Title

Registration of ‘UC-Capay’, a low-grain-protein, non—glycoside nitrile producing, California-adapted, two-rowed spring malting barley

Journal

Journal of Plant Registrations, 16(3)

ISSN

1936-5209

Authors

del Blanco, Isabel Alicia

Hegarty, Joshua M

Dubcovsky, Jorge

Publication Date

2022-09-01

DOI

10.1002/plr2.20240

Peer reviewed

Received: 6 December 2021 | Accepted: 25 April 2022

DOI: 10.1002/plr2.20240

Journal of Plant Registrations

REGISTRATION

Cultivar

Registration of 'UC-Capay', a low-grain-protein, non–glycoside nitrile producing, California-adapted, two-rowed spring malting barley

Isabel Alicia del Blanco[1] | **Joshua M. Hegarty**[1] | **Jorge Dubcovsky**[1,2]

[1]Dep. of Plant Sciences, Univ. of California, Davis, CA 95616, USA

[2]Howard Hughes Medical Institute, Chevy Chase, MD 20815, USA

Correspondence
Isabel A. del Blanco, Dep. of Plant Sciences, Univ. of California, Davis, CA 95616, USA.
Email: iadelblanco@ucdavis.edu

Assigned to Associate Editor Jamie Sherman.

Registration by CSSA.

Funding information
American Malting Barley Association; California Crop Improvement Association; Sacramento Region AgTech Innovation Center Development Project, Grant/Award Number: 077906923; Brewers Association

Abstract

California has a fast-growing malting industry in need of local production of malting barley (*Hordeum vulgare* L.) to provide malt to a well-established craft brewing industry. 'UC-Capay' (Reg. no. CV-376, PI 698168, PVP application number 202100205) is the third malting barley cultivar released by the University of California, following 'UC Tahoe' (2016) and 'Butta 12' (2019). UC-Capay is an early-flowering, two-rowed spring malting barley with low grain protein content, characterized by its exceptional large and plump grains. UC-Capay is adapted to the California's Central Valley (Sacramento and San Joaquin Valleys) and is resistant to all common diseases present in this region. UC-Capay is a non-glycoside nitrile producer, a trait highly valued by craft maltsters and distillers. UC-Capay meets the quality standards of a craft malting and brewing industry interested in sourcing locally grown barley.

1 | INTRODUCTION

The Barley Breeding Program at University of California (UC) Davis works closely with the developing Californian malting industry to improve malting barley (*Hordeum vulgare* L.) cultivars that are well adapted to the unique characteristics of California environments and its predominant pathogens. The Central Valley of California has a Mediterranean climate, with rainfall concentrated in the fall-winter months. With this characteristic climate, spring cereals are sown in the fall (end of October to beginning of December) to take advantage of the fall-winter rainy season and of an extended growing season. Fall-sown winter cereals or spring-sown spring cereals from other states usually perform poorly in this Mediterranean environment; therefore, a local breeding and selection effort is required to develop cultivars well adapted to California Supplemental Table S1.

Barley grown in the Central Valley requires strong resistance to stripe rust (caused by *Puccinia striiformis* Westend.), and tolerance to *Barley yellow dwarf virus* and *Cereal yellow dwarf virus*, collectively referred to here as *Yellow dwarf virus* (YDV). These cultivars need to have adequate malting quality to satisfy the requirements of the local California Craft Brewing Industry. The California Craft Beer Association (https://www.californiacraftbeer.com) reported in March 2021 that California has more than 1,100 craft breweries, producing more craft beer per year than any other state of the union (Brewers Association, 2021).

Abbreviations: DP, diastatic power; GN, glycoside nitrile; GPC, grain protein content; TKW, thousand-kernel weight; YDV, *Yellow dwarf virus*.

An important trait contributing to good malting quality is a moderate content of protein in the grain. The American Malting Barley Association guideline for grain protein content is ≤12% for all-malt two-row barleys, with a total malt protein of ≤11.8%. This low grain protein target imposes low N fertilization of barley crops, with a consequent reduction in grain yield potential. A grain protein content >12% is associated with several undesirable characteristics, including increased steep time and uneven water absorption during steeping and irregular germination during the malting process, leading to increased malt losses, excessive enzymatic activity, poorer mellowness of the malt, lower extract yields, higher content of nitrogenous compounds in wort during brewing, and the formation of haze in beer (Burger et al., 1979). Malting barley exceeding the protein standard is regularly subject to a significant penalty in price, or is rejected, at local and international markets.

'UC-Capay' (Reg. no. CV-376, PI 698168) carries the low grain protein content (GPC) haplotype, ("Karl's haplotype") at the *HvNAM-1* locus (Figure 1). This rare barley haplotype is hypothesized to be caused by an hypomorphic mutation in the *NAM-1* gene, which controls early senescence and remobilization of N and other nutrients from the leaves to the grains (Distelfeld et al., 2008). UC-Capay exhibits a reduction in GPC of around 8–10% compared with other two-row barley varieties with the wild-type *NAM1* gene when they are grown in the same field experiments. This gene also regulates the length of the grain-filling stage, which in the low-GPC genotypes is longer as a result of the delayed senescence or "stay-green," resulting in an increase of the size and plumpness of the grains. We do not know the origin of the low GPC allele in UC-Capay, but this allele is present in many varieties from North Dakota State University, one of which is part of UC-Capay pedigree.

Core Ideas

- UC-Capay is a new malting barley for the Central Valley of California.
- UC-Capay has low grain protein content.
- UC-Capay is non-glycoside nitrile producer.
- UC-Capay has exceptional large and plump grains.
- UC-Capay is resistant to the common barley pathogens present in the Central Valley.

2 | METHODS

2.1 | Early generation population development

UC-Capay was selected from the cross Orca/ND22202//29IB20. The first cross, Orca/ND22202, was made in April 2005; the F_1 of this cross was then crossed to 29IB20 in April 2006.

The three entries combined in the cross were the best two-rowed genotypes for both malting quality and adaptation to California Central Valley growing conditions at the beginning of the UC Davis two-rowed malting barley program (AMBA Annual Progress Reports, 2006, 2012). These three genotypes had similar malting quality as the Harrington check. The line 29IB20 (Canela/Gob//Aleli) came from ICARDA/CIMMYT and had excellent disease resistance and good agronomic performance. Orca, from Oregon State University, had resistance to stripe rust and YDV and had acceptable grain yield. ND22202, a line from North Dakota State University, had short plant height to counterbalance the tall stature of Orca.

After the original cross made in 2005–2006, the F_1 generation was grown out in the crop season 2006–2007. The progeny was self-pollinated, advanced as modified bulk, and selected from the F_2 (2007–2008) to the F_6 (2011–2012) generation at Davis Agronomy Field Station.

2.2 | Selection

UC-Capay was selected, in all generations, based on field observations of disease resistance, agronomic performance, and earliness. In advanced generations grain yield and malting quality data were added to the selection criteria. UC-Capay carries the low-GPC allele present in the cultivar 'Karl' (Burger et al., 1979; Distelfeld et al., 2008). This valued malting quality trait was discovered during our routine marker-assisted selection performed for this and other traits on UC Davis advanced malting barley lines and confirmed by sequencing (Figure 1). UC-Capay has on average 8% lower grain protein content than UC Tahoe and Butta 12 (5-yr average at several locations) (Table 1). This trait is linked to delayed senescence (Uauy et al., 2006), which in UC-Capay is around 14 d longer than the average of all other varieties in our UC Davis trials, allowing more time for grain filling and resulting in a much larger grain compared with other cultivars.

UC-Capay is also a non–glycosidic nitrile (GN) producer (Table 2), another highly valued trait in malting barley. Glycosidic nitrile is a compound present in malt resulting from the production of epiheterodendrin during the malting process; epiheterodendrin is a precursor to ethyl carbamate (EC)

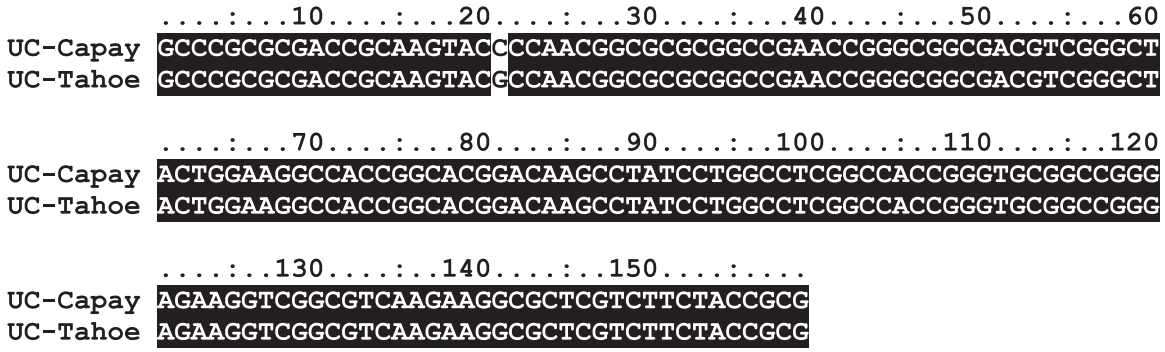

FIGURE 1 Sequences of the *GPC1* gene (*HvNAM-1*) from UC-Capay ('Karl', low-protein allele; GenBank EU368852) and UC Tahoe ('Lewis', wild-type or high-protein allele; GenBank EU368851). Identical nucleotides are indicated by white letters in a black background, and the diagnostic change 'G' to 'C' at position 304 of the coding region in Karl is marked with black letters in a white background. This polymorphism is reported in Distelfeld et al. (2008)

TABLE 1 Malting quality profile of UC-Capay

Cultivar	*n*[a]	TKW	Plump	ME	B. Prot.	Wort P.	S/T[b]	DP[b]	α-amylase[b]	β-glucan	FAN[b]
		mg			%			ASBC	20°DU	mg L^{-1}	mg L^{-1}
UC-Capay	11	49.18[c]	94.8[d]	81.6[c]	11.9[d]	4.8[d]	42.4[d]	101[c]	63.5	576[c]	200[d]
UC Tahoe	11	37.18	89.7	78.6	12.6	4.2	36.0	173	57.5	413	152
Butta 12	9	44.11	96.4	79.0	13.3	4.7	37.6	214	56.2	376	183
Harrington[e]	3	34.9	88.7	80.3	12.1	5.1	45.4	120	91	339	225
Metcalfe[e]	3	35.9	88.8	81.2	12.2	5.3	47.2	161	112	183	250
Merit 57[e]	3	38.3	86.8	80.8	12.3	5.2	45.0	155	113	242	237
USDA[f]		>42.0	>90.0	>81.1	11–13	4.4–5.6	40–47	>120	>45	<100	>190
AMBA ALL MALT[g]			>90.0	>81.0	<12	<5.3	38–45	110–150	40–70	<100	140–190

Note. Rows 1–3 are averages of multiple sites grown from 2015 to 2019 of UC-Capay, as compared with UC Tahoe and Butta 12 for thousand-kernel weight (TKW), on 6/64% or plump grains (Plump), malt extract (ME), barley protein (B. Prot.), wort protein (Wort P.), soluble to total protein (S/T), diastatic power (DP), α-amylase, β-glucan, and free amino-nitrogen (FAN). Rows 4–6 are 3-yr samples, from Davis 2017–2019, of three American Malting Barley Association (AMBA)-certified cultivars. Rows 7 and 8 are preferred values as described by the USDA and AMBA.

[a]Number of samples included for each line.

[b]S/T, soluble-to-total protein; DP, diastatic power measured in ASBC (level based on protocol from American Society of Brewing Chemists); α-amylase measured in 20 DU (dextrinizing units at 20 °C).

[c]Significantly different from UC Tahoe at the .001 level (LSD test).

[d]Significantly different from UC Tahoe at the .05 level (LSD test).

[e]Samples from the first UC Davis AMBA Pilot Malting trial in Davis, 2017–2019.

[f]USDA malt quality preference (adapted from Clancy & Ullrich, 1988).

[g]AMBA malt quality recommendations for all malt two-rowed applications (AMBA, 2017).

production in distilling, which is a known carcinogen regulated by some markets, such as Canada and the United Kingdom. We do not know the source of this trait, but some NDSU lines are non-GN producers, and one variety from this program is in UC-Capay pedigree.

UC-Capay was selected for having big and heavy grains, early flowering, field resistance or tolerance to the most important local diseases (YDV, stripe rust, and powdery mildew), high grain yield potential (mainly in rain-fed conditions), low GPC, low GN production, and excellent malting quality.

2.3 | Evaluation in replicated trials

Evaluation of UC-Capay started as unreplicated plots (F_7) in 2013, and the final selection was entered into the regional trials in 2014 (as UC1390). UC-Capay was evaluated during five growing seasons, from 2014/2015 to 2018/2019, in preliminary trials at Davis and in regional trials by the UC Davis Small-Grains Regional Testing Program (Table 3). Malting quality was evaluated all those years, starting in 2015, by the Malting Quality Laboratory at the USDA-ARS Cereal Crops Research Unit in Madison, WI.

TABLE 2 Glycoside nitrile (GN) genotyping: Detection of epiheterodendrin (EPH)-null allele using rhAMP assay

Sample	Call	RFU1	RFU2
UC-Capay	EPH null	331	1,567
UC Tahoe	EPH null	251	1,469
Butta 12	EPH null	256	1,498
Harrington	GN-producer	1246	150

Note. Nonproducers <0.5 g GN t^{-1}. RFU, relative fluorescence units.
Source: Aaron MacLeod (Hartwick College Center for Craft Food & Beverage, Oneonta, NY, 13820).

Experiments were organized as randomized complete block designs with four replications. The experimental units were small plots (1.5 m wide × 6 m long) with a density of 240 seeds m^{-2}.

2.4 | Malting quality

Testing for malting quality was conducted at the Malting Quality Laboratory at the USDA-ARS Cereal Crops Research Unit in Madison, WI, following their standard protocols. In early evaluations, samples sent for malting quality were from small, unreplicated plots. In advanced evaluations, samples were from replicated yield trials at different locations.

2.5 | Statistical analyses

UC-Capay was compared with 'UC Tahoe' (Hegarty et al., 2018; PI 678971) and 'Butta 12' (Gallagher et al., 2020; PI 692639). All statistical analyses were conducted using Proc GLM in SAS version 9.4 (SAS Institute, 2013). A linear mixed model with entry as a fixed effect and environment (each location-year combination was considered as an individual environment) as a random effect was used to analyze traits. Fisher's protected LSD method was used for separation of means. The Shapiro–Wilk test was conducted to test normality of residuals, and the Levene's test was used to test for homogeneity of variance. Data were transformed when needed.

2.6 | Disease resistance

Evaluation for the common diseases usually present in the California Central's Valley was conducted every year under field conditions. For stripe rust, besides the regular field observations, UC Davis conducts every year the Stripe Rust Nursery. This nursery was inoculated with a mix of races and strains collected the previous year in the experimental field at Davis. We injected the inoculum between the leaf sheath and the stem using a syringe and spread spores several times during the growing season over the plots. The stripe rust nurseries at Corvallis, OR, and in Mount Vernon and Pullman, WA, were grown and evaluated under natural field infections. For YDV, a scale of 0–8, were 0 is no disease and 8 highly susceptible, was applied for the evaluation.

2.7 | Seed production

Seed multiplication for all yield and quality testing as well as for breeder seed production originated from a single head-row in Davis during the 2013–2014 growing season. In June 2014, 250 spikes were collected from the plants originated from the seeds harvested from the initial row. Spikes were threshed individually and planted as 250 separate rows in July 2014 near Hollister, CA. Any row that was heterogeneous in appearance was entirely cut and discarded. In October 2014, 1,000 spikes were collected, threshed individually, and planted in Davis in November 2014 to produce pure breeder seed. Simultaneously, the remaining seed was harvested in Hollister in October 2014, bulked, and used for yield trials and quality testing. UC1390 was entered into the California small grains regional testing program for the first time in the 2014–2015 growing season and was planted at five locations: Davis, Fresno, Chico, Tehama, and Clarksburg. UC1390 was evaluated for a second year at the California small grains regional testing program in the 2015–2016 growing season in six locations. During the growing seasons 2016–2017, 2017–2018, and 2018–2019, UC1390 was evaluated at four locations in the San Joaquin and Sacramento Valleys under rain-fed conditions. Yield, disease resistance, and agronomic data for these locations are publicly available at https://smallgrains.ucdavis.edu/ (older data) and at https://smallgrains.ucanr.edu/Variety_Selection/ (newer data). Breeder seed was harvested in June 2015, and 23 kg of pure seed were delivered to the UC Davis Foundation Seed Program to produce foundation seed in half an acre during the 2018–2019 growing season.

3 | CHARACTERISTICS

3.1 | Botanical description

UC-Capay is a spring type barley that does not require vernalization to flower and is well adapted to fall planting in California. UC-Capay headed earlier than all other varieties and checks in our experiments. UC-Tahoe headed around 12–15 d later. UC-Capay has medium height, similar to 'Klages', shorter than 'Robust' by 7 cm, and taller than UC Tahoe by 13 cm. There is an absence of anthocyanins on the stem, which has four nodes and extends 10–15 cm between flag leaf and spike (flag-to-spike exertion at maturity), a straight

TABLE 3 Site locations of the experiments and years of evaluation (all locations in California)

Experiment name	Location	Planted	Harvest
Chico Regional 2015 (CH15)	Butte Co., Sierra Nevada Brewery, Chico	18 Nov. 2014	22 June 2015
Clarksburg Regional 2015 (CL15)	Yolo Co., Joe Perry Farm	14 Jan. 2015	June 2015
Fresno Regional 2015 (FR15)	Fresno Co., UC Westside REC, Five Points	8 Dec. 2014	June 2015
Davis Regional 2015 (DR15)	Yolo Co., UC Davis Agr. Farm, Davis	28 Nov. 2014	June 2015
Tehama Regional 2015 (TR15)	Tehama Co., Endres Ranch, Corning	3 Feb. 2015	June 2015
San Luis Obispo 2016 (SL16)	SLO Co., White Ranch, Shandon	18 Nov. 2015	20 June 2016
Clarksburg Regional 2016 (CL16)	Yolo Co., Joe Perry Farm, Clarksburg	1 Dec. 2015	27 June 2016
Fresno Regional 2016 (FR16)	Fresno Co., UC Westside REC, Five Points	19 Nov. 2015	13 June 2016
Davis Regional 2016 (DR16)	Yolo Co., UC Davis Agr. Farm, Davis	12 Nov. 2015	8 June 2016
Tehama Regional 2016 (TR16)	Tehama Co., Endres Ranch, Corning	2 Dec. 2015	29 June 2016
Tulare 2016 (TU16)	Tulare Co., Changala Farms, Ducor	20 Nov. 2015	16 June 2016
Tulare 2017 (TU17)	Tulare Co., Changala Farms, Ducor	29 Nov. 2016	8 June 2017
Fresno Regional 2017 (FR17)	Fresno Co., UC Westside REC, Five Points	30 Nov. 2016	9 June 2-17
Davis Preliminary 2017 (DP17)	Yolo Co., UC Davis Agr. Farm, Davis	10 Nov. 2016	June 2017
Davis Regional 2017 (DR17)	Yolo Co., UC Davis Agr. Farm, Davis	15 Nov. 2016	6 June 2017
Tulare 2018 (TU18)	Tulare Co., Changala Farms	28 Nov. 2017	20 June 2018
Fresno Regional 2018 (FR18)	Fresno Co., UC Westside REC, Five Points	29 Nov. 2017	18 June 2018
Davis Preliminary 2018 (D18)	Yolo Co., UC Davis Agr. Farm, Davis	7 Nov. 2017	5 June 2018
Davis Regional 2018 (DR18)	Yolo Co., UC Davis Agr. Farm, Davis	21 Nov. 2017	11 June 2018
Merced 2019 (MR19)	Merced	19 Nov. 2018	14 June 2019
Fresno Regional 2019 (FR19)	Fresno Co., UC Westside REC, Five Points	12 Nov. 2018	18 June 2019
Davis Preliminary 2019 (DP19)	Yolo Co., UC Davis Agr. Farm, Davis	11 Dec. 2018	June 2019
Davis Regional 2019 (DR19)	Yolo Co., UC Davis Agr. Farm, Davis	27 Nov. 2018	21 June 2019
Davis Preliminary 2020 (DP20)	Yolo Co., UC Davis Agr. Farm, Davis	12 Nov. 2019	11 June 2020

neck, and an open collar. The leaves are glabrous, dropping, without noticeable waxiness or anthocyanins. The spikes of UC-Capay are two-rowed, erect (no dense), parallel, with absence of waxiness in the head and without hairs in the rachis. The awns are longer than the spike and smooth. UC-Capay does not have lateral florets (Figure 2), as in deficiens genotypes.

3.2 | Field performance

UC-Capay was tested across 24 environments over 6 yr (Table 3), with a mean yield of 4,218 kg ha^{-1} (Table 3), which was not significantly different from UC Tahoe (4,558) or Butta 12 (4,383). UC-Capay (103 cm) is significantly taller than UC Tahoe (85 cm) and Butta 12 (88 cm), and for this reason UC-Capay is recommended for rainfed conditions. UC-Capay headed an average of 14 and 13 d earlier than UC Tahoe and Butta 12, respectively. UC-Capay did not have noticeable differences in physiological maturity relative to other varieties; it has delayed senescence (also regulated by the *HvNAM-1* locus), which may explain its larger and heavier grains. Average thousand-kernel weight (TKW) for UC-Capay was 52 g, whereas TKWs for UC-Tahoe and Butta 12 were 41 and 48 g, respectively (Table 4, Regionals and Preliminary data). Additional data supporting the larger grain size of UC-Capay (49 g) relative to UC-Tahoe (37 g) and Butta 12 (44 g) are provided in Table 1 (USDA laboratory results). UC-Capay was more resistant to lodging at grain fill than UC Tahoe and Butta 12 (Table 4). UC-Capay showed similar tolerance to YDV than UC Tahoe and was superior to Butta 12 for this trait (Table 4).

UC-Capay showed strong resistance to stripe rust in all the years that it was tested in the San Joaquín and Sacramento Valleys. The Barley Stripe Rust Screening Nurseries conducted for 4 yr at Davis under inoculation (DA17, DA18, DA19, DA20), 1 yr (2019) at Pullman, WA (PU19); Mount Vernon, WA (MV19); and Corvallis, OR (OR19) showed significant difference in resistance for UC-Capay (resistant) compared with UC Tahoe (intermediate resistance) and Butta 12 (susceptible) (Table 5).

FIGURE 2 UC-Capay spike deficiens genotype, without lateral florets

3.3 | Malting quality

Malting quality was evaluated on grain samples from 11 different environments (5 yr, different locations), and the results are shown in Table 1. The preferred values for each parameter according to "AMBA all malt" or "USDA adjunct brewing" (malt that will be used in adjunct brewing with other grains like rice or corn) are listed at the bottom of Table 1. Barley varieties that produce high wort protein, free amino-nitrogen, and higher enzymatic activity (diastatic power [DP] and α-amylase) are preferred for the USDA adjunct class.

UC-Capay is significantly superior to both UC Tahoe and Butta 12 in TKW, malt extract, and soluble to total protein (S/T) and superior to UC Tahoe in plumpness (on 6/64). UC-Capay has lower protein in grain compared with the other two cultivars. Its wort protein (4.8), though significantly superior to UC Tahoe, is well within the limits of USDA (4.4–5.6) and All Malt (<5.3). UC-Capay also has less DP than the other two cultivars.

The mandatory limits in protein content by USDA and All Malt also limit the amount of fertilizer that can be applied in malting barley crops. In the low-GPC cultivar UC-Capay, the control of the amount of protein translocated from the leaves to the grain will result in acceptable protein levels in the grain under higher N fertilization, allowing farmers to increase grain yield by increasing the fertilization applied to the crop.

A potential quality problem for UC-Capay in some environments is the high level of β-glucan, averaging 576 mg L^{-1}, which is well above the maximum ideal levels according to the USDA and Brewers Association at 100 and 140 mg L^{-1}, respectively. β-glucans are polysaccharides naturally present in the cell walls of cereals that are broken down during the malting process by the enzyme β-glucanase (Fincher, 1975). β-glucans are highly viscous and, when in excessive amounts, can cause problems in brewing, such as reduced rates of wort separation, poor beer filtration leading to the formation of hazes, and precipitates, with a final product with poor shelf stability (Barrett et al., 1973; Sá & Palmer, 2004; Vis & Lorenz, 1997). Although the amount of β-glucan in the grain is partially controlled by the genetics of the cultivar, it is also significantly influenced by the environment. High temperatures between heading and maturity, as well as number of days above 30 °C, increase β-glucan content (Zhang et al., 2001). Fortunately, β-glucan content can be reduced during malting by steeping barley at lower temperatures and by extending the germination time, allowing the β-glucanases to develop and act for a longer period, which diminishes β-glucan levels in the resulting malt (Li et al., 2008; Rimsten et al., 2002). As for UC Tahoe, the primary users of UC-Capay are expected to be local California craft-scale maltsters, who can work with flexible malting protocols. The higher levels of β-glucans in UC-Capay are not problematic for distilling quality, but the

TABLE 4 Agronomic characteristics and disease resistance of barley cultivar UC-Capay from 24 site-years from 2015 to 2020

Cultivar	Yield			Kernel wt.	Plant ht.	Days from planting to heading/maturity	Lodging at grain fill	*Yellow dwarf virus*
	All	Irrigated	Rainfed					
	kg ha^{-1}			mg	cm	d	1–8[a]	
UC-Capay	4,218	4,347	3,728	52.15[b]	103[b]	123/173[b]	2.91[b]	1.00[c]
UC Tahoe	4,558	4,839	3,634	40.58	85	137/174	3.92	1.08
Butta 12	4,383	4,417	3,499	48.00	88	136/174	4.04	3.00

[a]1 = no lodging, no disease; 8 = severely affected.
[b]Significantly different from Tahoe at the .05 level (LSD).
[c]No difference with UC Tahoe but significant difference with Butta 12.

TABLE 5 Stripe rust resistance scores from the Barley Stripe Rust Screening Nurseries over 4 yr at Davis and 1 yr (2019) at Pullman, WA (PU19); Mount Vernon, WA (MV19); and Corvallis, OR (OR19)

	UC-Capay		UC-Tahoe		Butta 12	
Envir.	**IT**	**Sev.**	**IT**	**Sev.**	**IT**	**Sev.**
	0–9	0–100	0–9	0–100	0–9	0–100
DA17	3	10	4	30	8	80
DA18	3	10	5	30	9	70
DA19	0	0	4	10	7	40
PU19	2	2	5	10	8	20
MV19	2	5	2	10	8	20
OR19	–	7	–	22	–	40
DA20	0	0	0	0	5	30
Mean	1.7[a]	5[a]	3.3	16	7.5	43

Note. Infection type (IT) scale: 0–3, resistant; 4–6, intermediate; 7–9, susceptible. Severity (Sev.) scale: 0–9, resistant; 10–19, moderately resistant; 20–39, intermediate; 40–49, moderately susceptible; 50–100, susceptible.

[a]$P < .001$ compared with UC Tahoe and Butta 12 (LSD test).

DP values of UC-Capay may be lower than desired by some distillers.

4 | CONCLUSIONS

UC-Capay, the third malting barley release from UC-Davis, is genetically unrelated to the previously released cultivars (Butta 12 is one of the parents of UC Tahoe; consequently, these two varieties are closely related). Therefore, it will be an important asset to the actual portfolio of UC malting barley cultivars by offering a wider genetic diversity to the challenge of pathogens present in California. UC-Capay has exceptional plump grains and carries the low-GPC allele, which will allow farmers the use of N fertilization to increase grain yields while maintaining the required grain protein levels. Finally, UC-Capay is a non-GN producer, another valuable trait for craft maltsters and distillers.

5 | AVAILABILITY

Breeder seed for UC-Capay was delivered to the UC Davis Foundation Seed Program in October 2019, which has maintained foundation seed since September 2020. US Plant Variety Protection of UC-Capay is PVP No. 202100205, submitted 10 Nov. 2020 and issued 10 Dec. 2021. Foundation seed can be produced on request by the UC Davis Foundation Seed program (https://fsp.ucdavis.edu/), and Certified seed is available for purchase from Adams Grain in Arbuckle, CA (http://www.adamsgrp.com/adams-grain.shtml). Seed of UC-Capay has been deposited into the USDA–ARS National Plant Germplasm System, where it will be available at the end of PVP protection. Small amounts of seed (5 g) for research purposes can be requested from the corresponding author for at least five years.

ACKNOWLEDGMENTS

The Malting Barley Breeding program at the University of California, Davis, is supported by the American Malting Barley Association, the California Crop Improvement Association, and the Brewers Association. Additional support came from the Sacramento Region AgTech Innovation Center Development Project, Award No. 07 79 06923. The authors thank Aaron MacLeod (Director, Hartwick College Center for Craft Food & Beverage) for the GN analysis and Dr. Lynn Gallagher for his initial efforts in the development of UC-Capay. Unfortunately, Dr. Gallagher passed away in 2020 and could not be listed as coauthor in this paper.

AUTHOR CONTRIBUTIONS

Isabel Alicia del Blanco: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Writing – original draft. Joshua M Hegarty: Funding acquisition; Investigation; Methodology; Writing – review & editing. Jorge Dubcovsky: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Supervision; Writing – review & editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Isabel Alicia del Blanco https://orcid.org/0000-0002-6305-6461

Jorge Dubcovsky https://orcid.org/0000-0002-7571-4345

REFERENCES

American Malting Barley Association (AMBA). (2006). *Annual progress report on malting barley research*.

American Malting Barley Association (AMBA). (2012). *Annual progress report on malting barley research*.

American Malting Barley Association (AMBA). (2017). *Malting barley breeding guidelines*.

Barrett, J., Clapperton, J. F., Divers, D. M., & Rennie, H. (1973). Factors affecting wort separation. *Journal of the Institute of Brewing*, *79*(5), 407–413. https://doi.org/10.1002/j.2050-0416.1973.tb03558.x

Brewers Association. (2021). *State craft beer sales and production, 2021*. https://www.brewersassociation.org/statistics/by-state/

Burger, W. C., Wesenberg, D. M., Carden, J. E., & Pawlisch, P. E. (1979). Protein content and composition of Karl and related barleys. *Crop Science*, *19*, 235–238. https://doi.org/10.2135/cropsci1979.0011183X001900020016x

Clancy, J. A., & Ullrich, S. E. (1988). Analysis and selection program for malt quality in barley by microcomputer. *Cereal Chemistry*, *65*(5), 428–430.

Distelfeld, A., Korol, A., Dubcovsky, J., Uauy, C., Blake, T., & Fahima, T. (2008). Colinearity between the barley grain protein content (GPC) Qtl on chromosome arm 6HS and the wheat *Gpc-B1* region. *Molecular Breeding*, *22*, 25–38. https://doi.org/10.1007/s11032-007-9153-3

Fincher, G. B. (1975). Morphology and chemical composition of barley endosperm cell walls. *Journal of the Institute of Brewing*, *81*(2), 116–122. https://doi.org/10.1002/j.2050-0416.1975.tb03672.x

Gallagher, L. W., Silberstein, R., Prato, L., & Vogt, H. (2020). 'Butta 12', a two-rowed malting barley adapted to the California Central Valley with proven floor-malting success and craft brewer acceptance. *Journal of Plant Registrations*, *14*, 250–265. https://doi.org/10.1002/plr2.20067

Hegarty, J. M., Blanco, I. A., Gallagher, L., & Dubcovsky, J. (2018). Registration of 'UCTahoe', a California adapted two-rowed spring barley for craft-scale malting. *Journal of Plant Registrations*, *12*, 163–167. https://doi.org/10.3198/jpr2017.09.0064crc

Li, Y., Schwarz, P. B., Barr, J. M., & Horsley, R. D. (2008). Factors predicting malt extract within a single barley cultivar. *Journal of Cereal Science*, *48*(2), 531–538. https://doi.org/10.1016/j.jcs.2007.12.004

Rimsten, L., Haraldsson, A.-K., Andersson, R., Alminger, M., Sandberg, A.-S., & Åman, P. (2002). Effects of malting on β-glucanase and phytase activity in barley grain. *Journal of the Science of Food and Agriculture*, *82*(8), 904–912. https://doi.org/10.1002/jsfa.1135

Sá, R. M., & Palmer, G. H. (2004). Assessment of enzymatic endosperm modification of malting barley using individual grain analyses. *Journal of the Institute of Brewing*, *110*(1), 43–50. https://doi.org/10.1002/j.2050-0416.2004.tb00179.x

SAS Institute. (2013). *SAS/ACCESS 9.4*. SAS Institute Inc.

Uauy, C., Distelfeld, A., Fahima, T., Blechl, A., & Dubcovsky, J. (2006). A NAC gene regulating senescence improves grain protein, zinc, and iron content in wheat. *Science*, *314*, 1298–1301. https://doi.org/10.1126/science.1133649

Vis, R. B., & Lorenz, K. (1997). β-Glucans: Importance in brewing and methods of analysis. *LWT - Food Science and Technology*, *30*(4), 331–336. https://doi.org/10.1006/fstl.1996.0196

Zhang, G., Chen, J., Wang, J., & Ding, S. (2001). Cultivar and environmental effects on (1→3,1→4)-β-D-glucan and protein content in malting barley. *Journal of Cereal Science*, *34*(3), 295–301.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: del Blanco, I. A., Hegarty, J. M., & Dubcovsky, J. (2022). Registration of 'UC-Capay', a low-grain-protein, non–glycoside nitrile producing, California-adapted, two-rowed spring malting barley. *Journal of Plant Registrations*, 1–8. https://doi.org/10.1002/plr2.20240