Stabilizing Yield and Quality: Early Maturing Chickpea for the Prairies

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Abstract
Progress in chickpea breeding has been constrained by lack of good sources of early maturity in the short-season temperate environment of western Canada. We hypothesized that the length of the chickpea lifecycle could be reduced through introgression of strategic genetic traits including short internode, double podding and early flowering. The result showed that both the double podding and early flowering traits had significant beneficial effects by reducing the duration of crop maturity in chickpea in the short-season temperate environment of western Canada. Pyramiding double podding, early flowering and other strategic genetic traits should lead to the development of extra short duration chickpea varieties more suited for cultivation in the Prairies and similar environments.

Introduction
Chickpea (*Cicer arietinum* L.) has recently become an important pulse crop in western Canada, following pea *(Pisum sativum L.*) and lentil (*Lens culinaris* Medik). This crop has a huge potential in the region, but its yield and quality is constrained partly by long maturity duration of the cultivars, which often expose the crop to fall frost. Early maturity is a key agronomic trait for chickpea breeding in western Canada. Progress has been made in developing somewhat earlier maturing varieties, but even these often take longer to mature than the length of the growing season in the area. This prompted us to look for novel strategies to induce earliness. We hypothesized that key genetic traits such as short internode, double podding and early flowering could be used as a strategy to accomplish this goal. The effective coordinated action of the genes for these traits would therefore reduce the seasonal length requirement of chickpea and subsequently minimize production risk. We therefore, conducted experiments with the main objective of determining the associated effects of short internode, double podding and early flowering alleles on earliness of crop maturity and other agronomic traits in chickpea in the short-season temperate environment of western Canada.

Materials and Methods
Four single crosses were made as E100Ym X CDC Anna, 272-2 X CDC Anna, 298T-9 X CDC Anna, and 298T-9 X CDC Frontier. The first parent in each cross had either short internode (E100Ym), double podding (272-2), or early flowering (298T-9) characteristics. From each cross, the F_1 and subsequent generations were grown in greenhouse and field to advance the generations to $F_{3:5}$. From these, three lines were selected from each cross for further testing. Selection was based on earliness to flower for the two early flowering populations, and expressivity of double podding for the double podding population. Expressivity of double

podding was taken as the number of double podding nodes divided by the total number of podding nodes expressed as a percentage (Kumar et al., 2000). However, the short internode segregants from the respective cross were too late to mature and were not advanced. Instead, only the three earliest maturing lines were selected from this cross.

During summer 2005 the twelve selected $F_{3:6}$ lines (3 lines X 4 crosses) were grown along with the four parental lines 272-2, 298T-9, CDC Anna, and CDC Frontier and two early maturing check varieties CDC Cabri and Myles at the Goodale farm near Saskatoon. Plots were arranged in a randomized complete block design with three replications. Plot size was three rows of 4 m length with 0.3m spacing between rows. Data on percent pod maturity at four months after planting (PPM), height at flowering (HF), plant height (PTHT), and days from seeding to when 90% of the pods turned brown (DM) were recorded. Seed yield (kg ha^{-1}) and 100 seed weight (g) were determined after cleaning the seeds. Analysis of variance was carried out using SAS PROC GLM (SAS Institute Inc., 1999) on phenological and agronomic traits recorded for the $F_{3:6}$ lines grown in the field. Means were separated using Fisher's protracted least significant differences (LSD) for $P < 0.05$.

Results and Discussion

Field comparison of genotypes ($F_{3:6}$ generation) selected from the populations for short internode, double podding, and early flowering revealed highly significant differences among these genotypes in phenological and other agronomic characters (Table 1). The three genotypes selected from the double podding population (Y9421-026, Y9463-028, and Y4912-039) were at least one week earlier maturing than the parents and standard checks. The mean expressivity of double podding was 32% for Y9421-026, 34% for Y9463-028, and 16% for Y4912-039 as compared to the 10% mean expressivity of double podding for the double podding donor parent 272-2. These genotypes attained over 80% PPM at four months after planting, whereas the check varieties CDC Anna, CDC Frontier, and 298T-9 had < 50% pods mature at this time. The presence of two pods per node instead of one produces a large sink more rapidly and places an increased demand for photosynthate on the crop, hastening the switch from vegetative to grain filling mode. This was supported by the evidence that double podding genotypes had a relatively small increase in height between flowering and maturity. The differences between PTHT and HF were 10 - 15 cm in the double podding lines compared to >20 cm in CDC Anna, 298T-9, CDC Cabri, and Myles.

The early flowering group, especially those from the 298T-9 X CDC Anna cross, were also relatively early to mature, but had only slight advantage over parents and check varieties. Our study showed that time to flowering influenced maturity duration in chickpea mainly through its effect on timing of the beginning of maturity of lower pods in the short-season temperate environment of western Canada. Early commencement of maturity of lower pods would be beneficial to progress towards full crop maturity before the occurrence of fall frost, and should reduce the risk of frost damage to chickpea crops in western Canada.

The present study revealed that the short internode allele had an undesirable effect, in that all the short internode segregants were extremely late to flower and mature. This was probably due to the pleiotropic action of the locus (Sandhu et al., 1990). The short internode allele is likely involved in gibberellin metabolism, which affected characters such as leaf size and color, flowering, and pod development and then crop maturity.

Table 4. Mean seed yield and some phenological and agronomic characters in selected chickpea lines ($F_{3:6}$ generation) derived from crosses with short internode, double podding and early flowering parents compared to their parents and other check varieties at the Goodale farm near Saskatoon in 2005.

Category	Entry	Percentage pod maturity	Days to maturity	Height at flowering (cm)	Plant height (cm)	Seed yield (kg ha^{-1})	100 seed weight (g)
Short internode (E100Ym x CDC Anna)	Y3842-005	55	146	40	68	3387	19.6
	Y3842-023	43	149	38	68	2729	15.2
	Y3861-041	71	139	40	60	3117	19.5
Double podding (272-2 X CDC Anna)	Y9421-026	88	129	38	52	3020	16.8
	Y9463-028	83	132	42	51	2896	13.2
	Y4912-039	83	134	39	56	2773	15.1
Early flowering (298T-9 X CDC Anna)	Y6161-009	77	138	40	54	3722	18.2
	Y6172-011	71	142	39	57	3435	17.8
	Y1611-040	53	149	39	70	2340	15.6
Early flowering (298T-9 X CDC Frontier)	Y7211-039	52	148	39	61	2015	21.8
	Y2721-065	43	147	37	67	2491	20.8
	Y2721-089	58	145	36	65	2779	20.2
Parental genotypes	272-2	76	142	34	54	2706	13.4
	298T-9	36	149	37	65	2256	18.6
	CDC Anna	25	153	41	80	1364	19.9
	CDC Frontier	35	151	46	62	2342	35.9
Check varieties	CDC Cabri	57	145	45	69	3277	29.2
	Myles	63	145	41	69	2132	18.8
CV (%)		11.4	3.6	8.4	12.1	16.2	3.8
$LSD_{0.05}$		21.2	9.2	5.5	12.6	1156	4.4

References

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