Developmental expansion of the hilum in chickpea seed coats

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Successful growth of seeds is dependent on the flow of nutrients from vegetative tissues to the developing ovules. In legumes like chickpea (*Cicer arietinum*), the pathway for this nutrient flow includes the pod wall surrounding the seeds, and ultimately the funiculus, which is the structure connecting the pod wall to the seed coat. The funiculus contains phloem and xylem vascular tissues, surrounded by parenchymatous cells (Esau 1977); these tissues provide the pathway for delivering solutes to the developing seed (Hardham 1976).

Because of the critical role that the funiculus plays in seed growth, we questioned whether the cross-sectional area of the funiculus might impose a restriction on the flow of nutrients. If funicular dimensions were rate-limiting to seed growth, then breeding for greater funicular cross-sectional area would be warranted to enhance chickpea productivity. Unfortunately, there are few data on the dimensions of the funiculus in chickpea (Lersten and Gunn 1981), and these data are limited to dry, mature seeds. Thus, as a first step in understanding the growth dynamics of the chickpea funiculus, we characterized the width and length of the hilum (the oval-shaped region where the funiculus is attached to the seed coat) throughout the course of seed development.

Five accessions of chickpea, PI 359716, PI 359753, PI 439831, PI 439858 and PI 509178, obtained from the USDA (United States Department of Agriculture) germplasm repository in Pullman, Washington, USA, were used to characterize hilum dimensions, relative to seed weight. Plants were grown in a synthetic soil mix in a greenhouse, as previously described (Ibrikci et al. 2003). All measurements were conducted with developing seeds, collected from green pods. Upon harvest, seeds were removed from pods and the funiculus was carefully detached from the seed coat. Each seed was then weighed, prior to measuring hilum width and length with the use of a dissecting microscope (Zeiss, West Germany; Stemi-SR) that was fitted with an eyepiece reticle (using magnifications of 20X or 50X). Measurements were taken from the inside edges of the raised seed coat tissues that define the boundaries of the hilum. Length was determined at the longest dimension; width was determined perpendicular to length, at the point of broadest lateral dimension. Seed weight was used as a proxy for seed development.

In general, the hilum region was found to expand as seed growth progressed (Fig. 1), with this expansion being quite rapid during early seed growth and then either

### Table 1. Regression analysis of hilum width or length, relative to seed fresh weight (FW), during the later stages of seed development in diverse chickpea accessions.

<table>
<thead>
<tr>
<th>Accession</th>
<th>Data range¹</th>
<th>Hilum width</th>
<th></th>
<th></th>
<th>Hilum length</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slope²</td>
<td>P value³</td>
<td>Slope²</td>
<td>P value³</td>
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<tr>
<td>PI 359716</td>
<td>0.07–0.29</td>
<td>NS⁴</td>
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<td>0.52</td>
<td>0.025</td>
<td></td>
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<tr>
<td>PI 359753</td>
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<td>0.59</td>
<td>0.000</td>
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</tr>
<tr>
<td>PI 439831</td>
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<td>1.12</td>
<td>0.000</td>
<td>0.58</td>
<td>0.013</td>
<td></td>
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<tr>
<td>PI 439858</td>
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<td>0.23</td>
<td>0.003</td>
<td>NS</td>
<td>0.796</td>
<td></td>
</tr>
<tr>
<td>PI 509178</td>
<td>0.14–1.03</td>
<td>0.54</td>
<td>0.000</td>
<td>NS</td>
<td>0.075</td>
<td></td>
</tr>
</tbody>
</table>

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1. FW (g) values of seeds used for the linear regression.
2. Hilum width (mm) or length (mm) per g seed FW.
3. Significance of described line differing from a line with slope of 0.
4. NS = Not significant.
Figure 1. Relationship between seed fresh weight and hilum width or length in developing chickpea seeds.
gradual, or non-changing, as seed growth continued. Based on the five accessions studied, three patterns of hilum dynamics were observed. In PI 439831 (Fig. 1A), an initial rapid expansion of the hilum region was found in seeds up to approximately 0.08 g fresh weight (FW), and then both hilum width and length demonstrated a significant, but gradual expansion throughout seed development (see statistics in Table 1). Hilum width increased by 0.35 mm and length increased by 0.18 mm as seeds grew from 0.08 to 0.39 g FW; these represented 27% or 11% of the maximum hilum width or length, respectively. Similar trends were seen for hilum width and length in PI 359753 (Table 1). In PI 439858 (Fig. 1B), hilum width and length increased dramatically until the seeds reached approximately 0.1 g FW, and then hilum width, but not length, expanded very gradually as seed growth continued (width increased 0.14 mm as seeds increased from 0.1 to 0.7 g FW, representing about 9% of maximum hilum width). Similar trends were seen for PI 509178 (Table 1). Finally, in PI 359716 (Fig. 1C), an initial expansion of the hilum was seen until seed weights of about 0.07 g FW; hilum length, but not width, continued to expand thereafter (length increased 0.11 mm as seeds increased from 0.07 to 0.29 g FW, representing about 6% of maximum hilum length).

These results demonstrate that the cross-sectional dimensions of the funiculus, at least at the point of attachment to the seed coat (ie, hilum region), and probably throughout funicular length, can change throughout the course of seed growth. Most of the change in hilum dimensions appears to be completed early in seed development (eg, in seeds ≤0.1 g FW); however, it also is clear that hilum width and/or length can continue to increase in certain accessions. Thus, any future studies designed to understand how cross-sectional area of the funiculus might benefit or hinder nutrient flow to developing chickpea seeds, must take into account the dynamic dimensional changes occurring within this important structure.

References


