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ABSTRACT

The chickpea or garbanzo bean (*Cicer arietinum* L.) germplasm PHREC-*Ca*-Comp. #1 (Reg. No. GP-282, PI 659664) was developed by the former Alternative Crops Breeding Program at the University of Nebraska Agricultural Research Division and was released in 2010. It was bred specifically for adaptation to growing conditions in Nebraska and for enhanced resistance to Ascochyta blight, a major disease of chickpea caused by *Ascochyta rabiei* (Pass.) Labr. PHREC-*Ca*-Comp. #1 is a composite of PI 315797, PI 343014, PI 379217, PI 471915, PI 598080, and W6 17256. The composite was developed in the fall of 2002 and was evaluated in six irrigated and four dryland environments at Scottsbluff, Sidney, and Alliance, NE, from 2004 to 2009. Across irrigated environments, PHREC-*Ca*-Comp. #1 had the lowest severity rating for Ascochyta blight and a higher yield under both irrigated and dryland conditions than 'Sierra', 'Dwelley', 'Dylan', and 'Troy'. PHREC-*Ca*-Comp. #1 is a small, round, cream-colored kabuli-type chickpea. It exhibits an upright, indeterminate growth habit. Plants average 66 cm in height and have excellent resistance to lodging. PHREC-*Ca*-Comp. #1 has a fern leaf structure and white flowers and blooms 44 d after planting. It is a midseason bean, maturing 116 d after planting. Although its seed size does not meet commercial standards, PHREC-*Ca*-Comp. #1 has value in breeding programs as a source of resistance to Ascochyta blight and because of its high yield potential.

Chickpea (*Cicer arietinum* L.) is the third most important food legume in the world. It is grown in 45 countries on all continents, with Asia, Africa, Oceania, and America contributing 90.6, 4.6, 2.6, and 1.7%, respectively, of the total planted area (11.5 million ha; FAOSTAT, 2008). India, Pakistan, Iran, and Turkey are the top producing countries with 65.3, 9.6, 6.8 and 4.2% of the total planted area, respectively. Chickpea is used extensively for human consumption. In the United States, it is primarily used in salad bars, whereas in the Middle East and India, it is more frequently cooked and blended with rice dishes (Margheim et al., 2004). The desi type, which is characterized by small brown seeds, accounts for nearly 90% of total chickpea production.

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One of the major factors limiting chickpea production is Ascochyta blight [caused by *Ascochyta rabiei* (Pass.) Labr.], a fungal disease that can affect all above-ground plant parts (Nene and Reddy, 1987; Kaiser, 1992; Ahmed et al., 2006). Economic losses result from reduced yields and quality (Harveson, 2007). Ascochyta blight is spread by infected seeds and the residue from diseased plants (Nene and Reddy, 1987; Kaiser, 1992; Akem, 1999). Cool, moist, and windy conditions favor the development and spread of the disease (Nene and Reddy, 1987; Kaiser, 1992; Akem, 1999).

Development of resistant cultivars is the preferred approach to controlling Ascochyta blight; however, this goal has proven elusive because resistance has not always been effective under high disease pressure or across locations, and shifts in levels of resistance have been observed over time or as plants mature (Singh and Reddy, 1996; Akem, 1999; Jayakumar et al., 2005). An integrated approach that combines all agronomic options, including cultivar selection, is recommended to economically and effectively manage this disease (Gan et al., 2006).

The pathogenicity of the Ascochyta blight varies greatly (Gowen et al., 1989; Jan and Wiese, 1991; Chongo et al., 2004). Such fluctuations have been attributed to the presence of different races (Grewal, 1984; Chongo et al., 2004) or pathotypes of the disease (Udupa et al., 1998). The presence of the sexual form of the pathogen (which is associated with overwintered chickpea residue) in some populations may contribute to such variability and the loss of resistance

over time (Nene and Reddy, 1987; Jan and Wiese, 1991; Akem, 1999; Peever et al., 2004).

Numerous patterns of inheritance of resistance to Ascochyta blight have been identified (Tekeoglu et al., 2000; Udupa and Baum, 2003; Cho et al., 2004; Danehloueipour, 2007), although resistance is now generally considered a quantitative trait involving multiple genes (Flandez-Galvez et al., 2003). Recent efforts have focused on identifying the loci or genomic locations associated with resistance and on the use of genetic markers to facilitate the breeding of resistant lines (Winter et al., 1999; Santra et al., 2000; Collard et al., 2003; Rakshit et al., 2003; Millan et al., 2006; Tar'an et al., 2007). Some efforts have been pathotype specific (Udupa and Baum, 2003; Cho et al., 2004), whereas others have evaluated the use of wild relatives of chickpea as sources of genetic material for crop improvement (Collard et al., 2003; Croser et al., 2003).

Chickpea is a relatively new crop in Nebraska, but it fits well with existing equipment, dry-bean processors, and the regional infrastructure. Initially, chickpea production grew rapidly (from 1500 acres in 2000 to almost 10,000 acres in 2006); however, planted acres declined to fewer than 300 in 2007 largely because of the threat of Ascochyta blight. Also of concern is the variability of yield, seed size, pest resistance, and quality of currently available varieties. For chickpea to be a viable crop in Nebraska, it is essential that well-adapted cultivars with desirable agronomic characteristics be developed. Therefore, we evaluated existing chickpea germplasm in field trials (Western Regional Chickpea Trial conducted by the USDA-ARS, Pullman, WA) from 2003 to 2009 to identify lines that are well adapted to this region, have desirable yield and quality characteristics, and are resistant to Ascochyta blight. Promising lines, including PHREC-*Ca*-Comp. #1 (Reg. No. GP-282, PI 659664), have been incorporated into our ongoing breeding efforts to develop economically viable chickpea cultivars for this region.

Methods

PHREC-*Ca*-Comp.[Composite] #1 is a small, round, cream-colored kabuli chickpea. It is a composite of PI 315797, PI 343014, PI 379217, PI 471915, PI 572509, PI 598080, and W6 17256. In 2002 these plant introductions showed good adaptation to western Nebraska and had high levels of resistance to Ascochyta blight. Seed was obtained from the Western Regional Plant Introduction Station, which maintains the seed for the National Plant Germplasm System. PI 315797 was donated by India in 1966. PI 343014 ('Kuban's 16') was collected in the former Soviet Union in 1969. PI 379217 ('Gorunbinski') was collected in what was formerly Serbia and Montenegro in 1972. PI 471915 ('ILC 3279') was collected in Tunisia. PI 572509 ('Califfo') was developed in Italy in 1993. PI 598080 ('Myles') was obtained from ICRISAT in 1990, and W6 17256 (FLIP 91–054) was developed by ICARDA, Aleppo, Syria.

An initial composite was developed in the fall of 2002 at Scottsbluff, NE, based on individual plant selections within each plant introduction showing resistance to Ascochyta blight. These were hand harvested and bulked. During the 2003 growing season, we selected within the composite for resistance to Ascochyta blight and root rot (caused by *Rhizoctonia solani* Kühn [teleomorph: *Thanatephorus cucumeris* (Frank) Donk]), for fern leaf type, and for seed type following harvest. A naturally occurring severe outbreak of Ascochyta blight and root rot provided the primary selection pressure. Ninety-five percent of the plants were severely affected and many produced no seed. Those plants that survived these extreme conditions were advanced to form the PHREC-*Ca*-Comp. #1. We added PHREC-*Ca*-Comp. #1 to the entries in the Western Regional Chickpea Trial (USDA-ARS, Pullman, WA) from 2004 through 2009 to evaluate its agronomic performance, where we compared it with four commercial checks—'Dwelley' (Muehlbauer et al., 1998), 'Dylan' (Muehlbauer et al., 2006), Sierra (Muehlbauer et al., 2004), and 'Troy' (Chen, personal communication, 2010)—at 10 environments (location-year combinations) in western Nebraska.

Locations

PHREC-*Ca*-Comp. #1 was evaluated at two research sites associated with the University of Nebraska (Scottsbluff and Sidney) and in a grower's field located near Alliance, NE. Soil at the Scottsbluff site (41°53.6′ N, 103°40.7′ W, 1200 m.a.s.l.) is a Tripp very fine sandy loam soil (coarse-silty, mixed, superactive, mesic Aridic Haplustoll). Soil at the Sidney site (41°2′ N, 103°0′ W, 1315 m.a.s.l.) is a silt loam (fine-silty, mixed, superactive, mesic Aridic Argiustoll). Soil at the Alliance site (42°25′ N, 102°96′ W, 1279 m.a.s.l.) is a fine-silty, mixed, superactive, mesic Aridic Argiustoll.

Experimental Design

We evaluated the adaptation of chickpea germplasm under irrigated and dryland conditions in the Nebraska Panhandle. These included six irrigated environments: Scottsbluff (2005, 2007, and 2009), Sidney (2005), and Alliance (2004, and 2005); and four dryland environments: Scottsbluff (2007), Sidney (2005), and Alliance (2004 and 2005). The severity of Ascochyta blight was evaluated in six irrigated environments: Scottsbluff (2005, 2007, 2008, and 2009) and Alliance (2004 and 2005).

Within each environment, genotypes were assigned to experimental units using a randomized complete block design with four replications at each location. All plots were 1.7 m wide and consisted of 8 rows. Row length varied by location: Alliance (6 m), Scottsbluff irrigated (3 m) and dryland (6 m), and Sidney irrigated (7.4 m) and dryland (10 m). Seed was planted at a density of 44.7 seeds m^{-2}. Before planting, seeds were inoculated with N-Dure (Microbials, LLC, Kentland, IN) at a rate of 2.2 kg inoculum 682 kg $seed^{-1}$. Trials were planted in early May when soil temperature at a depth of 5 cm was 7.2°C and rising, as recommended by Margheim et al. (2004). All trials were planted in fields where corn (*Zea mays* L.) had been grown the preceding year.

Phosphorus was applied at a rate of 4.8 kg ha^{-1} by broadcasting an 11-15-0 starter fertilizer. Plots were treated with 85 g ha^{-1} sulfentrazone (Spartan, FMC Corp., Philadelphia, PA) preplant and 170 g ha^{-1} of quizalofop-P ethyl (Assure II, DuPont, Wilmington, DE) post-plant to control broad-

leaf and grass weeds, respectively. Because the purpose of this study was to evaluate the inherent agronomic and resistance characteristics of the germplasm, no fungicide treatments were applied at the University of Nebraska sites (Scottsbluff and Sidney). However, the cooperating grower (Alliance) followed his customary production practices and applied 658 mL ha^{-1} pyraclostrobin (BASF, Ludwigshafen, Germany) at flowering to control Ascochyta blight. After emergence and throughout the growing season irrigated plots were watered approximately once a week with 1.3 cm of water using sprinkler irrigation systems. Plots were harvested with a Classic plot combine (Wintersteiger, Salt Lake City, UT).

Response Variables

To evaluate plant response to environments, we determined yield (kg ha^{-1}), 100-seed weight (g), and the number of days to harvest (when plants were dry enough to be harvested with a combine). The prevalence of Ascochyta blight in each plot was rated in mid-July using a 0–5 scale where 1 = 100% stand and no disease, 2 = 75% stand and <25% of plants showing symptoms, 3 = 50% stand and 50% of plants showing symptoms, 4 = 25% stand and up to 75% of plant showing symptoms, 5 = no stand or >75% of plant showing symptoms (Harveson et al., 2009).

Statistical Analysis

Data were analyzed using PROC MIXED (SAS Institute, 2004). Each environment was analyzed separately. Location and replication were treated as random effects and genotype was treated as a fixed effect. Homogeneity of the variances was evaluated using Barlett's χ^2 test (Steel and Torrie, 1980), and appropriate data were pooled. In the pooled analyses, year × location and replication were random effects and genotypes were fixed effects. Means were separated using an *F*-protected LSD. All tests were considered significant at $P \leq 0.05$.

Characteristics

Yield, 100-seed weight, and days to harvest differed ($P < 0.01$) with environment (each location-year combination), genotype, and their first-order interaction (data not shown).

Ascochyta Blight

Natural infection was the primary source of Ascochyta blight. Across irrigated environments, PHREC-*Ca*-Comp. #1 had the lowest severity rating for Ascochyta blight (Table 1). It had the lowest rating among all entries in each of the four irrigated environments at Scottsbluff, and its rating was significantly lower ($P < 0.05$) than that of the commercial cultivars in 2005, 2007, and 2009 (Table 1). The average incidence of Ascochyta blight tended to be lower at Alliance than at Scottsbluff except in 2008, possibly because of the grower's use of fungicide. Sierra and PHREC-*Ca*-Comp. #1 had the lowest severity rating for Ascochyta blight at Alliance in 2004 (1.9 and 2.0, respectively) (Table 1). PHREC-*Ca*-Comp. #1's worst ranking relative to the other entries occurred at Alliance in 2005, when the incidence of Ascochyta blight was relatively low for all entries (Table 1, Harveson et al., 2009). Based on the results from these six environments, PHREC-*Ca*-Comp. #1 shows promise as a source of resistance to Ascochyta blight. This potential was particularly evident in environments where the incidence of Ascochyta blight was moderately high (Scottsbluff 2005, 2007, and 2009).

Yield

PHREC-*Ca*-Comp. #1 had the highest yield across all irrigated environments (Table 2). It was the top yielder in each environment except Scottsbluff in 2005 (Table 2), where it ranked second behind Sierra; this difference, however, was not significant ($P > 0.05$). Averaged across irrigated environments, PHREC-*Ca*-Comp. #1 yielded 760, 1100, 1280, and 1480 kg ha^{-1} more than commercial cultivars, Sierra, Dwelley, Dylan, and Troy, respectively (Table 2).

PHREC-*Ca*-Comp. #1 had the highest yield across all dryland environments (Table 2). It had the greatest yield in each environment except at Alliance in 2005 (Table 2), where it ranked fourth behind Sierra, Dwelley, and Troy; this difference, however, was not significant ($P > 0.05$). Averaged across dryland environments, PHREC-*Ca*-Comp. #1 yielded 100, 210, 230, and 230 kg ha^{-1} more than Sierra, Dwelley, Dylan, and Troy, respectively (Table 2).

Seed Size

Seed size, as indicated by 100-seed weight, was lowest for PHREC-*Ca*-Comp. #1 both across and within each irrigated and dryland environment (ranging from 24 to 29 g and

Table 1. Severity of Ascochyta blight in the chickpea germplasm PHREC-*Ca*-Comp. #1 and four cultivars evaluated at six irrigated environments in western Nebraska from 2004 to 2009.

Genotype	2004	2005		2007	2008	2009	
	Alliance	Scottsbluff	Alliance	Scottsbluff	Scottsbluff	Scottsbluff	Average
	1–5†						
PHREC-*Ca*-Comp. #1	2.0	2.4	2.3	1.4	1.3	1.6	1.8
Sierra	1.9	3.3	2.1	2.4	2.1	3.5	2.5
Troy	—	3.3	1.8	2.6	1.9	3.6	2.6
Dylan	2.1	3.8	2.3	2.5	—	—	2.7
Dwelley	2.5	3.3	1.5	2.6	2.8	4.0	2.8
LSD (0.05)	0.5	0.9	0.7	0.5	1.0	1.2	

†1 = 100% stand and no disease, 2 = 75% stand and <25% of plants showing symptoms, 3 = 50% stand and 50% of plants showing symptoms, 4 = 25% stand and up to 75% of plant showing symptoms, 5 = no stand or >75% of plant showing symptoms.

Table 2. Mean yield of the chickpea germplasm PHREC-*Ca*-Comp. #1 and four cultivars evaluated at six irrigated and four dryland environments in western Nebraska from 2003 to 2009.

Genotype	2004 Alliance	2005 Scottsbluff	2005 Alliance	2005 Sidney	2007 Scottsbluff	2009 Scottsbluff	Average
			kg ha^{-1}				
				Irrigated			
PHREC-*Ca*-Comp. #1	3960	1470	1970	400	960	2990	1960
Sierra	2160	1510	1530	190	360	1420	1200
Dwelley	1740	850	1700	80	140	660	860
Dylan	930	870	1350	80	190	—	680
Troy		330	1120	170	70	710	480
LSD (0.05)†	880	410	280	80	120	1130	
				Dryland			
PHREC-*Ca*-Comp. #1	1080		1110	340	410		740
Sierra	800		1240	320	200		640
Dwelley	530		1160	320	90		530
Dylan	660		1050	200	140		510
Troy	—		1120	390	10		510
LSD (0.05)†	160		200	90	170		

†Comparison of means among genotypes.

Table 3. One-hundred-seed weight of the chickpea germplasm PHREC-*Ca*-Comp. #1 and four cultivars evaluated at five irrigated and three dryland environments in western Nebraska from 2003 to 2009.

Genotype	2004 Alliance	2005 Scottsbluff	2005 Alliance	2007 Scottsbluff	2009 Scottsbluff	Average
			g			
				Irrigated		
Dylan	45	34	57	43	—	45
Sierra	45	39	54	40	37	43
Dwelley	46	34	52	38	31	40
Troy	—	28	58	38	34	40
PHREC-*Ca*-Comp. #1	25	26	27	29	24	26
LSD (0.05)†	8	3	3	4	10	
				Dryland		
Dylan	36		53	50		46
Sierra	37		46	45		43
Dwelley	34		46	45		42
Troy	—		48	34		41
PHREC-*Ca*-Comp. #1	21		22	30		24
LSD (0.05)†	8		6	3		

†Comparison of means among genotypes.

from 21 to 30 g, respectively) (Table 3). The average 100-seed weight of PHREC-*Ca*-Comp. #1 was 7.7% lower under dryland than under irrigated conditions. Furthermore, it was 35.0–42.2% lower under irrigated conditions and 41.5–47.8% lower under dryland conditions than the average 100-seed weight of the commercial cultivars (Table 3).

Seed of PHREC-*Ca*-Comp. #1 varies somewhat in size. In a commercially graded 500-g sample, 0.6% of the chickpeas were 9 mm, 34.8% were 8 mm, 53.0% were 7 mm, and 11.6% were less than 7 mm in size.

Days to Harvest

Days to harvest varied among environments. PHREC-*Ca*-Comp. #1 had the greatest average days to harvest under irrigated conditions and the least under dryland conditions compared with the commercial cultivars (Table 4). PHREC-*Ca*-Comp. #1 was ready for harvest 5 d earlier under dryland than under irrigated conditions (Table 4). In contrast, each of the commercial cultivars was ready for harvest earlier under irrigated conditions (Table 4).

Other Characteristics

PHREC-*Ca*-Comp. #1 exhibits an upright, indeterminate growth habit. Plants averaged 66 cm in height during 2009 and had excellent resistance to lodging. PHREC-*Ca*-Comp. #1 has a fern leaf structure comprising several pairs of small oblong leaflets. PHREC-*Ca*-Comp. #1 has white flowers and blooms 44 d after planting. PHREC-*Ca*-Comp. #1 is a midseason bean maturing an average of 114 d after planting (range 110–123 d) (Table 4).

Summary

PHREC-*Ca*-Comp. #1 was ready for harvest in an acceptable time frame for this region. It had a greater yield than the commercial cultivars under irrigated conditions and was among the top yielders under dryland conditions, even though its seed size was much smaller. The incidence of Ascochyta blight in PHREC-*Ca*-Comp. #1 was consistently

Table 4. Days to harvest of the chickpea germplasm PHREC-*Ca*-Comp. #1 and four cultivars evaluated at three irrigated and two dryland environments in western Nebraska from 2003 to 2009.

Genotype	2005 Alliance	2007 Scottsbluff	2008 Scottsbluff	2009 Scottsbluff	Average
	d				
			Irrigated		
Sierra	123		105	91	106
Dylan	128		105	—	107
Troy	125		107	90	107
Dwelley	128		110	89	109
PHREC-*Ca*-Comp. #1	123		115	111	116
LSD (0.05)†	9.8		2.9	6.1	
			Dryland		
PHREC-*Ca*-Comp. #1	110	112			111
Sierra	120	109			114
Dwelley	120	112			116
Dylan	120	115			117
Troy	120	118			119
LSD (0.05)†	4.3	7.0			106

†Comparison of means among genotypes.

low (mean rating = 1.8, range = 1.3–2.4) across environments with relatively low to moderately high levels of Ascochyta blight. Although seed size does not meet commercial standards, PHREC-*Ca*-Comp. #1 has value in breeding programs as a source of resistance to Ascochyta blight and for its high yield potential.

Availability

A limited quantity of seed is available from Carlos A. Urrea (currea2@unl.edu). We ask that appropriate recognition of source be given when this germplasm contributes to the development of a new cultivar.

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