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Svalöf: a High Yielding Potato with Resistance to Late Blight in Nordic Latitudes

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Abstract
Svalöf is a yellow-skinned, light yellow-fleshed, high-yielding table potato cultivar for the high latitude of Scandinavia, showing partial resistance to *Phytophthora infestans* (causing late blight) and same specific gravity as the mealy cultivar King Edward, which is preferred in the fresh market by consumers in Sweden. It was selected as breeding clone SLU 1314015 in the first clonal generation (T_1) at the late-blight prone site of Mosslunda (Skåne, southern Sweden) in October 2015. The cross for obtaining it was made by the Swedish University of Agricultural Sciences in 2013 involving the breeding clone D09 1:2 1701 as female parent and the Dutch cultivar Carolus as male parent. Svalöf show very large, round-oval tubers with shallow eyes and smooth skin. Its tuber yield averaged above 6%, 23%, 25% and 59% of Dutch cultivars Connect, Fontane, Carolus and Bintje, respectively, across multi-site trials in Sweden. Its unstable reducing sugar in the tuber flesh, as determined by multi-site testing, suggests that it will not be suitable for the crisp or chip processing. SLU's Svensk potatisförädling is seeking registration to be included in the Svenska Sortlistan, which lists cultivars available and is a pre-condition for certification of planting materials in the European Union. The release of Svalöf as new potato cultivar will be the first entirely bred for this crop in Sweden since the mid-1990s.

Resumen Svalöf es una variedad de papa de mesa de piel amarilla, pulpa amarilla clara y alto rendimiento para la latitud alta de Escandinavia, que muestra resistencia parcial a *Phytophthora infestans* (que causa tizón tardío) y la misma gravedad específica que la variedad King Edward, que es preferida en el mercado fresco por los consumidores en Suecia. Fue seleccionada como clon de mejoramiento SLU 1314015 en la primera generación clonal (T1) en el sitio propenso al tizón tardío de Mosslunda (Skåne, sur de Suecia) en octubre de 2015. La cruza para obtenerlo fue realizada por la Universidad Sueca de Ciencias Agrícolas en 2013 involucrando al clon reproductor D09 1: 2 1701 como progenitor femenino y al cultivar holandés Carolus como progenitor masculino. Svalöf muestra tubérculos ovalados redondos muy grandes con ojos poco superficiales y piel lisa. Su rendimiento de tubérculos promedió por encima del 6%, 23%, 25% y 59% de las variedades holandesas Connect, Fontane, Carolus y Bintje, respectivamente, en ensayos multisitio en Suecia. Su azúcar reductor inestable en la pulpa del tubérculo, según lo determinado por las pruebas de múltiples sitios, sugiere que no será adecuada para el procesamiento freído o de hojuelas. Svensk potatisförädling de SLU está buscando el registro para ser incluido en el Svenska Sortlistan, que enumera las variedades disponibles y es una condición previa para la certificación de materiales de siembra en la Unión Europea. El lanzamiento de Svalöf como nueva variedad de papa será el primero completamente generado para este cultivo en Suecia desde mediados de la década de 1990.

Keywords Breeding · Genetic gains · Genomic prediction · Host plant resistance to late blight · Table potato

Introduction

Svalöf (SLU 1314015) is a table (fresh market) potato with big tuber size ensuing from crossing the breeding clone D09 1:2 1701 as female and the Dutch cultivar Carolus as male (Fig. 1), which was made by the Swedish University of Agricultural Sciences (SLU) in Alnarp (Skåne, Sweden) in 2013. SLU's Svensk potatisförädling produced seedling

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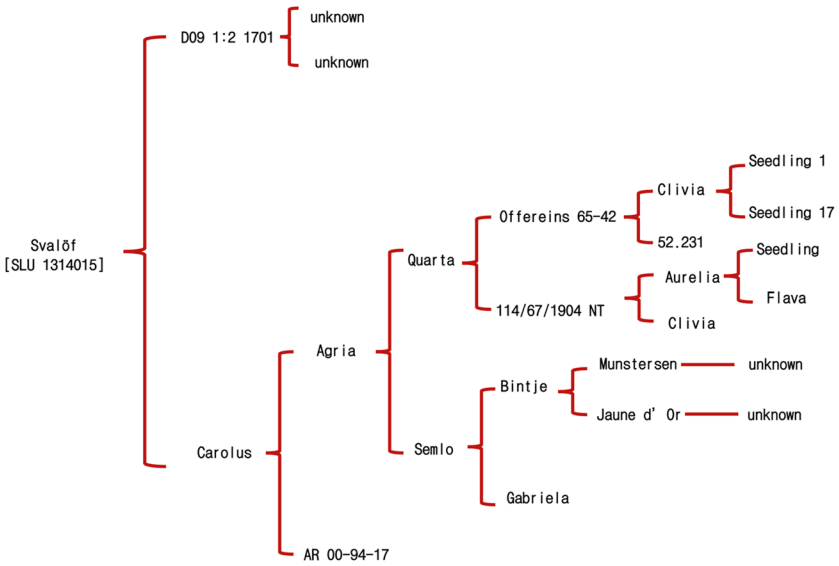

Fig. 1 Pedigree of Svalöf (SLU 1314015)

tubers from true seed in 2014 at Balsgård by Elitplantstationen. Tuberlings (seedling-derived tubers) were planted for first year selection (T_1) in the spring of 2015 in Mosslunda (near Kristiantad, 56°01′46″N 14°09′24″E), and the original selection (a round-oval yellow skin and flesh tuber) being made in the autumn of the same year by the authors of this article. The T_1 selection criterium for Svensk potatisförädling was based on tuber appearance, shape, and skin finish characteristics, as well as host plant resistance to *Phytophthora infestans* causing late blight (Ortiz et al. 2020). Its pedigree (Fig. 1) includes one potato mega-cultivar in Europe and North Africa (Bintje, released in 1910 and still grown today), as well as Dutch cultivars Carolus (2012) and Munstersen (< 1890), the German cultivars Agria (1985), Aurelia (1965), Clivia (1972), Flava (1931), Quarta (1979) and Semlo (1978), the Ecuadorian cultivar Gabriela (1982), and the French old cultivar Jaune D'or (< 1850) among others. Carolus is a known ware potato showing high–medium host plant resistance to *P. infestans,* while Agria is a processing potato due to its frying quality (for chips and crisps) and with known multiple virus resistance. Semlo and Clivia are also known ware potato cultivars with high dry matter and multiple virus resistance, while the ware potato Aurelia was selected due to its then medium–high host plant resistance to *P. infestans*. Gabriela is a potato cultivar for fresh consumption with medium to large oval tubers. Parents of the breeding clone D09 1:2 1701 are unknown because tech staff who did the crossing did not document this information.

Svalöf was first selected as a first-generation breeding clone (T_1) at harvest in October 2015 at a field in Mosslunda (Skåne, southern Sweden). Thereafter moved to the second-generation breeding clone (T_2) for field testing using a non-replicated 10-plant plot (Table 1). From T_3 until T_5 was evaluated using 20-plant plots in augmented designs with other released cultivars grown in Scandinavia. The field layout included the promising T_4 upwards grown in nonreplicated 20-plant plots and five cultivar checks (Bintje, Carolus, Connect, King Edward and Solist) in 20-plant plots replicated at least thrice in trials at Helgegården, Mosslunda and Umeå over two years (2018 and 2019); i.e., 4 replications at Mosslunda in 2018 and 2019, 6 replications at Helgegården and Umeå in 2018, and 3 replications at Helgegården and Umeå in 2019).

Beginning T_4 it was included in multi-site testing in Norrland (northern Sweden) and Skåne. Svalöf along with other breeding clones and released cultivars were included in replicated multi-site testing using a simple lattice design over two years in variety trials at Helgegården and Mosslunda (both in Skåne) and Umeå (Norrland). The decision to release Svalöf was based on its outstanding performance regarding tuber yield (viz-á-viz released cultivars grown by farmers in Scandinavia), the high host plant partial resistance to *Phytophthora infestans* (causing late blight) and its similar specific gravity as King Edward, which is the most preferred table potato in Sweden due to its mealy texture. The name, Svalöf, was given to acknowledge the first systematic potato breeding in Nordic Europe which was begun by the Sveriges Utsädesförening (Swedish Seed Association) at Svalöv (southern Sweden) in 1903.

Description

Figure 2 shows the leaf, plant, sprout, and flower characteristics of Svalöf, whose plant and tuber descriptions were done from field trials in Helgegården and Mosslunda since 2017.

Table 1 Tuber yield (t ha^{-1}) of Svalöf along with five check cultivars at late-blight prone site (Mosslunda, Skåne), high yield potential site under fungicide treatment (Helgegården, Skåne), and under very long days and short (90-day), cool season (Umeå, Norrland) 2016 (T_2), 2017 (T_3), 2018 (T_4) and 2019 (T_5). Area under late blight disease progress curve indicated in brackets below tuber yield in Mosslunda 2017

Cultivar	Mosslunda				Helgegården		Umeå	
	2016[z]	2017[z]	2018	2019	2018	2019	2018	2019
Svalöf	60.9	84.0 (94)	64.9 ab	66.4 a	49.5 a	65.1 b	38.5 a	58.7 a
Connect	66.8	42.2 (231)	77.0 a	54.2 b	60.0 a	79.3 a	36.0 ab	40.5 b
Carolus	56.0	N/A	54.2 bc	56.4 ab	58.4 a	52.7 b	40.8 a	47.7 ab
Solist	23.2	14.4 (323)	50.5 bc	32.7 c	36.1 ab	44.0 c	40.4 a	60.8 a
Bintje	28.1	4.4 (357)	54.9 bc	18.1 d	49.8 a	47.0 bc	37.7 a	38.8 b
King Edward	25.6	6.8 (354)	40.7 c	5.6 e	24.6 b	34.0 d	25.4 b	35.4 b

During 2018 trials in Skåne were under severe heat stress but without late blight due to low humidity. Mean values followed by the same letter are not significantly different from one another ($p \leq 0.05$) based on Fisher's protected least significant difference

[z] Nonreplicated trial using 10-plant plot for Svalöf and 2 rows of 20 plants per plot for check cultivars

Fig. 2 Plant (**A**), leaf (**B**), flower (**C–D**) and sprout (**E**) characteristics of Svalöf

Plants

Foliage structure of Svalöf (Fig. 2) were of intermediate type and had a semi-upright to spreading growth habit and a medium plant height. Svalöf has a medium (ready to harvest at 100 days after planting) maturity for Skåne. Stem was absent of anthocyanin pigment and without wings. Leaves were medium green, while lacking anthocyanin as also noted for the midrib. The terminal leaflets without coalescence were of broad shape with a thin tip and broad base. The size of the primary leaflets was medium and having on average 4 pairs. Leaflet arrangement was overlapping to touching. Secondary and tertiary leaflets had on average 5 pairs.

Tubers

The rating of the tuber characteristics (Fig. 3) follows the scales defined by Tiemens-Hulscher et al. (2013). Round-oval shape (as the cultivar Fabula), with yellow skin and light yellow flesh, shallow eyes, and intermediate to high uniformity for both shape and size. Skin finish similar as that of cultivar Fontane, and both are not significantly different than that of Bintje or Solist. The percentage of very large tubers (> 60 mm) was very high in Skåne (> 50%) but about 1/5 or less in Umeå, which was similar that those noted for the high yielding Dutch cultivar Connect.

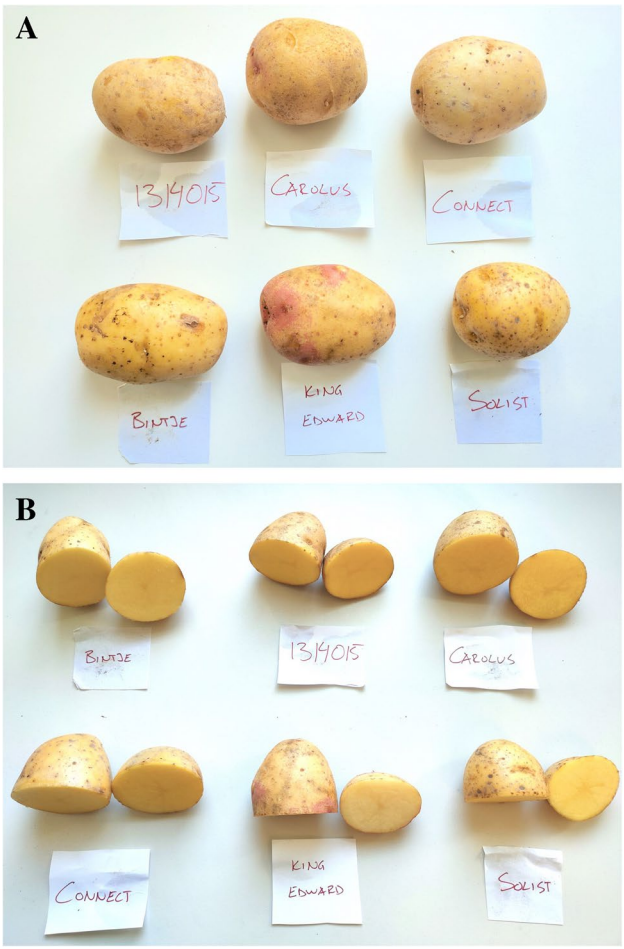

Fig. 3 Tuber shape (**A**), skin and flesh color (**B**) of Svalöf (1314015) vis-à-vis those of other cultivars grown in Sweden and used as checks in multi-site trials

Flowers

Medium sized white flowers (Fig. 2), averaging 10 florets per inflorescence. The corolla had a rotate shape, lacking anthocyanin on both surfaces, which was not noted in the green calyx that had regular symmetry. Cone shape, yellow–orange anthers and yellow–green, capitate shape stigma.

Light Sprouts

They had a spherical shape and did not showing pubescence it its base, and high amount anthocyanin (blue-violet) pigmentation (Fig. 2). The light sprout tip had an intermediate habit, lacking pubescence, and without anthocyanin pigments.

DNA Fingerprints

Svalöf was genotyped using both the Infinium Illumina 22 K SNP array (Selga et al. 2022 Additional file 1) and a DArTag marker set (Ortiz et al. 2022a https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10548617) along with obsolete Nordic cultivars and modern cultivars grown in Europe. This DNA fingerprinting led to determining genetic relationships with both cultigen pools. Svalöf is genetically related to other Svensk potatisförädling clones but distinct from obsolete Nordic cultivars and modern cultivars grown in Europe.

Agronomic Performance Including Yield Stability

Svalöf during the multi-site testing, particularly across sites in Skåne, had similar (non-significantly different) tuber yield to the high-yielding Dutch cultivar Connect (Tables 2 and 3) and, on average, above that of its parent Carolus and Fontane (a half-sib of Carolus), which became recently the potato cultivar with more acreage for multiplying certified planting material in Sweden. At a plant density of 44,444 (i.e., 75 cm between rows and 30 cm within rows), its total tuber yield in the testing sites in Skåne across years was about 74 t ha^{-1}, while those of Connect and Carolus were 71 and 60 t ha^{-1}, respectively.

Table 2 Average total tuber yield (t ha^{-1}) and according to tuber size (%), tuber specific gravity, and tuber flesh reducing sugars over two years of Svalöf along with five check cultivars at high yield potential site under fungicide treatment (Helgegården, Skåne, southern Sweden)

Cultivar	Total tuber yield	Tuber yield (%) according to size (mm)				Specific gravity	Reducing sugars[z]
		< 40	40 – 50	50 – 60	> 60		
2020							
Svalöf	66.1 a	2.0 ab	12.3 c	36.7 b	49.0 b	1.093 a	3.0 ab
Connect	76.9 a	3.0 ab	10.0 c	30.7 b	56.4 a	1.081 d	4.0 b
Carolus	52.8 b	4.1 ab	27.0 ab	43.8 b	25.2 cd	1.086 c	4.0 b
Fontane	73.1 a	3.1 ab	17.3 bc	49.1 a	30.5 bc	1.091 ab	4.0 b
Solist	44.1 b	2.2 b	27.6 bc	48.9 b	21.4 d	1.076 d	3.5a b
Bintje	49.3 c	5.6 a	36.5 a	51.9 b	6.0 d	1.088 bc	2.0 a
King Edward	46.2 b	4.5 ab	26.0 bc	41.8 b	27.8 cd	1.092 ab	4.0 b
2021							
Svalöf	88.2 a	1.4 a	5.0 b	14.8 b	78.8 a	1.086 a	0.0 a
Connect	81.2 a	1.1 a	5.0 b	16.9 b	77.0 a	1.080 a	2.5 b
Carolus	75.1 a	1.0 a	3.4 b	16.9 b	78.7 a	1.076 a	0.5 a
Fontane	74.9 a	1.1 a	9.4 b	13.7 b	75.8 ab	1.087 a	2.5 b
Solist	47.2 bc	1.2 a	7.9 b	25.6 b	65.3 b	1.064 b	0.5 a
Bintje	70.1 ab	4.1 a	22.2 a	58.3 a	15.3 b	1.083 a	0.0 a
King Edward	24.2 c	8.8 a	31.7 b	37.3 b	22.1 b	1.085 a	0.0 a

Mean values followed by the same letter are not significantly different from one another ($p \leq 0.05$) based on Fisher's protected least significant difference

[z] Based on glucose strip test (0 – 4 scale), where 0 = 0%, 1 = 1/10%, 2 = ¼%, 3 = ½%, 4 > 2%

Table 3 Average total tuber yield (t ha^{-1}) and according to tuber size (%), tuber specific gravity, tuber flesh reducing sugars, and host plant resistance to late blight as measured by the area under disease progress curve (AUDPC) over two years of Svalöf along with five check cultivars at late-blight prone site (Mosslunda, Skåne, southern Sweden)

Cultivar	Total tuber yield	Tuber yield (%) according to size (mm)				Specific gravity	Reducing sugars[z]	AUDPC
		< 40	40 – 50	50–60	> 60			
2020								
Svalöf	80.8 a	1.7 ab	8.9 b	20.8 bc	68.7 a	1.073 a	4.0 b	89.3 a
Connect	83.5 a	2.9 ab	11.3 ab	30.8 a	55.0 a	1.073 a	4.0 b	111 ab
Carolus	58.7 b	5.5 ab	26.6 a	29.4 c	38.6 b	1.076 a	2.0 a	153 b
Fontane	45.3 bc	6.3 ab	23.7 ab	51.4 ab	18.6 c	1.069 ab	3.0 ab	282 c
Solist	40.6 bc	1.8 b	30.8 ab	59.0 ab	8.4 c	1.064 b	2.0 a	289 c
Bintje	21.1 d	21.6 a	44.3 ab	22.3 d	11.8 c	N/A	3.5 b	295 c
King Edward	27.4 cd	11.3 ab	43.3 ab	41.3 cd	4.1 c	1.074 a	4.0 b	276 c
2021								
Svalöf	61.5 a	2.3 a	8.7 b	26.9 ab	62.1 a	1.091 a	0.5 ab	119 a
Connect	40.6 c	4.1 a	15.9 b	29.5 ab	50.4 b	1.081 ab	3.5 c	165 b
Carolus	53.2 a	1.5 a	11.1 b	38.1 a	49.3 b	1.080 b	1.0 ab	182 b
Fontane	43.7 bc	2.7 a	16.2 b	39.4 ab	41.7 bc	1.084 ab	1.0 ab	246 d
Solist	29.7 d	2.0 a	14.7 b	52.7 ab	30.6 c	1.064 c	2.0 bc	302 e
Bintje	25.8 d	9.1 a	59.7 a	28.5 bc	2.7 c	1.076 b	0.0 a	289 d
King Edward	11.1 e	16.2 a	51.6 b	21.4 c	10.7 c	1.074 bc	1.5 b	242 e

Mean values followed by the same letter are not significantly different from one another ($p \leq 0.05$) based on Fisher's protected least significant difference

[z] Based on glucose strip test (0 – 4 scale), where 0 = 0%, 1 = 1/10%, 2 = ¼%, 3 = ½%, 4 > 2%

Table 4 Average total tuber yield (t ha^{-1}) and according to tuber size (%), tuber specific gravity, and tuber flesh reducing sugars over two years of Svalöf along with five check cultivars under very long days and short (90-day), cool season (Umeå, Norrland, northern Sweden)

Cultivar	Total tuber yield	Tuber yield (%) according to size (mm)				Specific gravity	Reducing sugars[z]
		< 40	40 – 50	50 – 60	> 60		
2020							
Svalöf	44.3 ab	10.3 bc	33.0 b	34.9 a	21.8 a	1.070 ab	2.0 ab
Connect	35.0 c	8.4 c	31.3 b	34.8 ab	25.5 a	1.057 c	2.5 b
Carolus	38.3 abc	14.1 bc	44.0 ab	41.3 a	0.5 b	1.065 b	2.5 b
Fontane	44.4 ab	19.9 b	50.4 a	23.8 ab	5.9 b	1.069 ab	2.5 b
Solist	46.1 a	10.3 bc	50.7 a	31.2 a	7.8 b	1.056 c	2.5 b
Bintje	37.0 b	42.1 a	52.5 ab	4.9 c	0.5 b	1.064 bc	1.5 a
King Edward	32.8 c	19.4 b	55.5 ab	23.8 b	1.4 b	1.074 a	1.5 a
2021							
Svalöf	38.6 bc	11.5 c	42.8 a	30.0 ab	15.8 b	1.036 bc	0.0 a
Connect	41.0 b	23.1 ab	42.6 a	21.0 bc	13.3 b	1.027 d	0.8 ab
Carolus	26.1 c	18.1 c	51.1 a	18.0 c	12.7 bc	1.045 a	1.2 b
Fontane	27.4 bc	16.7 c	40.4 a	33.5 bc	9.5 bc	1.015 e	0.2 ab
Solist	53.6 a	10.9 bc	34.4 a	34.1 a	20.6 a	1.028 cd	1.0 ab
Bintje	35.1 bc	36.9 a	45.1 a	18.0 bc	0.0 c	1.038 ab	0.0 a
King Edward	30.0 bc	28.8 b	47.5 a	19.2 bc	4.5 bc	1.034 cd	0.0 a

Mean values followed by the same letter are not significantly different from one another ($p \leq 0.05$) based on Fisher's protected least significant difference

[z] Based on glucose strip test (0 – 4 scale), where 0 = 0%, 1 = 1/10%, 2 = ¼%, 3 = ½%, 4 > 2%

In the short (about 90 days), cool cropping season under very long days of Umeå (Table 4), Svalöf had lower tuber yield (42 t ha^{-1}) than the early maturing cultivar Solist (50 t ha^{-1}) but above those of Connect (38 t ha^{-1}), Fontane (36 t ha^{-1}) and Carolus (32 t ha^{-1}). Further analysis revealed that Svalöf had the most stable tuber yield across these testing sites (viz-á-viz the other cultivars included herein) according to both the coefficient of variation (Francis and Kannenberg 1978) and the site regression analysis (Crossa and Cornelius 1997).

Tuber set per plant was 12 ± 1 in for Svalöf in trials using 0.3 m × 0.75 m spacing within and between rows, respectively; whereas Bintje has 13 ± 1 tubers per plant. The average tuber weight for Svalöf was 142 ± 17 g, while its tuber length was 100 ± 4 mm and its tuber diameter measured and 59 ± 3 mm. In the same trial, Bintje had an average tuber weight of 69 ± 5 g, and its tubers measuring 82 ± 2 mm for length and 47 ± 2 mm for diameter.

Tuber Quality and Usage

Specific gravity (SG) was determined after weighting tuber weight in air (A) and in water (W) as follows: SG = [A/(A-W)] (Schippers 1976). Although the actual values were affected by site and year, Svalöf had slightly above specific gravity (1.086) than King Edward (1.081) –the preferred mealy cultivar for table potato in Sweden, or a 0.001 difference in specific gravity in Skåne (Tables 2 and 3). The potato processing industry prefers cultivars whose specific gravity should be about 1.085, though it may also process within the 1.080–1.095 range without adverse effects (Wang et al. 2017). Svalöf had lower reducing sugars in the tuber flesh across sites over years (1.9) than King Edward (2.4) using the glucose strip test (Mann et al. 1991) based on 0–4 scale. Tubers were cut in half and a strip was put flat to the length of the cut tuber and each half pressed against the other to moisturize the whole strip, which was removed thereafter, and after waiting for 1 min it was compared against a color chart (Indigo Instruments, Waterloo, ON). A strip darker that 1/10% (1000 ppm) color indicates that a very likely dark color after frying. Neither Svalöf nor King Edward seem to be suitable for processing as chips or crisps.

Tuber Defects

Svalöf has shown low incidence of both tuber defects (e.g. growth cracks, second growth, hollow heart) and common scab in multi-site trials undertaken in Scandinavia. Its major drawback is the high grading percentage for tubers above 60 mm, which may relate to its round-oval shape rather than size per se. Increasing plant density and harvesting early, as

done with other cultivars producing very large tubers, may help on reducing tuber size of Svalöf.

Host Plant Resistance to *P. infestans*

Despite occupying only 0.9% of the area under cultivation in Sweden, potato production still consumed 21% of all fungicides in Swedish agriculture due to late blight (Eriksson et al. 2016). Host plant resistance is an effective alternative to fungicides (on average 8.4 times applications per season) that minimize *P. infestans* attacks. The assessment of host plant resistance to this oomycete was based on data from replicated field trials over a minimum of two years in late-blight prone sites in Skåne using the area under disease progress curve (AUDPC, Fry 1978) EU_41_A2 is the more prevalent clone of *P. infestans* in Fennoscandia (Euroblight 2021). As noted in Table 3, Svalöf had the highest host plant resistance to *P. infestans* and significantly above all released cultivars over the two years of testing in Mosslunda.

Genetic Gains and Breeding Value

Although potato productivity increased throughout the 20th Century in both USA and Europe, the overall annual genetic gain for tuber yield were small (Douches et al. 1996; Ortiz et al. 2022b). For example, it was about 0.25% for cultivars released in Europe across testing sites in Skåne (Ortiz et al. 2002b), which is significantly below that setup by the CGIAR as a key performance indicator (Hunt 2021). Considering that the pedigree of Svalöf includes four cultivars released between 1910 and 2012, the estimated annual genetic gains to be achieved by releasing this breeding clone for farming in southern Scandinavia under the name of Svalöf, will be around 0.54% for tuber yield and about 0.6% for host plant resistance to *P. infestans* (using the data from Ortiz et al. 2022b). Furthermore, according to Ortiz et al. (2022a), Svalöf ranks among the top breeding clones and cultivars grown in Europe according to its genomic estimated breeding value for tuber yield in Skåne and for host plant resistance to *P. infestans* in southern Scandinavia. These estimates show the significant progress made by Svensk potatisförädling with breeding and release of this cultivar.

Tuber Availability

Tissue culture plantlets of Svalöf will be produced with the aim of releasing pathogen-tested propagules. Small amounts of tubers of Svalöf are available only for research purposes. They can be obtained through a standard material transfer agreement by writing to Mr. Fredrik Reslow (SLU, Fredrik.Reslow@slu.se). SLU is seeking plant variety protection certificate for Svalöf with Jordbruksverket (Swedish Board of Agriculture) to allow including it in the Svenska Sortlistan, which is a pre-condition for certification of planting materials of available cultivars in the European Union.

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Data Availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflicts of Interest The authors have no competing interests to declare that are relevant to the content of this article.

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