

REGISTRATION

Cultivar

Registration of ‘UC Southwest Gold’ heirloom-like gold and white mottled bean

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Registration by CSSA.

Abstract

‘UC Southwest Gold’ (Reg. no. CV-337, PI 693470) is a dry bean (*Phaseolus vulgaris* L.) descended from ‘Zuni Gold’ and UCD 9634 pink bean. UC Southwest Gold is an F_{3:7} line with an heirloom-like seed coat similar to Zuni Gold but with resistance to *Bean common mosaic virus* and yields 60% higher than its heirloom parent. Culinary evaluations have shown that it displays cooking properties comparable to Zuni Gold. Field trials were carried out on certified organic ground. UC Southwest Gold will contribute toward satisfying an increasing market demand for more productive and economical heirloom-type common bean cultivars.

1 | INTRODUCTION

‘UC Southwest Gold’ (Reg. no. CV-337, PI 693470) is an F_{3:7} line of common bean (*Phaseolus vulgaris* L.) descended from crossing the gold and white mottled ‘Zuni Gold’ (maternal parent) with UCD 9634 pink bean (paternal parent). Zuni Gold is also known as Four Corners Gold, and is available from Native Seeds/SEARCH as FD062. Genotypes with seed patterns like Zuni Gold were grown in the southwestern United States before the historic era (Kaplan, 1956). Heirloom types like Zuni Gold can be sold for a premium due to consumer demand for unique seed patterns and a reputation for superior cooking quality (Swegarden, Sheaffer, & Michaels, 2016). Despite this, Zuni Gold exhibits susceptibility to *Bean common mosaic virus* (BCMV), relatively poor yields, an undesirable sprawling type III-b growth habit, and a long growing season (Palkovic, Parker, & Gepts, 2015). In contrast, UCD 9634 demonstrates a type II-B growth habit, high yields, heat tolerance, and an intermediate season length (Palkovic et al., 2015). It was descended from the cross Yolano/BAT 1763 at the University of California Agricultural Experiment Station and carries the dominant *I* allele for resistance to BCMV. The *I* allele leads to hypersensitive field-level resistance or immunity against BCMV and *Bean com-*

mon mosaic necrosis virus, respectively (Feng, Poplawsky, Nikolaeva, Myers, & Karasev, 2014). The informal but well-enforced agreement among bean breeding programs in the United States and Canada calls for BCMV resistance in all bean cultivars (Haley, Afanador, & Kelly, 1994; Miklas, Kelly, Beebe, & Blair, 2006). Absence of this resistance results in rapid accumulation of the virus in seed stocks because it is transmitted mechanically, by seed, and by aphids (Schwartz & Pastor-Corrales, 1989). In many dry bean types without vibrant colors (such as pinto, black, and white-seeded market classes), *I* is linked to the dominant *B* allele, leading to expression of darker seed colors. UCD 9634 includes the resistant *I* allele in tight linkage with recessive *b*, allowing the expression of lighter seed color. The haplotype *I-b* is descended from ‘Pompadour Checa’ (G6616), one of the first cultivars with this pairing (Kelly, 1988a). Zuni Gold and UCD 9634 are not protected by utility patents (<http://patft.uspto.gov/netathtml/PTO/search-adv.htm>) and are therefore suitable for use in breeding. Both parents also have type S phaseolin (Parker, Palkovic, & Gepts, 2015), indicating that each are Middle American in origin (Gepts, Osborn, Rashka, & Bliss, 1986; Kami, Velásquez, Debouck, & Gepts, 1995). This pairing was chosen to reduce the potential for hybrid weakness, which sometimes occurs in types with parents of differing gene pools (Gepts & Bliss, 1985; Kelly, 1988b, 2018; Koinange & Gepts 1992; Hannah et al., 2007).

Abbreviations: BCMV, *Bean common mosaic virus*.

UC Southwest Gold is intended primarily for production in the semi-arid western United States, with a specific focus on organic production. Cultivars with heirloom-type seed coats allow smaller scale growers to fill a unique market niche. These cultivars can provide farm revenues 5–10 times greater than that of major commercial market classes (Brouwer, Winkler, Atterberry, Jones, & Miles, 2016; Walters, Brick, & Ogg, 2011). On average, restaurant managers who use heirloom cultivars are willing to pay US\$10.52/kg for heirloom beans that were grown organically and locally. At farmers markets, participating customers were willing to pay between \$13.20 and \$17.60/kg for the same types (Swegarden et al., 2016). UC Southwest Gold will help satisfy the market demand for heirloom-type bean that thrives under organic conditions.

2 | METHODS

Zuni Gold and UCD 9634 were initially crossed in autumn 2015. The F_1 and F_2 generations were grown in a greenhouse in early 2016. The 119 F_3 families developed from this cross were grown on an organic farm in Knight's Landing, CA, in summer 2016. Each plot in this evaluation included 30 individuals. Cultivars susceptible to BCMV, including Zuni Gold, were grown as controls and as a source of virus at all field sites. Field selections in 2016 focused on seed phenotype and BCMV resistance, while selections in 2017 included these plus an evaluation of yield. UC Southwest Gold was included in multilocation replicated trials in 2018 and 2019 based on its performance in the 2017 season. UC Southwest Gold is the F_7 bulk-harvested progeny of a single F_3 progenitor.

Field-based BCMV evaluations, based on aphid-mediated transmission of the virus, were complemented by off-season greenhouse inoculations of harvested seeds at each generation from the F_4 to the F_7 . These inoculations were done 7 d after planting in the greenhouse. Inoculation buffer was prepared by first making a 1:10 solution of BCMV-infected leaf tissue and 0.01 M pH 7.4 potassium phosphate buffer. Approximately 5 mg of Celite was added to this mixture as an abrasive; then it was homogenized with a mortar and pestle. Approximately 5 mg of Celite abrasive was added to the first simple leaves of each plant to be inoculated. Inoculation buffer was then rubbed into the Celite-coated leaves with a pestle, and symptoms appeared in susceptible plants within 2 wk. A minimum of 50 total plants were involved in these screenings, and these were all virus resistant in all cases. This indicates that the F_3 progenitor was homozygous resistant to BCMV. To confirm this, CAPS marker screenings (Bello et al., 2014) were conducted on four individuals at the F_6 generation and 21 individuals at the F_7 generation. These CAPS marker screenings involved extraction of DNA from immature trifoliate leaves using a modified cetyl trimethylammonium bromide

(CTAB) method. This DNA was used to amplify a region tightly linked to *I*, and polymerase chain reaction (PCR) products were digested with the *TaqI* restriction enzyme (Bello et al., 2014). These digested PCR products were then run on a 2% agarose gel. All samples of UC Southwest Gold and its virus-resistant parent (UCD Pink 9634, used as a control) were homozygous resistant to BCMV in these screenings, validating the results of the inoculations. In contrast, the parent Zuni Gold showed the homozygous susceptible pattern. Selection for UC Southwest Gold thus involved a combination of phenotypic and marker-assisted selection strategies (Assefa et al., 2019; Beaver & Osorno, 2009).

All field trials were conducted on certified organic ground, and seed was inoculated with Guard-N N_2 -fixing bacteria before planting. Fields were organized in augmented designs in 2016 and 2017, while randomized complete block designs were used in 2018 and 2019. In 2018 and 2019, each field site included three replications of each genotype, with three locations in each year. These replicated plots were each 9.3 m² in area and included 120 seeds planted into 12.2 m of row space. Yield was measured by harvesting each plot with a small-plot thresher and weighing the dry contents from each plot. A paired two-sample *t*-test of block yield data from field trials was used to compare whether UC Southwest Gold had significantly higher yields than its phenotypically similar parent, Zuni Gold.

Flavor evaluations were conducted to determine if UC Southwest Gold differed in culinary appeal from Zuni Gold. To do this, samples of F_6 seed of each cultivar were cooked using identical methods. This started with 8 h of soaking of 100 g of each type in 0.15% NaCl solution. The solution was drained and replaced with tap water before cooking, then brought to a boil for 10 min and left to simmer on low heat for an additional 20 min. Ten minutes before turning off the heat, 1.5 g of NaCl was added to the broth of each cultivar. During the culinary evaluations, cooked samples were maintained at equal temperature using a hot water bath. Evaluators were recruited from attendees at an organic farm event in Davis, CA, and were therefore considered fairly representative of the target market. Evaluators were highly demographically diverse. Evaluators were asked to compare the two cultivars based on flavor (1–5 scale; 1 = inferior, 5 = superior) and cooked visual appearance (1–5 scale; 1 = inferior, 5 = superior). Thirty-two individuals evaluated the flavor of both cultivars, and 29 of these evaluated the cooked visual appearance. No market standards currently exist for these types, and since no training on color or flavor would be given to a typical consumer, no training was given to attendees to avoid bias regarding what they “should” want in a bean. The sample order was randomized and evaluators were given numeric codes rather than names to maintain objectivity during the evaluation. Statistical analysis of the results was conducted using a paired *t*-test based on the data pairs of each taster.

TABLE 1 Comparison of yield and *Bean common mosaic virus* (BCMV) between UC Southwest Gold and Zuni Gold, by year and location

Year	Location	Yield		BCMV observed ^a	
		UC Southwest Gold	Zuni Gold	UC Southwest Gold	Zuni Gold
————— kg ha ⁻¹ —————					
2018	Davis	739	187	–	+
2018	San Juan Bautista	2,981	2,757	–	+
2018	Valley Center	1,581	230	–	+
2019	Davis	2,969	1,216	–	+
2019	Pescadero	2,479	2,353	n.d.	n.d.
2019	Valley Center	1,611	982	–	+
Mean		2,060*	1,288	0%	100%

^a– indicates no symptoms present; + indicates symptoms were observed; n.d. indicates no data.

*indicates significant difference ($p < .05$) by paired two-tailed t -test of block data.

3 | CHARACTERISTICS

UC Southwest Gold produces edible seed similar to Zuni Gold, with a gold and white mottled pattern. Plants produce white flowers and green stems, and grow upright until pod set, facilitating weed cultivation. The cultivar often lodges later in the season. UC Southwest Gold is relatively early, with 50% flowering by 44 d after planting and plot maturity occurring at 85 d at Davis in 2019. The cultivar has strong and uniform dry-down when stands are dense. Plants are indeterminate but very compact, expressing a type IIIa growth habit (Singh, 1982). All seed include white and gold, but the ratio of the two colors is environmentally influenced. UC Southwest Gold has a 100-seed weight of 33 g, similar to 32 g for Zuni Gold.

UC Southwest Gold had statistically significantly higher yields than Zuni Gold in the multilocation, multiyear trials ($p = .001$, paired two-sample t -test, Table 1). UC Southwest Gold yielded an average of 2,060 kg/ha compared with 1,288 kg/ha for Zuni Gold, a 60% increase. UC Southwest Gold plants did not display any symptoms of BCMV infection in any year, whether in the field or in the greenhouse. In contrast, Zuni Gold plots at every evaluated field site showed symptoms of BCMV. No significant change in culinary quality occurred during the development of UC Southwest Gold. UC Southwest Gold and Zuni Gold are not significantly different in flavor or cooked appearance ($p = .28$ and $p = .93$ respectively, paired two-sample t -test, Table 2). This indicates that UC Southwest Gold has significantly improved agronomic properties relative to Zuni Gold without a loss of cooking quality.

UC Southwest Gold may be better adapted to warm environments than Zuni Gold. In the warm-summer climates of Valley Center (July average high/low temperatures = 33/15 °C) and Davis (July averages = 34/14 °C), UC Southwest Gold yielded an average of 1,732 kg/ha compared with Zuni Gold's 822 kg/ha. This represents a 111% increase for the new cultivar. The difference was smaller in the relatively

TABLE 2 Zuni Gold and UC Southwest Gold culinary evaluation (1–5 scale, where 1 indicates inferior and 5 indicates superior)

Scale	Zuni Gold	UC Southwest Gold
Flavor		
Mean	3.19	2.97
SD	1.10	1.05
SE	0.19	0.18
n	32	32
Paired t -test p value	.28	
Cooked appearance		
Mean	3.45	3.43
SD	1.00	0.91
SE	0.19	0.17
n	29	29
Paired t -test p value	.93	

cool field sites of San Juan Bautista (July averages = 27/1 °C) and Pescadero (July averages = 22/11 °C). In these locations, UC Southwest Gold averaged 2,730 kg/ha and Zuni Gold averaged 2,555 kg/ha, an improvement of 7%.

In addition to providing higher yields, UC Southwest Gold may also mature more quickly than Zuni Gold. At Davis in 2019, the three UC Southwest Gold plots matured in 84–86 d, while none of the Zuni Gold plots were fully mature at 108 d after planting. Southwest Gold had similar scores to Zuni Gold for both flavor and cooked appearance, and the difference between the two was not significant ($p = .28$, and $p = .93$; $n = 32$ and $n = 29$ respectively, paired two-sample t -test, Table 2). This indicates that UC Southwest Gold is of comparable culinary quality to Zuni Gold.

No BCMV symptoms were noted in UC Southwest Gold plots in any field site or season. In contrast, BCMV was identified in Zuni Gold plots at all five evaluated field sites, at times approaching 100% of individuals infected in a plot (Table 1). Inoculations with BCMV ($n \leq 50$) and CAPS marker

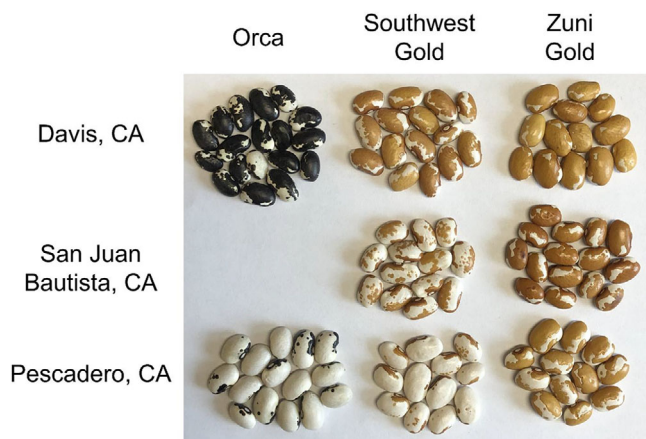


FIGURE 1 Seed patterns of UC Southwest Gold compared with other cultivars. White-mottled seed coat patterns encoded by the *t* locus vary somewhat by environment. This can be seen in Orca (Hang et al., 2003), UC Southwest Gold, and Zuni Gold

screenings ($n = 25$) failed to identify any UC Southwest Gold individuals that were BCMV susceptible or heterozygous BCMV susceptible.

Like Zuni Gold, UC Southwest Gold places pods relatively close to the soil. This trait makes the cultivar poorly suited to direct harvest, which is practiced most regularly outside of the target growing region. Lodging may also increase pod exposure to moisture, leading to a higher incidence of certain bacterial and fungal issues when grown in humid environments. In the semiarid target environment, relatively dry summer conditions prevent these diseases from being problematic. Lodging could be improved in the future by incorporating the major quantitative trait locus for lodging resistance on Pv07 (MacQueen et al., 2020; Moghaddam et al., 2016; Parker, Palkovic, & Gepts, 2020). Growers in humid environments are advised to trial UC Southwest Gold under their local conditions before increasing the production scale. Both parents of UC Southwest Gold carry the *PvPdh1* mutation leading to resistance to pod shattering, and pod shattering occurred at low levels in UC Southwest Gold even when grown in arid environments (Parker, Berny Mier y Teran, Palkovic, Jernstedt, & Gepts, 2020; Parker, Sousa, Floriani, Palkovic, & Gepts, 2020).

The recessive *t* allele of common bean causes seed mottling that is variable based on the environment, possibly due to the effects of temperature. The amount of white on seeds tends to be somewhat higher for UC Southwest Gold than Zuni Gold, particularly in lower temperature environments. The same pattern occurs in the compact heirloom-like cultivar Orca (Figure 1; Hang, Silbernagel, & Miklas, 2003).

UC Southwest Gold is descended from a single F_3 individual. Even though no obvious traits are still segregating within the cultivar, there is probably residual heterogeneity within

the line, a characteristic that is generally viewed favorably by organic producers.

4 | AVAILABILITY

The UC Davis Foundation Seed Program will maintain and provide UC Southwest Gold seed. The corresponding author may be able to provide small quantities of seed for breeding and research purposes. Seed has been deposited with the USDA–ARS National Plant Germplasm System, where it will be available upon publication.

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AUTHOR CONTRIBUTIONS


Travis Parker: Parent evaluation; Methodology planning; Crosses; Methodology planning; Field trial design and management; Genotyping; Phenotyping; Intern mentorship; Data analysis and selections; Manuscript writing. **Antonia Palkovic:** Parent evaluation; Field trial design and management; Intern mentorship. **E. Charles Brummer:** Conceptualization; Funding acquisition. **Paul Gepts:** Conceptualization; Parent evaluation; Methodology planning; Manuscript writing; Funding acquisition. All authors have read and approved the final draft of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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