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‘USDA EdleFrucht’: An Early-harvest, High-yielding Noble-style Hop Cultivar

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The Agricultural Research Service (ARS) released US Department of Agriculture (USDA) ‘EdleFrucht’, a new early-maturing, high-yielding noble hop (*Humulus lupulus* L.) cultivar. The defining characteristics of USDA ‘EdleFrucht’ are its “noble-hop” flavor profile that excels in lagers and pilsners, early harvest window, and high yield potential in comparison with other widely grown aroma hop lines. Noble hops are considered hop cultivars with similar flavor profiles as the landraces present in Central Europe, including Halletauer Mittelfrüh, Tettnanger, Spalt, and Saaz. It is expected that brewers will use this cultivar in hop-forward lager/pilsner beer-styles with mild floral-fruity flavor. Furthermore, this cultivar’s early harvest coupled with high yields, even though harvested early, will benefit both growers and brewers by extending the harvest window for growers (and thus increasing harvest potential without expansion of harvest picking capacity) while providing brewers a relatively inexpensive hop for kettle brewing and dry-hopping for hop-forward lagers and pilsners.

Origin

USDA ‘EdleFrucht’ arose as a selection from a cross made at Corvallis, OR, USA in 2000 between female USDA ‘Nugget’ (Haunold et al. 1984a) and the male line USDA ‘21328M’. USDA ‘Nugget’ is a descendent of ‘USDA 65009’ (Haunold et al. 1984b) and ‘USDA 63015M’ (Haunold et al. 1983). USDA 21328M is a descendent of USDA ‘Comet’ (Zimmermann et al. 1975) and USDA ‘21110M’. USDA 21110M resulted from a cross between ‘Bullion’ and USDA ‘64035M’ (Haunold et al. 1985). As such, USDA ‘EdleFrucht’ is a diploid (2n = 2X = 20) female with composition of 1/2 ‘Nugget’, 1/4 Comet, 1/8 ‘Bullion’, 1/16 ‘Halletauer Mittelfrüh’, and 1/16 unknown.

USDA ‘EdleFrucht’ was first grown at the USDA–Agricultural Research Service hop research facility near Corvallis as experimental line ‘2000010-008’. Because of initial aroma assessments and superior agronomic characteristics, it was expanded into five-hill plots in 2007. Subsequent pilot brewing tests were performed by Oregon State University Fermentation Science Department using hops from the USDA plots during 2012. The resulting single-hopped lager beer received extremely favorable responses from industry stakeholders and significant interest in its future release was expressed. USDA EdleFrucht was subsequently expanded into a 32-hill plot near Hubbard, OR, USA during 2012. Subsequent pilot brewing trials published in 2015 (https://brulosophy.com/2016/01/07/the-hop-chronicles-usda-008/) in an IPA-style brew resulted in very favorable blind taste tests with strong tropical fruit flavors followed by pine notes. Continued internal brewing trials (data not available) by members of the Hop Research Council (https://hopresearchcouncil.org) generated additional interest in expansion of this line. In 2018, council members sponsored commercial scale plots of USDA EdleFrucht in Oregon. The commercial nursery was established in 2019 in a 0.82-ha plot located outside Donald, OR, USA. Three years of production data were taken, and internal pilot brewing by members along with nonmembers were conducted (data not available). Production data consisted of total kilograms per hectare, along with basic chemistry with plots being treated with normal production treatments from horticultural practices, pest control, harvesting, kiln drying, baling, and storage.

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Description and Performance

This cultivar produces moderately large (4–5 cm long), compact cones that mature earlier than most cultivars: 15 Aug to 30 Aug in Oregon (Fig. 1). Observed yields (2003–04) at the USDA hop farm located near Corvallis were 3.98 kg per hill, suggesting an estimated yield of 1966.25 kg·ha^{-1} (Table 1). Yields in advanced nursery plots (32 hills) located in Hubbard averaged 4.8 kg per hill for a predicted yield of 2375 ± 441 kg·ha^{-1}. Predicted yields on advanced plots ranged from 1680 to 2950 kg·ha^{-1} (2013–19). Average yields for USDA cultivars Nugget (maternal parent) and Triumph (half-sister) located in the same plots during the same timeframe were 2427 ± 423 and 2498 ± 254 kg·ha^{-1}, respectively. Harvest dates for this cultivar in both small plots and larger Advanced-stage plots ranged from as early as 12 Aug through as late as 30 Aug with most harvests occurring around 15 Aug. Elite line grow-out of USDA ‘EdleFrucht’ in a 0.82 ha commercial plot located outside Donald averaged 2411 ± 158 kg·ha^{-1} from 2021 to 2023. Harvest dates for elite plots ranged from 15 to 30 Aug.

Bittering acid chemistry is an important determinate for a hop cultivars ultimate usage in brewing. Hops with high alpha acids levels are typically subjected to supercritical CO_2 extraction and the extracted alpha acids used for simple bittering in the brewing process. Hops with lower bittering acids but selected for superior aroma and flavor characteristics are used as “whole hops” or pelleted hops during various stages of brewing. Alpha acids are generally considered the primary source of bittering in beer (Neve 2012) and are reported as a percentage of total bittering acids. Beta-acids are not water soluble and as such are not directly responsible for bittering flavor in hop. However, beta-acids do break down eventually over time and in beer styles with long conditioning time have more stable bittering flavor (Neve 2012). Cohumulone and colupulone are two chemical components making up the hop bittering resins found in lupulin glands of hop cones. Levels of these two compounds provide brewers an indication of a hop cultivar’s perceived bittering flavor potential. Colupulone has been reported as contributing to a cleaner, crisper bittering, so higher levels are desired by brewers. In addition to influencing perceived

Fig. 1. EdelFrucht hop cones (left) and production yard (right).

Table 1. Production and chemistry data covering all stages of testing for USDA EdelFrucht.

	Single hill plots		Advanced plots		Commercial plots	
EdelFrucht	Range/avg	*SD*	Range/avg	*SD*	Range/avg	*SD*
Harv Date	8/24–8/30		8/12–8/27		8/24–8/30	
Yield (kg)	3.98	0.28	4.79	0.91	NA	NA
Yield (kg/ha)	1966.2	138.86	2374.75	441.12	2411.17	157.82
Alpha acids (%)	11.95	1.58	10.32	0.9	11.8	0.57
Beta acids (%)	2.97	0.55	3.21	0.31	2.97	0.12
HSI	0.27	0.04	0.29	0.02	0.26	0.04
Cohumulone (%)	22.39	0.5	25.35	0.26	NA	NA
Colupulone (%)	57.21	7.59	47.32	2.86	NA	NA
Oil (mL/100 g)	0.64	0.37	1.02	0.37	1.47	0.33
B-Pinene (%)	0.08	0.12	0.65	0.3	NA	NA
Myrcene (%)	27.29	18.28	37.9	18.89	NA	NA
Limonene (%)	1.12	1.08	0.43	0.16	NA	NA
Linalool (%)	0.59	0.1	0.56	0.1	NA	NA
E-beta-caryophyllene (%)	11.63	3.33	12.19	2.55	NA	NA
Beta-farnesene (%)	1.22	0.23	0.03	0.04	NA	NA
Humulene (%)	33.47	10.24	34.46	7.96	NA	NA

HSI = Hop Storage Index; NA = not applicable; *SD* = standard deviation.

bittering flavor in beer, cohumulone also contributes to foam stability in beer.

Table 2 contains statistical data for advance-stage USDA-ARS nurseries located outside of Hubbard, OR, USA. Bittering acids analyses of USDA 'EdleFrucht' from advanced-stage nurseries from 2013 to 2019 and commercial-sized plots suggest its primary use as an aroma hop with higher bittering capabilities than most aroma hops but significantly lower than bittering or "Super-Alpha" hops. Levels of alpha acids in both advanced-stage nurseries and commercial-sized plots for USDA 'EdleFrucht' (10.05% ± 0.40% v/v) and 11.8% v/v ± 0.57%, respectively) are generally lower than those for the check cultivar (maternal parent USDA 'Nugget') grown in advanced-stage nurseries (13.2% v/v ± 0.46% *SE*; Table 2), similar to those published for USDA 'Triumph' (11.12% ± 0.4% v/v; Henning et al. 2021), but significantly higher than published values for 'Halletauer Mittelfrüh' (3.5% to 5.5% v/v, Neve 2012). Beta acids levels in advanced and commercial plots of USDA 'EdleFrucht' (3.34% ± 0.05% v/v and 2.97% v/v ± 0.12% v/v, respectively) were lower than averages observed for USDA 'Nugget' and similar to USDA 'Triumph' (Table 2). In comparison, published levels of beta acids in 'Halletauer Mittelfrüh' range from 3.5% to 5% (Neve 2012).

Dialing in on specific compounds making up bittering acids, the compounds cohumulone and colupulone provide important information on aspects of brewing like foam stability and perceived bitterness. In advanced-stage nursery plots, the cohumulone levels for USDA 'EdleFrucht' were slightly higher (25.29% ± 0.19% v/v) than values observed in either USDA 'Nugget' or USDA Triumph but lower than USDA 'Cascade' (Table 2). Conversely, USDA 'EdleFrucht' had levels of colupulone (47.32% ± 2.86%) similar to USDA 'Nugget' and USDA 'Triumph' but lower than those reported for USDA 'Cascade'.

Essential oils contribute greatly to a hop cultivar's flavor and aroma. Total essential oil levels in USDA 'EdleFrucht' in advanced-line plots (0.833 mL/100 g ± 0.23) were similar to those observed for USDA 'Nugget' and USDA 'Triumph' and match those published for 'Halletauer Mittelfrüh' (1.0 mL/100 g: Neve 2012). USDA 'EdelFrucht' produced an average of 1.467 ± 0.29 mL/100 g in the commercial scale production yard from 2021 to 2023.

Table 2. Comparative chemistry of check cultivars produced in advanced-stage nurseries located outside Hubbard, OR, USA.

	Cultivar					
	USDA Triumph		USDA Nugget		USDA Cascade	
Statistic	Avg	*SE*	Avg	*SE*	Avg	*SE*
Alpha acids (%)	11.46	0.72	13.17	0.46	6.90	0.10
Beta acids (%)	3.72	0.05	4.43	0.28	5.90	0.15
HSI	0.25	0.00	0.26	0.01	0.23	0.01
Cohumulone (%)	21.04	3.17	24.30	0.31	35.00	1.15
Colupulone (%)	46.10	3.62	48.57	0.58	55.00	1.00
Oil (mL/100 g)	1.08	0.27	1.47	0.29	1.78	0.04
B-pinene (%)	0.49	0.17	0.62	0.02	1.10	0.17
Myrcene (%)	33.19	9.72	45.58	1.17	66.85	2.12
Limonene (%)	0.36	0.16	0.12	0.06	0.60	0.03
Linalool (%)	0.76	0.13	1.02	0.06	0.56	0.02
E-beta-caryophyllene (%)	10.27	0.47	9.29	0.32	5.98	0.57
Beta-farnesene (%)	0.05	0.03	0.12	0.07	1.85	0.64
Humulene (%)	33.86	2.18	20.30	0.75	19.36	2.54

HSI = Hop Storage Index; *SE* = standard error; USDA = US Department of Agriculture.

Myrcene makes up most of the essential oils present in almost all hop cultivars, and USDA EdleFrucht is no different. Myrcene levels for this cultivar (32.43% ± 13.35% v/v) were similar to USDA 'Triumph' but significantly lower than observed in USDA 'Cascade'. Levels of limonene and linalool in USDA 'EdleFrucht' (0.38 ± 0.15%; 0.52 ± 0.06% v/v, respectively) were lower than from USDA 'Cascade' or USDA 'Triumph'. Levels of E-beta-caryophyllene in 'EdelFrucht' (12.19% ± 1.82% v/v) were higher than those observed in USDA 'Cascade' or USDA 'Triumph'. Another important essential oil found in hops is the compound humulene, which is thought to provide the "hoppy" aroma people associate with hops. Levels for this compound in USDA 'EdleFrucht' (36.13 ± 6.06% v/v) were similar to those seen in USDA 'Triumph' but were significantly higher than those found in USDA 'Nugget' or USDA 'Cascade'. High levels of humulene are desirable for noble-style hop cultivars. Values for other essential oils are listed in Table 2.

Hop storage-ability is a measure of how much alpha acids is lost over time during storage. One measure of a hop's storage ability is called the Hop Storage Index (HSI; Nickerson and Likens, 1979), with lower values indicating a better storage potential for a cultivar. USDA 'EdleFrucht' exhibited moderately good storage potential in advanced cultivar plots with an HSI value of 0.27 ± 0.005, which is slightly higher than its mother, USDA 'Nugget', as well as half-sister, USDA 'Triumph' (Table 2). HSI values for commercial scale production averaged 0.262 ± 0.03, which matches that of its mother. The lower HSI values on the commercial production yard represent greater accuracy of expected storage-ability of USDA 'EdelFrucht' than what was observed in small plots.

Field evaluations of downy mildew [caused by *Pseudoperonospora humuli* (Miyabe and Takah) G.W. Wilson] in nurseries were conducted following naturally produced inoculum. Plots were treated for disease with regular prophylactic sprays, as was customary for the farm where plots were located. Multiple year evaluations were taken from 2013 to 2016. Two check cultivars were included in these plots: USDA 'Nugget' (susceptible check) and USDA 'Willamette' (moderately resistant check) (O'Neal et al. 2015). An ordinal scale of 1 to 5 was used for scoring with the following definition: 1 = no infected shoots, 2 = one or two infected shoots per plant, 3 = three to five infected shoots per plant, 4 = approximately two-thirds of the shoots infected, and 5 = all shoots infected. The susceptible check USDA 'Nugget' had an average score across years of 2, whereas the "moderately resistant" check cultivar USDA Willamette scored an average value of 1. The results of field scoring suggest USDA 'EdleFrucht' is tolerant to moderately susceptible to this disease with an average score across years of 1.2. Nevertheless, like 'Nugget', plants are prolific in shoot production and can overcome early shoot infection following normal practices for production. Under normal growing conditions, early and

midseason downy mildew infections are best controlled with a physical or chemical pruning of early growth coupled with regular prophylactic applications of fungicides registered in the United States for use on hop.

Field-based observations in the advanced-stage plots across 2013 through 2016 show USDA 'EdleFrucht' to be resistant under normal field production practices to strains of powdery mildew (caused by *Podosphaera macularis* Braun and Tak) present in the Willamette Valley (OR, USA) at the time of evaluation. Inoculations under controlled conditions were conducted using five isolates of *P. macularis* that represent the known pathogenic diversity of the fungus in the Pacific Northwest and in Europe (Gent et al. 2020; Wolfenbarger et al. 2014). No disease developed on leaves of USDA 'EdleFrucht' when challenged with isolates possessing various combinations of the virulence factors Vb, V1, V2, V3, and V5 or the virulence factor associated with Cascade-adaptation in the cultivar Cascade (Gent et al. 2020). However, USDA 'EdleFrucht' was susceptible when challenged with isolates possessing virulence V4 or V6, which are commonly found in *P. macularis* in the Pacific Northwest (Wolfenbarger et al. 2014). On the basis of phenotyping following these inoculations, resistance is presumed to be due to the presence of R4/R6 resistance derived from the female parent USDA 'Nugget', with disease susceptibility similar to that observed in 'Nugget'. Field observations at harvest showed no yield or cone quality loss due to powdery mildew. Prophylactic spraying for this disease is recommended where the population of *P. macularis* possess V4/V6 virulence. At present, this virulence is not known to occur in the United States outside the Pacific Northwest, so USDA 'EdleFrucht' should be resistant to powdery mildew in the upper Midwest, Northeast, and other production regions (Weldon et al. 2021) No cases of Verticillium wilt (caused by *V. nonalfalfae* or *V. dahliae*) were observed in nursery plots. Growers are cautioned against growing USDA 'EdleFrucht' in known *Verticillium*-infested fields due to the potential susceptibility of this cultivar based upon its parentage.No information is available on susceptibility of USDA 'EdleFrucht' to hop aphid (*Phorodon humuli* Schank) or twospotted spider mite (*Tetranychus urticae* Koch), although infestations of these pests have not caused losses in commercial test plots.

Availability

Genetic material of this release has been deposited in the National Clean Plant Network and is available for purchase (http://nationalcleanplantnetwork.org/HOPS_CPN). Producers are encouraged to work with local propagators to obtain and clonal propagate material for expansion into commercial yards. This material is also available for research purposes including the development and commercialization of new cultivars from the USDA-Pacific Northwest Clonal Repository (https://www.ars.usda.gov/pacific-west-area/corvallis-or/national-clonal-germplasm-repository). It is requested that appropriate recognition be given if this germplasm contributes to the development of a new breeding line or cultivar.

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