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COEFICIENTE DE EXTINCIÓN LUMÍNICA EN MAÍZ: RELACIÓN ENTRE LÍNEAS ENDOCRIADAS Y SU PROGENIE F1

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LIGHT EXTINCTION COEFFICIENT IN MAIZE: RELATIONSHIP BETWEEEN INBREDS AND THE F1 PROGENY

ABSTRACT

An indirect effect of maize breeding was the selection of a more erectophile leaf habit, represented by a decreased attenuation coefficient (k) in the response of light interception efficiency (e_i) to the leaf area index (LAI). The objective of current research was to quantify the variation in k among maize inbreds and their F1 progeny in a complete diallel design, and analyze the corresponding parent-progeny relationships. Six inbreds (I) and their 30 F1 hybrids (H) were grown in the field at Pergamino during two growing seasons at a single stand density of 7 pl m^{-2}. LAI and e_i evolutions were assessed between crop emergence and silking. The value of k was obtained for each I and pair of Hs (direct and reciprocal) from the exponential model fitted to the relationship between e_i and LAI (e_i= 1- $\exp^{(-k\times LAI)}$). The range of k values was larger among Hs (0.54-1.09) than among Is (0.49-0.68). Despite the larger mean k value of Hs (0.82) respect to Is (0.59), a significant parent-progeny relationship (R^2=0.48, P= 0.004) was established between them. Extreme Is tended to reproduce the corresponding habit in their Hs and this trend was stronger for the most planophile than for the most erectophile.

Palabras Clave
Atenuación lumínica, Zea mays L., Líneas, Híbridos, Diseño dialélico.

Keywords
Light attenuation, Zea mays L., Inbreds, Hybrids, Diallel mating design.

INTRODUCTION

Leaf habit is described by the leaf angle respect to the main stem, and species (or genotypes within a species) are classified as erectophile (upright leaves) or planophile (horizontal leaves) depending upon this angle. The effect of leaf habit is clearly represented in the parameter *k* of the exponential model usually fit to the response of light interception efficiency (ei) to the leaf area index (LAI). This parameter is described as the attenuation or extinction coefficient, and its value decreases from a more planophile to a more erectophile leaf habit (Loomis and Connor, 1993).

It has been demonstrated that maize breeding based almost exclusively on grain yield had indirect effects on several secondary traits, including a much more erect leaf habit (Duvick, 2005). Such trend may result in an enhanced radiation use efficiency linked to an improved light distribution across the canopy (Maddonni *et al.*, 2006), which may explain the improved tolerance to increased stand density found among modern maize hybrids (Cooper *et al.*, 2004; Di Matteo *et al.*, 2016). There are, however, few studies addressing the genetic control of k. Using a complete diallel mating design, Mason and Zuber (1976) indicated that general as well as specific combining ability effects controlled the expression of leaf angle. Their research, however, did not include the estimation of *k* and was based on relatively low stand densities (34600-65000 plants ha^{-1}), for which the upright habit produced a decrease in grain yield rather than the expected increase observed by breeders.

The **objective** of current research was to quantify the variation in *k* among 6 maize inbreds and their F1 progeny in a complete diallel design, and analyze the corresponding parent-progeny relationship.

MATERIALS AND METHODS

Field experiments were performed at the INTA Pergamino station (33°57’34”S, 60°34’20”O) during two growing seasons (2014/15 and 2015/16). Two groups of genotypes (G) were evaluated, 6 maize inbreds (L1: B100, L2: LP2, L3: ZN6, L4: LP561, L5: LP662, L6: LP611) and all possible F1 crosses (30 hybrids). Details of inbreds can be found in D’Andrea *et al.* (2006). A split plot design was used, with G (I: inbreds; H: hybrids) in the main plots and cultivars of each group in the subplots (hereafter termed plots). Sowing date took place in October and a single stand density of 7 pl m^{-2} was used. Plots were 5-row width, with rows at 0.7 m, and 5 m length. Crops were fertilized and irrigated to avoid abiotic constraints. Weeds, insects and diseases were permanently controlled.

Five plants were tagged in each plot at V3, and the number of newly expanded leaves was assessed weekly on each tagged plant between V3 and R1. The area of each newly expanded leaf (LA_n) was measured as in eq. 1

(1) LA_n = length × maximum width × 0.75

On each observation date, the computation of plant leaf area was exclusively based on the sum of all fully expanded green leaves and multiplied by stand density to obtain the leaf area index (LAI, in m^{-2} of leaves per m^2 of soil).

Light interception efficiency (e_i) was assessed fortnightly in each plot as described in eq. 2.

(2) e_i= 1 – (PARb/PARa)

PARa and PARb represent incident photosynthetically active radiation above the canopy and immediately below the lowermost green leaves, respectively. A sigmoid model was fitted to the evolution of e_i and used to estimate the value of this trait at each date of LAI measurement.

The response of e_i to the LAI was established for each inbred and each pair of hybrids (direct and reciprocal), and an exponential model fitted to the data (eq. 3)

(3) $e_i = 1 - \exp^{(-k \times LAI)}$

Differences in k among cultivars of each G group were evaluated by regression analysis. The parent-progeny relationship for k was established, with $k_{Parental\ n}$ represented by the average of the parental inbreds of each hybrid.

RESULTS & DISCUSSION

A large variation was registered among Hs and Is in the evolution of LAI and e_i, partially depicted in Figure 1 (a, d and b, e; respectively). The variation in these traits led to a wide range in k values (Fig 1 c, f), which was particularly larger among Hs (0.54-1.09) than among Is (0.49-0.68). Interestingly, only two inbreds had clearly contrasting k values (Fig. 2, inset) that allowed their classification as erectophile (L6) or planophile (L3) respect to the mean value of all Is (I_{kmean}= 0.59). Contrary, a more continuous gradient was registered in k values among the 15 pair of hybrids (direct and reciprocal) produced from all possible crosses of the six Is (Fig. 2), indicative of the predominantly quantitative nature of this trait (Falconer and Mackay, 1996). This trend was accompanied by an increase in mean k value (H_{kmean}= 0.82) of 39% respect to I_{kmean}. There were, however, two remarkable aspects among hybrids. On the one hand, the strong trend to reproduce the habit by each of the extreme Is, yielding predominantly erectophile (L6) or planophile (L3) hybrids (Fig. 2). This trend was verified in the significant parent-progeny relationship obtained for the whole data set (R^2=0.48, P= 0.004), and is in agreement with the high general combining ability detected for leaf angle (Mason and Zuber, 1976). On the other hand, the apparently stronger effect of the planophile habit respect to the erectophile habit, because (i) all crosses of the most planophile I (L3) yielded hybrids with k values larger than H_{kmean}, whereas (ii) only three of the five possible crosses of the most erectophile I (L6) yielded hybrids with k values smaller than H_{kmean}.

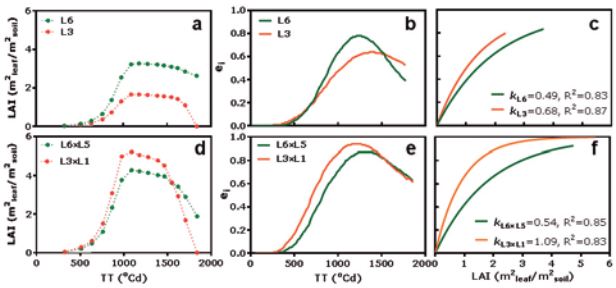

Figure 1. Evolution of leaf area index (LAI) (a, d) and light interception efficiency (e_i) along the cycle (b, e), and response of e_i to LAI (c, f). Data correspond to Inbreds (a, b, c) and Hybrids (d, e, f) with the most contrasting k values.

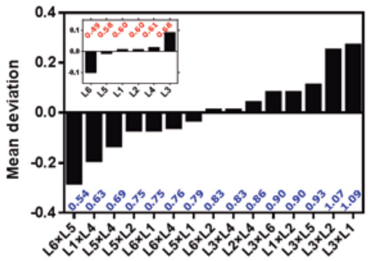

Figure 2. Deviation in k values of hybrids respect to the mean of the group (represented by 0). The inset corresponds to the six parental inbreds (L1 to L6). Hybrids are described by the corresponding inbred crosses. Mean k values across genotypes were 0.82 for hybrids and 0.59 for inbreds.

CONCLUSION

An indirect effect of maize breeding based on grain yield was the selection of a more upright leaf habit. Hybrids tended to reproduce the leaf habit of their parental inbreds. Among the germplasm evaluated in our research, however, the described trend seemed stronger for the planophile than for the erectophile habit, suggesting the need of a well-planned inbred selection criterion when aimed to modify light attenuation across the profile. A possible practical tool for classifying inbreds in a large breeding program would be to combine (i) drone images for estimation of ground cover among those with similar cycle duration, indicative of ei, and (ii) measurement of ear leaf area at silking, indicative of variation in plant leaf area and LAI.

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