Influence of morphological head traits of sunflower on "eared dove" (*Zenaida auriculata*) depredation

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Abstract

- Depredation of sunflower by granivorous birds, like "eared dove" (*Zenaida auriculata*), is regarded as a major impediment to profitable sunflower in some areas. For bird-resistance studies, two main strategies were recognized: chemical (repellents) and morphological characteristics (for example head angle and down-facing head). The aims of this work were i) determine the genetic variability of morphological traits in sunflower and ii) evaluate the damage of "eared dove" on contrasting hybrids in a natural infestation area.

- This research was carried out during the 2010/2011 growing season in Reconquista (29° 11' S; 59° 52' W) and Tostado (29° 14' S, 61° 46' W), Santa Fe, Argentina. The field experiments were conducted in a randomized complete block design with three replications, using 93 commercial hybrids and lines from breeding programs of sunflower in Reconquista and 15 commercial hybrids in Reconquista and Tostado. In all cases, experimental units were four rows 0.7 m apart and 6 m long. Morphological traits measured were: i) Head Angle (HA) the angle by which the general surface of a sunflower head makes with the horizontal (i.e. 90° and 0° surface head were parallel and perpendicular to the surface of soil respectively); ii) Down-Facing Head (DFH) the distance of head to the top of the stems in cm. Bird damage was only measured in Tostado due to high pressure of "eared doves" depredation. This measurement was based on the percentage of damaged head surface area on each sunflower head. All measurements had been done at the phenological stage of physiological maturity (R9).

- The HA varied between genotypes among 33° and 100° and DFH varied between genotypes among 2 and 33 cm (p≤0.0001). Both morphological traits showed high genetic variability, however DFH showed higher genotypic variation than HA among genotypes. Both morphological traits have shown significant GxA interaction (p≤0.0020) which means different genotypes performance across locations. Eared doves depredation in Tostado varied among 7 and 54 % of the capitulum. HA and DFH were linearly and negatively related with bird depredation (p≤0.0004), which accounted for 48% and 51% of the variation respectively. Nevertheless more locations and years are needed to confirm these results. Only four hybrids (out of 15 sowed in Tostado) were striped hull but they seem to be less affected by eared dove consumption than black hull sunflower. This means that several studies remain to determine other morphological traits to increase tolerance of sunflower to bird damaged.

- High genetic variability of these morphological traits had been found in commercial hybrids of sunflower as well as those from INTA breeding program. Hybrids with high HA and DFH may reduced the "eared dove" depredation.

- The hybrid selection strategy by HA and DFH morphological traits could be a good tool to reduce losses by "eared dove" depredation and improving crop management.

Key word: head angle, down-facing head, bird damage, genetic variability, sunflower hybrids, GxA interaction.

INTRODUCTION

Depredation of sunflower by granivorous birds, like "eared dove" (*Zenaida auriculata*), is regarded as one of the major impediments to profitable sunflower in some areas. Eared doves are considered both national and provincial pests due to important damages caused in several crops as sunflower, wheat and sorghum (Bucher, 1974; Bruggers y Zaccagnini, 1994). This granivorous bird is one of the most common species in Córdoba, Santa Fe, Entre Ríos and Western Uruguay (Bruggers et al, 1998). The eared doves were weakly related to land use, but higher densities were related to landscapes combining forestall and agricultural land (Gavier-Pizarro et al, 2011).

For bird-resistance studies, two main strategies were recognized: chemical as repellents (Crase y Dehaven, 1976; Rodriguez et al, 1995) and morphological characteristics as head angle and down-facing head. Allen (1986) found that hybrids with high Down-Facing Head (DFH) reduced cockatoo damage in Australia and North America, while Fleming et al, (2002) found that different hybrids were equally susceptible to damage of cockatoo probably because of insufficient differences in pendulousness and head height. More uniform crops are reputedly less susceptible to damage by cockatoos (Allen, 1990). Canavelli (2010) recommended using hybrids of sunflower with bigger HA and/or DFH as part of crop management practices.

No research has been done on actual performance of these morphological traits (HA and DFH) and its genetic variability to reduce or avoid eared dove depredations. Neither research was found about the efficiency of these morphologic traits to reduce doves depredation. The aims of this work were i) determine the genetic variability of morphological traits in sunflower and ii) evaluate the damage of eared dove on contrasting hybrids in a natural infestation area.

MATERIALS AND METHODS

This research was carried out during the growing season 2010-2011 in Reconquista (29° 11' S; 59° 52' W) and Tostado (29° 14' S, 61° 46' W), Santa Fe, Argentina. The Experiment 1 was conducted in Reconquista with seventeen commercial hybrids and twenty three lines from INTA breeding programs of sunflower. The Experiment 2 was conducted in Reconquista and Tostado with fifteen commercial hybrids. Genotypes were arranged in a randomized complete block design with three replications in each environment. Each plot was 4 rows and 5 m long, consisting of four rows of a single genotype. In Tostado experiment, plots were located inside a commercial sunflower field of 100 hectares. Mean plant densities were 4.5 pl m^{-2}. The inter-rows spacing was 70 cm and inter-plant spacing was 30 cm. The soil laboratory measured organic matter 1.5 and 3.1 %, pH 5.9 and 6.5, phosphorus availability 27.3 and 113.4 mg.kg^{-1} and N-NO$_3$ 16.5 and 15 mg.kg^{-1}, for Reconquista and Tostado, respectively. Pest and diseases were adequately controlled.

At the physiological maturity stage (R9, Schneiter and Miller, 1981), when the development of sunflower heads had ended and morphologic traits had became unchanging, plant measurements were made. Morphological traits measured were: Head Angle (HA) and the Down-Facing Head (DFH, Fig. 1). Head angle was measured with a tool designed in INTA Reconquista, which consist on a protractor with a stick in the middle. This tool measured the angle head of sunflower with respect the horizontal line of soil (i.e. 0° and 90° surface head were parallel and perpendicular to the surface of soil, respectively). DFH was measured with a slide rule (centimeter) the distance between the base of the capitulum and the top of the stem.

Bird damage was only measured in Tostado due to high pressure of "eared doves" depredation. Head of one row in Experiment 2 in Tostado was covered with white mesh bags to avoid eared dove depredation. In the other rows, the dove depredation estimation was based on the head surface area on each sunflower head.
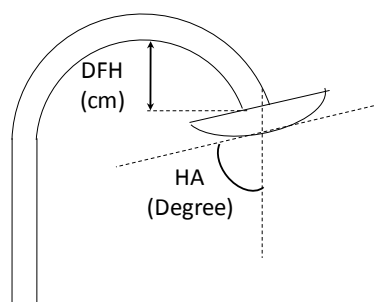
Fig. 1. Schematic representation of Head Angle (HA, degree) and Down-Facing Head (DFH cm) measurement in sunflower hybrids.

In both experiments, HA and DFH was processed by analysis of variance procedures (Infostad, 2009). When statistical differences were detected, only the highest P value is presented. Differences between treatment means were evaluated with the Tukey test (Exp 1: $p<0.05$; Exp2: $p<0.05$, 0.01 and 0.001). Data of bird damage (in percentage of sunflower head) versus HA and DFH were adjusted to lineal models. Sigmaplot software (Sigmaplot 8.0, SPSS Inc., Chicago, Illinois) was used to establish the relationships.

Results

In experiment 1, HA varied among 33° and 100° between commercial genotypes and varied between 73° and 97° in genotypes of INTA breeding programs ($p\leq0.0095$, $R^2\geq0.68$, Table 1). DFH varied between commercial genotypes among 1 and 34 cm and between 5 and 17 cm in genotype ($p\leq0.0001$, $R^2\geq0.87$). Both morphological traits showed high genetic variability, however DFH showed higher genotypic variation than HA among genotypes. On the other hand, commercial hybrids of sunflower showed larger range of HA and DFH than genotypes of INTA breeding programs.

Table 1. Summary of statistical measurement of Head Angle (HA) and Down-Facing Head (DFH) in commercial hybrids and hybrids from INTA breeding programs of sunflower. Data correspond to Experiment 1.

	HA		DFH	
	Commercial Hybrids	INTA Breeding Programs	Commercial Hybrids	INTA Breeding Programs
n	70	23	70	23
Average	81.5	90.1	10.3	11.0
Median	84.7	91.7	8.7	10.7
Standard Error	11.8	5.5	5.5	2.9
Maxima	100	97	34	17
Minimum	33	73	1	5
Curtail 1	76.3	88.3	7	8.7
Curtail 3	90	93.3	12.7	13

In experiment 2, HA varied among genotypes between 35° and 95° and 52° to 90° in Reconquista and Tostado, respectively (Table 2). DFH varied from 1.3 to 20.3 cm and from 6.0 to 12.0 cm in Reconquista and Tostado respectively between genotypes. Significant interaction has been detected between genotypes and environment for these morphological traits ($p\leq 0.0010$, $R^2\geq0.79$) which mean different genotypes performance across locations.

Table 2. Head Angle (HA) and Down-Facing Head (DFH) for different environments (Reconquista and Tostado) of 15 commercial genotypes of sunflower corresponding Experiment 2

Genotypes	HA (Degree)		DFH (cm)	
	Reconquista	Tostado	Reconquista	Tostado

65A25	92 ± 2.5 [a]	90 ± 0.1	16.0 ± 1.0	8.5 ± 0.7
A 975	90 ± 5.5	77 ± 10.6	13.7 ± 3.2	7.0 ± 0.1
ACA 885	79 ± 7.5	90 ± 0.1	7.0 ± 0.1	8.0 ± 1.4
AD-68 GY	82 ± 7.6	75 ± 11.6	18.0 ± 3.5	12.0 ± 5.7
AGUARA 4	78 ± 2.9	77 ± 10.6	5.0 ± 1.0	6.0 ± 0.1
AGUARA 5	68 ± 10.4	80 ± 0.1	8.3 ± 2.1	8.0 ± 1.4
Argensol 20	95 ± 4.6	75 ± 7.1	7.7 ± 2.5	5.5 ± 2.1
DK 3820	83 ± 11.5	80 ± 0.1	5.3 ± 0.6	5.5 ± 0.7
DK 3948 CL	93 ± 5.7	80 ± 14.1	15.3 ± 1.2	11.5 ± 4.9
DK 4045 DM	83 ± 5.7	80 ± 14.1	11.3 ± 1.2	9.5 ± 6.4
MG2	65 ± 5.0	52 ± 10.5	7.7 ± 3.8	4.5 ± 0.7
PAN 7034	77 ± 11.5	85 ± 7.1	14.5 ± 0.5	8.5 ± 2.1
SPS 3800 CL	87 ± 6.4	85 ± 7.1	7.3 ± 0.6	8.0 ± 1.4
SY 4075	35 ± 6.4	70 ± 14.1	1.3 ± 0.5	6.0 ± 0.1
TOB 3000	87 ± 6.4	85 ± 7.1	20.3 ± 2.5	10.0 ± 2.7
Environment	NS		*	
Genotypes	***		***	
GxE	**		***	

[a] mean value and standard deviation

*, **, *** Significant a P=0.05, P=0.01 and P=0.001 probability levels, respectively.

Eared dove consumption varied between 7 and 54% of commercial sunflower head in Tostado (Exp. 2). HA and DFH were linearly and negatively related with eared dove consumption (p≤0.0004; Fig. 2), which accounted for 48% and 51% of the variation respectively. The major damage due to eared doves was found in MG2 genotype, which also had shown the less value for HA and DFH. On the other hand, DK 4045 DM genotypes had shown the less damage by eared doves and higher value of HA and DFH. Nevertheless more locations and years are needed to confirm these results. Only four hybrids (out of 15 sowed in Tostado) were striped hull but they seem to be less affected by eared dove consumption than black hull sunflower.
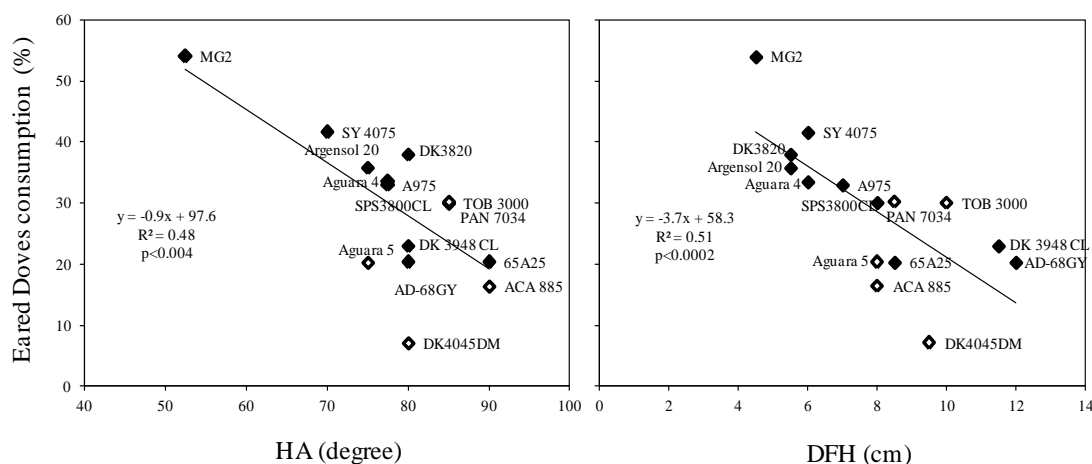

Fig. 2. Eared dove consumption as a function of a) HA (degree) and b) DFH (cm) of fifteen commercial hybrids of sunflower. Data correspond to Experiment 2 in Tostado. Full and open symbols correspond to black and striped hull, respectively.

Discussion

In the Argentine seed market exists several hybrids with different HA and DFH. In this research, we found an important variation for head inclination between commercial hybrids. The easy and practical technique of measurement proposed in this work could be used to determine the best inclination hybrids

in each sowing area. Miller (1987) proposed that head shape and inclination are important for discouraging bird depredations (for example eared doves) but could have important negative effect in areas with high rain in the final growth stage of sunflower. The moisture provides favorable microclimate conditions for diseases such as Rhizopus (*Rhizopus microsporus* Namm), Botrytis (*Botrytis cinerea* Pers.) or Bacterial rot (*Pseudomonas* spp.). Also, hybrids with high inclination may be desired to prevent sun scald in production areas of high temperature and intense sunlight.

High range of variation of HA and DFH in the INTA breeding programs was not found in this work. The inheritance of these morphological traits seems to be controlled by a few genes; however combining all the traits involves complex inheritance (Miller, 1987). This breeding program needs the introgression of sunflower lines to improve these morphological traits in the hybrids.

Although high genetic variability had been found for these morphological traits, the significant interaction GxA has been found between the two environments analyzed in this work. This means that environment affect the HA and DFH of each genotype in different ways. Probably the genes that control these morphological traits were affected by temperature, water availability, soil characteristic or other environmental condition (Khaleghizadeh, 2011). Previous works from Parfitt and Fox (1986) found significant differences to bird damage when analyzed the interaction between genotype and environment and described a large amount of additive genetic variance for resistance to damage by red-winged blackbirds. Seiler and Rogers (1987) reported that head angle was consistent across genotypes and years (sparrows and finches damage). On this way, more research needs to be done to understand the effect of environmental condition and these morphological traits to reduce eared dove damage.

Several researchers had recommended sown sunflower hybrids tolerant (with higher head inclination) in those environments with high probability of damage by granivorous bird population (for example eared doves, Canavelli, 2010). In this work, the HA and DFH were significant correlated to eared dove damage (less damage on hybrids highly inclined). Although the correlation coefficients (R^2) were low, these morphological traits could be used for hybrids selection in areas with elevated population of eared doves. Mah y Nuechterlein (1991) suggested that head angle was not an effective morphological barrier to Red-Wingled Blackbird depredation. On the contrary, Khaleghizadeh (2011) found a positive correlation between "house sparrow" damaged rate and the distance of petiole from head. Although in this research a diagrammatic schema was used, the results were similar to reported in our work. However, there was not found a significant relationship between stem hanging and "house sparrow" damage rate. This researcher proposed that some factors such as soil structure, water availability (also cited by Rauf et al, 2008), sowing depth is known to affect stem hanging. We proved that also exist genetic variability to this morphological traits. Even though the achene color was not an objective of this work, hybrids with striped hull seem to be less affected by eared doves depredations than black hull.

High genetic variability of these morphological traits had been found in commercial hybrids of sunflower as well as those from INTA breeding programs. Hybrids with high HA and DFH may reduce the "eared dove" depredation. The hybrid selection strategy by HA and DFH morphological traits could be a good tool to reduce losses by "eared dove" depredation and improving crop management. Eared doves resistant hybrids should play an important role into an integrated pest management program of sunflower.

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