Final Report

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Comparison of six selections of the heirloom tomato *Cuor di bue*

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1. Summary

Pro Specie Rara (PSR) is Switzerland's seed savers exchange focuses on Swiss heirloom vegetable varieties. Six selections of the heirloom tomato *Cuor di bue* were compared in order to be included into the PSR collection. For acceptance in the collection the selection has to produce good yield for growers, be the more similar to the tomato *Cuor di bue* type and well appreciated for consumers. Several quality variables were measured to establish which one of the selections might be the best suitable for PSR collection. Alb-O was shown to be the most promising variety. It produces the highest yield of marketable fruits (4.7 kg/m^2) with a total yield of 9.5 kg/m^2.Cracking and yellow shoulder disorder were very common in all the six selections. Alb-O was the less affected presenting the lees percentage of total yield fruits affected (8% and 26% respectively). It showed the distinctive ribbed pear shape of a *Cuor di bue* tomato type with a re-orange color at maturity stage. It was also outstanding in terms of solid content (5.3 ºBrix) and flavour index (2.14) but it was not one of the best appreciated by consumers tested. Other selection that emerged as suitable for PSR collection was Alb-E except it was more affected by cracking disorder producing a lower marketable fruit yield.

2. Introduction

The tomato (*Solanum lycopersicum* L.) stands out among horticultural crops as one of the most versatile and important on a global scale. It is one of the most widely cultivated vegetables both for fresh and processed produce, and its consumption is of great nutritional importance (Rao *et al*., 1998; Lozano *et al*., 2001; García-Closas *et al*., 2004; Hernández Suárez *et al*., 2008). In 2011, over 150 million metric tons were produced with the 5 leading countries being (in descending order) China, India, US, Turkey and Egypt. Tomato consumption has shown a general increased trend over a period of time. Tomatoes supply a mean of 20 kg/cap/yr with consumption in Switzerland of 25 kg/cap/yr (FAOSTAT, 2013).

The tomato was introduced to Europe in the sixteenth century. There have long existed controversies regarding the place of domestication, early history, and taxonomy of tomato. The wild tomato species are native to western South America, from Ecuador south to northern Chile, and the Galapagos Islands. There are two competing hypotheses of the place of domestication of tomato, one supporting Peru, another in Mexico. Tomatoes were first recorded outside the Americas in Italy in 1544. They were cultivated first as ornamental or curiosity plants and thought by many to be poisonous. It was first accepted as a vegetable crop in southern Europe during the late sixteenth century. The first European cultivars had yellow to red flattened fruits, with deep furrows. Derived cultivars had a wider range of fruit colors, shapes and sizes (Peralta and Spooner, 2007).

Nevertheless most of the modern commercial tomato varieties have poor organoleptic and reduced nutritional qualities in part causes by the secondary importance of selecting for flavour and nutritional traits in conventional breeding programmes (Berry and Uddin, 1991) and the negative correlations between yield and sugar content (Kaloo, 1988). Traditional varieties are considered to have a higher internal quality than the modern varieties leading a growing interest in promoting the survival of traditional varieties. Furthermore, Traditional varieties represent an important genetic and crop heritage, and possess sensory characteristics that consumers esteem (Ruiz *et al.,* 2005). The main problem with these varieties is their high market price, a direct consequence of production costs basically due to lower productivity than commercial hybrids. Old or autochthonous strains of many cultivated species have been replaced by genetically or biotechnologically improved varieties (Díaz del Cañizo *et al*., 1998; Cebolla-Cornejo *et al*., 2002) that are more productive and more resistant to diseases and pests. There is currently concern to encourage sustainable and balanced models of agricultural production, consistent with better conservation both of the wider environment and of genetic diversity. On the other hand, consumers also miss the traditional taste of tomato and demand healthy products rich in bioactive compounds.

It is relevant to consider the importance that organic cultivation is acquiring in the context of world food production as a whole. There is consistent growth in consumer demand for organic produce, different in character from conventional foods but nevertheless of excellent quality (Rivera and Brugarolas, 2003). Organic horticulture represents a sustainable and alternative agricultural model with the potential to provide both environmental improvements and high quality outputs (González *et al*., 2002).

Pro Specie Rara (PSR) is Switzerland's seed savers exchange PSR focuses solely on Swiss heirloom varieties: in order for a seed to be accepted into the PSR collection, it should have been grown in Switzerland for at least thirty years. In addition to the vegetable varieties, PSR also promotes the stewardship of traditional animals and fruits. PSR recruits gardeners to adopt heirloom varieties for seed production and provides a network for home gardeners to exchange these heirloom seeds with each other. These 300 seed-producing members, called "actives" are the seed guardians for one to forty varieties. All of the seeds exchanged through Pro Specie Rara go directly through the gardeners/growers, and in no small way contributes to the building of a larger seed oriented community. PSR has also succeeded in expanding their stewardship of the heirloom vegetable varieties in two unique ways. They contract growers and seed companies to grow out the heirloom seed and offer it commercially. Gardeners can purchase

PSR varieties through at least three different seed companies. Not content to let only the home gardeners enjoy the heirloom fruits and vegetables, PSR joined forces with the second largest grocery chain in the country, the COOP. In 1999 the COOP began offering organically grown PSR varieties in its produce section. Since then people throughout the country have been able to buy seasonal heirloom tomatoes, carrots, beets, salad greens, and more at their local supermarket (Kleeger, 2007).

Traditional Swiss agriculture was heavily influenced by its neighboring countries (Germany, Austria, Italy, and France) so the *Pro Specie Rara* inventory is quite varied. *Cuor di bue* tomato is an Italian heirloom variety that is considered to be included in PSR catalogue. This variety has large fruits mostly heart-shaped, most are pink or red with numerous small seed compartments distributed throughout the fruit, sometimes displaying pronounced ribbing similar to ancient pre-Columbian tomato cultivars. While popular among home growers because its flavour and consistency. However it is not grown commercially as often as other types, since they are not considered as suitable for mechanization and storage. Moreover, this variety is susceptible to physiological problems during the cultivation of the fruits mainly to yellow shoulder disorder.

The objective of the present study was the comparison among six different *Cuor di bue* selections coming from five different seed companies. We have tested the yield (total yield and marketable yield), the susceptibility to physiological disorder, the total soluble solid content, the titratable acidity, the consumer preference and the external characteristics in order to establish which selection might be the best suitable for PSR collection. In this context the goal is to figure out which selection fulfills the following criteria: to produce good yield for growers, to look similar to the tomato *Cuor di bue* type and to be well appreciated for consumers.

3. Materials and Methods

3.1 Plant material and growing conditions

A group of six different selections of tomato *Cuor di bue* type (Table 1) were selected for the comparison, all of them open-pollinated. Plants were cultivated in plastic tunnel under organic conditions in the Research Institute of Organic Agriculture Fibl (Switzerland). The tunnel is in north-south orientation. Below a temperature of 20°C at the beginning of the season and of 16ºC, over the summer, the sides of the tunnel close automatically. Transplanting was carried out on May 7th 2013. The trial was set out with two replicates. Each replicated plot consisted of 4 plants except the second plot of Alb-S, Alb-C and Alb-O selections that consisted of 5 plants.

The two replicates were grown in a single row. Inter-row spacing was 1.1 m while within row spacing was 35 cm between plants (Fig. S1). Plants were drip-irrigated.

Table 1. Sources of the compared tomato selections

Name	Source	Description
CdB-S	Sativa-Rheinau AG	Red-violet color, heart shape, excellent flavour
Alb-H	Hortus Sementi	Distinctive ribbed pear shape, red color, great taste.
Alb-E	ESASEM	Distinctive ribbed pear shape, red - orange color when fully ripe.
Alb-S	Sativa-Rheinau AG	Seed information not available.
Alb-C	Max Schwartz	Distinctive pear shape.
Alb-O	Orto Olter	Shape of ox heart with a round base, corrugated of an orange red color.

CdB: Cuor di Bue; Alb: Cuor di Bue selection Albenga

Before planting the soil was fertilized with composted manure (0.005m^3/m^2), Biorga vegi (35 g/m^2), horn chips (40 g/m^2) and Kalimagnesia (20 g/m^2). Biorga vegi is an organic NPK fertilizer based in grinded malt sprouts and Kalimagnesia is high effective potassium-magnesium fertilizer with low chlorine content. Additionally, it was carried out a crop protection management against aphids, the application calendar and products used are listed in table 2.

Table 2. Crop protection planning against *Macrosiphum euphorbiae*

Date	Product	Amount of spraying solution	Area
27-May	Pyrethrum 0.1 % + Rapeseed oil 0.5 %	2 L	Only spots treated
31-May	NeemAzal T/S 0.3%	4 L	Only spots treated
06-June	Pyrethrum 0.1 % + Rapeseed oil 0.5 %	4 L	Only spots treated
11-June	NeemAzal T/S 0.3%	8 L	Whole tunnel
12-July	Parasitoids: Aphidius / Aphelinus Mix		
02-July	NeemAzal T/S 0.3%	8 L	Whole tunnel

3.2 Harvesting

All the tomato fruits at the ripping stage were manually harvested every week from 15th July to September 18th,, 17 harvest points in total. A tomato fruit was considered at ripening stage when it showed red color (from color stage 8 in Fig. S2) and softness at the bottom end. Fruits of each plot were graded into five categories prior to counting and weighing. The categories were set up according to a quality evaluation based in the size and appearance of the harvested tomato fruits: marketable (no disorders), cracking, presence of yellow shoulders, presence of blossom end rots and other disorders (too small, too big, zippering fruit…).

3.3 Total soluble solids content (TSS), titratable acidity

Ten fruits of each selection harvested at the same time (12th August) were used to determine total soluble solids (TSS) and titratable acidity.

TSS and titratable acidity were determined for each line using a homogenate prepared from ten fruits in a commercial juicer (OSCAR DA-900, DONG AH IND CO., LTD, Korea) and filtered using a metal strainer. TSS was measured by means of a 30PX digital refractometer (Mettler Toledo, Greifensee, Switzerland). Two measurements were performed for each homogenate and the results were expressed as °Brix. Titratable acidity was determined using a semi-automatic titrator against an alkaline solution of 0.33 M NaOH to pH 7 instead to pH 8.1 as usual (Anonymous, 2008). The maturity index has been calculated as the ratio TSS to titratable acidity, and the flavour index [(TSS/20 x titratable acidity) + titratable acidity] has also been calculated (Navez *et al*., 1999; Nielsen, 2003).

3.4 Consumer preferences

Approximately 80 consumers participated in a taste preference test performed in the open day at Fibl (August 25th). The fruits were harvested from both plot of each selection, bite-sized cuted and placed side by side on plates. Each selection was designed by a letter from A to F, and ordered randomly. The test persons were asked to give a taste appreciation of tomatoes on a four degrees scale (bad, moderate, good and very good) in a panel using red dot stickers. To calculate the preference score value the number of dots per degree were counted and the responses “bad”, “moderate”, “good” and “very good” were given values of 1, 2, 3 and 4 respectively. The formula used was (N_{bad} x 1 + $N_{moderate}$ x 2 + N_{good} x 3 + $N_{verygood}$ x 4)/N_{total}, being N the number of red dot stickers counted per each category per selection.

3.5 Firmness, color and shape

Firmness, color, shape and ribbing of fruits were estimated visually as the average value of ten tomato fruits of each selection harvested on 12th August according to the table of characteristics of the Guidelines for the conduct of tests for distinctness, uniformity and stability (TG/44/11) published by the International Union for the Protection of New Varieties of plants (UPOV, 2011).

3.6 Statistical analysis

The relationship between TSS content and flavour index was tested using Pearson´s correlation ($p<0.05$). SPSS 18.0 (SPSS Inc., Chicago, IL, USA) was used for the analysis.

4. Results

4.1 Cumulative yield

Results were based on 17 harvest points during the growing season from July 15th to September 18th. The cumulative total yield was similar among the selections ranging from 8 to 10 kg/m^2 with the exception of CdB-S that presented the lowest yield value 5.5 kg/m2 (Fig. 1). The cumulative yield curve shape was similar for all of them, presenting an upward tendency in August, and reaching the plateau phase at the first week of September. Probably high temperatures induced the blossom drop observed in July that caused a deficient fruit set in tomatoes. July was the month with the highest temperatures and solar radiation (Table S1).

At each harvest point tomato fruits per plot were weighted and counted and the average weight per date was calculated as well as the total average weight (Table S2). In general, the highest values are reached in the middle of the harvest period getting an average weight of 200g per fruit approximately with the exception of CdB-S selection (10g/fruit) which is the selection producing the largest number of fruit per square metre (Fig. 2 and Fig.3). The trend line of fruits per square metre curve is the same as the fruit yield curve, presenting the upward tendency in August (Fig. 2).

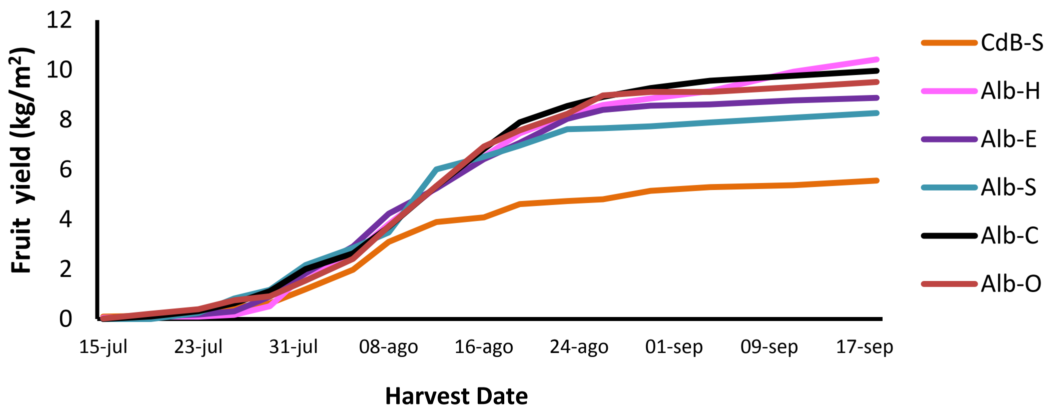

Figure 1. The cumulative yield (kg/m^2) of tomato fruits during the harvest season (from 15th of July to 18th of September).

The trial had only two replicates so it is not possible to perform a statistic analysis. The Supplemental Figure 3 shows the comparison of the yield between the replicates. In general, the replicates did not present high differences, with the exception of Alb-H selection. It could be due because both replicates were positioned in both row extremes so the ambient conditions for each replicate possibly were very dissimilar.

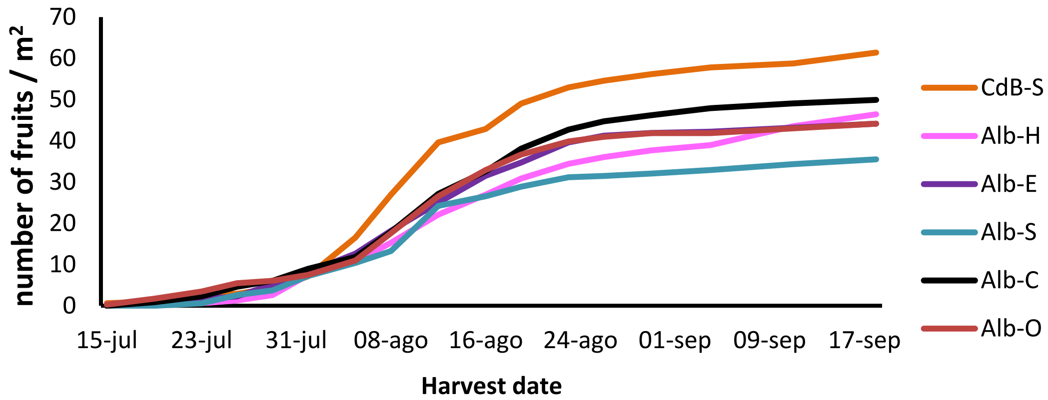

Figure 2. The cumulative number of tomato fruits harvested per square metre during the harvest season (from 15th of July to 18th of September).

When comparing the marketable yield Alb-O selection has the highest marketable tomato yield and number of fruits per square metre, follow by Alb-E selection. CdB-S and Alb-S showed the less marketable fruit values, being CdB-S the selection that yielded more non-marketable fruits per area (Fig. 3). Nevertheless, all selections showed a high percentage of the non-marketable tomato fruits respect to the total crop yield ranging from 50% (Alb-O) to 82 % (CdB-S) (Fig. 4).

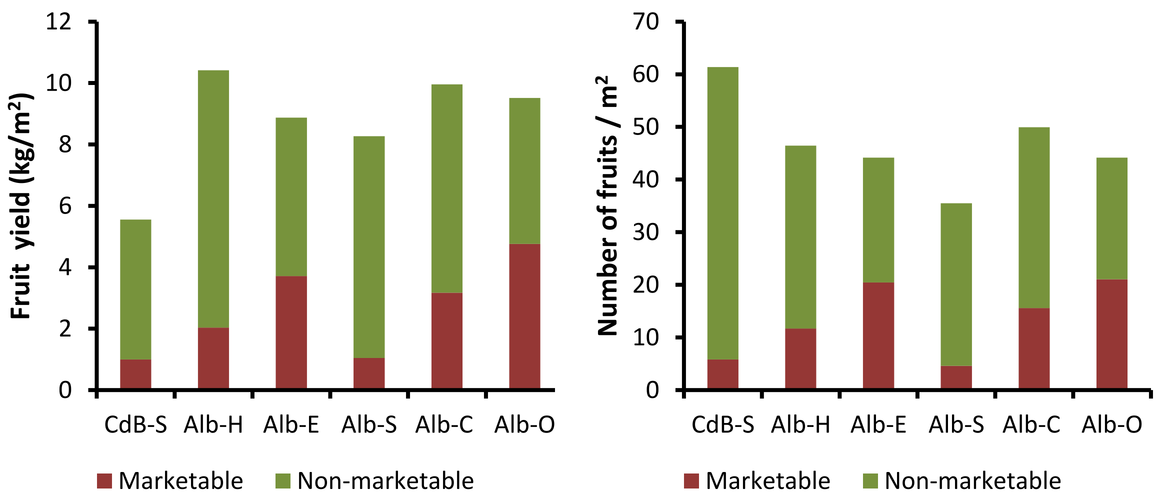

Figure 3. Crop production obtained by the tomato selections for marketable (no disorders) and non-marketable (disorders) fruits. On the left tomato fruit yield expressed in kg per m². On the right crop productions in number of fruits per square metre.

Respects to the susceptibility to present disorders, all the six selections are very susceptible for the presence of yellow shoulder (Fig. 4 and Fig. S4). In CdB-S the 65% of the tomato fruits harvested present yellow shoulder disorder. Alb-O and Alb-E are less susceptible with a 27 % of fruits with yellow shoulder disorder. Alb-H and alb-E are the more affected by cracking disorder. The blossom end rot was not very important in this experiment. In the category called “other” the main disorders founded were too small and too big fruits (outside the range 350-500 g and diameter below 50 mm), deformed fruits and heterogeneous ripening.

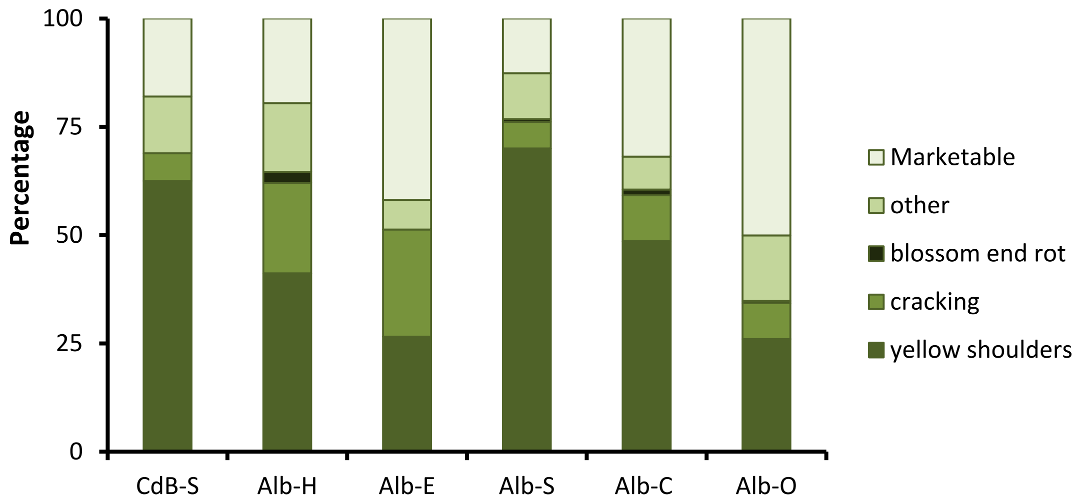

Figure 4. Percentage respect to the total crop yield of the five categories that tomato fruits were graded in the study.

4.2 Total soluble solids content (TSS) and titratable acidity (TTA)

The results obtained for these variables from the six tomato selections analyzed are shown in table 2. The selections that presented the highest TSS values were CdB-S, Alb-O and Alb-E with a value of 5.8, 5.3 and 5.1 respectively. The highest values for both TSS and titratable acidity were found for CdB-S (5.8 ºBrix, 2.20 g citric acid/l). The lowest values were found for Alb-C (4.2 ºBrix, 1.36 g citric acid/l). The maturity index (ratio TSS to titratable acidity) gives a good indication of tomatoes ripeness. Alb-H (high maturity index, 3.60) and Alb-S (low maturity index, 2.31) stood out in this study (Table 2). The flavour index [(TSS/20 × titratable acidity) + titratable acidity] has also been calculated; two varieties CdB-S and Alb-C, stand out in this variable, with a value of 2.84 and 1.65 respectively. The results for these two indexes suggest that CdB-S, would be the best selection in this context follow for Alb-E and Alb-O with high values for both indexes.

Table 2. Quality variables of the studied selections

Selection	TSS (°Brix)	TTA (g citric acid/l)	maturity index	flavour index
CdB-S	5.8	2.20	2.63	2.84
Alb-H	4.7	1.30	3.60	1.61
Alb-E	5.1	1.69	3.01	2.13
Alb-S	4.3	1.86	2.31	2.26
Alb-C	4.2	1.36	3.08	1.65
Alb-O	5.3	1.69	3.13	2.14

4.3 Consumer preferences

Visitors to the open day at Fibl were asked to taste the compared tomato selections and to give a preference vote for each one. Figure 5 shows the consumer flavour preferences. The selection with the high percentage of "good" votes and score was CdB-S. Nevertheless Alb-C selection presented the lowest values. The selections more appreciated by consumers presented also the highest TSS contents. A significant correlation ($p<0.05$) was found between the two variables with a coefficient *r* of 0.722.

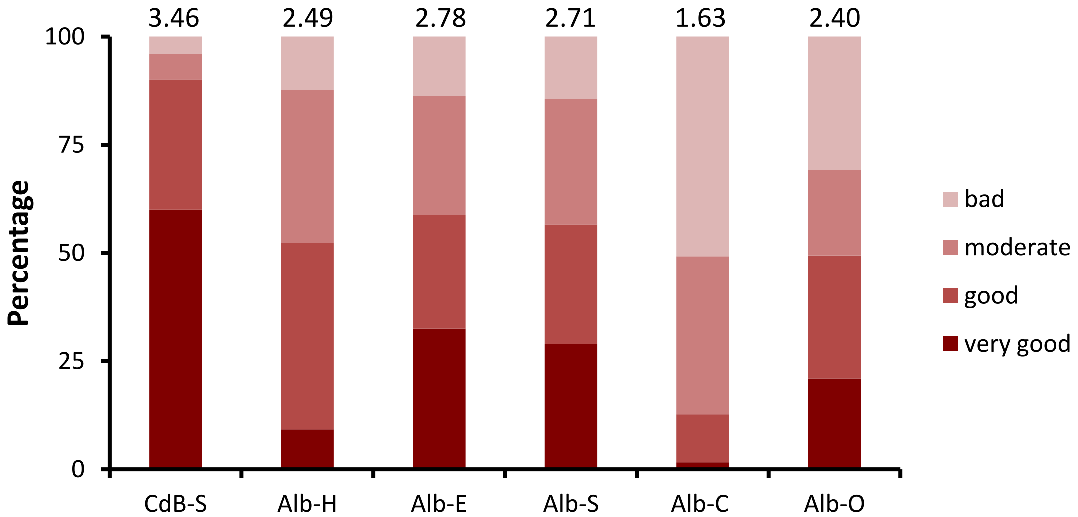

Figure 5. Consumer preference scores for tomato taste. The barchart represents the porcentage of taste apreciation responses obtained for each selection. Numbers above indicate the preference score value calculated for each selection.

4.4 Firmness, color and shape

Ten mature tomato fruits of each selection harvested at the same date were evaluated for physical characteristics according to the table of characteristics of the Guidelines for the conduct of tests for distinctness, uniformity and stability (UPOV, TG/44/11). The results are presented in table 3. The softness was very similar among the selections. The ribbing at peduncle end was strong in all selections with the exception of CdB-S (Fig. S4). CdB-S and Alb-S selections were very different in fruit color and longitudinal shape respects the other *Cuor di bue* selections. This fact was expected for CdB-S because it is an old variety but not for Alb-S that it is supposed to be multiplied from Alb-O seeds. Alb-S did not have the distinctive pear-shaped of the *Cuor di bue* sel. Albenga presenting a flattened shape (Fig. 6).

Table 3. Physical characteristics of the selections compared

Selection	Softness 1) hard 9) very soft	Ribbing 1) weak 9) very strong	Fruit color (at maturity)	Shape in longitudinal section
CdB-S	6	2	red	heart-shaped
Alb-H	4.5	9	Orange-red	pear-shaped
Alb-E	4.5	8	Orange-red	pear-shaped
Alb-S	5	8	pink-red	flattened
Alb-C	5.5	8	Orange-red	pear-shaped
Alb-O	5	8	Orange-red	pear-shaped

Figure 6. Shape in longitudinal section of the six heirloom tomato selections compared. Scale bar = 1 cm.

Respects to the transverse section fruit these selections had six or more locules, except Alb-E and Alb-C that had five or more locules. CdB-S and Alb-S fruits showed a very thin pericarp and a very large diameter of core in cross section in relation to total diameter. On the other hand, Alb-H, Alb-O and Alb-E fruits had a large diameter of core and a medium pericarp. By contrast, Alb-C selection had a thin pericarp and a small core having the bigger locular cavity and air spaces (Fig. 7).

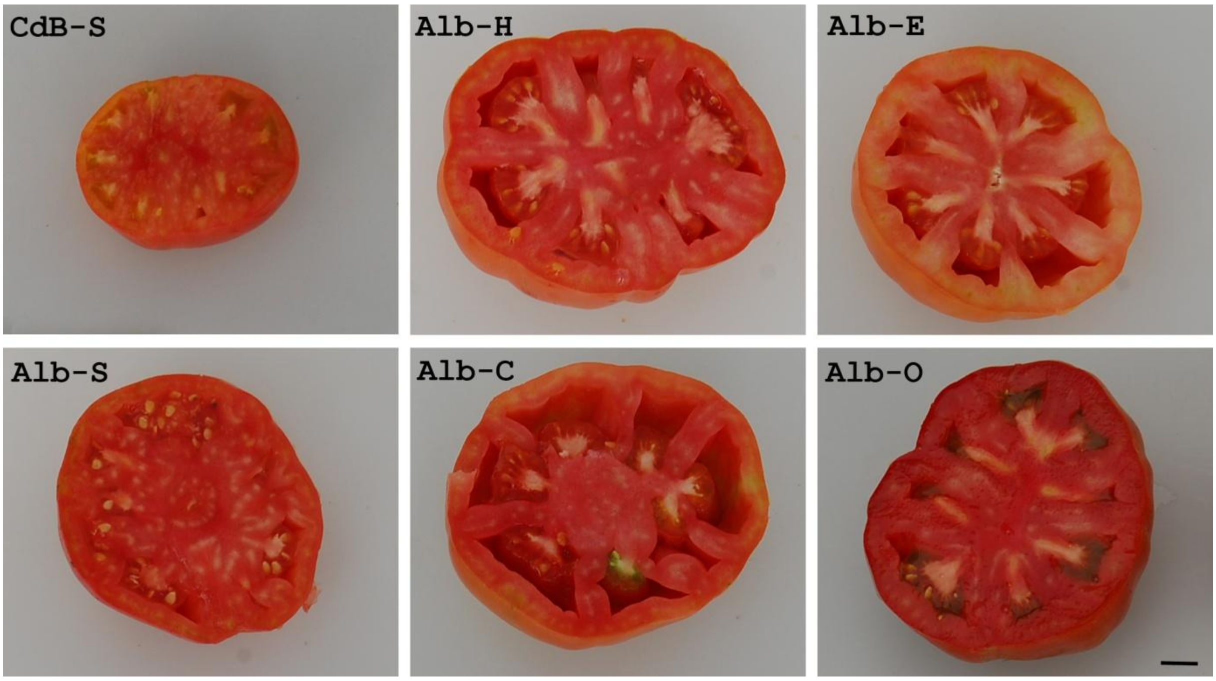

Figure 7. Transverse section of the six tomato *Cuor di bue* selections compared. Scale bar = 1cm

5. Discussion

The overall results of the total yield produced of the selections in this study were appropriated for the expected normal yield of organically grown tomatoes in Central Europe in a plastic tunnel (growing season: May-September) of about 6-9 kg / m² (Hornischer and Koller, 2005). The selections compared had a similar yield (8 to 10 kg/m2) and a similar number of fruits per m2 (aprox. 40 fruits/m2) with the exception of CdB-S (Fig. 2). This CdB-S selection produced the lowest yield but the highest number of fruits due to the small size of the fruits (10 g/fruit on average). Based on the results for the marketable yields (Fig. 3), losses due to unmarketable quality tomatoes were lower in Alb-O and Alb-E while CdB-S and Alb-S suffered the highest number of losses for unmarketable tomato fruit. The principal cause of unmarketable fruits was the incidence of yellow shoulder disorder (YSD) that is characterized by a ring of tissue around the stem scar that upon ripening remains yellow. Yellow shoulder is a disorder that involves modified development, not delayed ripening of fruit .These alterations are triggered very early in fruit development and are not reversed by delaying harvest (Francis *et al*., 2000). The severity of YSD appears to have a genetic component (Fogleman, 1966). Alb-O and Alb-E selections were the less susceptible to YSD although Alb-E was more affected by cracking disorder. The incidence of cracking could be reduced controlling irrigation. In addition, climatic and nutrition conditions could contribute to yellow shoulder so management practices could be tested to decrease its incidence and improving the percentage of marketable fruits. Based on our results, Alb-O is the most promising selections, followed by Alb-E, with respect to its yield giving the largest number of marketable fruit and the highest weight of marketable fruit per square meter and one of the highest potential yield in kg per square metre. On the other hand, the CdB-S selection resulted undesirable from an economic point of view because it is needed the most effort in harvesting and sorting with the lowest production.

The flavour of tomatoes is strongly affected by TSS and titratable acidity, which are therefore considered good indicators of sensory quality (Thybo *et al*., 2006). The higher the solids content, the higher the fruit flavour (Jones, 2008). The taste index was calculated using the values of Brix degree and acidity, applying the equation performed by Navez *et al*. (1999). We should point out that our results are not equivalent to similar studies because for titratable acidity measurement we adjusted the pH to 7.0 not to 8.1. Taking this into account the maturity index calculated is overestimated and the flavour index is underestimated. But we consider the results are useful for comparison between the selections. The results obtained for TSS from all the varieties analysed fell within the range stipulated by Arana *et al*. (2006) for tomatoes of good organoleptic quality. The Brix values of selections compared were similar to other types of tomato in organic farming (Regnat, 2008, Koller *et al*.,2004, Gonzalez-Cebrino *et al*., 2011). Another parameter related with the flavour index is maturity which is usually a better predictor of an acid's flavour impact than Brix degree or acidity alone. Acidity tends to decrease with the maturity of the fruits while the sugar content increases (Raffo *et al*., 2002). CdB-S, Alb-S and Alb-O seem to be the varieties with fruits of greater organoleptic quality than the others as a result of a better balance between TSS and acidity.

The quality of fruit and vegetables is an extremely complex matter, difficult to describe objectively. The consumer is not in a position to judge the nutritional quality of a given fruit and vegetable, however he is able to communicate their feelings by giving statements such as like or dislike. In order to know which selections were more appreciated by consumer we performed a preference test at Fibl. We found a positive correlation between flavour index and consumer preferences. In general, selections that showed high flavour index, as CdB-S, were more appreciated than selections with low value as Alb-C.

By measuring the total soluble solid content and total acidity of a fruit, a primary quality characteristic can be assessed. But attributes such as color, size, shape and external defects of fruit and vegetables predominantly determine the choice made by the consumers. The morphological characteristics of the selections have been compared to determine if they exhibited the distinctive characteristics of *Cuor di bue* type. This variety of tomato is well known and valued by consumer mainly for the consistency of the pulp, the near absence of seeds and the sweet taste.

Cuor di bue tomatoes are larger than traditional round tomatoes, with a typical heart-pear shape marked by ribs, weighing 180-250 g and containing five or more locules (Costa and Heuvelink, 2005). CdB-S and Alb-S did not fulfill all the principal characteristics. CdB-S is an old selection different from Albenga one that came from a sort of natural selection and mutations by crosses of ancient selections that intended to obtain the largest and most attractive berries. Alb-S exhibited a flattened shape (Fig. 6) that is very different from the distinctive shape of *Cuor di bue* but had marked ribs, large fruits and contained more than six locules. This selection it is supposed to be multiplied from Alb-O seeds, but based on the morphological characteristics we consider that it could had been crossed with other variety during the amplification process. Alb-H, Alb-E, Alb-C and Alb-O showed the expected appearance of *Cuor di bue* selection Albenga tomatoes.

Softness values could be a good indicator of the maturity stage of the fruits, so we could expect that the highest softness value correspond to the highest maturity index. Nevertheless, our results were not in concordance to this assumption. It could be due to the fact that the softness was estimated manually. According to Zapata *et al.* (2007), firmness is a very important component of quality, both in terms of commercialization and of the assessment of organoleptic properties, so it could be interesting to improve the measure method to figure out the best selection choice for this characteristic.

The texture of the flesh itself, which includes the radial wall, locular cavities and the outer pericarp, also affects the quality of the fruit. There was a range of variability in the number and size of locules found among the six tomato selections in this study. The locular cavities are important to the firmness of the tomato fruit and protect it from mechanical damage (Li *et al.,* 2010). Locules should be filled with gel and not air spaces, as noted in the selections CdB-S, Alb-S, Alb-H and Alb-O (Fig. 7). These air spaces noted, or hollow areas, in the tomato fruit are not acceptable to consumers and do not transport well because of their relative softness (Masarirambi, *et al*. 2009). Pericarp thickness is also an important feature of the tomato fruit, as varieties with thicker pericarp are better able to withstand travel over long distances and remain firm for a longer period (Kumari and Sharma, 2011). Respect to these issues Alb-H and Alb-O seems to be the most suitable selections for transportation and storage compared with the rest.

As final conclusions, the selection Alb-O stands out quantitatively from the others, mainly because of its high marketable yield, low physiological disorder incidence and good morphological characteristics. It also has high TSS content and flavour index. In spite of that it was not so well appreciated by consumers compared with other selections as CdB-S or Alb-E. Other selection that showed good yield and quality characteristic was Alb-E. We conclude, therefore, that these two selections compared have the greatest potential for its inclusion in *Pro Specie Rara* inventory and commercial use in organic tomato production. The results of this study are based on only one year of data and to replicates so further studies are required in order to make a more detailed assessment of the yield and quality characteristics.

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7. Appendix

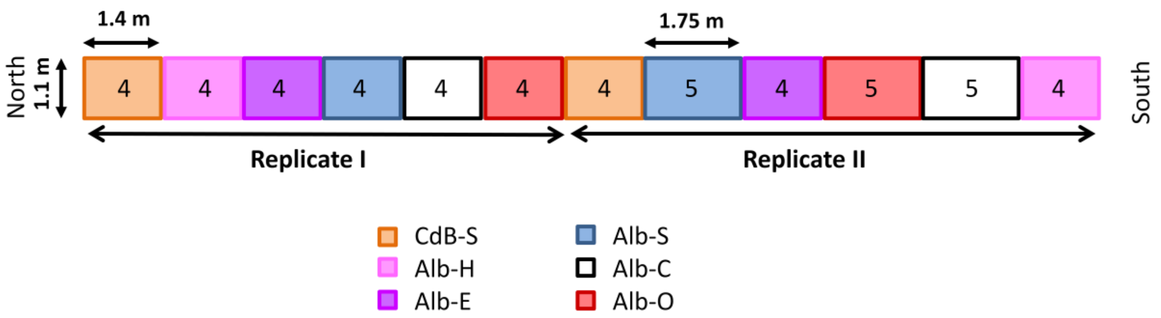

Figure S1. Experimental designed. Numbers inside the box indicates the number of tomato plants per plot.

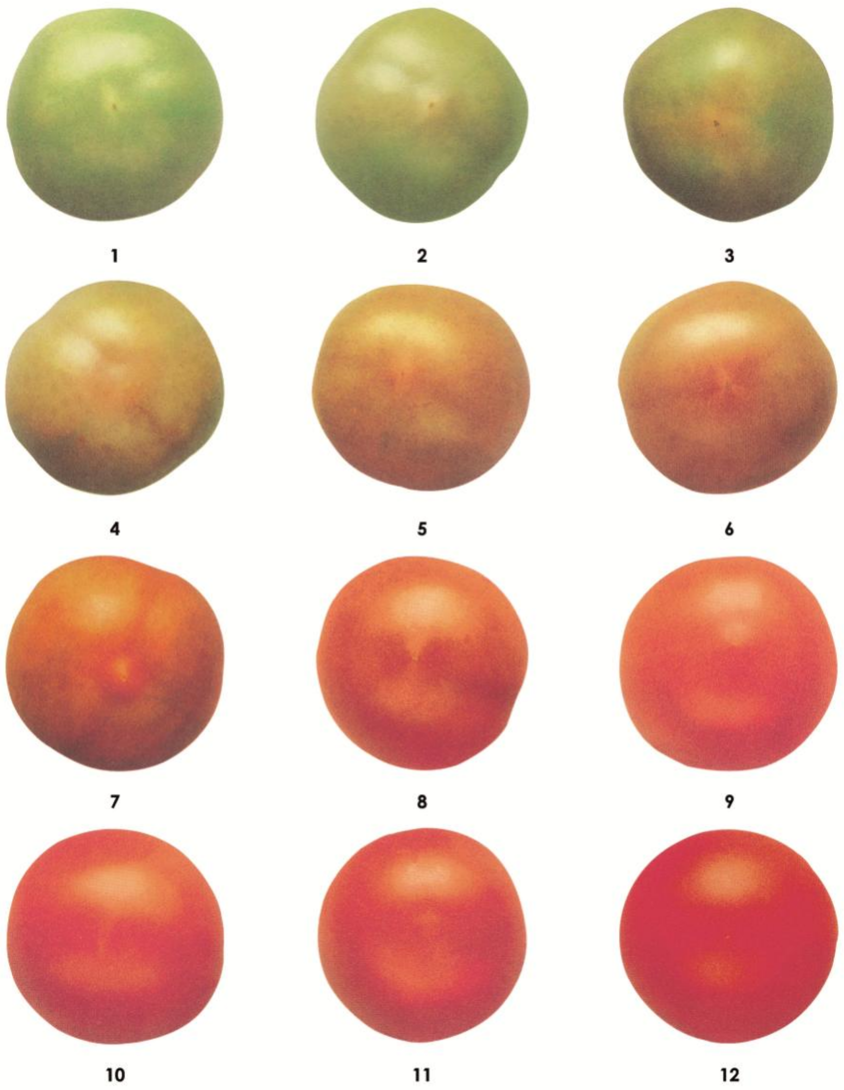

Figure S2. Tomato color chart 1-12 (Swiss quality regulations for vegetables) http://www.qualiservice.ch/pdf/Tomate_2004_d.pdf

Table S1. Monthly mean values of temperature and global radiation from May to September 2013. Location Frick, Switzerland.(http://www.agrometeo.ch/)

Parameter	Temperature ºC			Solar radiation Wh/m2
	Average	Minimun	Maximun	
May-2013	11.5	2.6	23.4	133821
June-2013	16.7	4.4	34.5	168494
July-2013	21.3	9.8	36.1	198845
August-2013	19.1	9.7	33.4	165840
September-2013	15.3	7.1	29.9	98988

Table S2. Total weight (W), number (N) and average weight (AW) of tomato fruits harvested per selection by date. The crop surface for each selection is indicated. The total average weight (last row, grey) is calculated by taking the total weight and total number of tomato fruits harvested along the period. W and AW are expressed in kg.

Selection	CdB-S			Alb-Sementi			Alb-E			Alb-Sativa			Alb-C			Alb-Olter		
Surface	2.8 m^2			2.8 m^2			2.8 m^2			3.85 m^2			3.85 m^2			3.85 m^2		
	W	N	AW	W	N	AW	W	N	AW	W	N	AW	W	N	AW	W	N	AW
15. Jul	0.30	2	0.15	0.16	1	0.16	-	-	-	-	-	-	-	-	-	0.06	1	0.06
19. Jul	0.09	1	0.09	0.14	1	0.14	0.32	3	0.11	-	-	-	0.35	3	0.12	0.66	5	0.13
23. Jul	0.67	4	0.17	-	-	-	0.23	2	0.12	0.85	2	0.43	0.73	5	0.15	0.64	6	0.11
26. Jul	0.41	2	0.21	0.21	2	0.11	0.40	2	0.20	1.99	7	0.28	1.09	8	0.14	1.24	7	0.18
29. Jul	0.47	4	0.12	1.07	4	0.27	1.82	9	0.20	1.22	4	0.30	1.69	5	0.34	0.55	2	0.28
01. Aug	1.74	9	0.19	4.01	15	0.27	2.88	9	0.32	3.45	12	0.29	3.09	10	0.31	2.19	5	0.44
05. Aug	2.40	29	0.08	2.46	10	0.25	3.30	14	0.24	2.37	11	0.22	2.17	10	0.22	3.02	12	0.25
08. Aug	3.44	32	0.11	3.68	14	0.26	4.06	17	0.24	2.17	10	0.22	3.69	21	0.18	4.52	23	0.20
12. Aug	2.46	39	0.06	4.52	21	0.22	3.12	21	0.15	8.77	38	0.23	5.66	32	0.18	5.60	31	0.18
16. Aug	0.58	10	0.06	3.81	15	0.25	3.62	20	0.18	1.75	8	0.22	5.17	19	0.27	5.50	22	0.25
19. Aug	1.64	19	0.09	2.88	12	0.24	2.02	10	0.20	1.56	8	0.20	3.71	19	0.20	2.26	13	0.17
23. Aug	0.37	12	0.03	2.21	11	0.20	2.97	15	0.20	2.28	8	0.29	2.28	16	0.14	2.29	11	0.21
26. Aug	0.22	5	0.04	1.29	5	0.26	1.10	5	0.22	0.12	1	0.12	1.25	7	0.18	2.54	4	0.64
30. Aug	1.05	5	0.21	0.81	5	0.16	0.52	2	0.26	0.27	2	0.14	1.24	5	0.25	0.51	3	0.17
04. Sep	0.46	5	0.09	0.91	4	0.23	-	-	-	0.53	3	0.18	1.02	6	0.17	-	-	-
11. Sep	0.24	3	0.08	2.39	14	0.17	0.48	3	0.16	0.67	5	0.13	0.68	4	0.17	0.65	4	0.16
18. Sep	0.57	8	0.07	1.53	9	0.17	0.32	3	0.11	0.66	4	0.16	0.69	3	0.23	0.72	4	0.18
Total	17.11	189	0.09	28.17	120	0.23	27.18	132	0.21	27.32	114	0.24	34.51	173	0.20	32.96	153	0.22

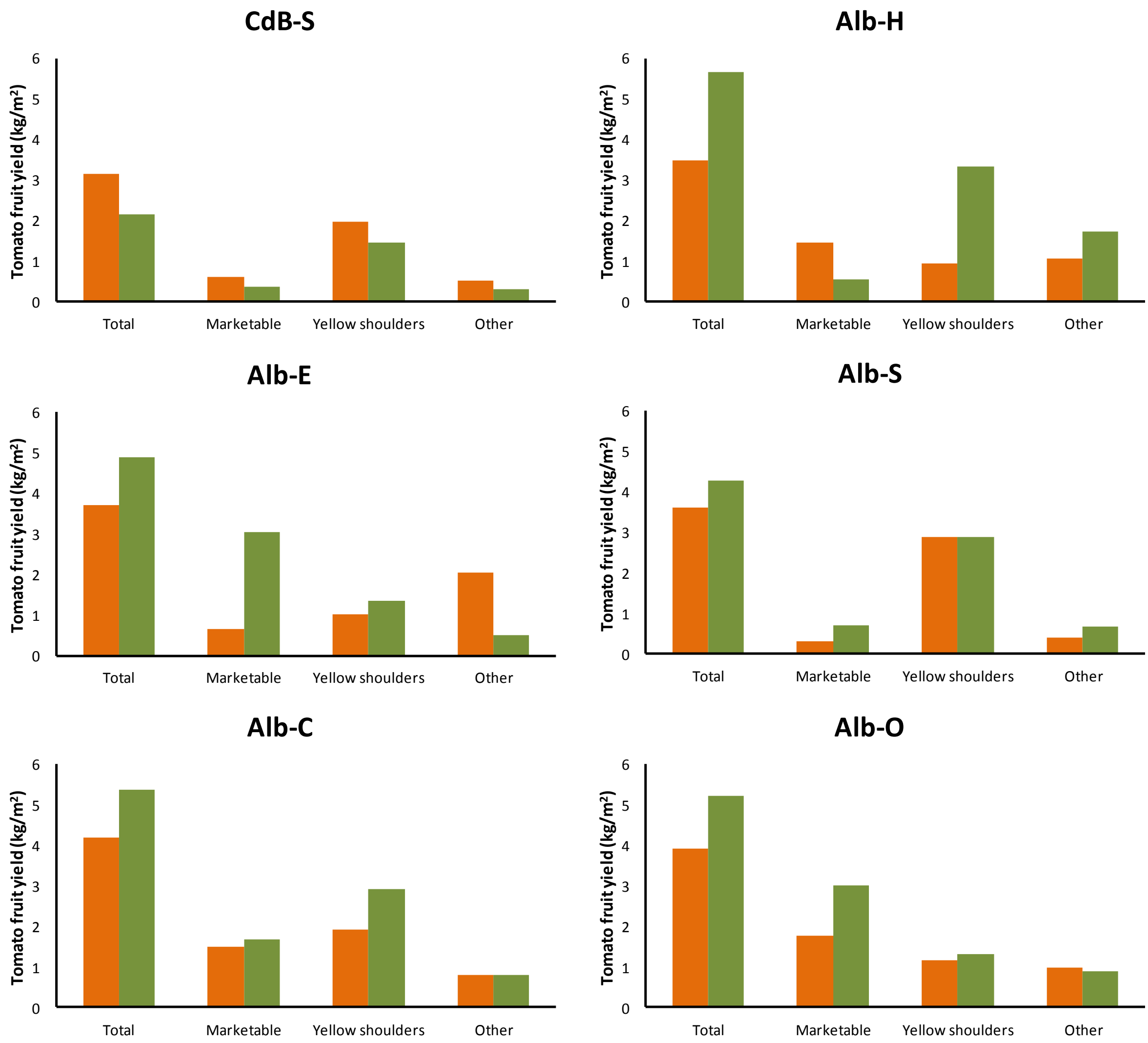

Figure S3. Fruit yield per replicate. Orange: replicate I; green: replicate II.

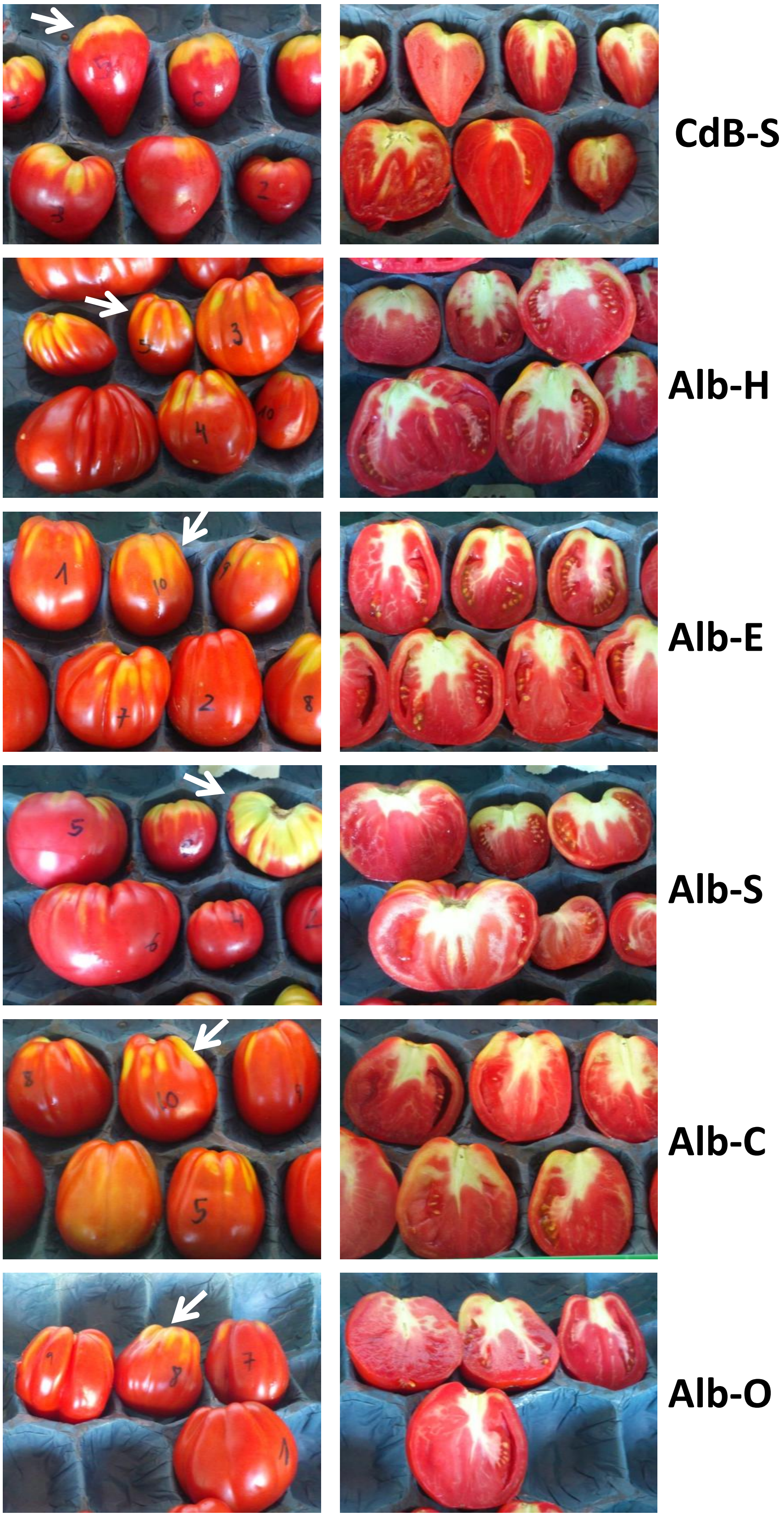

Figure S4. Shape in longitudinal section, external (left panel) and external (right panel) aspect. White arrows indicate yellow shoulder disorder.

8. Acknowledgment

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