	10.5	6.8
Correlation coefficient[2]	1.21[ns]	0.44*	0.65*	0.24*	0.43*	0.54*

[1]Mean values followed by the same letter do not differ at 5% probability by the Scott-Knott test (1974). CV = coefficient of experimental variation; [2]linear correlation coefficient between the characteristic and the percentage loss in grain yield due to bird attack (yield with protected capitula = 100%): ns and * = not significant and significant at 5% probability by t-test

The Aguará 06 and Paraíso 65 cultivars presented the largest capitulum diameter, did not differ and were superior to the other cultivars, which also did not differ in relation to this characteristic (Table 2).

The linear correlation was positive between yield loss due to bird attack and the period to full flowering and physiological maturity, the capitulum and stem diameter, and plant height (Table 2). Although the linear correlation coefficient does not necessarily indicate a correlation of cause and effect, there can be some speculation about the correlations found in the present study. Later plants would spend more time in the field and would be more prone to bird attack. The earliest cultivars are probably the most tolerant to birds due to the escape effect, and together proved to be the least productive in the environment where the experiment on which the present study was based was carried out. Larger capitula should attract more birds; although it is not usual to establish a functional relationship between grain yield (y) and capitulum diameter (x), using regression analysis Heldwein *et al*. (2014) concluded that $y = 358.6 x - 3007.3$ ($R^2 = 0.81$). Taller plants exhibit their capitula more, and should also attract more birds.

There was an effect from the cultivars on the number of leaves per plant, the angle of the capitulum with the stem and on the distance from the capitulum to the stem and the capitulum to the ground surface (Table 3). The Paraíso 104 CL cultivar showed the lowest number of leaves per plant (Table 4). One group formed by the Aguará 05, CF 101 and Paraíso 55 cultivars showed an intermediate number of leaves, and the remaining cultivars showed the greatest number of leaves, including Aguará 06, the most productive cultivar (Table 4).

Table 3 - Summary of the analysis of variance for plant height, number of leaves per plant and stem diameter, in sunflower cultivars

Source of variation	Degrees of freedom	Number of leaves per plant		Angle of the capitulum with the stem (°)	Distance from the capitulum to the stem (cm)	Distance of the capitulum to the ground (cm)
		Original data	Data transformed by the square root			
		---------- Mean squares ----------				
Blocks	3	4.24	0.05	6.78	1.21	144.78
Cultivars	7	44.87*	0.47*	1221.35*	30.48*	1255.71*
Residual	21	2.31	0.02	97.35	0.57	66.73

*Significant corresponding values at 5% probability by F-test respectively

Table 4 - Mean values for the number of leaves per plant, the capitulum angle with the stem and the distance from the capitulum to the stem and to the ground, in sunflower cultivars[1]

Cultivar	Number of leaves per plant		Angle of the capitulum with the stem (°)	Distance from the capitulum to the stem (cm)	Distance of the capitulum to the ground (cm)
	Original data	Data transformed by the square root			
Aguará 05	22.8	4.8 b	104.0 b	9.0 b	65.5 c
Aguará 06	28.8	5.4 a	127.0 a	4.3 c	106.8 a
CF 101	21.0	4.6 b	107.0 b	4.5 c	68.3 c
Charrua	23.4	5.2 a	143.8 a	3.3 c	102.3 a
Hélio 250	26.3	5.1 a	93.0 b	11.0 a	74.0 c
Paraíso 55	21.9	4.7 b	134.0 a	5.0 c	84.8 b
Paraíso 65	26.1	5.1 a	132.0 a	4.0 c	111.3 a
Paraíso 104 CL	19.5	4.4 c	126.0 a	4.5 c	86.5 b
CV, %	-	3.2	8.2	13.2	9.4
Correlation Coefficient[2]	-	0.29[ns]	0.56*	- 0.38*	0.72*

[1]Mean values followed by the same letter do not differ at 5% probability by the Scott-Knott test (1974). CV = coefficient of experimental variation; [2]linear correlation coefficient between the characteristic and the percentage loss in grain yield due to bird attack (yield with protected capitula = 100%): ns and * = not significant and significant at 5% probability by t-test

The Aguará 05, CF 101 and Helio 250 cultivars showed the smallest capitulum angles with the stem, being surpassed by the other cultivars, which did not differ in relation to this characteristic. The Helio 250 cultivar displayed the greatest distance from the capitulum to the stem, followed by the Aguará 05 cultivar, which in turn was followed by the remaining cultivars that showed no difference in relation to this characteristic (Table 4).

Three cultivars displayed the largest distances from the capitulum to the ground surface (Aguará 06, Charrua and Paraiso 65), two showed intermediate distances (Paraiso 55 and Paraiso 104 CL) and the remainder had the shortest distances (Table 4). There was a positive correlation between the yield loss due to bird attack (YL) and the capitulum angle with the stem and the distance from the capitulum to the ground (Table 4). Capitula that are further from the stem and capitula further from the ground (taller plants) would favor bird attacks. A negative correlation and the absence of correlation were seen between YL and the number of leaves, and YL and capitulum distance to the stem respectively (Table 4). The capitulum of the sunflower is located at the top of the plant and is therefore above the leaves, so no correlation between the number of leaves and bird attacks is expected. Smaller distances from the capitulum to the stem would make it difficult for birds to attack, possibly due to the proximity of the upper leaves.

Although there were several species of birds in the experimental area, the most frequent and most numerous species was *Paroaria dominicana* L., known locally in the northeast of Brazil as the *galo-de-campina* (red-cowled cardinal). The bird measures around 17.0 to 18.0 cm with

red feathers on the head, and gray, black and white feathers at the back. The ventral part has white feathers. Based on several authors, Carvalho *et al*. (2007) describe the red-cowled cardinal as a granivorous bird with a thick, conical beak that can eat small arthropods and mollusks. Visits to the plants occur almost throughout the day, although they are more frequent from 7 am to 11 am. The length of the visits varies from 15 seconds to 4 minutes (GOMES; QUIRINO; ARAUJO, 2014).

There was an effect on grain yield from the cultivars (C) and from the protection against bird attack (P), but not from the C x P interaction (Table 5). On average, the Aguará 06 cultivar was the most productive, with the Helio 250 cultivar in second place; this was followed by a group formed by the CF 101 and Charrua cultivars (Table 6). The remaining cultivars formed the least productive group. On average, grain yield increased with increases in the proportion of capitulum protection against bird attack, as shown by the regression equation, demonstrating that the use of non-woven fabric caps is effective in protecting sunflower capitula against bird attack (Table 6). As shown by the equation $y = 2514.55 + 0.22\ x^2 - 0.00002\ x^4$ (Table 6), the mean grain yield of the cultivars (around 3193 kg ha^{-1}) would be obtained by protecting the capitula of approximately 82% of the plants.

The coefficient of experimental variation (CV) of the yield data (Table 6) was classified as high (CARVALHO *et al*., 2003). There are at least two reasons for this high value (= s/mean), both related to the very nature of the experiment. Firstly, the overall mean value of the yield was reduced due to bird attack on the unprotected capitula, which contributed to raising the value of the CV; secondly, the distribution of the bird attack may not have been uniform in each experimental block, including due to natural randomization. Randomness in the treatments is necessary to validate the estimate of the experimental error. However, this principle of experimentation may result in those plots that are planted with cultivars, having characteristics that favor bird attacks and contributing to the unevenness of such attacks. For example, cultivars at the sides of the blocks may be more attacked by the birds. In the present study, it was found that the birds landed on trees and fences near the experiment, and it is possible that some edges of the experiment suffered more damage than did others. Fleming, Gilmour and Thompson (2002) found that attacks by *Cacatua* spp. on fields of sunflower first started at the edges, but then included the whole crop. According to these authors, there may be a bias in sampling fields attacked by birds if the damage at the edges of the field is greater than the damage in the field.

No information was found in the literature on the type of distribution of a bird attack on the sunflower. Silva *et al*. (2014) found that the spatial distribution of an insect attack could be aggregated, random or uniform depending on the pest (SILVA *et al*., 2014). In *Pistacia vera* L., a tree species, the distribution of a bird attack was random or aggregate depending on the species of bird (CRABB; MAROIS; SALMON, 1994).

There was an effect from the cultivars (C), the protection against bird attack (P) and the C x P interaction on the number of grains per capitulum (Table 5). Despite the different behavior of the cultivars in response to the protection against bird attack, the Aguará 06 and Helio 250 cultivars, the most productive (Table 6), had the highest number of grains per capitulum (Table 6).

In the Helio 250, Paraíso 55 and Paraíso 104 CL cultivars, the number of grains per capitulum was the same with or without protection against bird attack (Table 6). This could indicate a greater resistance of these cultivars to bird attack (unprotected capitula had a similar number of grains per capitulum as that of protected capitula). However, it seems more probable that the lack of fit of the regression equations to these cultivars is due more to experimental error than resistance to birds, since in these

Table 5 - Summary of the analysis of variance of the capitulum angle with the stem, distance from the capitulum to the stem and distance of the capitulum to the ground, in sunflower cultivars

Source of variation	Degrees of freedom	Grain yield (kg ha^{-1})	Number of grains per capitulum	1000-grain weight (g)
		---------- Mean squares ----------		
Blocks	3	3574207.9	10243.9	551.0
Cultivars (C)	7	6932672.7*	479207.6*	215.1^{ns}
Residual (a)	21	911550.7	44661.9	128.8
Protection (P)	3	2806980.7*	275258.9*	107.7^{ns}
C x P	21	416320.1^{ns}	42052.0*	806.6^{ns}
Residual (b)	72	358433.9	17051.2	79.3

$^{ns, *}$* Corresponding non-significant and significant values at 5% probability by F-test respectively

Table 6 - Mean values for grain yield, number of grains per capitulum and 1000-grain weight, in sunflower cultivars in response to protection of the capitulum with non-woven fabric caps after physiological maturity[1]

Cultivar	Proportion of protected capitula (%, x)				Mean	Regression equations
	0	33.3	66.6	100		
Grain yield (kg ha^{-1}, y)						
Aguará 05	2369	2335	2613	2730	2512 d	-
Aguará 06	3919	4023	4402	4542	4221 a	-
CF 101	2648	2731	3144	2684	2802 c	-
Charrua	2456	2838	3482	3033	2952 c	-
Hélio 250	3165	3272	3501	3370	3327 b	-
Paraíso 55	2160	2373	2678	2592	2451 d	-
Paraíso 65	1671	1727	3622	3094	2529 d	-
Paraíso 104 CL	2014	2147	1958	2352	2118 d	-
Mean	2550	2681	3175	3050	2864	$y = 2514.55 + 0.22\ x^2 - 0.00002\ x^4$. $R^2 = 0.98$
CV_{plots} %			33.3			
$CV_{sub\text{-}plots}$ %			20.9			
Number of grains per capitulum (y)						
Aguará 05	686 b	735 b	893 b	832 b	-	$y = 676.05 + 0.07\ x^2 - 0.000006\ x^4$. $R^2 = 0.99$
Aguará 06	1061 a	1164 a	1229 a	1131 a	-	$y = 1057.2 + 3.83\ x^2 - 0.0003\ x^3$. $R^2 = 0.99$
CF 101	891 a	924 b	940 b	936 b	-	$y = 890.9 + 1.29\ x^2 - 0.008\ x^2$. $R^2 = 0.99$
Charrua	655 b	798 b	984 b	943 b	-	$y = 659.0 + 0.17\ x^2 - 0.001\ x^3$. $R^2 = 0.99$
Hélio 250	936 a	1280 a	1130 a	1165 a	-	y = 1128
Paraíso 55	692 b	749 b	715 c	724 c	-	y = 720
Paraíso 65	405 c	685 b	927 b	1022 a	-	$y = 401.9 + 9.05\ x - 0.0003\ x^3$. $R^2 = 0.99$
Paraíso 104 CL	645 b	724 b	659 c	851 b	-	y = 720
CV_{plots} %			24.1			
$CV_{sub\text{-}plots}$ %			14.9			
1000-grain weight (g, y)						
Aguará 05	74.3	78.5	70.9	78.0	75.5 a	-
Aguará 06	77.1	83.8	74.6	69.5	76.3 a	-
CF 101	74.5	70.3	76.9	62.8	71.1 a	-
Charrua	73.5	68.6	85.5	73.8	74.6 a	-
Hélio 250	78.5	77.1	77.3	71.8	76.2 a	-
Paraíso 55	71.2	81.8	82.2	79.7	78.7 a	-
Paraíso 65	72.2	70.3	66.4	66.5	68.9 a	-
Paraíso 104 CL	66.8	69.6	71.5	68.1	69.0 a	-
Mean	73.5	75.0	75.3	71.3	73.8	$y = 73.48 + 0.06\ x - 8.37\ x3$. $R^2 = 0.99$
CV_{plots} %			15.4			
$CV_{sub\text{-}plots}$ %			12.1			

[1]Mean values followed by the same letter do not differ at 5% probability by the Scott-Knott test (1974)

cultivars, there was, as in the other cultivars, a tendency towards an increase in the number of grains per capitulum with increases in the proportion of protected capitula. As with grain yield, as the proportion of protected capitula increased, there was an increase in the number of grains per capitulum. However, after reaching a certain proportion (which depended on the cultivar), there was a decrease in the number of grains per capitulum in the majority of cultivars under evaluation, in accordance with the adjusted equations (Table 6).

For 1000-grain weight, analysis of variance did not indicate any effect from the cultivars (C), from the protection against bird attack (P), or from the C x P interaction (Table 5). However, regression analysis showed that increasing the proportion of protected capitula resulted in an increase in grain weight (Table 6). This increase occurred only up to a proportion of approximately 50% of the protected capitula, when there was a decrease in the 1000-grain weight in accordance with the adjusted equation. As mentioned above, similar observations were made for grain yield and the number of grains per capitulum (Table 6).

The effects of protecting the capitula against bird attack on the 1000-grain weight and the number of grains per capitulum, was reflected in grain yield. There was a decrease in grain yield after approximately 82% protection of the capitula (as mentioned above), in accordance with the adjusted equation (Table 6).

There are at least two reasons for the reductions in grain weight, in the number of grains per capitulum, and consequently in grain yield, after reaching certain proportions of protected capitula, as indicated by the adjusted equations. Firstly, it is possible that protection of the capitula, supposedly made after physiological maturity, was carried out in at least some plants before physiological maturity, and hindered complete grain formation. Physiological maturity is determined visually, and errors may occur in its evaluation. However, it is most likely that covering the capitula led to reductions in grain yield and its components. The air temperatures in Mossoró are high (CARMO FILHO; OLIVEIRA, 1989) and covering the capitula may have contributed to raising the temperature even more. Some authors have found that submitting sunflower capitula to high temperatures caused a reduction in grain yield, and was attributed to reductions in grain weight and increases in the proportion of grains with reduced filling (RONDAMINI *et al*., 2006).

In addition to the aspects already discussed, another aspect should be emphasized from the data in Table 6. Covering the capitula may result in underestimating the yields of sunflower grain in studies that attempt to assess the damage to sunflower yield from bird attack and with protection of the capitula. Moreover, this underestimation may differ between cultivars if the cultivar x protection interaction is significant. Since in most experiments, researchers do not use different proportions of capitulum protection (generally, in order to avoid losses, all the capitula are protected), this interaction cannot be detected.

CONCLUSIONS

1. The most frequent and most numerous bird species in the experimental area was *Paroaria dominicana*;
2. The Aguará 06 cultivar was the most productive (and more tolerant to bird attack), followed by the Helio 250, CF 101 and Charrua cultivars;
3. There was a positive correlation between yield loss (YL) due to birds and the flowering period, YL and the period for physiological maturity, YL and capitulum diameter, YL and stem diameter, YL and plant height, YL and the angle of the capitulum with the stem, and between YL and the distance of the capitulum from the ground. A negative correlation and the absence of correlation were seen between YL and the number of leaves, and YL and distance of the capitulum to the stem respectively;
4. The effects of protecting the capitula were similar to grain yield in the cultivars under test. Use of the caps was efficient, since an increase in the proportion of protected capitula determined an increase in grain yield, number of grains per capitulum and 1000-grain weight. These increases continued up to a certain proportion, after which there was a decrease in the three characteristics.

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