

INTRODUCTION

In maize (*Zea mays*, L.), previous studies have indicated that the total number of completely developed flowers per ear was not affected by contrasting assimilate availability per plant, such as those promoted by contrasting plant population densities (Otegui, 1997; Cárcova et al., 2000), sowing date (Cirilo and Andrade, 1994; Otegui and Melón, 1997), nutrient availability (Uhart and Andrade, 1995) and water regime (Otegui et al., 1995). Contrary, silking dynamic of the plant population and silks exertion from the ears were greatly affected by abiotic stress effects on plant growth rate around silking (Otegui, 1997; Cárcova et al., 2000). Collectively, these results indicate that the number of completely developed flowers per ear is a very stable genotype trait, but the number of silks emerged few days after the first silk is visible, is profoundly affected by the production of assimilates around silking. There is, however, little information of nitrogen (N) x plant population density effects on the progress of: (i) flower development, (ii) silking dynamic, and (iii) silks emergence, and the relationships of mentioned floral events with plant growth rate during the pre-silking period.

The objective of this work was to evaluate floret development, silking dynamic, silks emergence, and kernel number per plant of two hybrids with contrasting tolerance to crowding stress, under contrasting N availabilities and plant population densities.

MATERIALS AND METHODS

Field experiments were conducted during the growing seasons of 2006/2007 and 2007/2008 at Pergamino (34°56' S 60°34' W), Argentina.

- Treatments:** (i) two hybrids with contrasting tolerance to crowding stress (tolerant AX820 MG and intolerant AX877 MG)
(ii) two (2006/07) or three (2007/08) intensities of interplant competition. In 2006/07: 9 plants m⁻² (D9) and 12 plants m⁻² (D12); in 2007/08: 6 plants m⁻² (D6), D9 and D12.
(iii) two N levels (N0: no N added; N1: 200 Kg N ha⁻¹ applied at V6)

Experimental design: factorial experiment, with N in the main plot and hybrids x plant population density in the sub-plots, with three replicates.

Measurements (10-12 plants per sub-plot):

- Floret development of the uppermost ear-shoot was surveyed between V6 and silking. The following measurements were made at each sampling date: rows per ear, spikelets per row and floral development along the rows (Otegui and Melón, 1997). A flower with a silk >1mm was classified as a completely developed flower.
- Silking dynamic (proportion of plants at silking)
- Number of exerted silks per ear, measured on four days after the first silk was visible.
- PGRps: plant growth rate pre-silking (from V7 to V13); PGRs: plant growth rate around silking (from R1-12 days to R3).

Developmental and flowering dynamics were described by a sigmoid function (Hall et al., 1980; 1981): $y = a + b / (1 + e^{-(x-c)/d})$; where y = completely developed flowers per row or proportion of plant population with silks emerged; $a + b$ = maximum y ; c and $a+b/2 = x$ and y coordinates of the inflection point of the function, respectively; and $1/bd$ = proportionality constant. The maximum flower development rate (flowers row⁻¹ °Cd⁻¹) was the first derivative at the inflection point (c).

The proportion of non-exposed silks was estimated as: $1 - (\text{number of exposed silks} / \text{number of completely developed flowers per ear})$.

RESULTS AND DISCUSSION

FLORET DEVELOPMENT

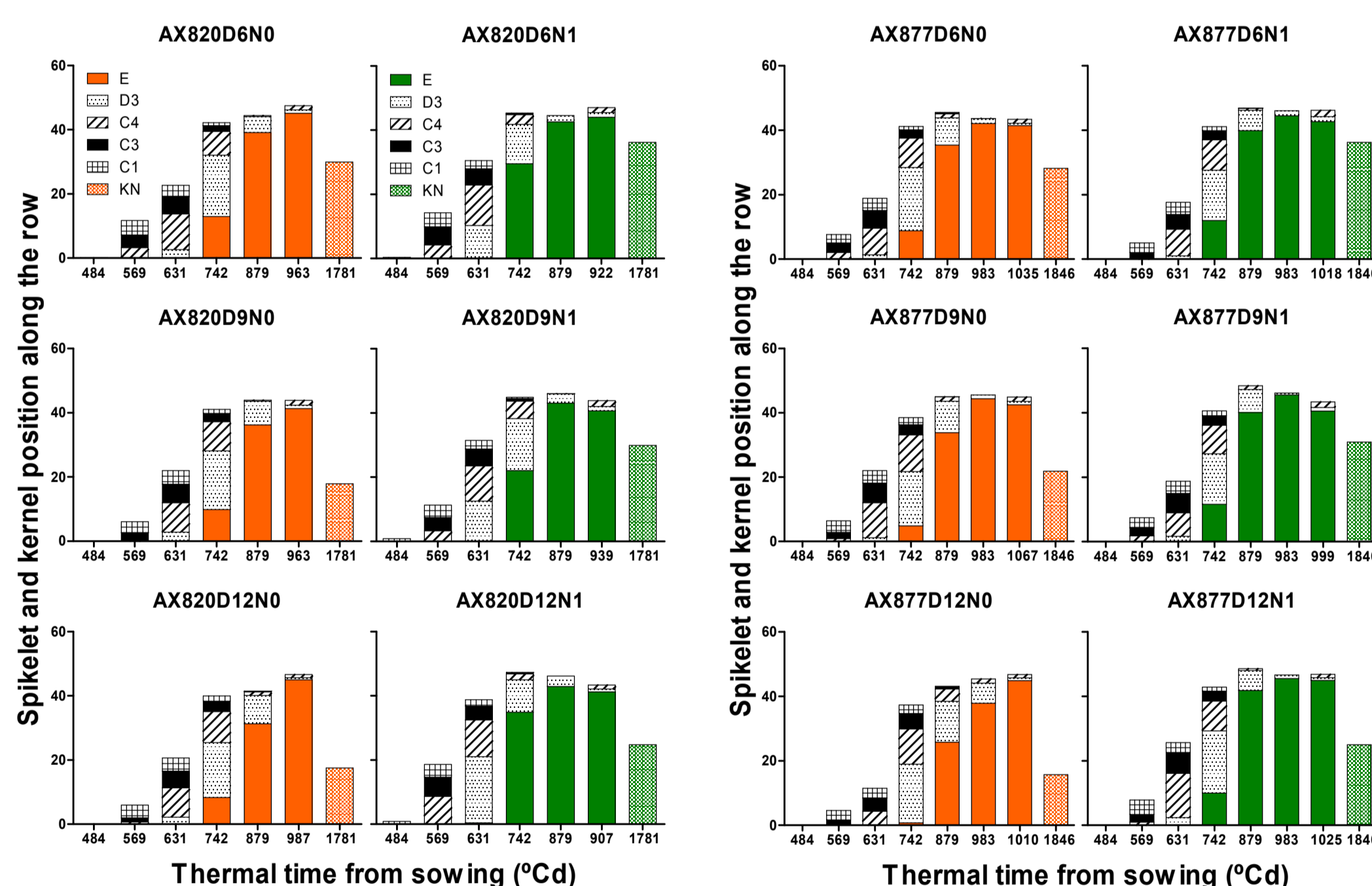


Figure 1: Evolution of the number of spikelets per row and stage of floral development along the row of the apical ear during 2007/08. Developmental stages: (C1) differentiation of lateral primordia; (C2) differentiation of two spikelet per primordium; (C3) flowers with glumes; (D3) differentiation of anthers and the gynoecia; (E) completely developed flowers (silks > 1mm); (KN) kernel number per row at physiological maturity.

Since early stages of ear morphogenesis (742 °Cd from sowing), a delayed ear development was detected in apical ears of N0 plants. These ears exhibited a smaller number of flowers ($p < 0.10$) at the most advanced developmental stage (E stage) than observed in ears of N1 plants (Figure 1). Five days after silking (last ear morphogenesis observation), N0 plants at D9 and D12 exhibited a reduced number of E flowers than those of N1 plants ($p < 0.01$). N fertilization did not modify this trait for plants at D6. Kernel number per row was reduced by increased stand density ($p < 0.001$) and reduced N availability ($p < 0.05$).

References

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DEVELOPMENTAL PROGRESS

Maximum number of E flowers was affected by plant population density in both experiments (Figure 2). During 2007/08, N0 reduced this number at D9 and D12 ($p < 0.05$), but did not affect it at D6. The lowest ($p < 0.06$) flower developmental rate (i.e. progress to E stage) was recorded on N0 plants during 2006/07, and the highest one was attained by N1 plants of AX820 during 2007/08 (N x H interaction; $p < 0.05$). During both experiments, thermal time to 50% of maximum E number (c parameter) was delayed by N stress ($p < 0.01$). Plants of AX877 at D12 had the greatest c parameter ($p = 0.08$) during 2006/07.

For AX820, flower development rate and thermal time to 50% of maximum E value were significantly ($p < 0.01$) related to PGRps (Figure 3a, c). For AX877, only the parameter c was related to PGRps (Figure 3b, d).

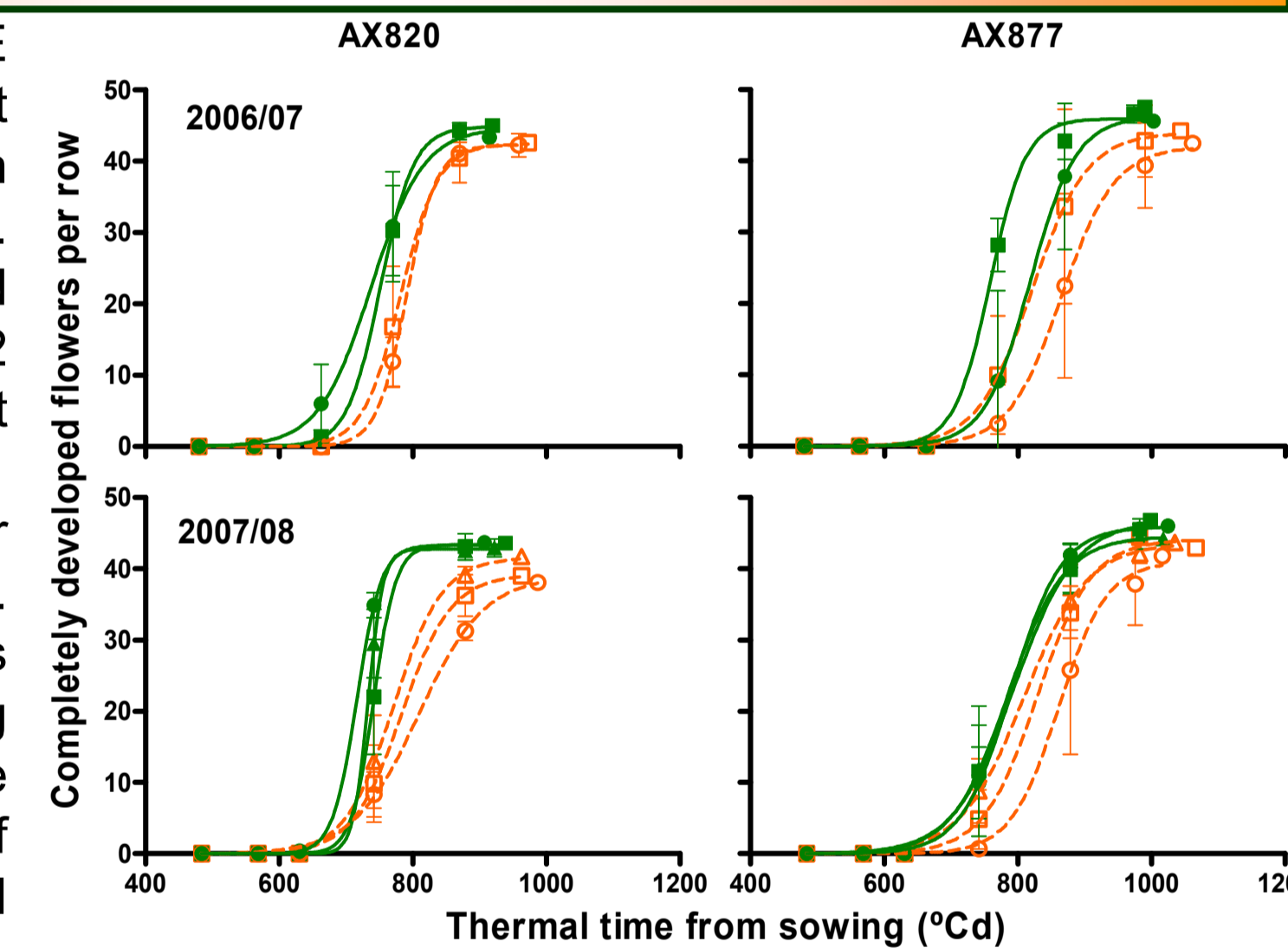


Figure 2: Evolution of the number of completely developed flowers (E stage) per row (triangle: 6 pl m⁻²; square: 9 pl m⁻²; circle: 12 pl m⁻²). Green symbols and solid lines for N1; empty symbols and dotted lines for N0.

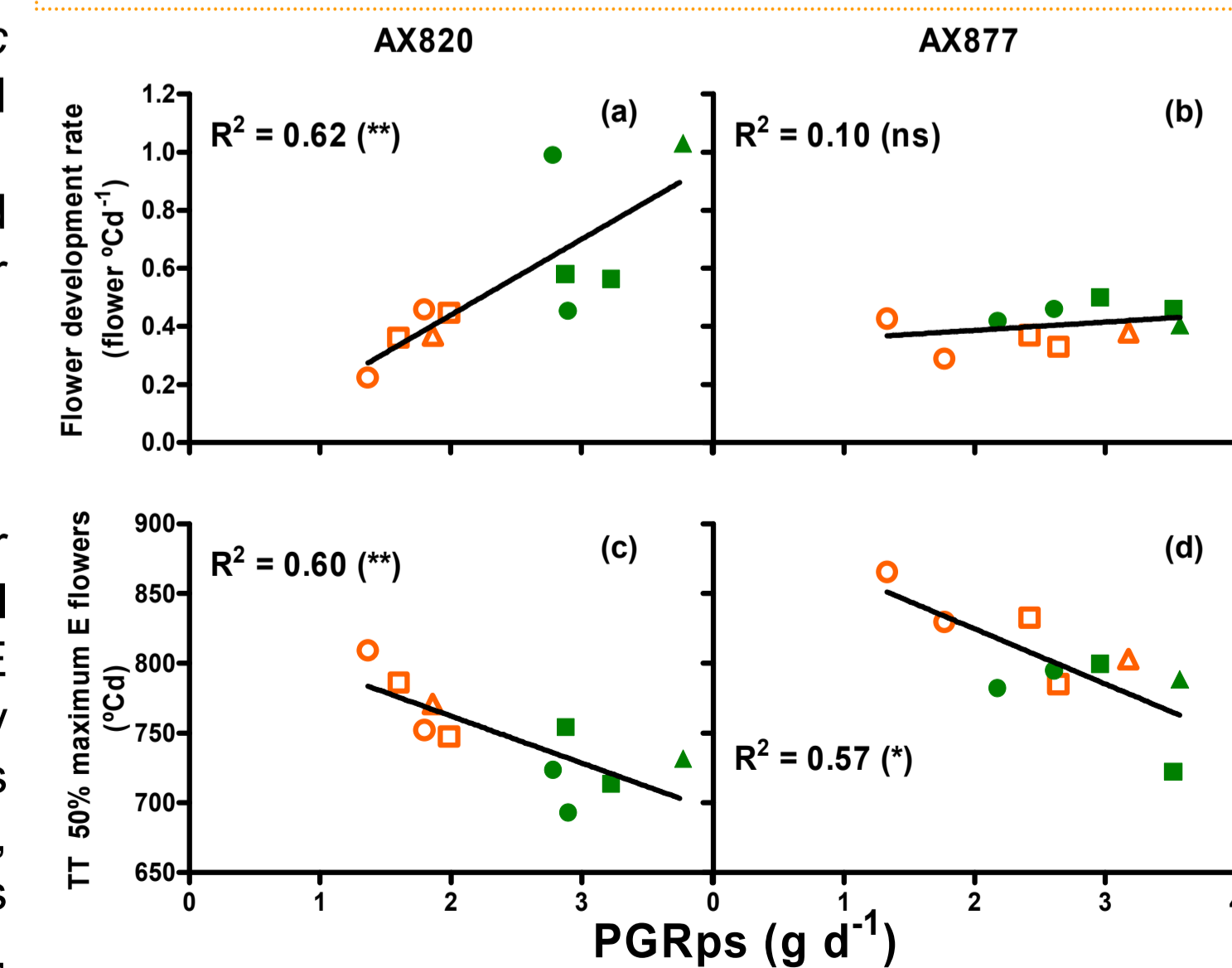


Figure 3: Flower development rate (a, b) and thermal time to 50 percent of maximum number of E flowers (c, d) as function of plant growth rate during the pre-silking period (PGRps). Triangles: 6 pl m⁻²; squares: 9 pl m⁻²; circles: 12 pl m⁻². Green symbols for N1; empty symbols for N0. Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

SILKING DYNAMICS

Nitrogen stress delayed (c parameter) silking dynamics ($p < 0.1$) during both seasons (Figure 4). This dynamic differed between N levels for AX877 during 2006/07 (N x H interaction, $p < 0.09$), and the lowest rate of silking progress was recorded for AX877 at D12 (H x D interaction $p = 0.08$). For AX820, rate of silking progress was affected by N stress (N x H interaction, $p < 0.05$). The silking stage was not reached by all plants of AX877 at the most stressful condition (N0 x D12) during 2007/08.

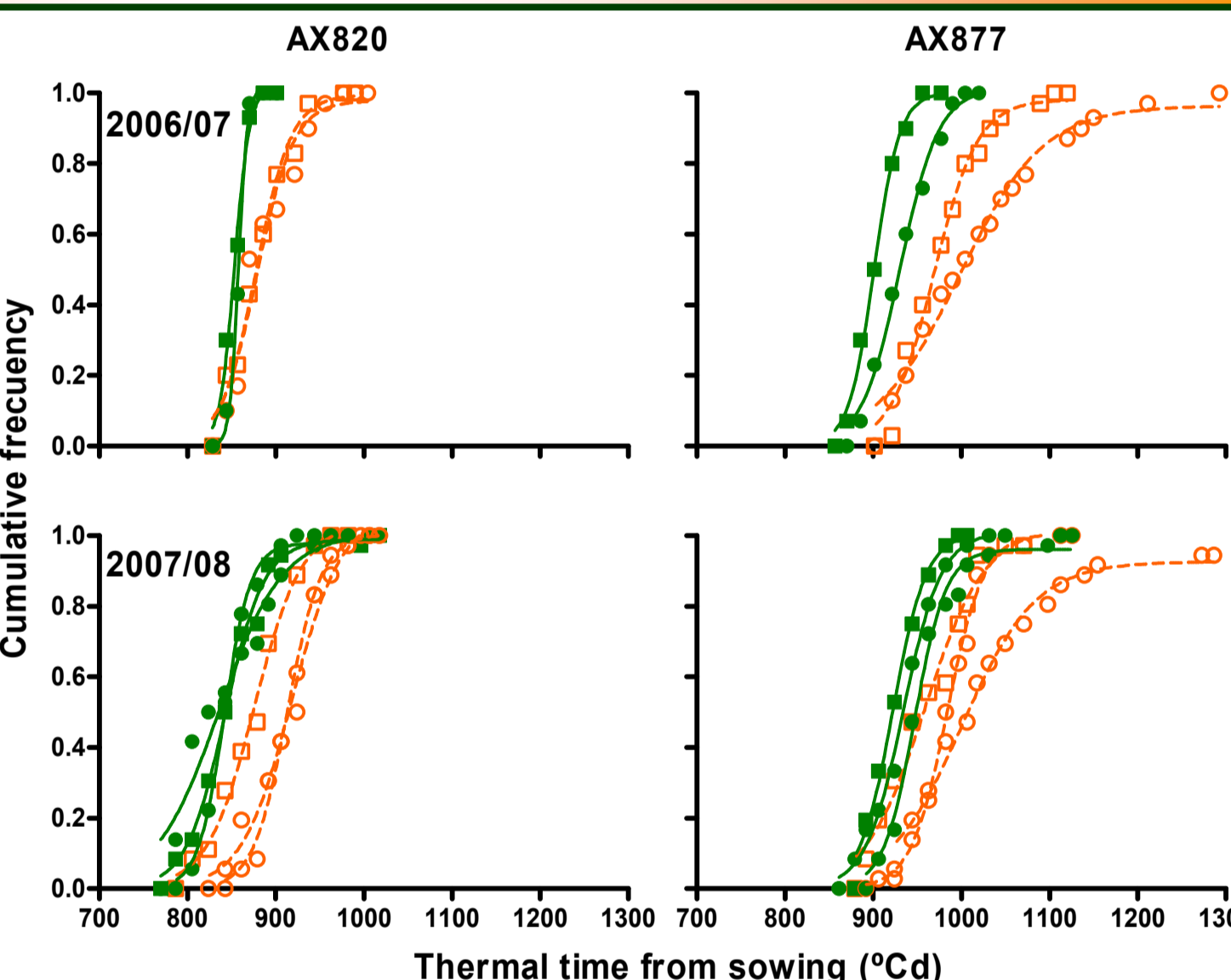


Figure 4: Silking dynamics evolution (triangles: 6 pl m⁻²; squares: 9 pl m⁻²; circles: 12 pl m⁻²). Green symbols and solid lines for N1; empty symbols and dotted lines for N0.

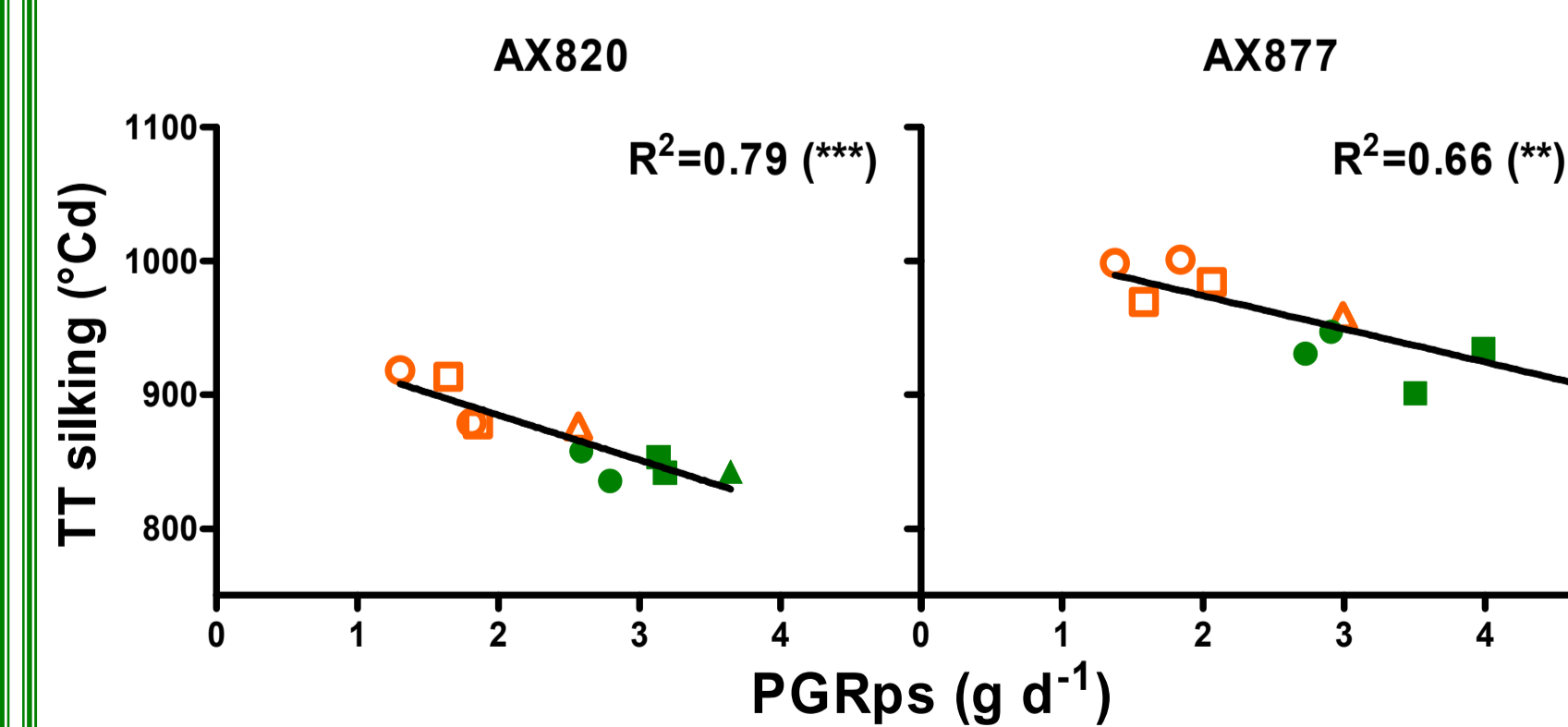


Figure 5: Response of thermal time to 50 percent of the maximum proportion of plants with silks visible to plant growth rate during the pre-silking period (PGRps). Triangles: 6 pl m⁻²; squares: 9 pl m⁻²; circles: 12 pl m⁻². Green symbols for N1; empty symbols for N0. Significance levels * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

For both hybrids, plant growth rate during the pre-silking period accounted for 66 to 79% of thermal time variability to 50% of maximum proportion of plants with silks exerted (Figure 5), but didn't explain differences among treatments in the silking progress rate.

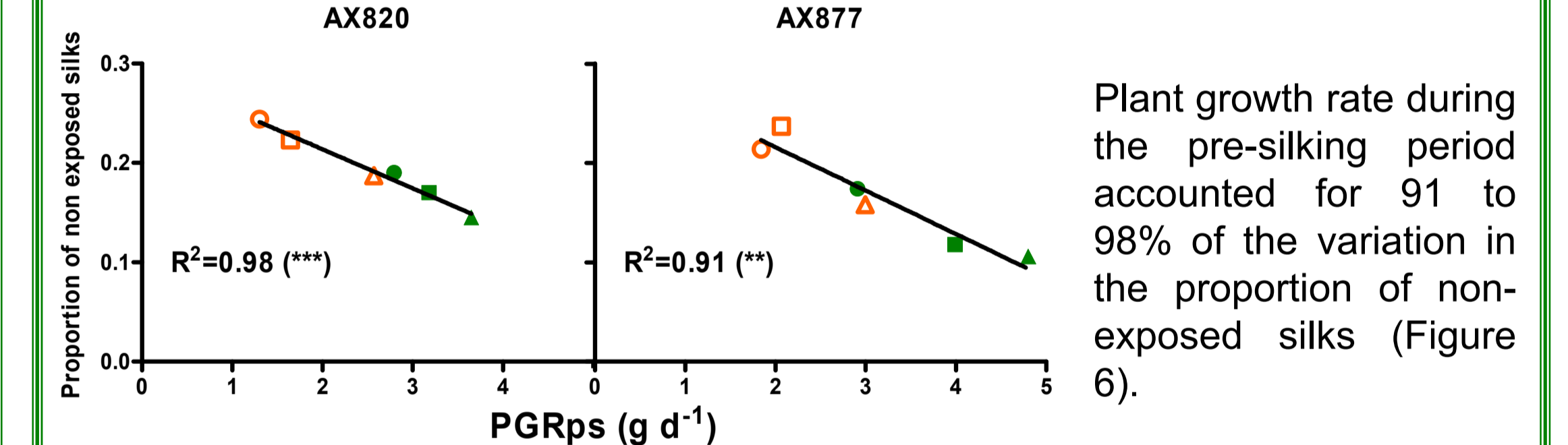


Figure 6: Proportion of completely developed flowers per ear with non-exposed silks on 5 days after silking as a function of plant growth rate during the pre-silking period (2007/08 data set). N0: empty symbols; N1: green symbols. Triangles: 6 pl m⁻²; squares: 9 pl m⁻²; circles: 12 pl m⁻². Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

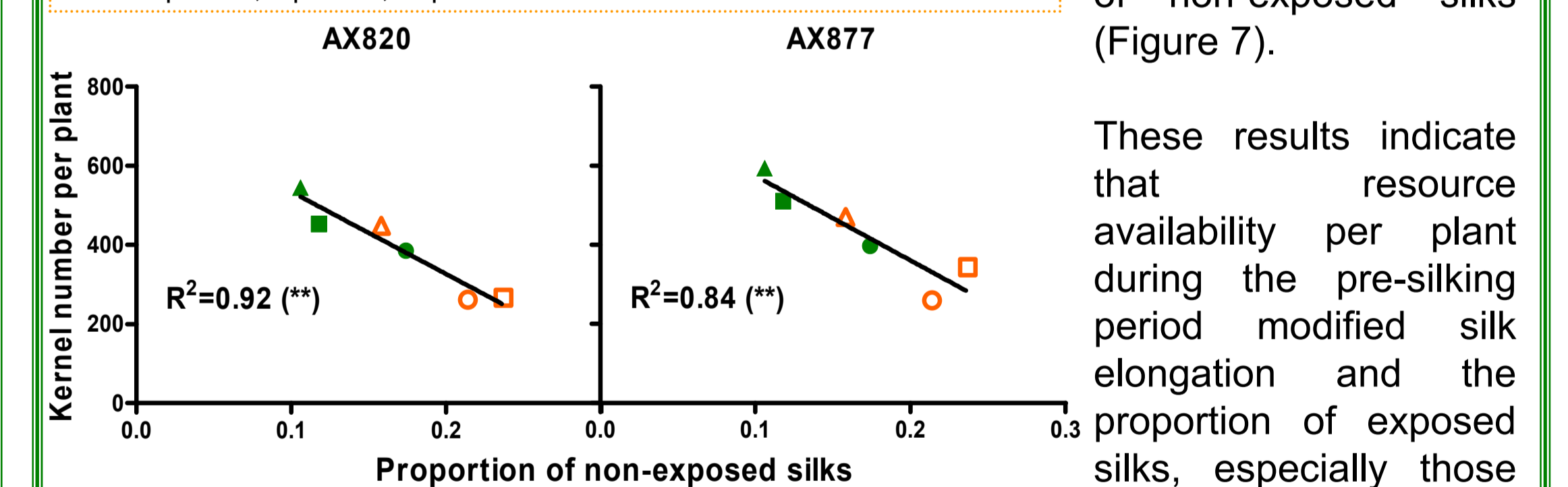


Figure 7: Kernel number per plant as a function of the proportion of non-exposed silks (2007/08 data set). N0: empty symbols; N1: green symbols. Triangles: 6 pl m⁻²; squares: 9 pl m⁻²; circles: 12 pl m⁻². Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Plant growth rate during the pre-silking period accounted for 91 to 98% of the variation in the proportion of non-exposed silks (Figure 6).

Kernel number per plant was significantly related to the proportion of non-exposed silks (Figure 7).

These results indicate that resource availability per plant during the pre-silking period modified silk elongation and the proportion of exposed silks, especially those of apical positions of the ear, affecting final kernel set.

CONCLUSIONS

Abiotic stresses affected the dynamics of flower development, silking achievement and silks exertion. The intensity of abiotic stress, quantified by plant growth rate during the pre-silking period, accounted for changes in the analyzed developmental parameters. The high correlation between PGRs and PGRps (R=0.82-0.89, data not shown), indicates that the physiological state of a plant at the beginning of the critical period conditions its reproductive fate, i.e. kernel set.