2023 Pulse Quality Evaluation

Lentil

Saskatchewan Food Industry Development Centre Inc.
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Pulse Quality Program—*Mission*

The Pulse Quality Program launched in spring 2022 with a partnership between Saskatchewan Pulse Growers and the Saskatchewan Food Industry Development Centre with the mission to add in best management practices for pulses grown in Western Canada and to help the development of pulse-based ingredients/products in the food industry.

The program aims to develop a comprehensive database of composition, functionality, and nutrition for pulses that provides information to growers, agronomists, breeders, buyers, and end users to make more informed choices. This program implements a genotype by environment (G x E) evaluation of quality parameters of peas, faba beans, lentils, chickpeas, and dry beans.

Phase 1 of the program analyzes up to 3000 samples annually from regional variety trials. The main focus of parameters includes seed quality (i.e., thousand kernel weight, amount of damage, seed size, and seed hardness), nutritional composition (i.e., ash, moisture, and protein content), milling, and colour. The generated data are compared across pulse varieties, locations, and years. Additional parameters will be considered in future years in Phase 2 and Phase 3.

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2023 Lentil Quality

The **2023** lentil quality evaluation comprised **405** lentil samples harvested from **5** locations. There were **27** varieties, and three replicates of each variety were cultivated in each location. **Table A** and **Figure A** provide the samples' information and locations in detail. **Figure B** provides the cumulative rainfall from April 1 to October 16, 2023. Overall, there was more rainfall in the southeast, east-central, northeast, and northwest regions than in the southwest and west-central regions. According to the 2023 Crop Reports by the Ministry of Agriculture, seeding started in early May due to cool weather and excess moisture in April, and seeding was wrapped up in the beginning of June. During the growing season, warm temperatures have accelerated crop development in the majority of the province, especially the southwest and west-central regions, and harvest began in these regions at the end of July. Harvest of lentils was completed by the end of September.

Table A. Description of 2023 lentil samples tested for the Pulse Quality Program. Varieties also present in 2022 are shown in black, and new varieties that entered in 2023 are shown in red.

Type		Variety		Site	Number of samples
Green	Large green	CDC Greenstar	CDC Lima	Avonlea Elrose Redvers Rosthern St Brieux	405
	Small green	CDC Kermit CDC 6964	CDC Jimini		
Red	Large red	CDC Sublime	CDC Monarch		
	Medium red	CDC 7005-3			
	Small red	6928-5 7014-1 CDC 6928 CDC 6956 CDC Impulse CDC Maxim	CDC Nimble CDC Proclaim CDC Redmoon CDC Simmie CDC 7301-6		
	Extra small red	CDC Imani	CDC Imp		
Specialty	Spanish brown	7026-13Y	CDC SB-4		
	French green	CDC 7333-2-4	CDC Marble		
	Black	CDC 8587-1-H2-13-bk	CDC 8627-1-H2-4		

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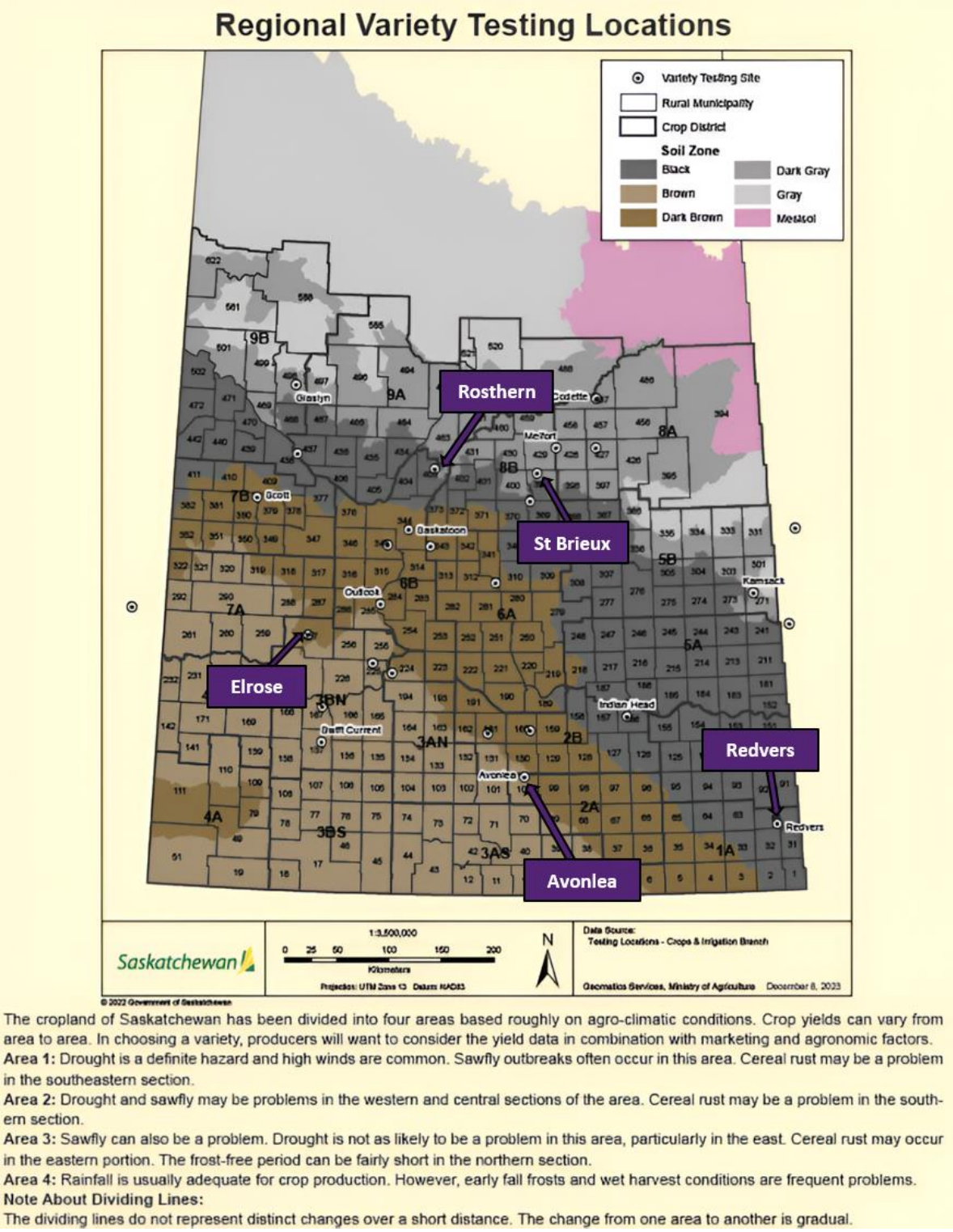

The cropland of Saskatchewan has been divided into four areas based roughly on agro-climatic conditions. Crop yields can vary from area to area. In choosing a variety, producers will want to consider the yield data in combination with marketing and agronomic factors.

Area 1: Drought is a definite hazard and high winds are common. Sawfly outbreaks often occur in this area. Cereal rust may be a problem in the southeastern section.

Area 2: Drought and sawfly may be problems in the western and central sections of the area. Cereal rust may be a problem in the southern section.

Area 3: Sawfly can also be a problem. Drought is not as likely to be a problem in this area, particularly in the east. Cereal rust may occur in the eastern portion. The frost-free period can be fairly short in the northern section.

Area 4: Rainfall is usually adequate for crop production. However, early fall frosts and wet harvest conditions are frequent problems.

Note About Dividing Lines:

The dividing lines do not represent distinct changes over a short distance. The change from one area to another is gradual.

Figure A. Locations for lentil quality testing in 2023 and the corresponding soil zones. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

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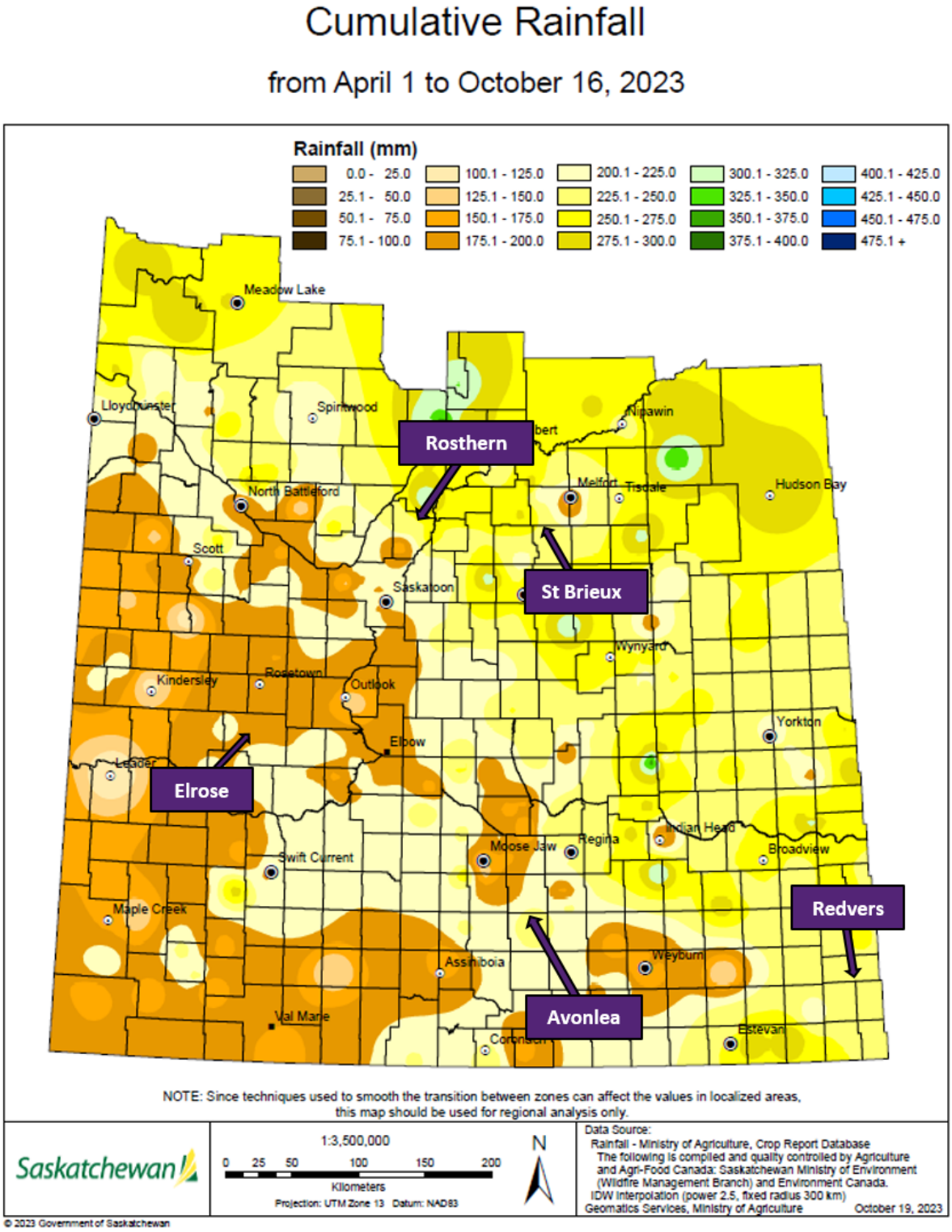

Figure B. Locations for lentil quality testing and cumulative rainfall from April 1 to October 16, 2023. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

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This report includes three sections: **1)** 2023 green lentil varieties, **2)** red lentil varieties, and **3)** specialty lentil varieties. Each section includes ten subsections for the results of the following quality parameters:

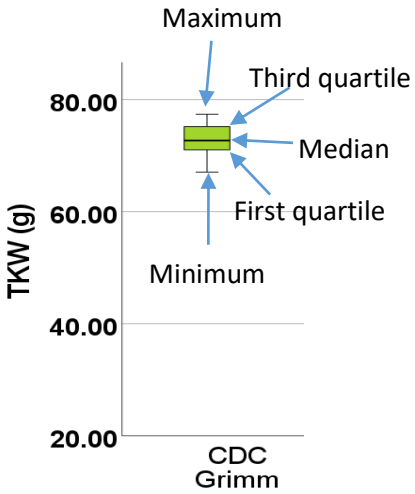
1. Yield
2. Thousand kernel weight (TKW)
3. Seed size distribution
4. Peeled + split + broken seeds
5. Other damage
6. Hardness of whole seed
7. Ash content
8. Protein content
9. Protein productivity
10. Colour (*L*, a*,* and *b**)

The **method** used to evaluate each quality parameter is provided at the beginning of each subsection.

For the **results**, a **Box and Whisker** plot is first provided to show the full dataset of each variety, where the minimum, median, maximum, first quartile (the median of the lower half of the dataset), and third quartile (the median of the upper half of the dataset).

In addition, a **Bar** graph is included to provide the mean values by variety to show the variety performance and by location to show how the locations differed.

Furthermore, the effects of variety, location, and variety x location on the characteristic are given in a **table**.



For **statistics**, a one-way analysis of variance (ANOVA) along with a post-hoc Tukey test (SPSS, Chicago, IL, USA) was performed to identify the differences in the quality parameters, including yield, TKW, seed size, seed hardness, split + cracked seed coat, other damage, protein, protein productivity, ash, Hausner ratio, colour, and particle size, by location for all lentil types and by variety for small green and small red lentils. An independent T-test was conducted to identify the differences in the quality parameters by variety for large green, large red, extra small red, black, French green, and Spanish brown lentils.

A two-way analysis of variance (ANOVA) was conducted to determine the effects of variety, location, and their interaction on each parameter.

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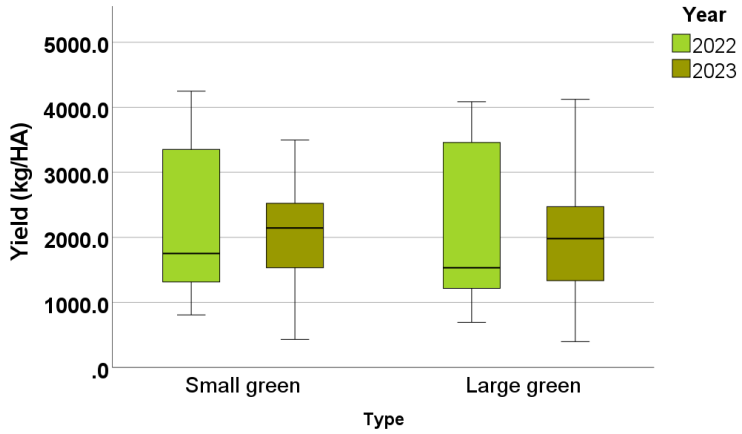
1) 2023 Green Lentil Quality

1. Yield

Method: Yield refers to how much crops are produced and how efficiently land is used to produce food or agricultural commodities. The yield of each variety from each location is provided as kilogram per hectare (kg/HA).

Results: Figure 1.1.1. & **Table 1.1.1.** Yield of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).



	Large green	Small green
2022	2051.3 ± 183.5[a]	2150.4 ± 149.1[a]
2023	2026.0 ± 193.5[a]	2007.9 ± 117.4[a]

Note: different small letters within a column indicate significant differences.

Large green: Mean yield of both years had no differences (p>0.05).
Small green: Mean yield of both years had no differences (p>0.05).

Figure 1.1.2. Box and Whisker plot of 2023 green lentils for yield. Results by type were reported from highest to lowest.

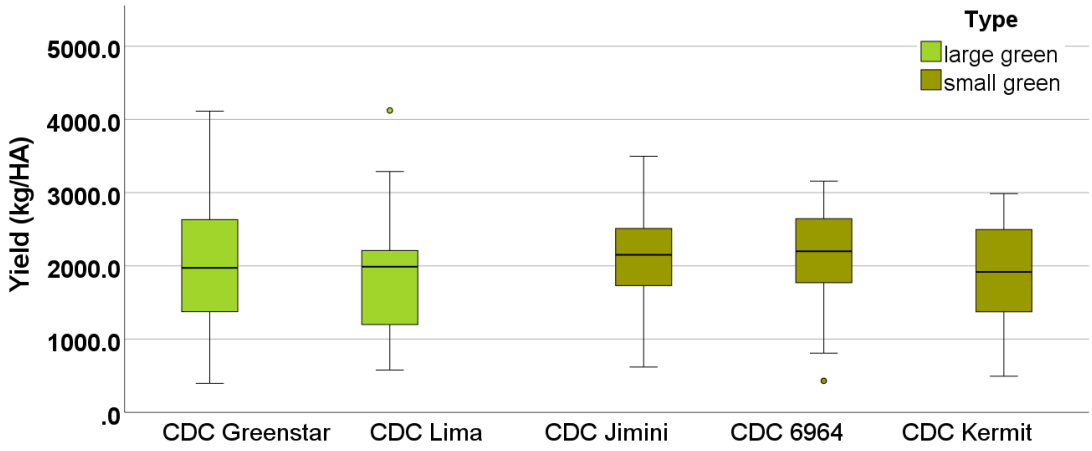


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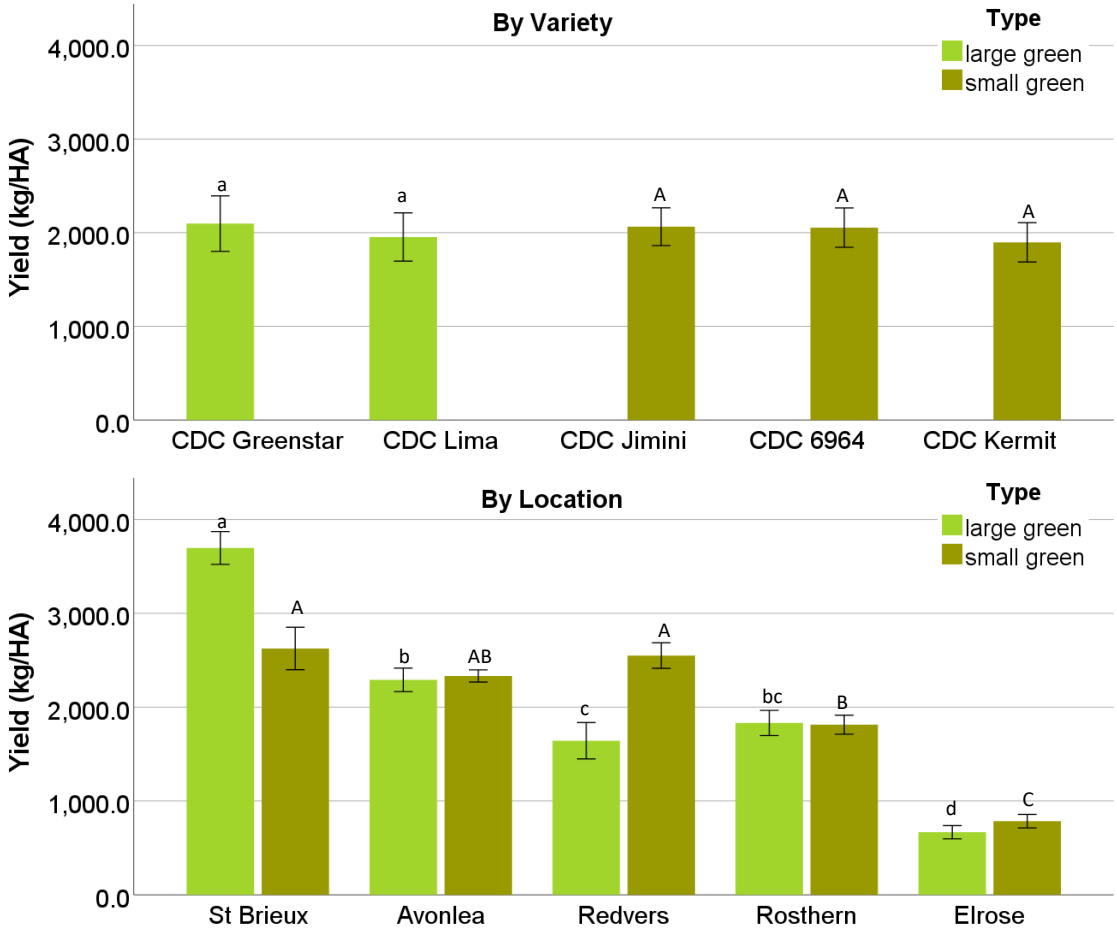
Figure 1.1.3. Mean yield of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** no differences.
- **Small green:** no differences.

By Location:

- **Large green:** The yield in St Brieux was more than four times that of Elrose.
- **Small green:** The yields in St Brieux, Redvers, and Avonlea were more than three times that of Elrose.

Table 1.1.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	*NS*
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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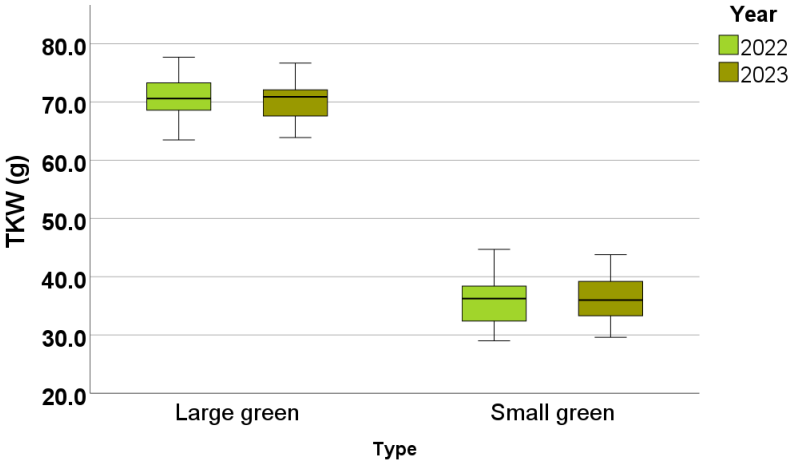
2. Thousand Kernel Weight

Method: Seed weight is an important parameter to indicate seed size and yield production. This test was conducted by weighing 300 seeds with duplicated measurements per sample, and the thousand kernel weight (TKW) was reported.

Results: Figure 1.2.1. & **Table 1.2.1.** TKW of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

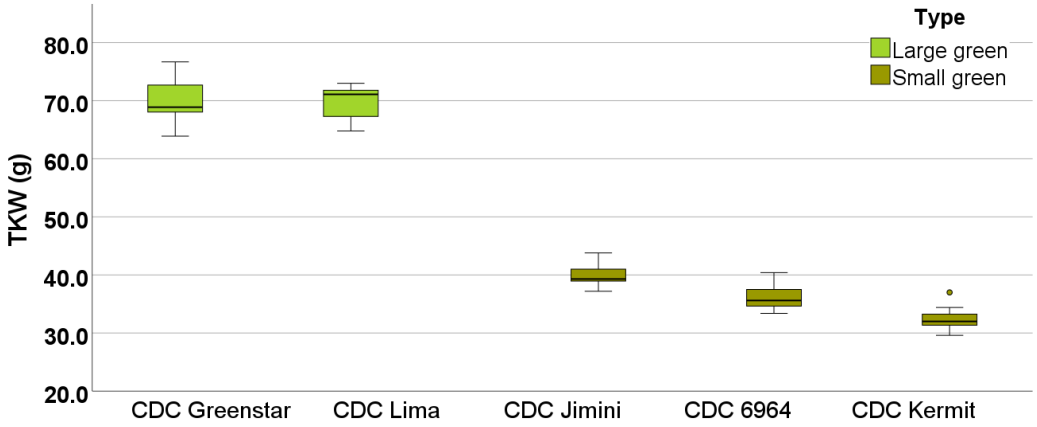


	Large green	Small green
2022	70.9 ± 0.6[a]	35.6 ± 0.5[a]
2023	70.0 ± 0.6[a]	36.2 ± 0.5[a]

Note: different small letters within a column indicate significant differences.

Large green: Mean TKW of both years had no differences (p>0.05).
Small green: Mean TKW of both years had no differences (p>0.05).

Figure 1.2.2. Box and Whisker plot of 2023 green lentils for TKW. Results by type were reported from highest to lowest.



Large green: CDC Greenstar had a larger variability.
Small green: CDC Jimini had the largest TKW with little variability, while CDC Kermit had the smallest TKW.

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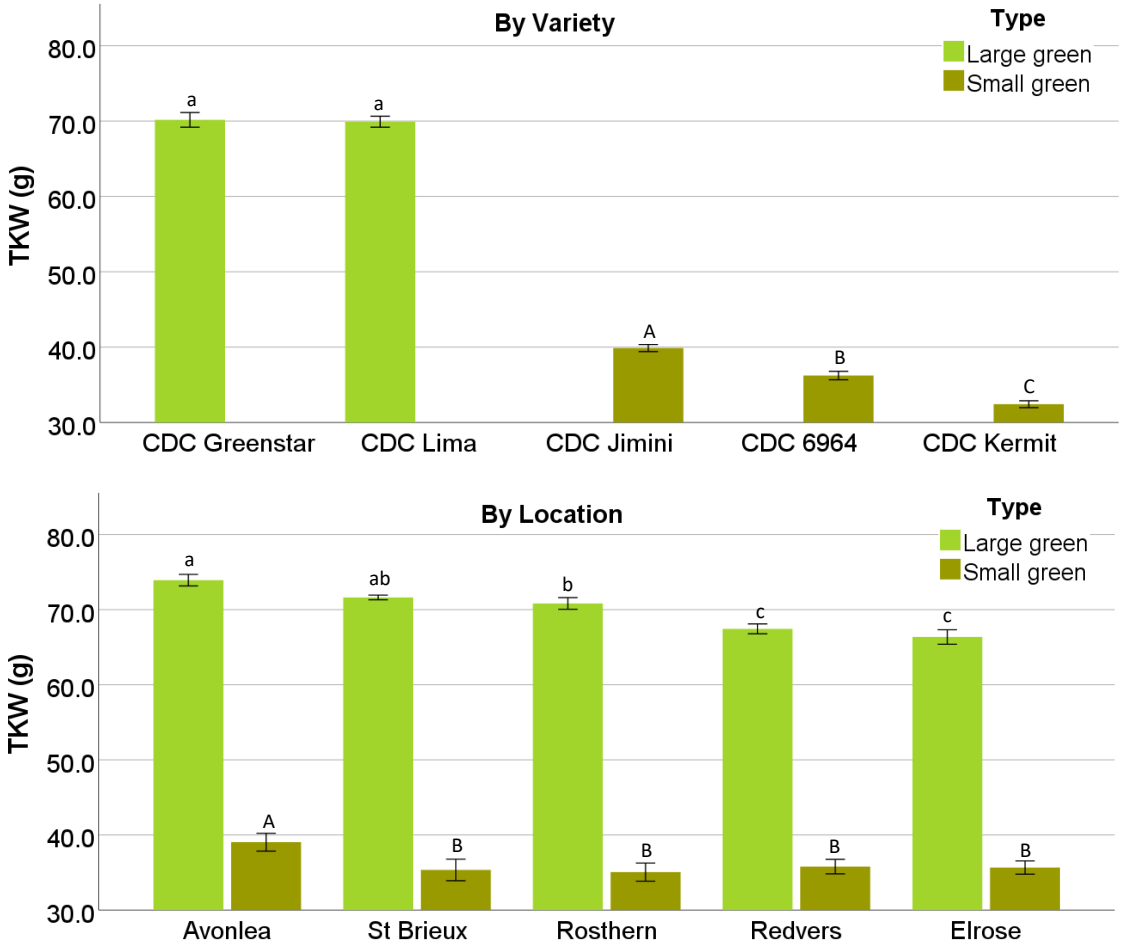
Figure 1.2.3. Mean TKW of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** no differences.
- **Small green:** TKW of CDC Jimini was about 4 g and 7.5 g higher than CDC 6964 and CDC Kermit, respectively.

By Location:

- **Large green:** A 7 g difference is found between highest and lowest.
- **Small green:** Avonlea was about 4 g higher than all other locations.

Table 1.2.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	***
Location	***	***
Variety x Location	*NS*	*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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3. Seed Size Distribution

Method: 250 g of seeds were placed on a series of round-hole opening sieves. The weight of seeds retained on each sieve was determined and reported as % of seeds retained. Duplicated measurements were performed.

Sieves used for green lentils:

a. #18R: 7.14 mm
b. #16R: 6.35 mm
c. #14R: 5.56 mm
d. #12R: 4.76 mm
e. #10R: 3.97 mm

Results: Table 1.3. Seed size distribution (%) of each 2023 green lentil variety. Data represent mean ± one standard deviation.

Type	Variety	> 7.14 mm (%)	> 6.35 mm (%)	> 5.56 mm (%)	> 4.76 mm (%)	> 3.97 mm (%)	Below 3.97 mm (%)
Large green	CDC Greenstar	3.7 ± 2.6^{a}	62.5 ± 11.6^{a}	27.4 ± 9.9^{b}	3.9 ± 2.8^{b}	1.5 ± 1.0^{a}	1.4 ± 0.7^{a}
	CDC Lima	0.3 ± 0.2^{b}	43.0 ± 8.4^{b}	47.8 ± 4.9^{a}	6.7 ± 3.7^{a}	1.1 ± 0.8^{a}	1.1 ± 0.8^{a}
Small green	CDC Jimini	0.0 ± 0.0^{A}	0.0 ± 0.1^{A}	0.4 ± 0.3^{A}	55.6 ± 4.6^{A}	41.3 ± 3.4^{C}	2.7 ± 1.5^{B}
	CDC 6964	0.0 ± 0.0^{A}	0.0 ± 0.0^{A}	0.1 ± 0.1^{B}	52.1 ± 7.5^{A}	45.1 ± 6.5^{B}	2.7 ± 1.4^{B}
	CDC Kermit	0.0 ± 0.0^{A}	0.0 ± 0.0^{A}	0.0 ± 0.0^{B}	19.9 ± 3.9^{B}	73.3 ± 5.1^{A}	6.8 ± 2.9^{A}

Note: Small letters within a column indicated significant differences ($p<0.05$) between large green varieties. Capital letters within a column indicated significant differences ($p<0.05$) between small green varieties.

- The majority of large green lentils ranged in size from 7.14 mm to 5.56 mm.
- The size of small green lentils ranged from 5.56 mm to 3.97 mm.

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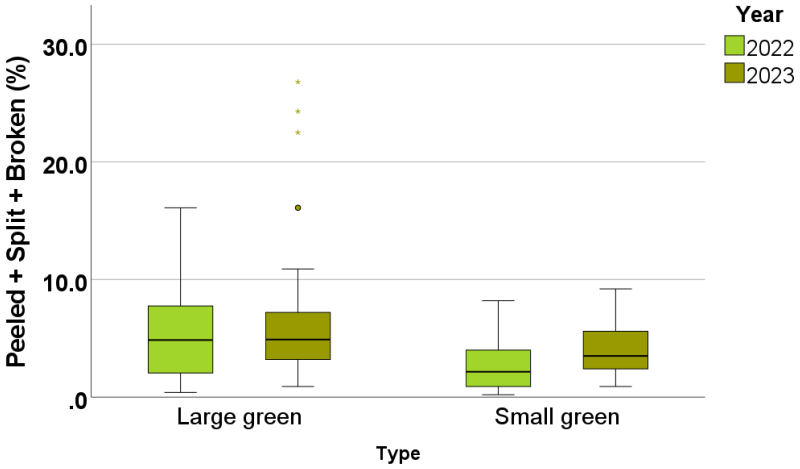
4. Peeled + Split + Broken

Method: 50 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Results included splits, cracks, seed coat damage, partially missing hull, and partially missing cotyledon.

Results: Figure 1.4.1. & **Table 1.4.1.** The peeled + split + broken green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

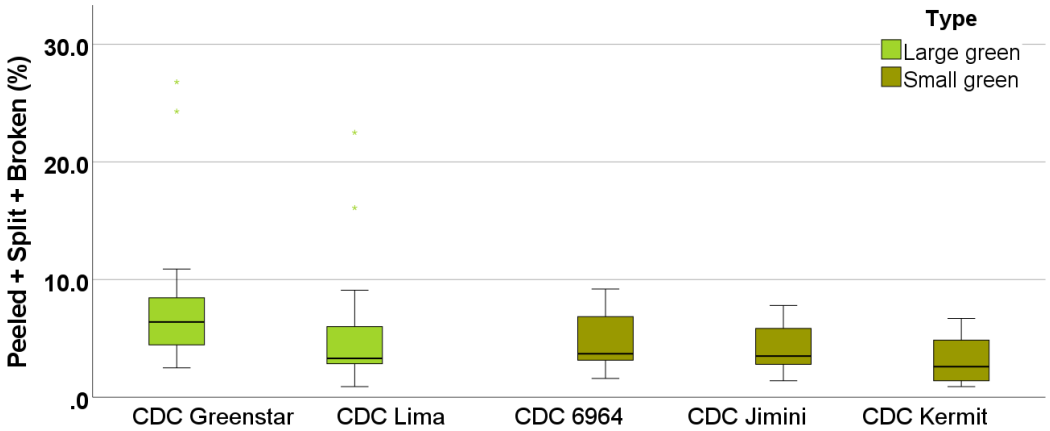


	Large green	Small green
2022	5.2 ± 0.6[a]	2.5 ± 0.3[b]
2023	7.2 ± 1.2[a]	4.0 ± 0.3[a]

Note: different small letters within a column indicate significant differences.

Large green: Mean had no statistical difference.
Small green: Increased split seeds were observed in 2023.

Figure 1.4.2. Box and Whisker plot of the peeled + split + broken green lentils in 2023. Results by type were reported from highest to lowest.



Large green: Extreme outliers were found in both varieties.
Small green: CDC Kermit had the lowest damage.

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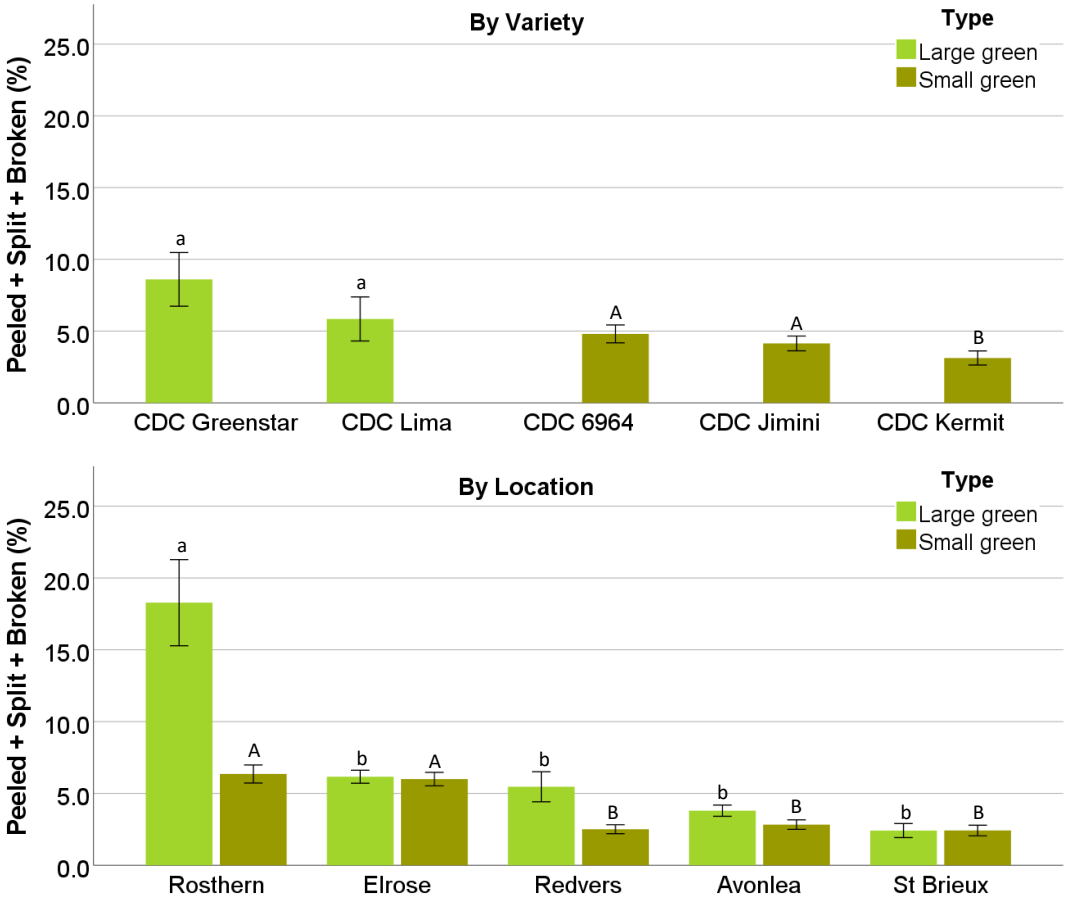
Figure 1.4.3. Mean peeled + split + broken (%) of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** Both were higher than 5%.
- **Small green:** CDC Kermit was over 1% lower than CDC Jimini and CDC 6964.

By Location: Location effect played a significant role.

- **Large green:** Rosthern was over 12% higher than the other locations.
- **Small green:** Rosthern and Elrose were 4% higher than the other three locations.

Table 1.4.2. Effects of variety and location.

	Large green	Small green
Variety	*	***
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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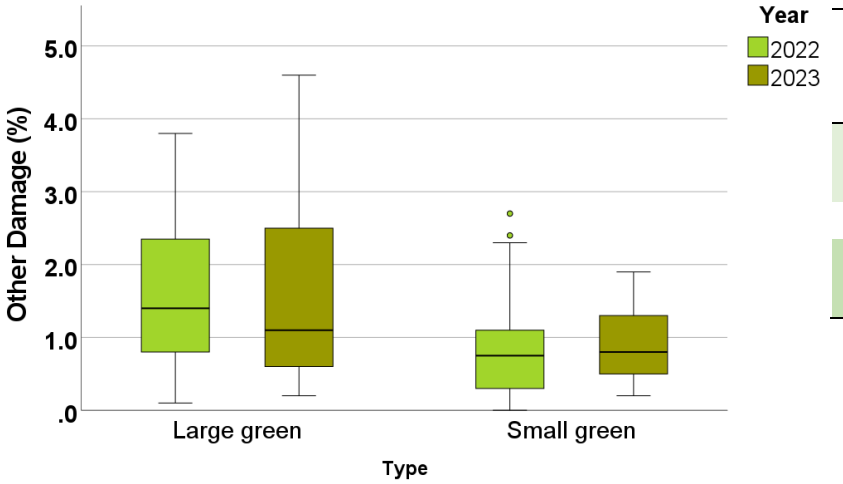
5. Other Damage

Method: 50 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included sprouting, distinct immaturity, distinct deterioration or discolouration by weather or disease, insect damage, heat damage, and any other damage that affects appearance.

Results: Figure 1.5.1. & **Table 1.5.1.** Other damage of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

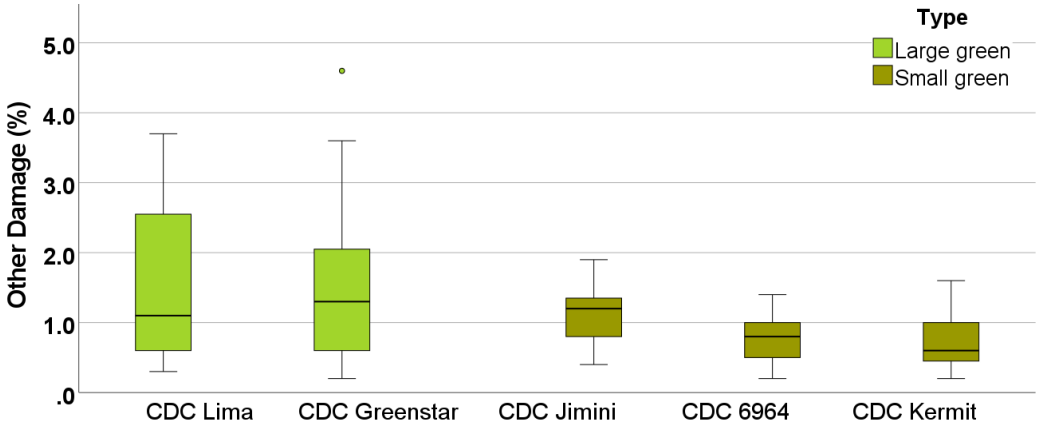


	Large green	Small green
2022	1.5 ± 0.2[a]	0.8 ± 0.1[a]
2023	1.6 ± 0.2[a]	0.9 ± 0.1[a]

Note: different small letters within a column indicate significant differences.

Large green: Mean had no differences.
Small green: Mean had no differences, but 2023 samples had a smaller variability.

Figure 1.5.2. Box and Whisker plot of the 2023 green lentils for other damage. Results by type were reported from highest to lowest.



Large green: Large variability was seen in both varieties.
Small green: CDC Kermit and CDC 6964 had less damage.

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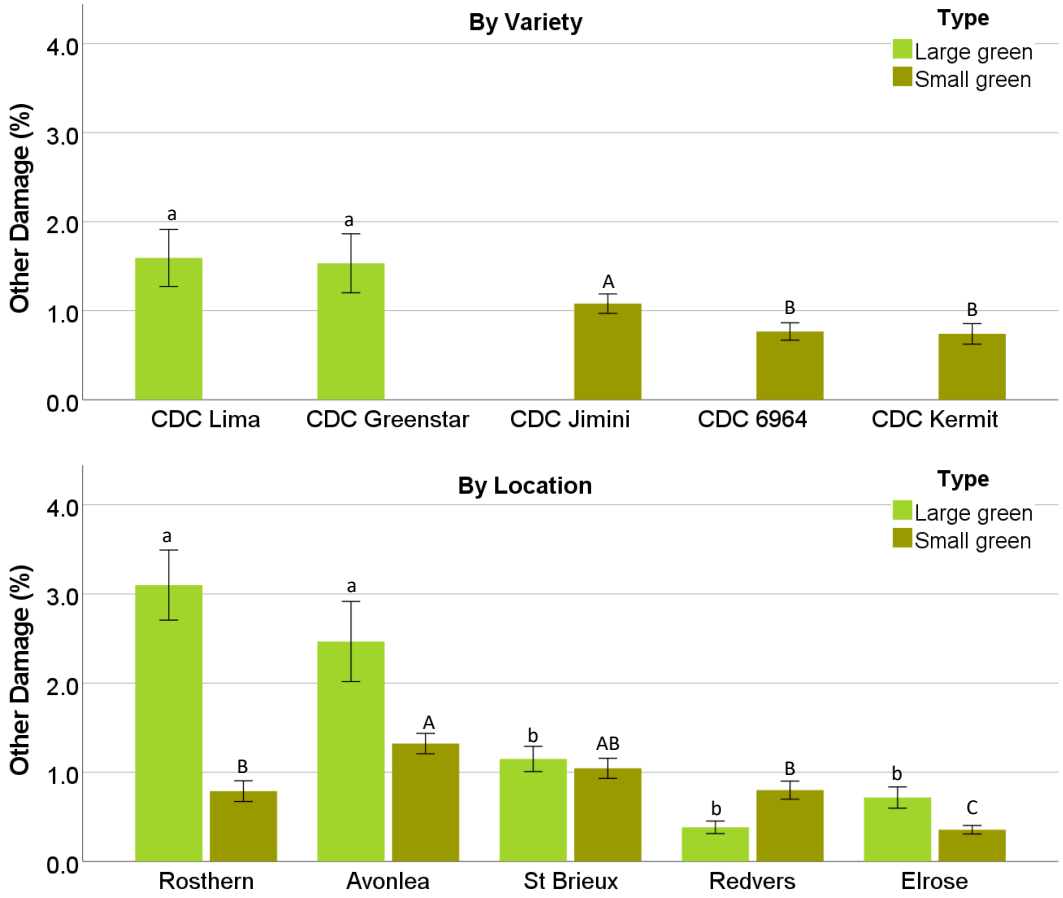
Figure 1.5.3. Mean other damage of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety: Large green in general had more other damage than small green.

By Location: Redvers and Elrose had less other damage.

Table 1.5.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	***
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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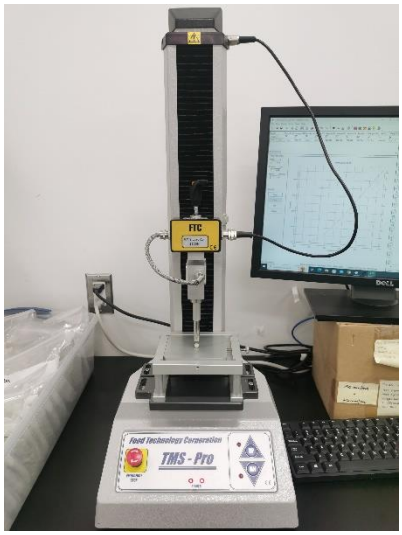
6. Hardness of Whole Seed

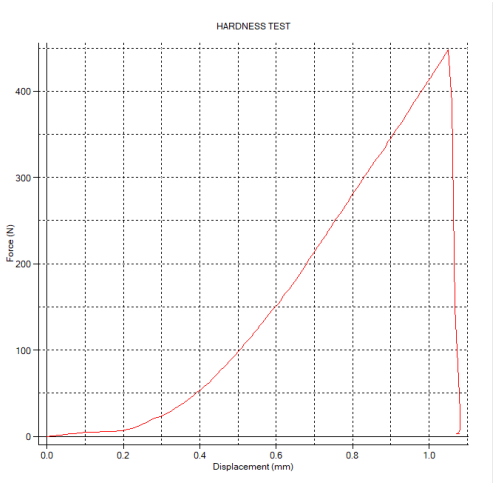
Seed hardness is an important parameter to indicate milling yield and cooking quality. Seed hardness is affected by seed size, shape, density, composition, etc.

Method:

Seed hardness was determined by measuring the force of breaking a seed using a texture analyzer (TMS-Pro, Food Technology Corporation, USA) equipped with a 2500 N load cell with a modified method from Karami et al. (2017) and Lovas-Kiss (2020)[1].

In brief, a seed was placed under the 10 mm cylinder probe that was lowered with a speed of 50 mm/min. The forces to lower the probe till a seed was broken were monitored. The mean peak force (N) of 10 seeds was reported.

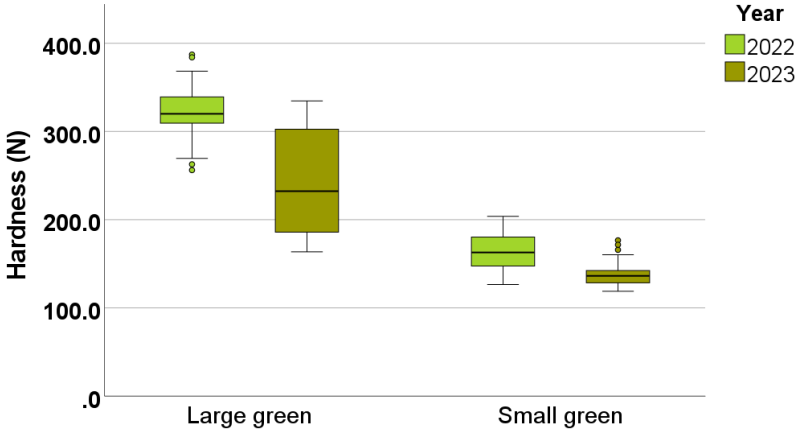




[1] Karami, S., Sabzalian, M. R., Rahimmalek, M., Saeidi, G., & Ghasemi, S. (2017). Interaction of seed coat color and seed hardness: An effective relationship which can be exploited to enhance resistance to the safflower fly (Acanthiophilus helianthi) in Carthamus spp. Crop Protection, 98, 267-275.

Lovas‐Kiss, Á., Vincze, O., Kleyheeg, E., Sramkó, G., Laczkó, L., Fekete, R., ... & Green, A. J. (2020). Seed mass, hardness, and phylogeny explain the potential for endozoochory by granivorous waterbirds. Ecology and Evolution, 10(3), 1413-1424.

Results: Figure 1.6.1. & **Table 1.6.1.** Hardness of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

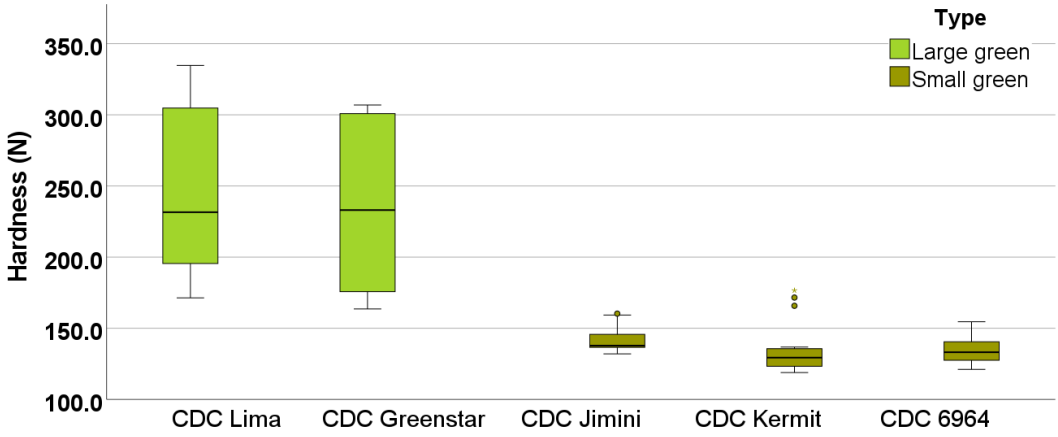


	Large green	Small green
2022	322.3 ± 4.9[a]	163.8 ± 2.5[a]
2023	237.1 ± 10.4[b]	137.8 ± 2.1[b]

Note: different small letters within a columnw indicate significant differences.

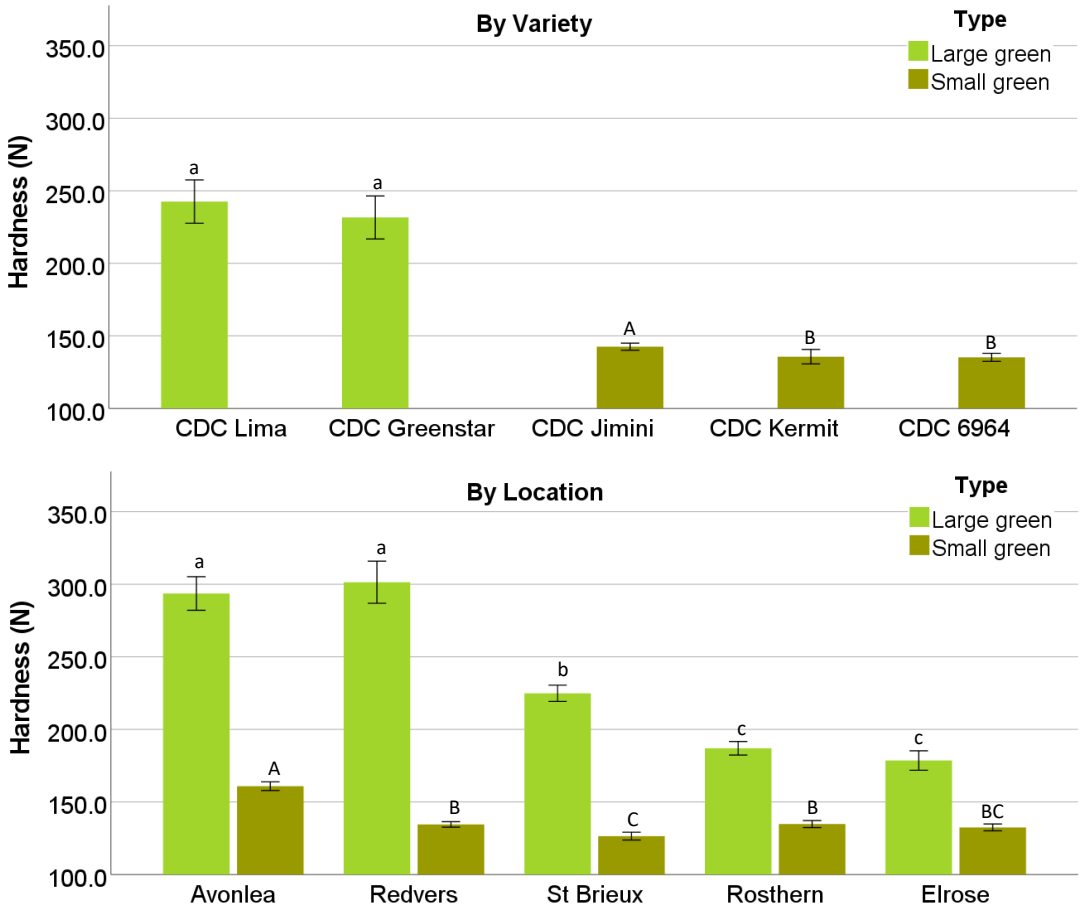
Large green: Smaller hardness and greater variability were observed in the 2023 samples.
Small green: Seed hardness in 2023 was smaller ($p<0.05$).

Figure 1.6.2. Box and Whisker plot of the 2023 green lentils for seed hardness. Results by type were reported from highest to lowest.



Large green: Both varieties had large variability.
Small green: Little variability was presented in each sample, but some outliers were noted in CDC Kermit.

Figure 1.6.3. Mean seed hardness of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety: Hardness of large green was much higher than small green.

- **Large green:** No difference.
- **Small green:** Only a 7 N difference was observed from highest to lowest.

By Location: Location effect is significant, especially for large green lentils.

- **Large green:** About a 120 N difference was observed from highest to lowest.
- **Small green:** About a 30 N difference was observed from highest to lowest.

Table 1.6.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	***
Location	***	***
Variety x Location	*NS*	***

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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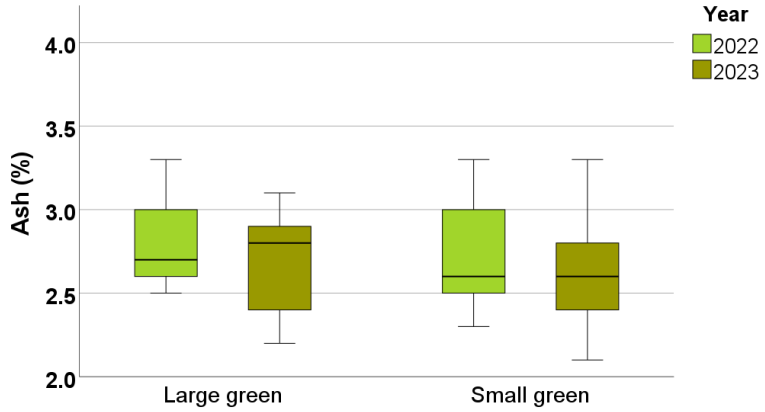
7. Ash Content

Method: Ash content (%) was determined using AACC 08-01.01[2] with modification. Samples were heated at 560°C till they turned white. Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

Results: Figure 1.7.1. & **Table 1.7.1.** Ash of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

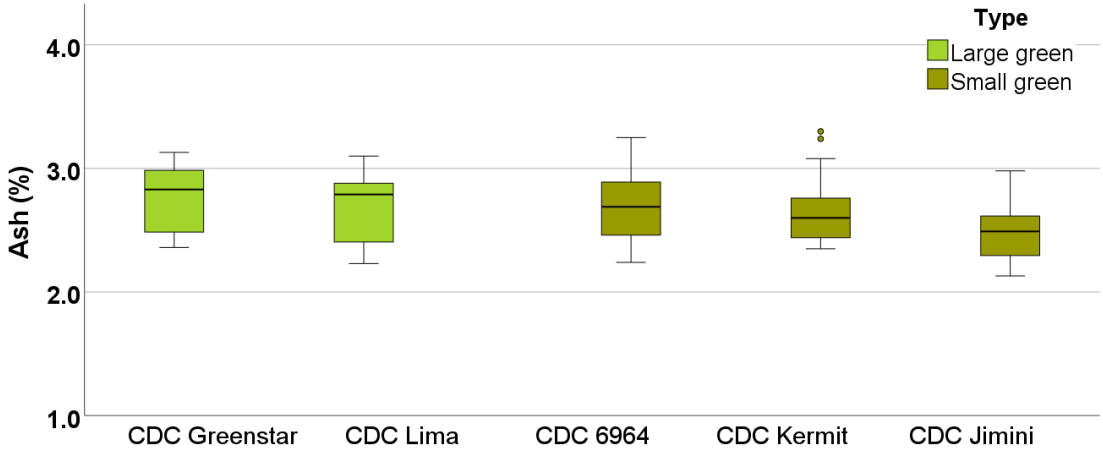


	Large green	Small green
2022	2.8 ± 0.0[a]	2.7 ± 0.0[a]
2023	2.7 ± 0.1[a]	2.6 ± 0.0[a]

Note: different small letters within a column indicate significant differences.

Large green: There is no difference (p>0.05) in mean between both years.
Small green: There is no difference (p>0.05) in mean between both years.

Figure 1.7.2. Box and Whisker plot of 2023 green lentils for ash content. Results by type were reported from highest to lowest.



[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

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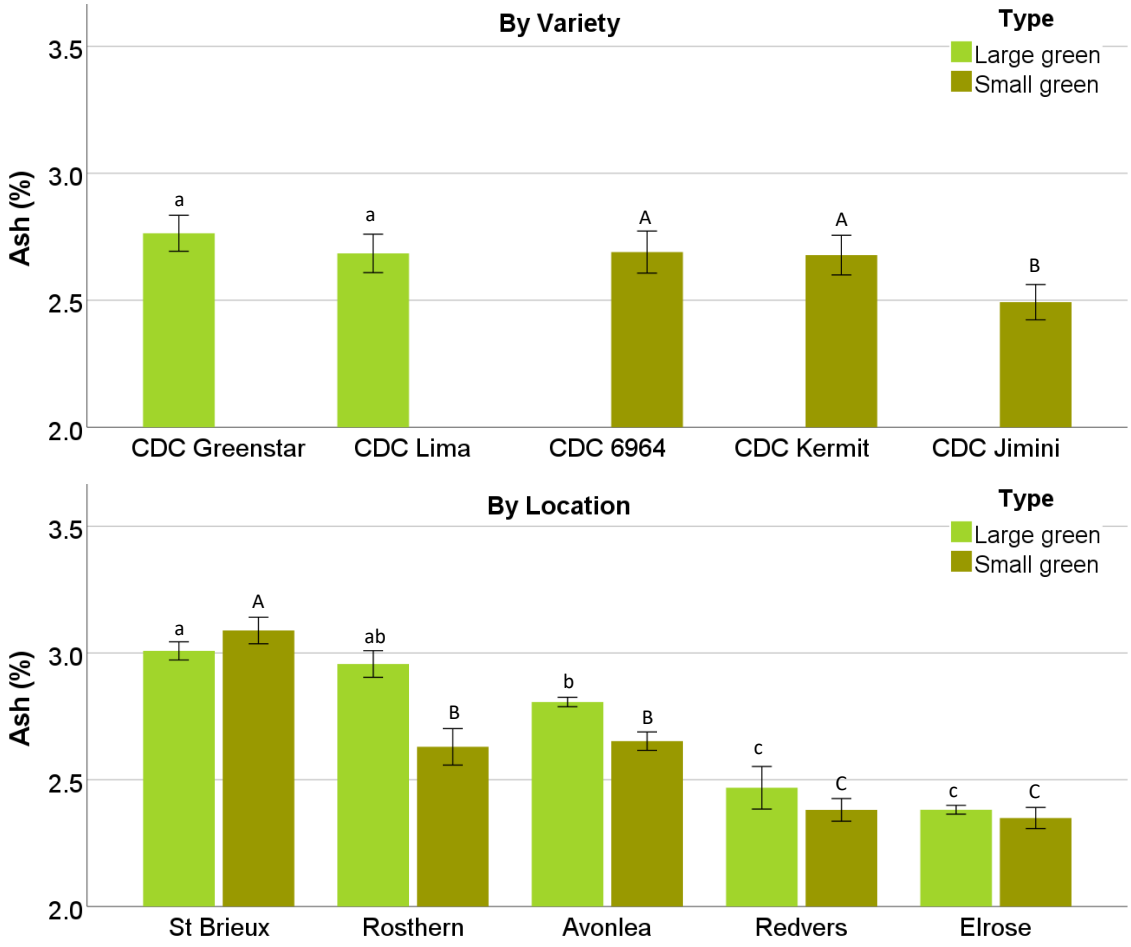
Figure 1.7.3. Mean ash of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** no difference (p>0.05).
- **Small green:** A 0.1% difference was found from highest to lowest.

- **By Location:** A 0.5% difference was found from highest (St Brieux) to lowest (Redvers and Elrose).

Table 1.7.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	***
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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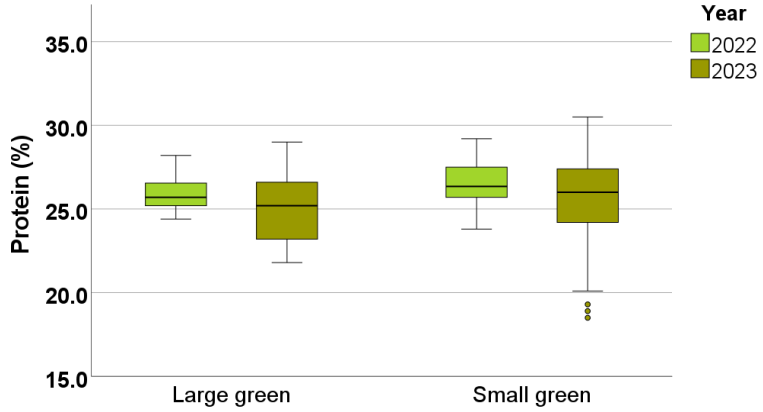
8. Protein Content

Method: The protein content (%) of each flour was determined through AACC 46-30[2] using the combustion method through a Rapid N Exceed (Elementar, USA). Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

Results: Figure 1.8.1. & **Table 1.8.1.** Protein of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

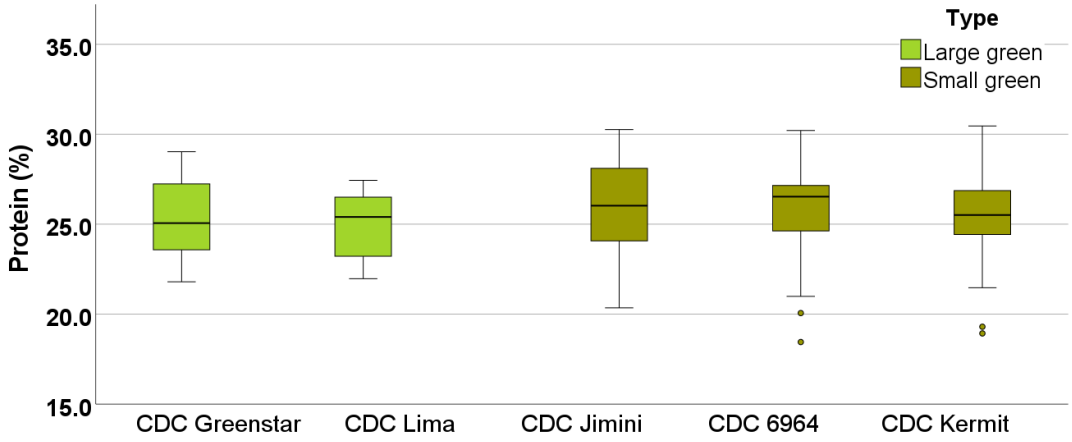


	Large green	Small green
2022	25.9 ± 0.2[a]	26.6 ± 0.2[a]
2023	25.1 ± 0.4[a]	25.5 ± 0.5[b]

Note: different small letters within a column indicate significant differences.

Large green: Larger variability was observed in 2023 samples.
Small green: The 2023 samples had a lower mean protein and greater variability.

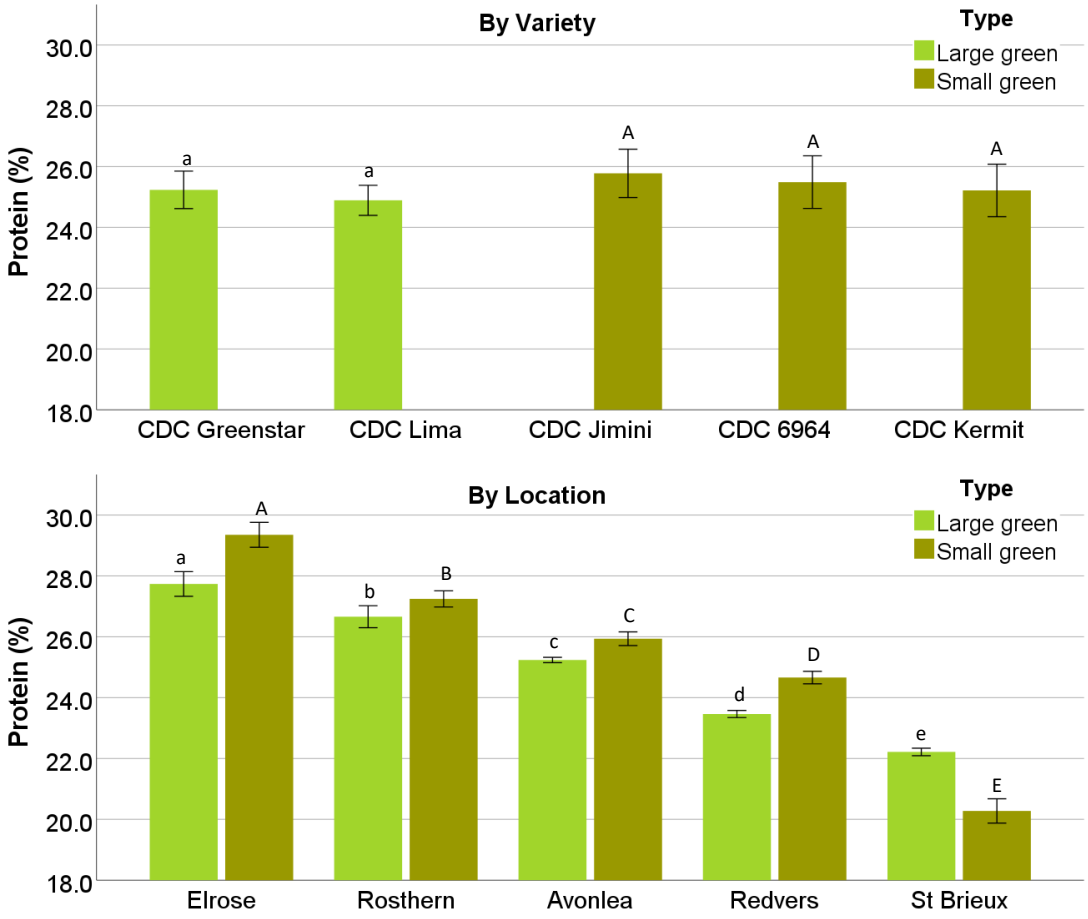
Figure 1.8.2. Box and Whisker plot of 2023 green lentils for protein content. Results by type were reported from highest to lowest.



- The small green type had greater variability than the large green.

[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 1.8.3. Mean protein of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** no statistical difference.
- **Small green:** no statistical difference.

By Location: Location effect is significant. Elrose had the highest protein for both types, while St Brieux had the lowest protein for both types.

- **Large green:** A 5.5% difference from highest to lowest.
- **Small green:** A 9% difference from highest to lowest.

Table 1.8.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	*NS*
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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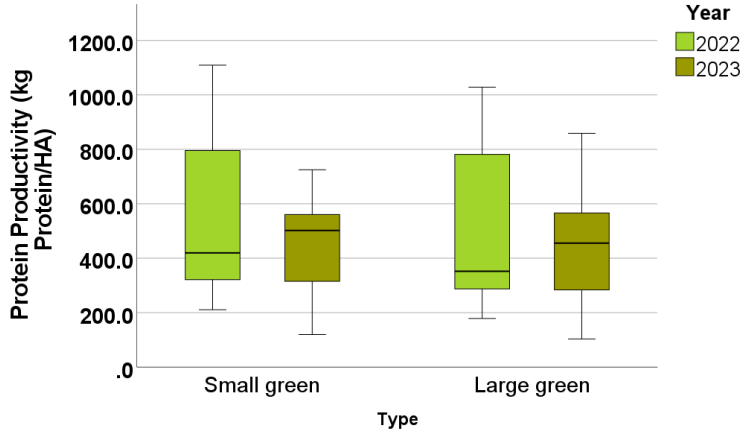
9. Protein Productivity

Method: Protein productivity (kg protein/HA), which is calculated using yield (kg/HA) multiplied by protein content (%), refers to the amount of protein produced per unit of land. It evaluates how much protein is being harvested from a given area.

Results: Figure 1.9.1. & **Table 1.9.1.** Protein productivity of green lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).



	Large green	Small green
2022	484.0 ± 43.4[a]	524.3 ± 37.0[a]
2023	449.0 ± 38.3[a]	456.1 ± 23.9[a]

Note: different small letters within a column indicate significant differences.

Large green: Mean protein productivity of both years had no differences (p>0.05).
Small green: Mean protein productivity of both years had no differences (p>0.05).

Figure 1.9.2. Box and Whisker plot of 2023 green lentils for protein productivity. Results by type were reported from highest to lowest.

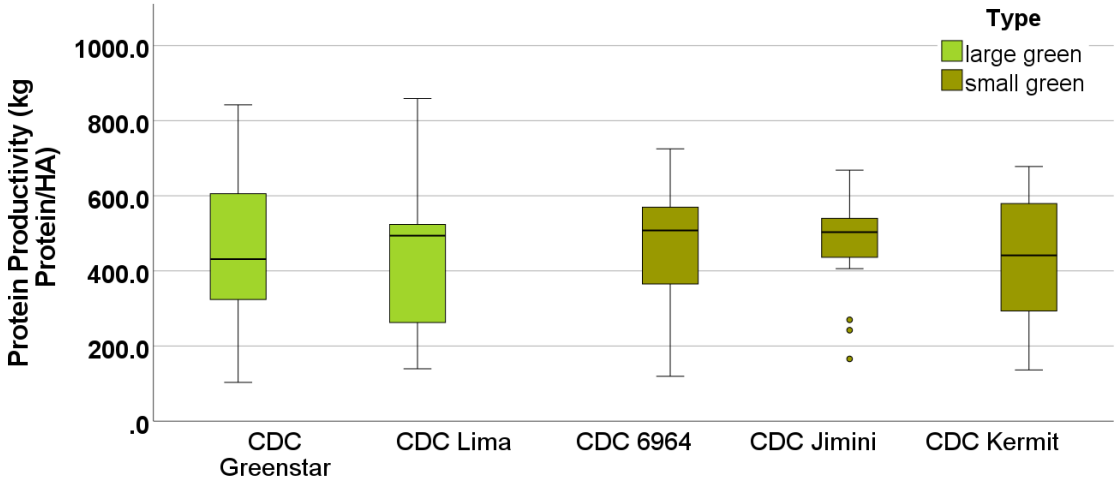
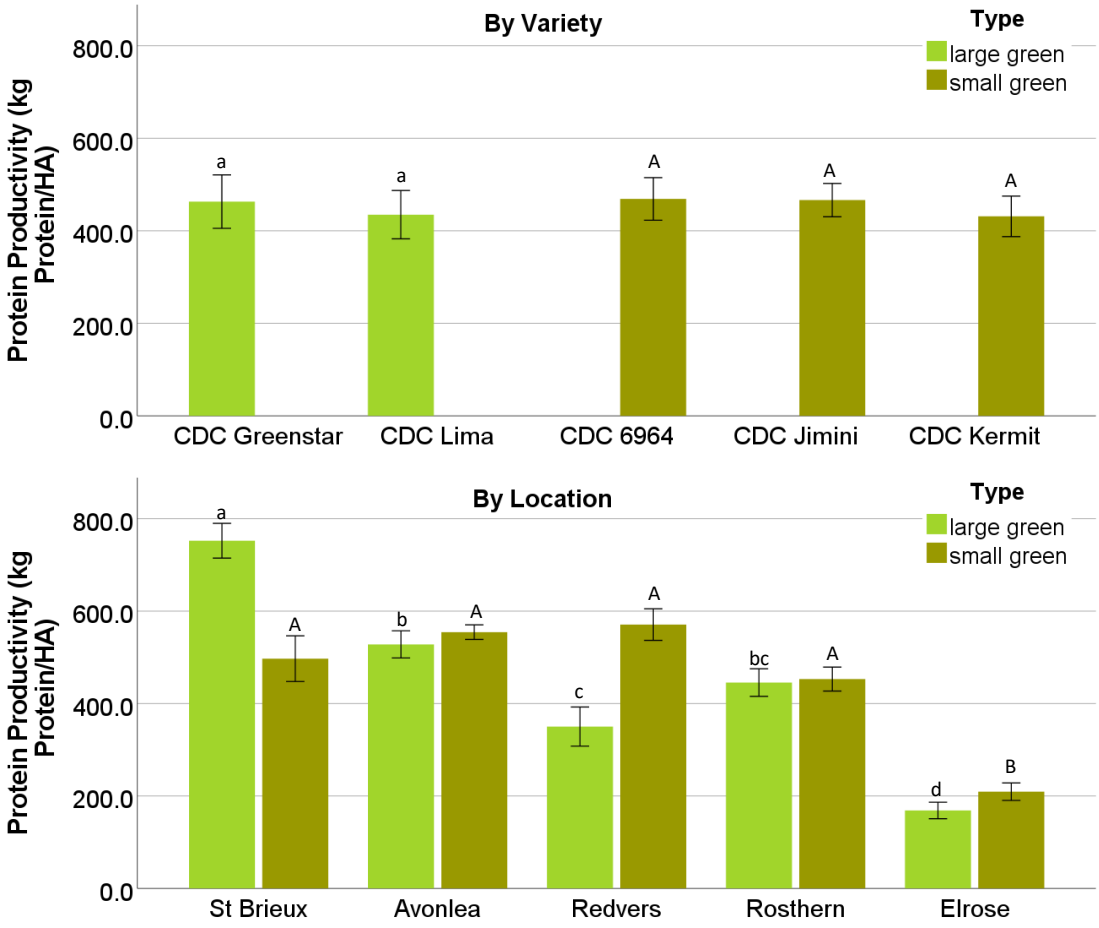


Figure 1.9.3. Mean protein productivity of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** no statistical difference.
- **Small green:** no statistical difference.

By Location: Location effect was significant.

- Although St brieux had the lowest protein content for both types, it achieved the highest protein productivity due to its highest yield.
- In contrast, Elrose had the lowest protein productivity because of its lowest yield, despite having the highest protein content for both types.

Table 1.9.2. Effects of variety and location.

	Large green	Small green
Variety	*NS*	*NS*
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant*

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10.Colour

Method: The absolute colour of each flour was determined using the Konica Minolta CR-400 Chroma meter, where *L*, a*,* and *b** values were reported. Three measurements were made for each sample, and the mean value was reported.

- ***L* (lightness):*** white (100) to black (0)
- ***a*:*** red (+) to green (-)
- ***b*:*** yellow (+) to blue (-)

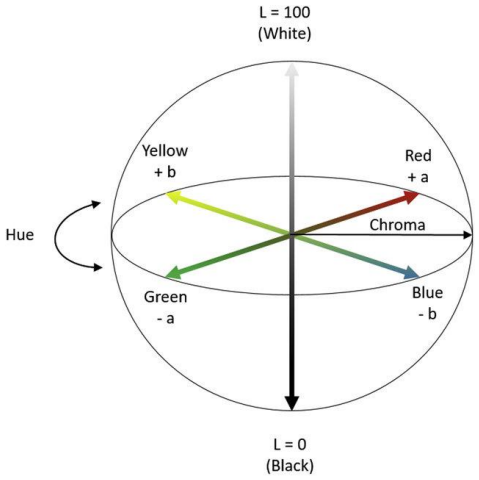
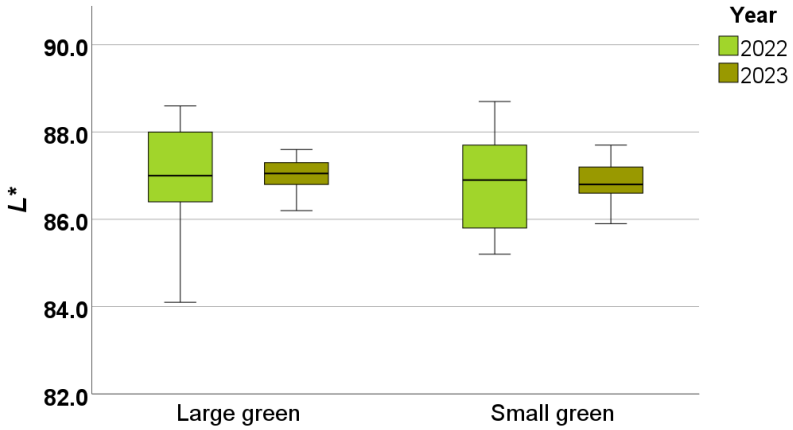


Figure 1.10.1. The CIELAB color spacediagram[3].

a) ***L* (lightness):*** white (100) to black (0)

Results: Figure 1.10.2. *L** values of green lentil flours in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).



[3] Ly, B. C. K., Dyer, E. B., Feig, J. L., Chien, A. L., & Del Bino, S. (2020). Research techniques made simple: cutaneous colorimetry: a reliable technique for objective skin color measurement. *Journal of Investigative Dermatology*, *140*(1), 3-12.

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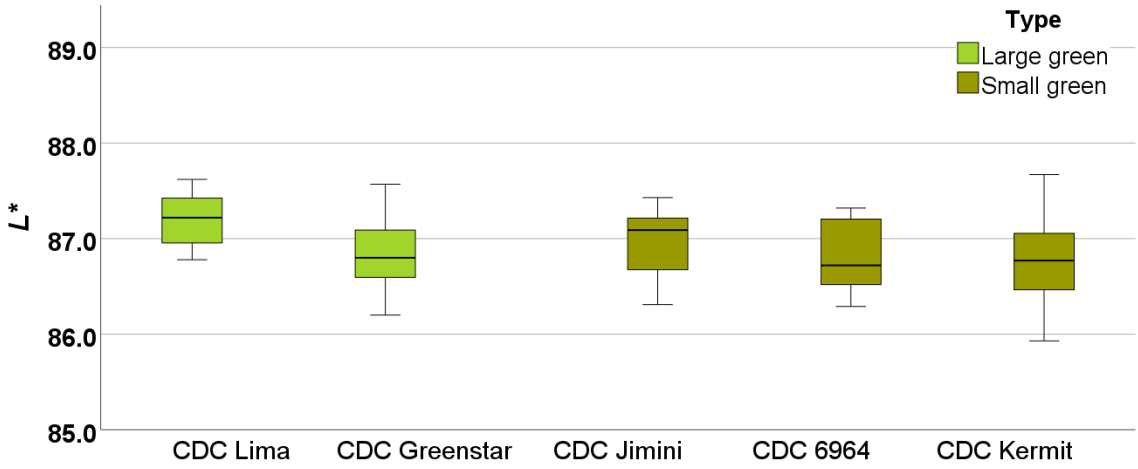
Table 1.10.1. *L** values of green lentil flours in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large green	Small green
2022	87.1 ± 0.2[a]	86.8 ± 0.1[a]
2023	87.0 ± 0.1[a]	86.8 ± 0.1[a]

Note: different small letters within a column indicate significant differences.

- No significant difference in lightness was observed in both years for both lentil types.

Figure 1.10.3. Box and Whisker plot of 2023 green lentils for *L** values. Results by type (large and small lentils) were reported from highest to lowest.



- **Large green:** CDC Lima had greater lightness and less variability.
- **Small green:** CDC Kermit had greater variability.

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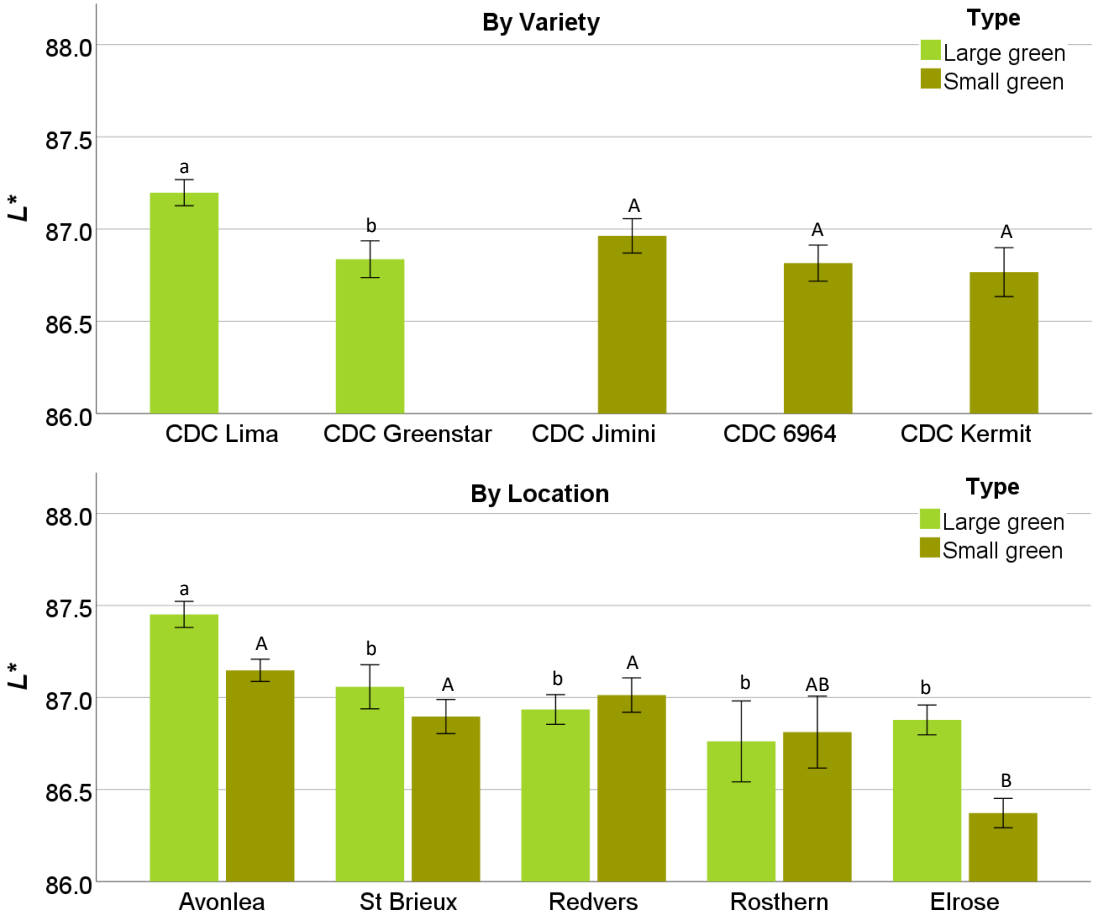
Figure 1.10.4. Mean *L** values of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** Only a 0.4-unit difference was found between 2 varieties.
- **Small green:** no statistical difference.

By Location: The mean differences of *L** values from highest to lowest were 0.7 units for both types.

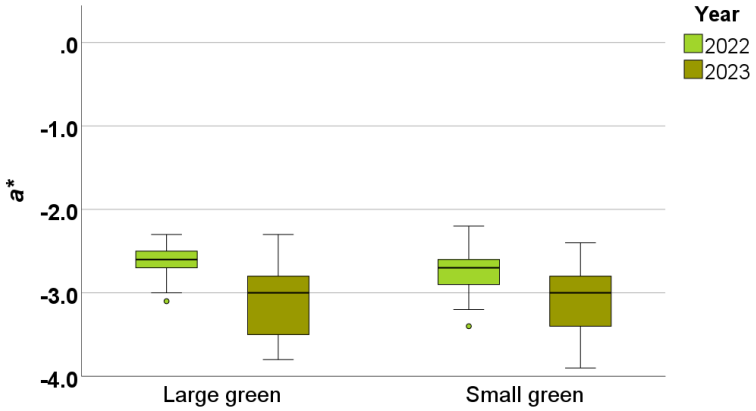
Table 1.10.2. Effects of variety and location.

	Large green	Small green
Variety	***	*NS*
Location	***	***
Variety x Location	*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

b) ***a*:*** red (+) to green (-)

Results: Figure 1.10.5. & **Table 1.10.3.** *a** values of green lentil flours in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

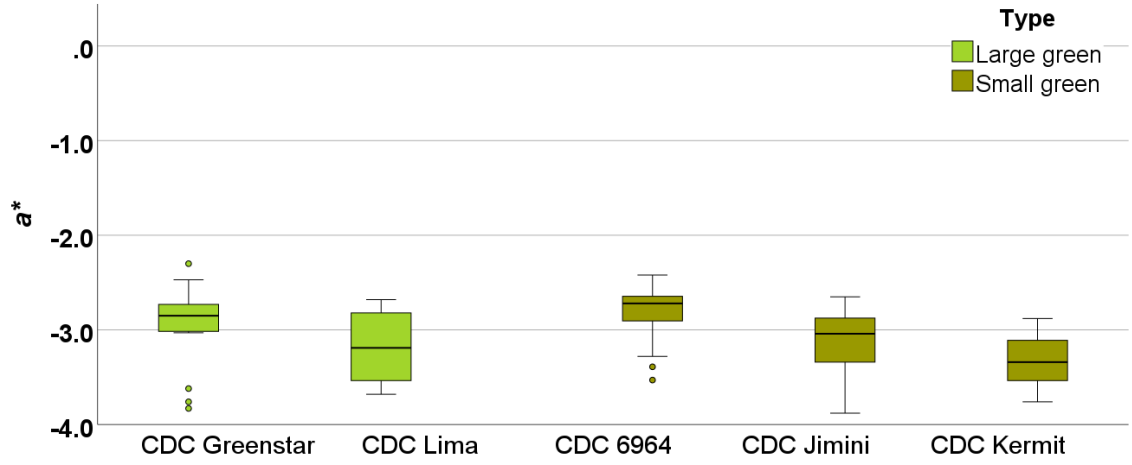


	Large green	Small green
2022	-2.6 ± 0.0[a]	-2.7 ± 0.0[a]
2023	-3.1 ± 0.1[b]	-3.1 ± 0.1[b]

Note: different small letters within a column indicate significant differences.

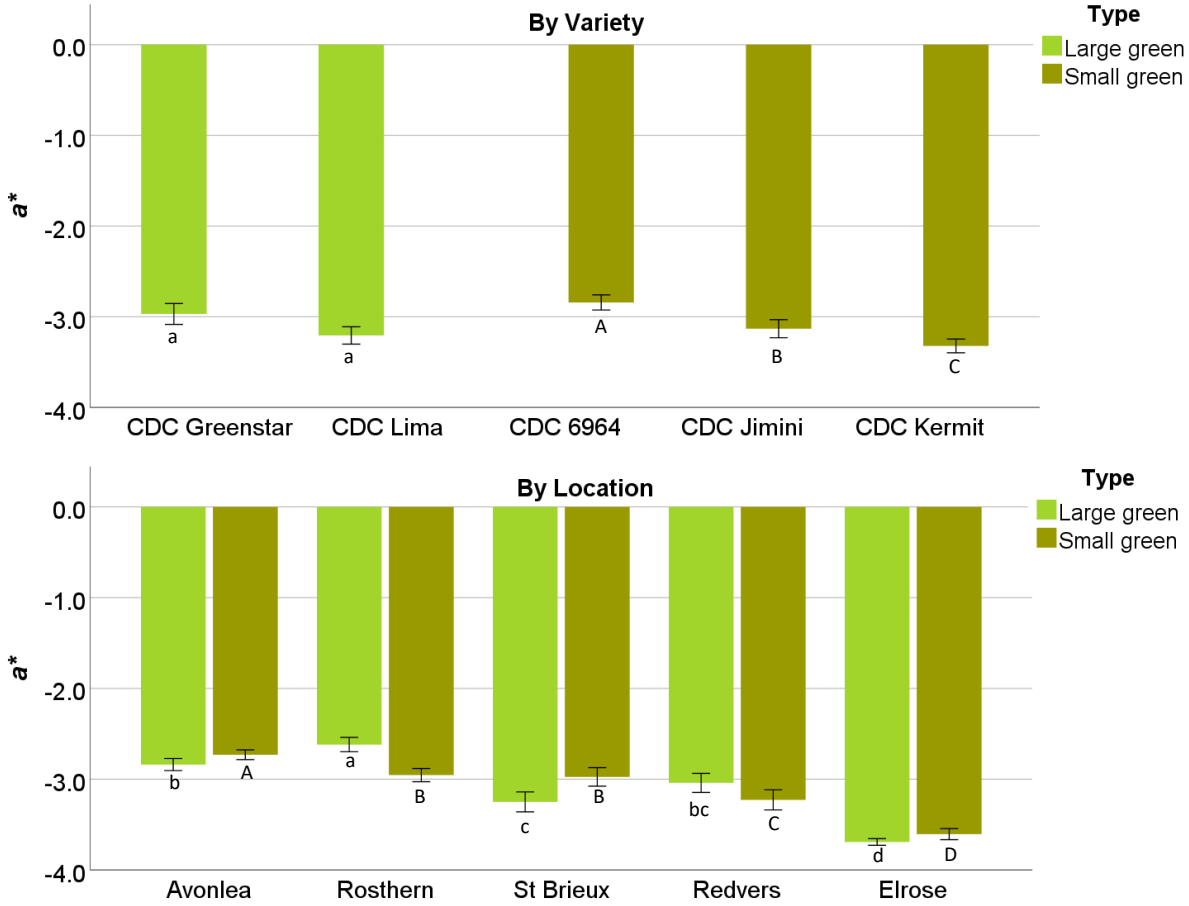
- Stronger greenness and greater variability were observed in the 2023 samples.

Figure 1.10.6. Box and Whisker plot of 2023 green lentils for *a** values. Results by type were reported from highest to lowest.



- Overall, variation was seen in each variety, and some outliers were present.

Figure 1.10.7. Mean *a** of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** no differences (p>0.05).
- **Small green:** A 0.5-unit difference was found from highest to lowest.

By Location: About a 1-unit difference was observed from highest to lowest for both types.

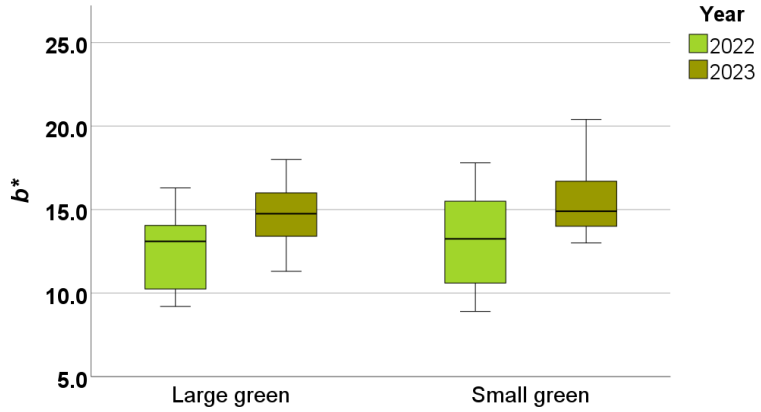
Table 1.10.4. Effects of variety and location.

	Large green	Small green
Variety	***	***
Location	***	***
Variety x Location	**	*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

c) ***b*:*** yellow (+) to blue (-)

Results: Figure 1.10.8. & **Table 1.10.5.** *b** values of green lentil flours in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

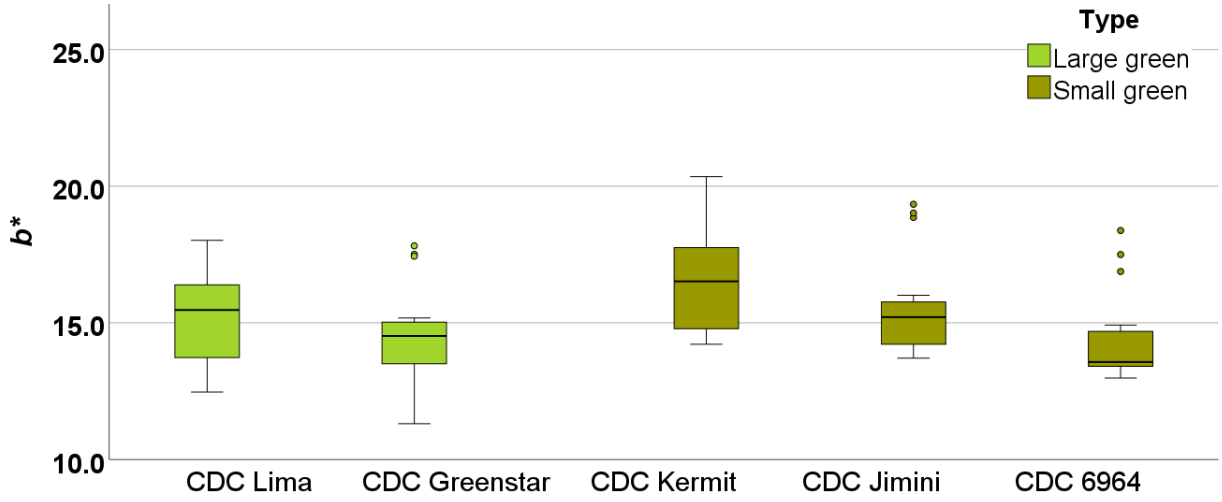


	Large green	Small green
2022	12.6 ± 0.4[b]	13.2 ± 0.4[b]
2023	14.8 ± 0.4[a]	15.6 ± 0.3[a]

Note: different small letters within a column indicate significant differences.

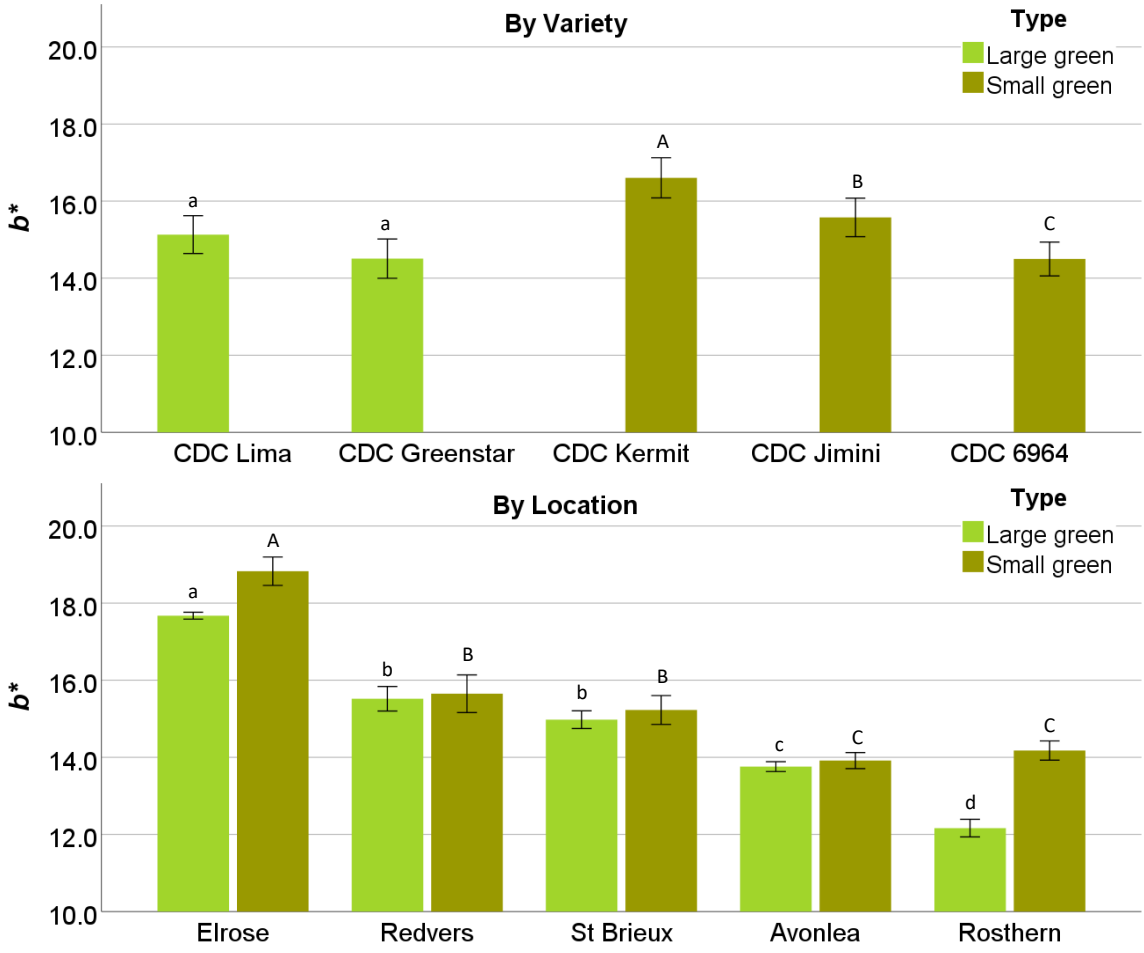
- The 2023 samples exhibited higher yellowness.

Figure 1.10.9. Box and Whisker plot of 2023 green lentils for *b** values. Results by type were reported from highest to lowest.



- Overall, variation was seen in each variety, and some outliers were present.

Figure 1.10.10. Mean *b** of 2023 green lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by large green variety. Capital letters indicated significant differences (p<0.05) by small green variety.

By Variety:

- **Large green:** not significant.
- **Small green:** A 1.6-unit difference was observed.

By Location: Location played a role on both types. A difference of over 5 units was observed from highest to lowest for both types.

Table 1.10.6. Effects of variety and location.

	Large green	Small green
Variety	***	***
Location	***	***
Variety x Location	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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2) 2023 Red Lentil Quality

1. Yield

Method: Yield refers to how much crops are produced and how efficiently land is used to produce food or agricultural commodities. The yield of each variety from each location is provided as kilogram per hectare (kg/HA).

Results: Figure 2.1.1. Box plot of yield of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

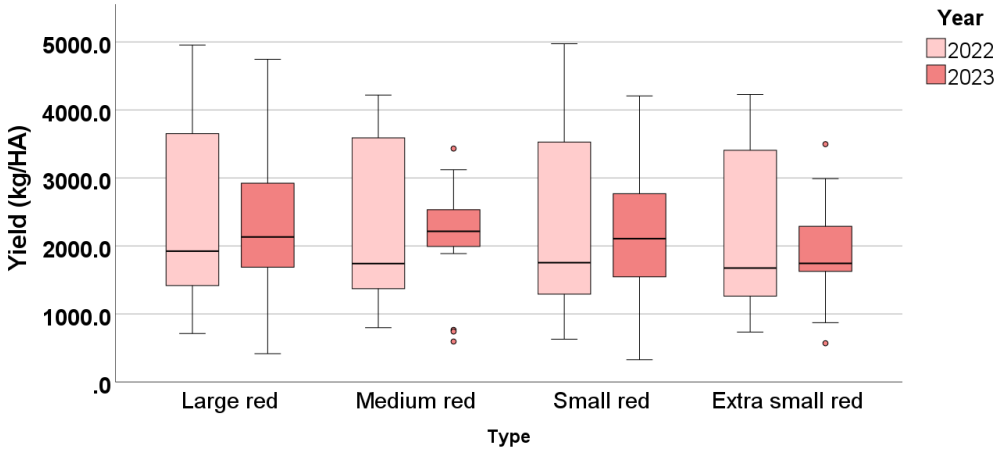


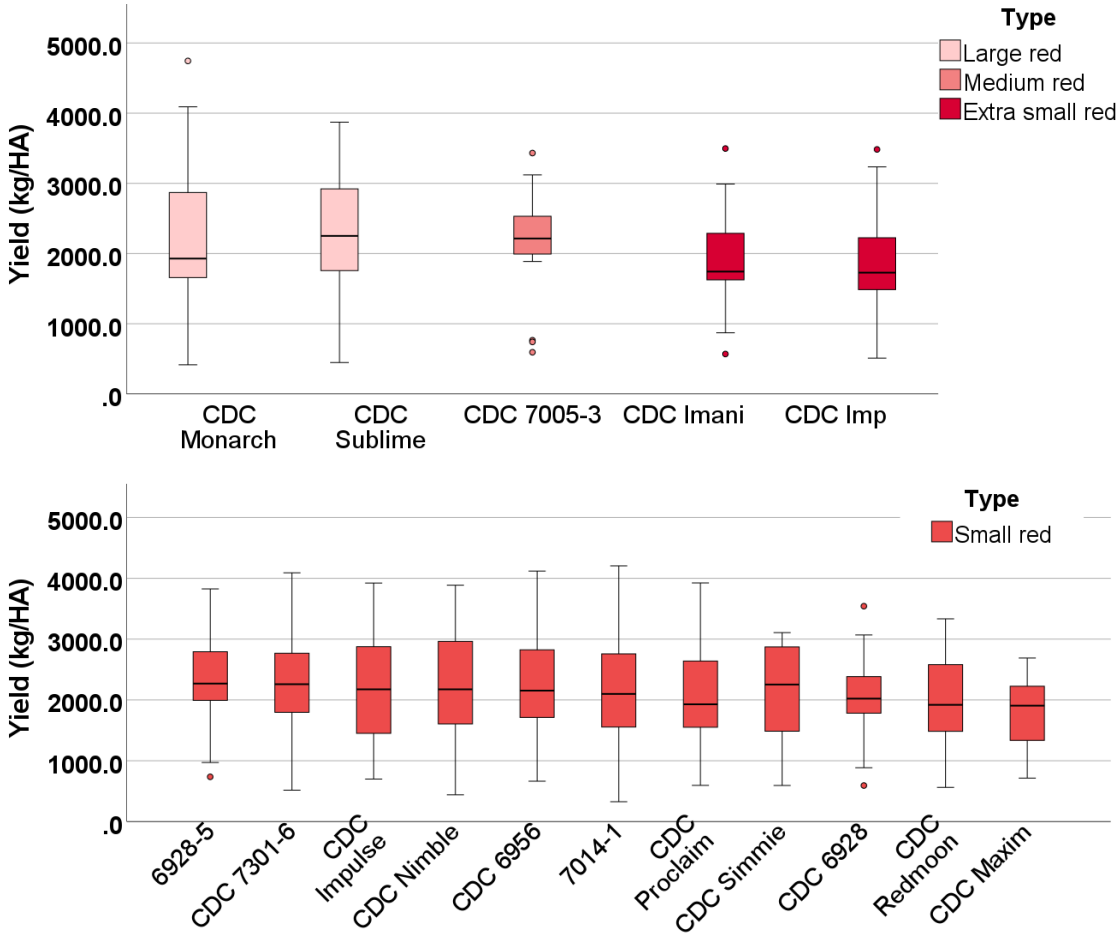
Table 2.1.1. Yield of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	2383.7 ± 221.8[a]	2207.8 ± 282.3[a]	2227.0 ± 93.2[a]	2157.0 ± 278.8[a]
2023	2226.2 ± 201.0[a]	2108.7 ± 214.1[a]	2091.8 ± 73.3[a]	1905.2 ± 213.0[a]

Note: different small letters within a column indicate significant differences.

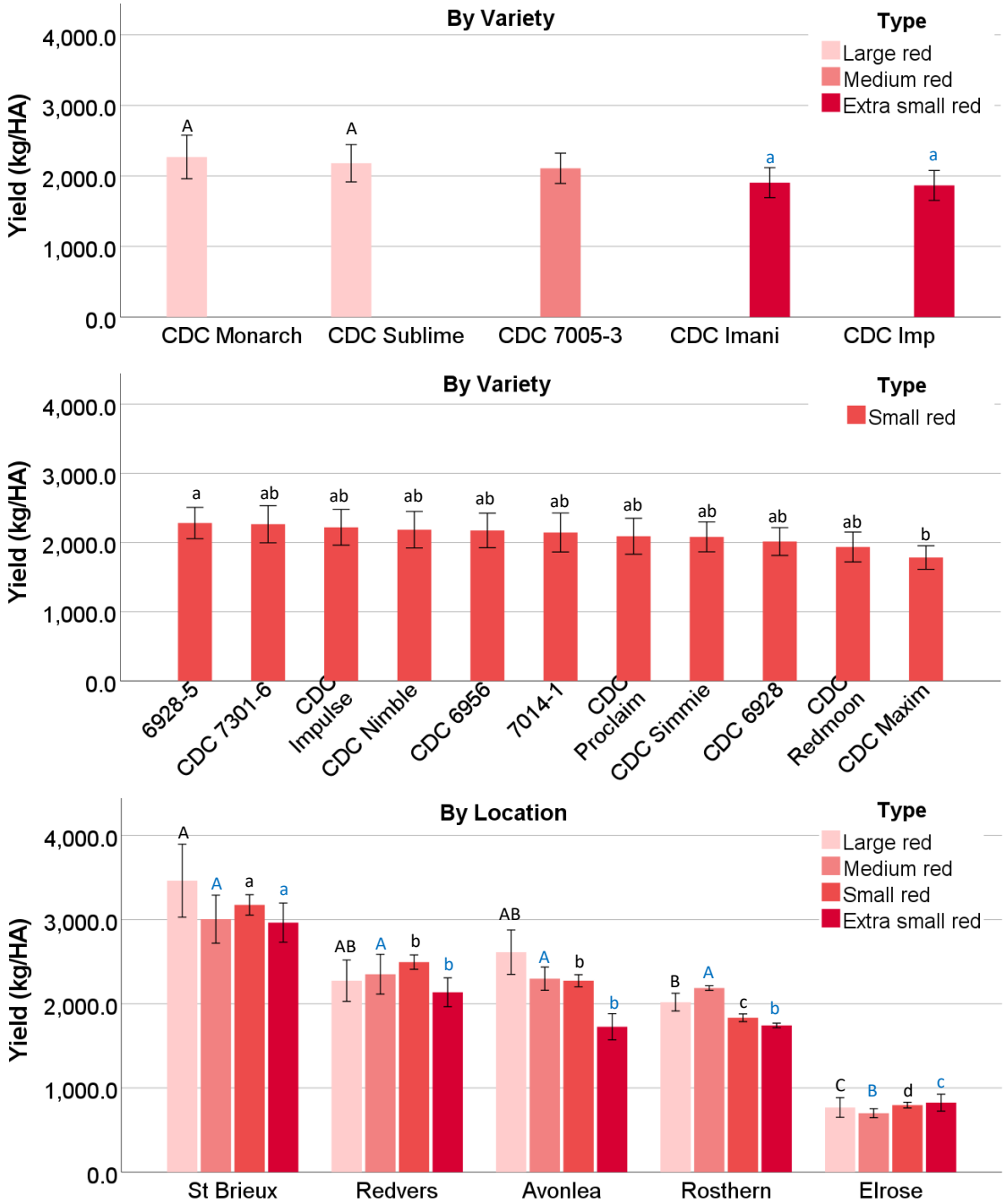
- There were no significant differences in yield between the two years for either red lentil type.

Figure 2.1.2 Box and Whisker plot of 2023 red lentils for yield. Results by type were reported from highest to lowest.



- **Large red:** Both varieties had large variability.
- **Medium red:** A few outliners were observed.
- **Small red:** CDC Maxim had the lowest yield.
- **Extra small red:** Both varieties were similar.

Figure 2.1.3. Mean yield of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No statistical difference.
- **Medium red:** Mean was just above 2000 kg/HA.
- **Small red:** Line 6928-5 was 500 kg/HA higher than CDC Maxim.
- **Extra small red:** No statistical difference.

By Location: Yield was highest in St Brieux. Redvers, Avonlea, and Rosthern were similar. Elrose was the lowest.

- **Large red:** The yield in St. Brieux was more than four times that of Elrose.
- **Medium red:** The yield in St. Brieux was more than four times that of Elrose.
- **Small red:** The yield in St. Brieux was more than four times that of Elrose.
- **Extra small red:** The yield in St. Brieux was almost four times that of Elrose.

Table 2.1.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	*	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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2. Thousand Kernel Weight

Method: Seed weight is an important parameter to indicate seed size and yield production. This test was conducted by weighing 300 seeds with duplicated measurements per sample, and the thousand kernel weight (TKW) was reported.

Results: Figure 2.2.1. Box plot of TKW of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

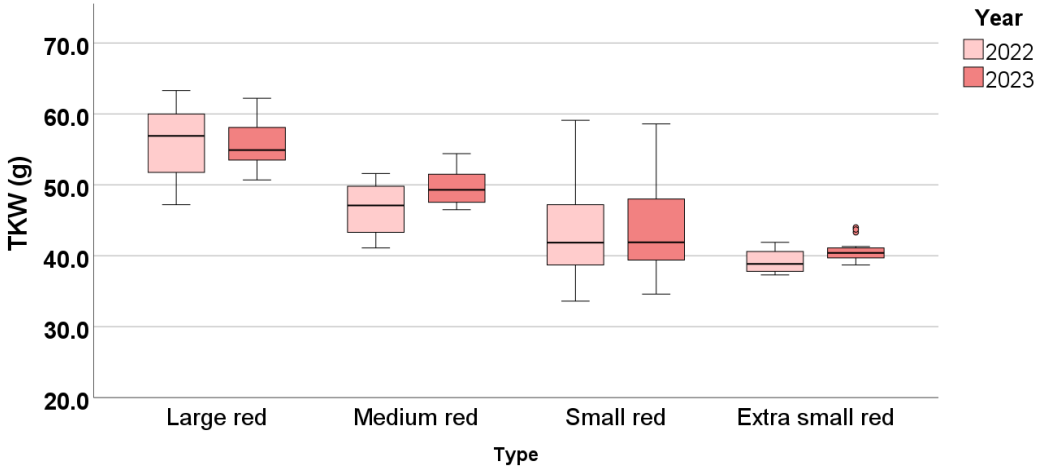


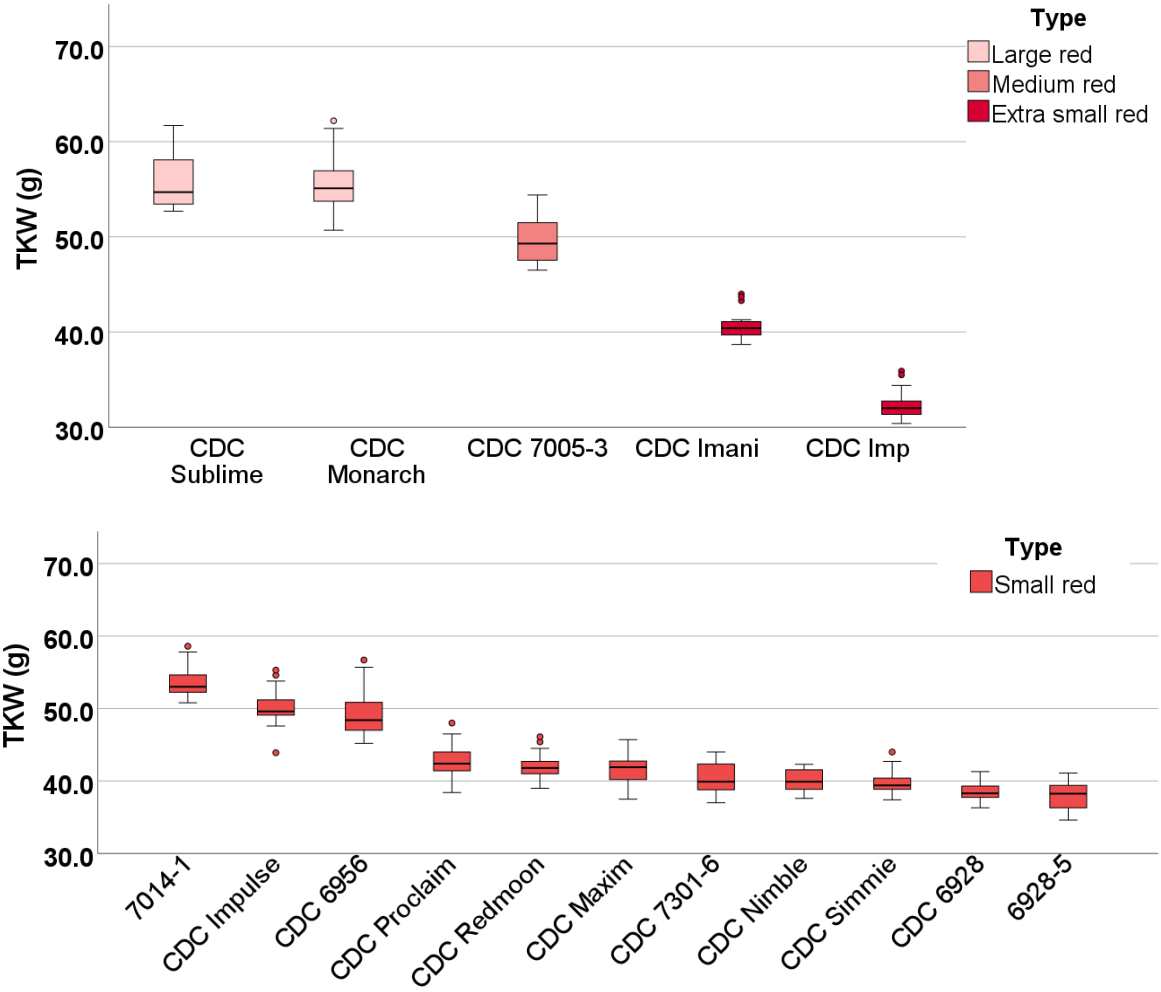
Table 2.2.1. TKW of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	55.9 ± 0.8[a]	46.5 ± 0.8[b]	43.3 ± 0.5[a]	39.2 ± 0.4[b]
2023	55.8 ± 0.6[a]	49.7 ± 0.7[a]	43.7 ± 0.5[a]	40.8 ± 0.4[a]

Note: different small letters within a column indicate significant differences.

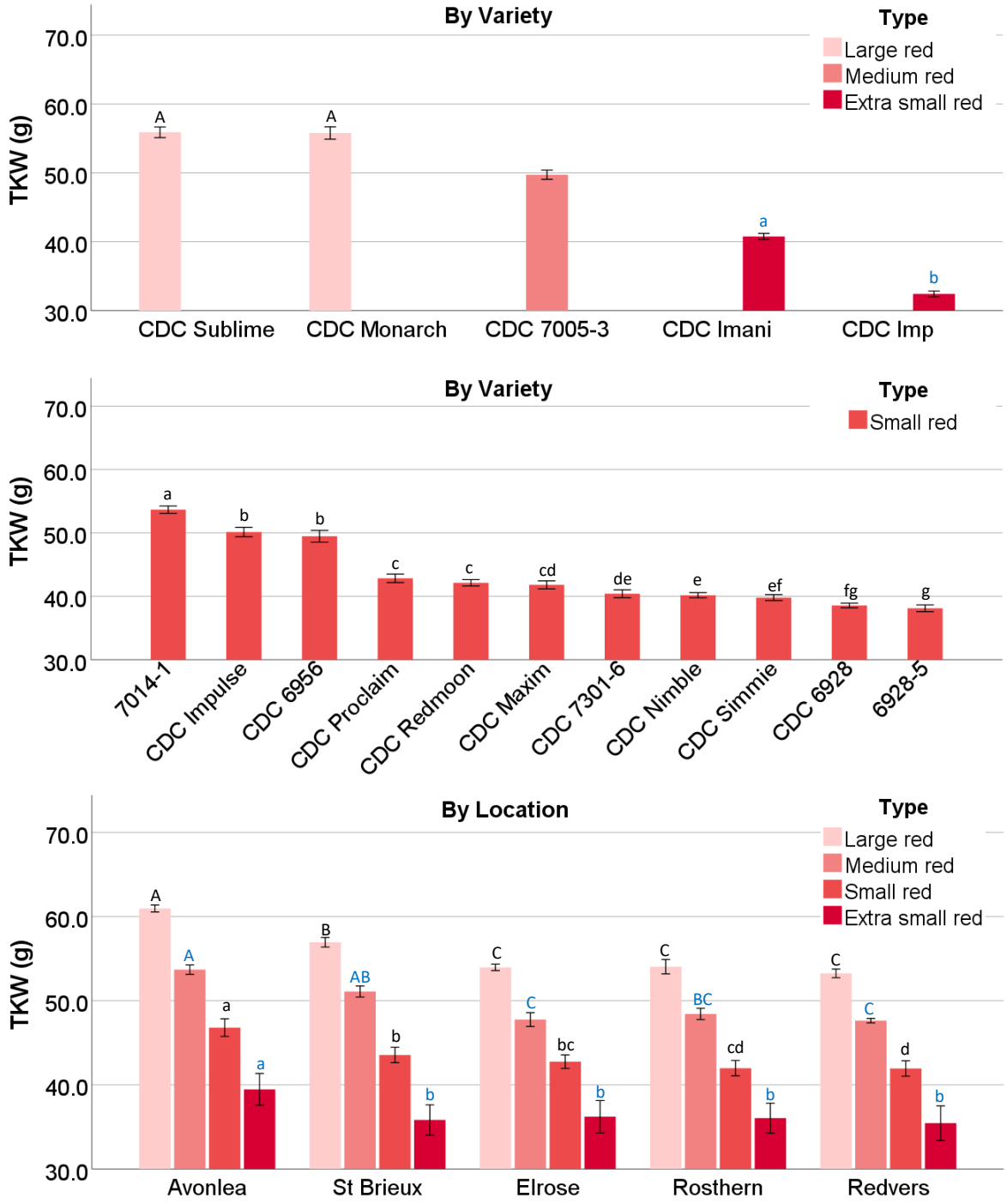
Large red: Mean had no difference.
Medium red: TKW of 2023 was 3 g higher.
Small red: Mean had no difference.
Extra small red: TKW of 2023 was 1.6 g higher.

Figure 2.2.2 Box and Whisker plot of 2023 red lentils for TKW. Results by type were reported from highest to lowest.



- **Large red:** CDC Monarch had greater variability.
- **Medium red:** Results ranged from 45 g to 55 g.
- **Small red:** Line 7014-1 was the largest. CDC 6956 and CDC Impulse were similar and larger than the other 8 varieties.
- **Extra small red:** CDC Imp was much smaller.

Figure 2.2.3. Mean TKW of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No statistical difference.
- **Medium red:** Mean was 50 g.
- **Small red:** Line 7014-1 (largest) was over 15 g larger than line 6928-5 (smallest).
- **Extra small red:** CDC Imani was 8 g higher than Imp.

By Location: TKW was highest in Avonlea, followed by St Brieux for all types. Redvers was the lowest.

- **Large red:** Avonlea was 7 g higher than Redvers.
- **Medium red:** Avonlea was 6 g higher than St Brieux.
- **Small red:** Avonlea was 5 g higher than St Brieux.
- **Extra small red:** Avonlea was 4 g higher than St Brieux.

Table 2.2.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	***
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	***	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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3. Seed Size Distribution

Method: 250 g of seeds were placed on a series of round-hole opening sieves. The weight of seeds retained on each sieve was determined and reported as % of seeds retained. Duplicated measurements were performed.

Sieves used for lentils:

a. #16R: 6.35 mm
b. #14R: 5.56 mm
c. #12R: 4.76 mm
d. #10R: 3.97 mm

Results: Table 2.3. Seed size distribution (%) of each 2023 red lentil variety. Data represent mean ± one standard deviation.

Type	Variety	> 6.35 mm (%)	> 5.56 mm (%)	> 4.76 mm (%)	> 3.97 mm (%)	Below 3.97 mm (%)
Large red	CDC Sublime	3.4 ± 1.8^{a}	66.1 ± 11.1^{a}	26.5 ± 9.8^{b}	2.6 ± 2.1^{a}	1.3 ± 1.0^{a}
	CDC Monarch	0.8 ± 0.9^{b}	62.1 ± 9.4^{a}	33.6 ± 7.7^{a}	2.5 ± 1.9^{a}	0.9 ± 0.4^{a}
Medium red	CDC 7005-3	0.0 ± 0.0	15.9 ± 6.0	71.7 ± 3.6	11.1 ± 5.6	1.3 ± 0.7
Small red	7014-1	0.3 ± 0.3^{b}	51.3 ± 12.1^{a}	44.6 ± 10.4^{e}	2.8 ± 2.2^{g}	1.0 ± 0.7^{e}
	CDC Impulse	0.4 ± 0.3^{a}	48.1 ± 6.8^{b}	46.3 ± 4.3^{e}	4.2 ± 2.4^{g}	1.0 ± 0.6^{e}
	CDC 6956	0.0 ± 0.0^{c}	14.6 ± 5.8^{c}	70.7 ± 7.0^{bc}	11.9 ± 6.6^{f}	1.4 ± 0.8^{de}
	CDC Maxim	0.0 ± 0.0^{c}	4.1 ± 2.0^{d}	74.0 ± 4.0^{ab}	20.3 ± 5.1^{de}	1.6 ± 0.6^{cd}
	CDC 7301-6	0.0 ± 0.1^{c}	3.3 ± 1.7^{de}	71.8 ± 7.6^{bc}	23.1 ± 7.8^{d}	1.7 ± 0.9^{cd}
	CDC 6928	0.0 ± 0.0^{c}	3.0 ± 1.4^{de}	60.6 ± 4.4^{d}	33.3 ± 4.8^{ab}	3.1 ± 0.8^{a}
	CDC Proclaim	0.0 ± 0.0^{c}	2.0 ± 1.4^{de}	78.0 ± 4.7^{a}	18.5 ± 4.4^{e}	1.5 ± 0.8^{d}
	CDC Simmie	0.0 ± 0.0^{c}	1.3 ± 1.1^{de}	69.1 ± 5.8^{c}	27.6 ± 6.1^{c}	2.0 ± 1.1^{bc}
	6928-5	0.0 ± 0.0^{c}	1.3 ± 0.6^{de}	60.1 ± 3.8^{d}	36.2 ± 3.4^{a}	2.3 ± 0.9^{b}
	CDC Nimble	0.0 ± 0.0^{c}	0.8 ± 0.5^{e}	64.1 ± 5.7^{d}	32.3 ± 5.0^{b}	2.9 ± 1.5^{a}
	CDC Redmoon	0.0 ± 0.0^{c}	0.9 ± 0.8^{e}	62.9 ± 6.5^{d}	34.0 ± 6.7^{ab}	2.2 ± 1.1^{b}
Extra Sm red	CDC Imani	0.0 ± 0.0^{a}	0.7 ± 1.1^{a}	61.4 ± 3.7^{a}	35.9 ± 3.2^{b}	2.0 ± 0.9^{b}
	CDC Imp	0.0 ± 0.0^{a}	0.0 ± 0.0^{b}	20.8 ± 7.1^{b}	72.3 ± 6.4^{a}	6.8 ± 3.0^{a}

Note: Different small letters within each type in a column indicated significant differences (p<0.05).

- Seed size results corresponded to the TKW results.

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4. Peeled + Split + Broken

Method: 50 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Results included splits, cracks, seed coat damage, partially missing hull, and partially missing cotyledon.

Results: Figure 2.4.1. Box plot of the peeled + split + broken red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

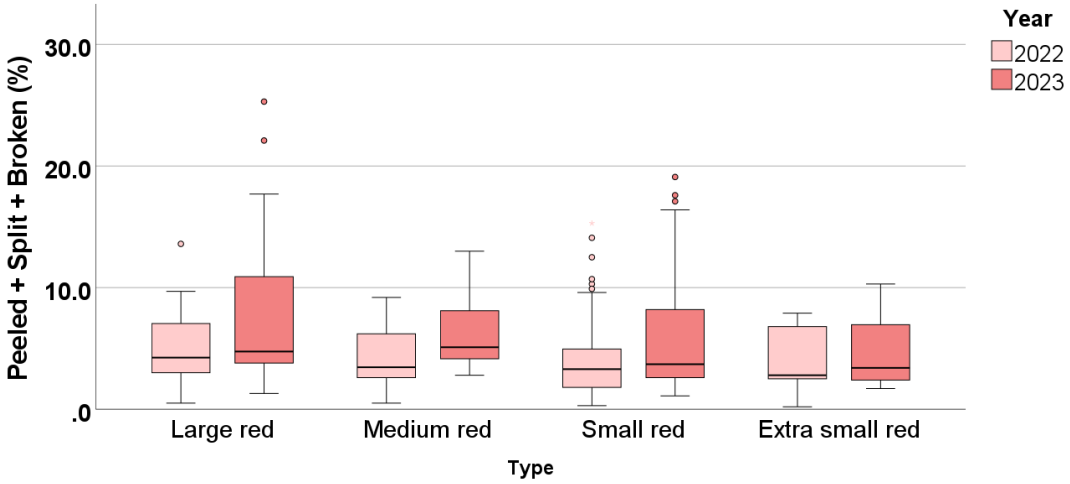


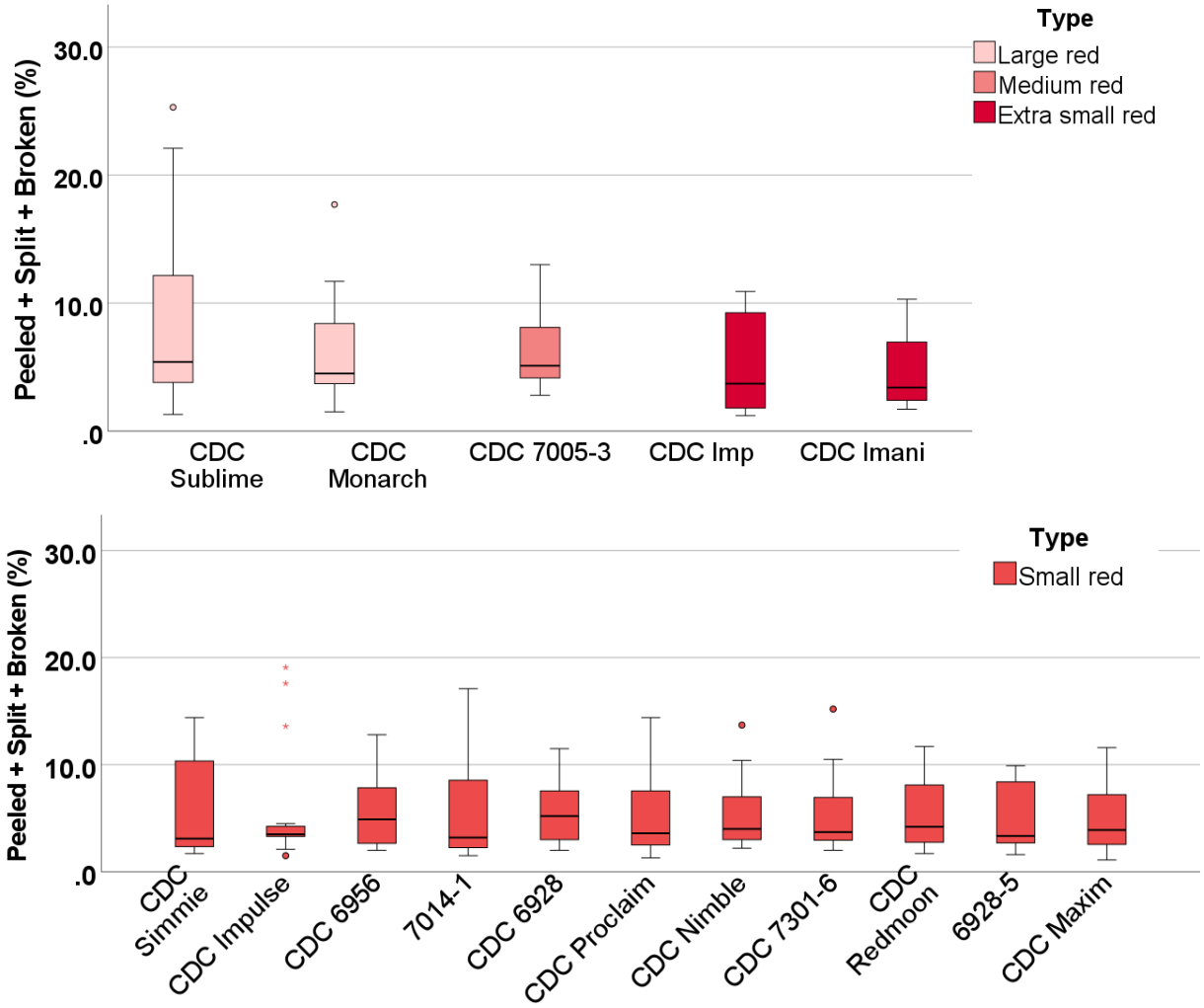
Table 2.4.1. Peeled + split + broken red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	4.8 ± 0.5[b]	4.2 ± 0.6[b]	3.8 ± 0.2[b]	4.0 ± 0.6[a]
2023	7.5 ± 1.1[a]	6.5 ± 0.9[a]	5.6 ± 0.3[a]	4.6 ± 0.7[a]

Note: different small letters within a column indicate significant differences.

- Overall, there were more split seeds ($p<0.05$) in 2023.

Figure 2.4.2. Box and Whisker plot of the peeled + split + broken red lentils in 2023. Results by type were reported from highest to lowest.



- **Large red:** CDC Sublime had greater variability.
- **Small red:** Some outliers were observed.
- **Extra small red:** CDC Imp had greater variability.

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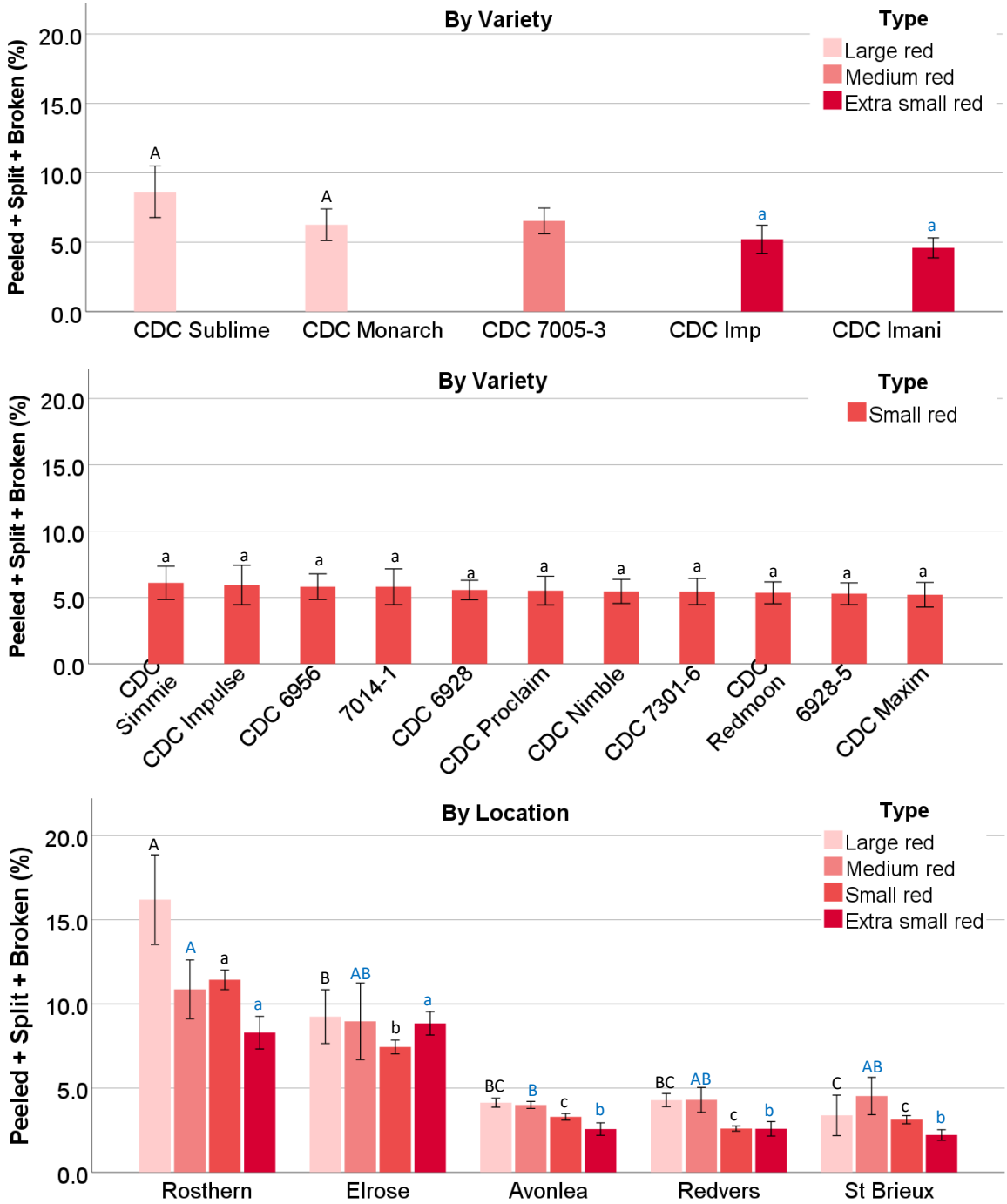
Figure 2.4.3. Mean peeled + split + broken (%) of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety: No statistical difference (p>0.05) in split was observed within each type.

By Location: The amount of peeled + split + broken lentils was extremely high in Rosthern and Elrose for all types. In contrast, low damage was observed in seeds harvested in other locations, where post-harvest processing may play a role.

Table 2.4.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	*NS*	*NS*
Location	***	*	***	***
Variety x Location	*NS*	*n.a.*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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5. Other Damage

Method: 50 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included wrinkles, sprouting, distinct immaturity, distinct deterioration or discolouration by weather or disease, insect damage, heat damage, and any other damage that affects appearance.

Results: Figure 2.5.1. Box plot of other damage of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

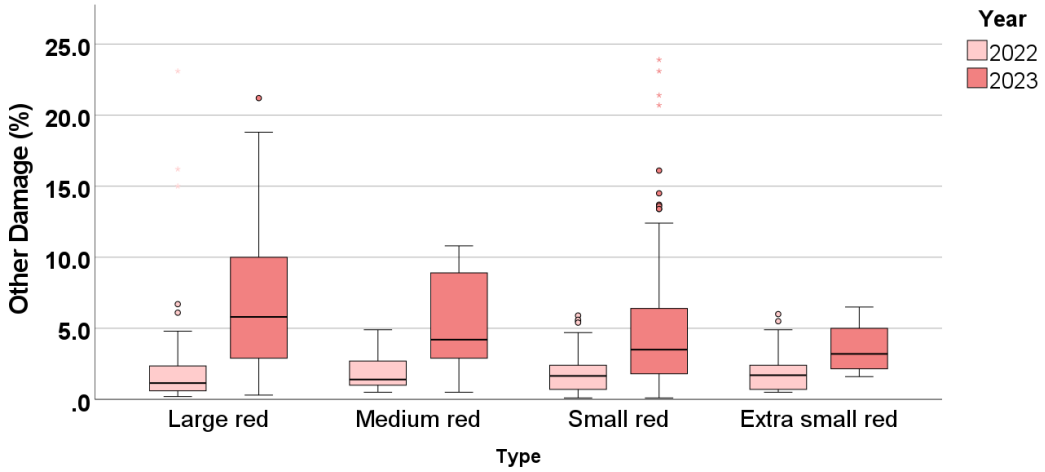


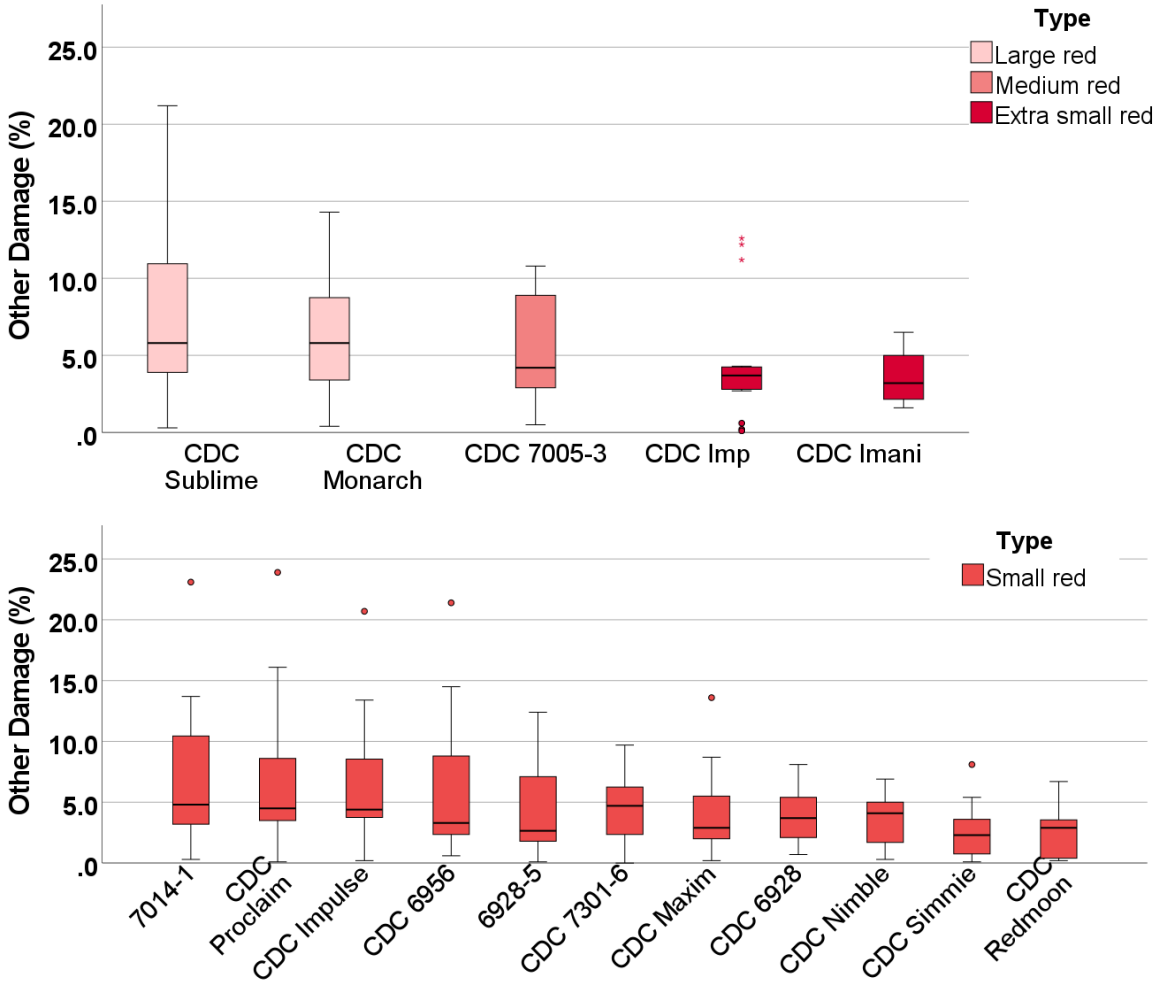
Table 2.5.1. Other damage of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	3.0± 0.8[b]	2.0 ± 0.3[b]	1.8 ± 0.1[b]	2.0 ± 0.4[b]
2023	7.0± 1.0[a]	5.3 ± 0.9[a]	4.8 ± 0.4[a]	3.6 ± 0.4[a]

Note: different small letters within a column indicate significant differences.

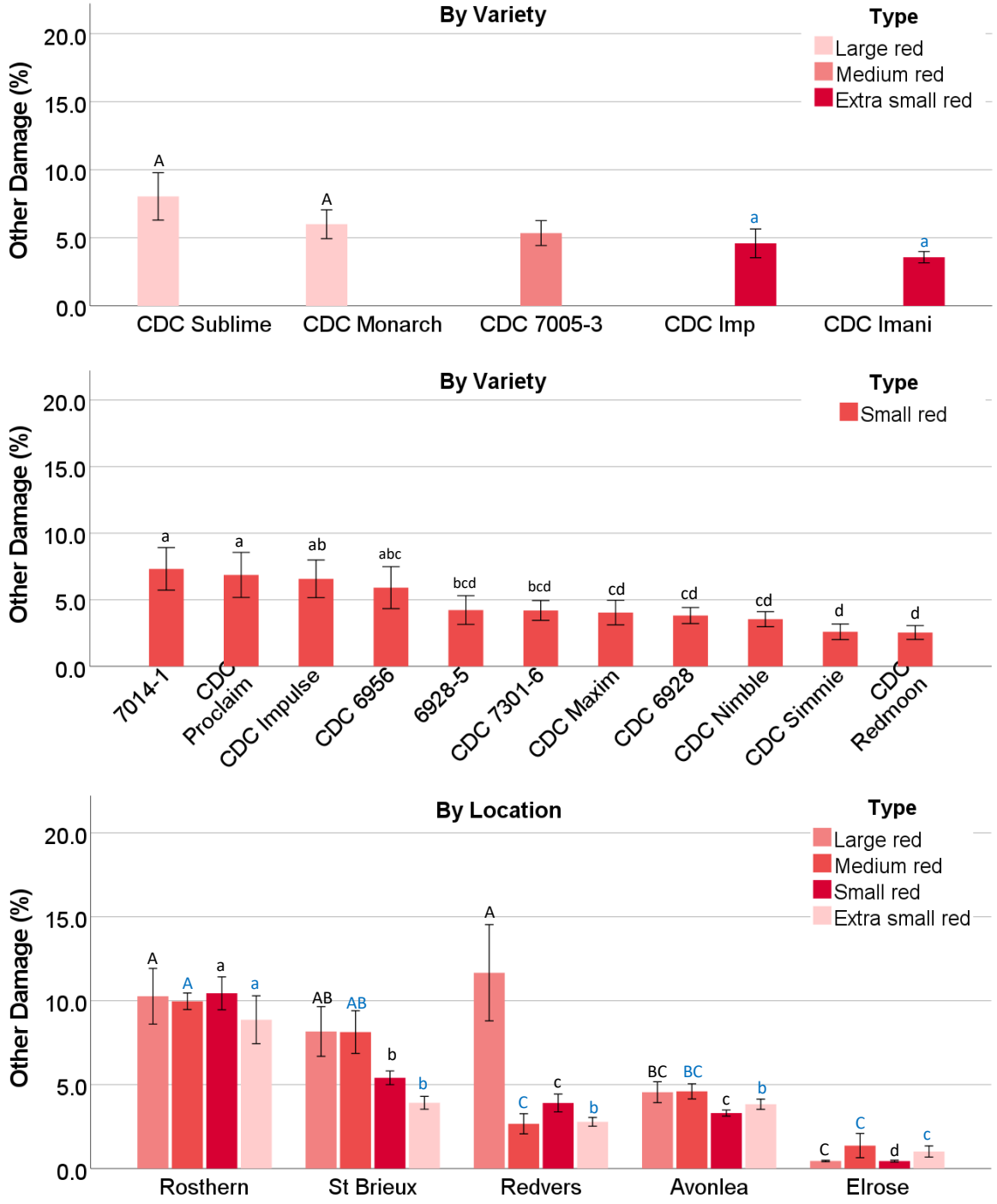
- Overall, other damage results were high in 2023, with a high number of wrinkled seeds observed (data not shown).

Figure 2.5.2. Box and Whisker plot of 2023 red lentils for other damage. Results by type were reported from highest to lowest.



- **Large red:** CDC Monarch was smaller with less variability.
- **Small red:** CDC Redmoon and CDC Simmie had less other damage.
- **Extra small red:** Extreme outliers were observed in CDC Imp.

Figure 2.5.3. Mean other damage of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** CDC Monarch was 2% lower than CDC Sublime.
- **Medium red:** Mean was 5%.
- **Small red:** About a 5% difference was observed from highest (7014-1, CDC Proclaim) to lowest (CDC Simmie, Redmoon).
- **Extra small red:** No statistical difference.

By Location: Elrose had the lowest other damage for all seed types.

- **Large red:** Other damage was extremely high in Redvers, Rosthern, and St Brieux. Other damage in Redvers and Rosthern was 20 times higher than Elrose.
- **Medium red:** Rosthern had the highest other damage.
- **Small red:** Other damage in Rosthern was 20 times higher than Elrose.
- **Extra small red:** Rosthern was 8 times higher than Elrose.

Table 2.5.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	***	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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6. Hardness of Whole Seed

Method: Seed hardness is an important parameter to indicate milling yield and cooking quality. Seed hardness is affected by seed size, shape, density, composition, etc. Seed hardness was determined by measuring the force of breaking a seed using a texture analyzer (TMS-Pro, Food Technology Corporation, USA). The detailed procedure is outlined in the hardness section for green lentils (pg. 15).

Results: Figure 2.6.1. Box plot of hardness of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

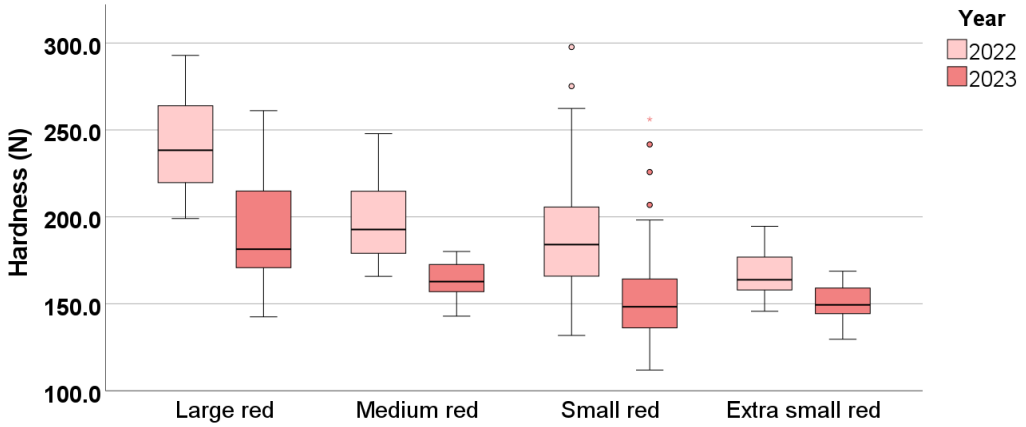


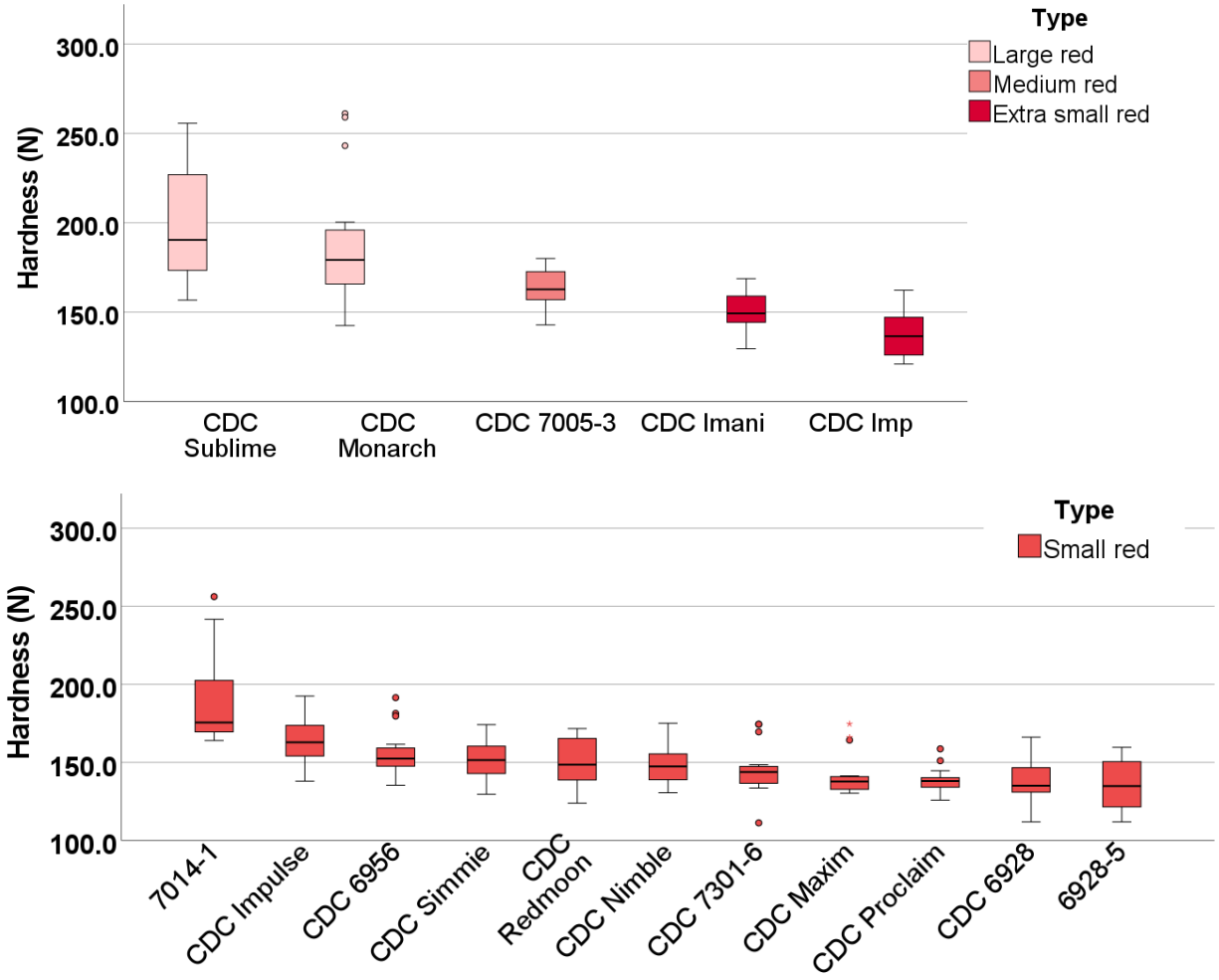
Table 2.6.1. Hardness of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	244.1 ± 4.4[a]	194.9 ± 5.3[a]	187.1 ± 2.2[a]	167.2 ± 3.2[a]
2023	194.5 ± 6.5[b]	164.2 ± 2.7[b]	151.7 ± 1.8[b]	150.7 ± 3.0[b]

Note: different small letters within a column indicate significant differences.

- The hardness of 2022 seeds was higher than the 2023 seeds.

Figure 2.6.2. Box and Whisker plot of 2023 red lentils for seed. Results by type were reported from highest to lowest.



- **Large red:** CDC Monarch was smaller but had some outliers.
- **Medium red:** Mean was between that of large and extra small types.
- **Small red:** Line 7014-1 was the largest, followed by CDC Impulse. Other varieties had the medium values close to or below 150 N.
- **Extra small red:** CDC Imp was smaller.

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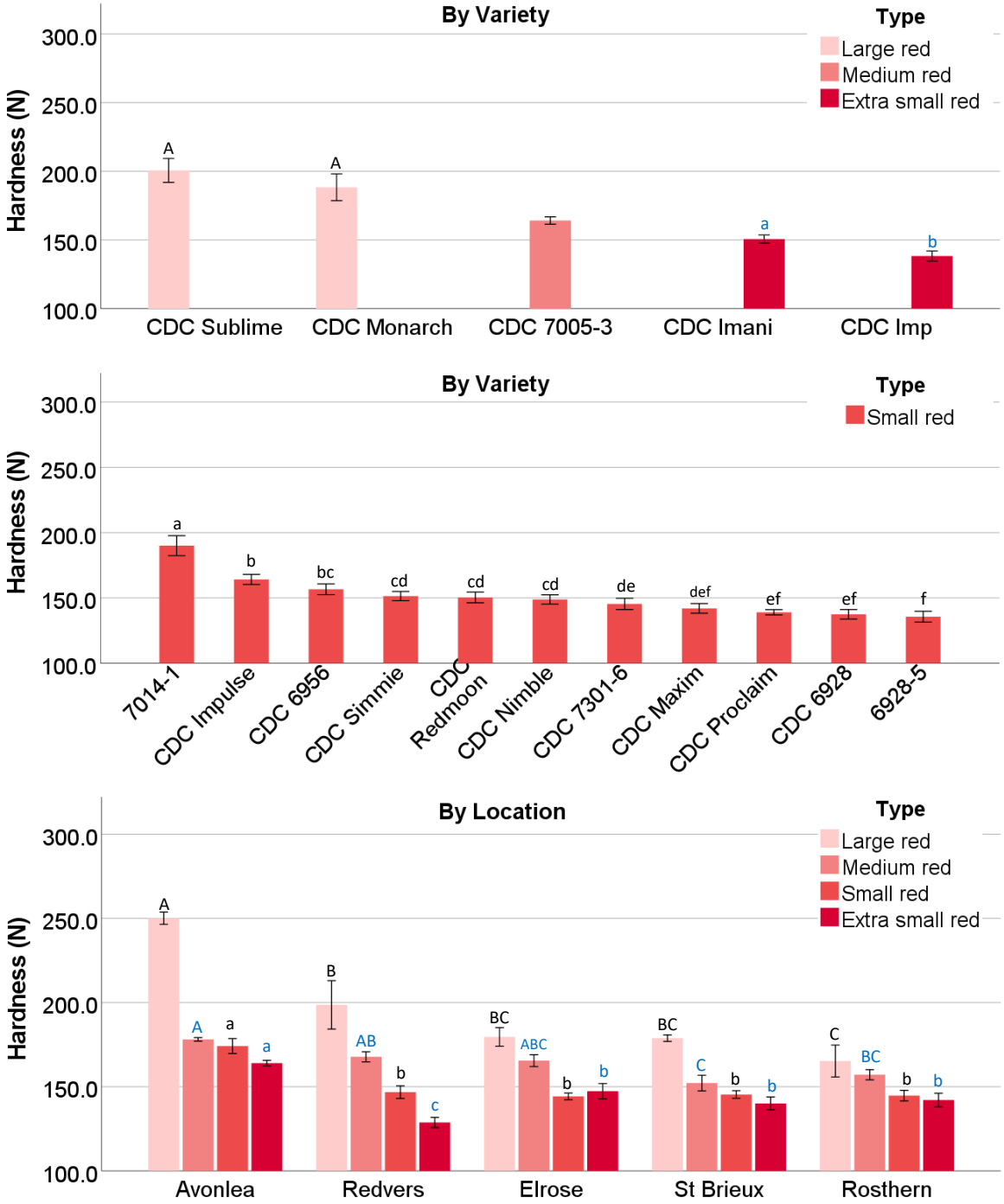
Figure 2.6.3. Mean seed hardness of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No statistical difference.
- **Medium red:** Mean was 164 N.
- **Small red:** Hardness of line 7014-1 was 55 N higher than line 6928-5.
- **Extra small red:** A 12N difference was seen.

By Location: Location also impacted the hardness of red lentils. Seed hardness in Avonlea was higher than other locations.

- **Large red:** A 85 N difference was found from highest to lowest.
- **Medium red:** A 26 N difference was found from highest to lowest.
- **Small red:** A 30 N difference was found from highest to lowest.
- **Extra small red:** A 36 N difference was found from highest to lowest.

Table 2.6.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	*
Location	***	**	***	***
Variety x Location	*NS*	*n.a.*	***	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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7. Ash Content

Method: Ash content (%) was determined using AACC 08-01.01[4] with modification. Samples were heated at 560°C till they turned white. Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

Results: Figure 2.7.1. Box plot of ash content of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

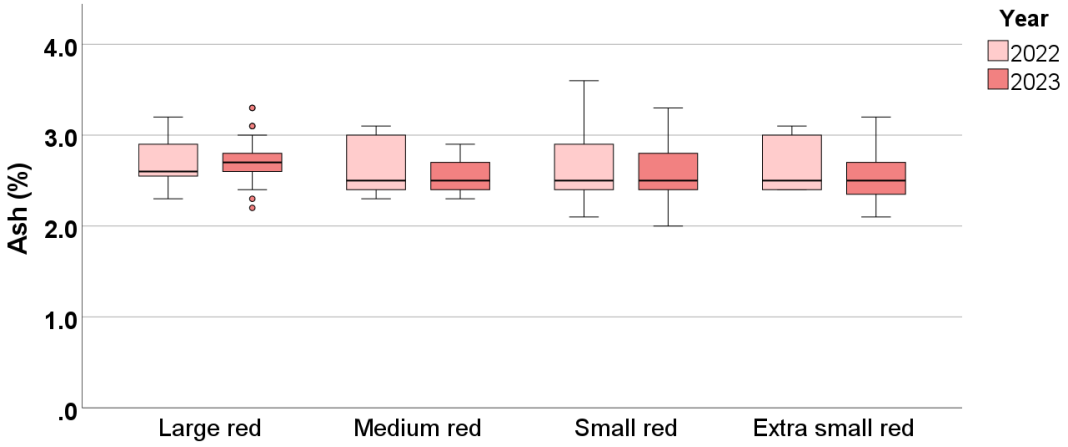


Table 2.7.1. Ash content of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

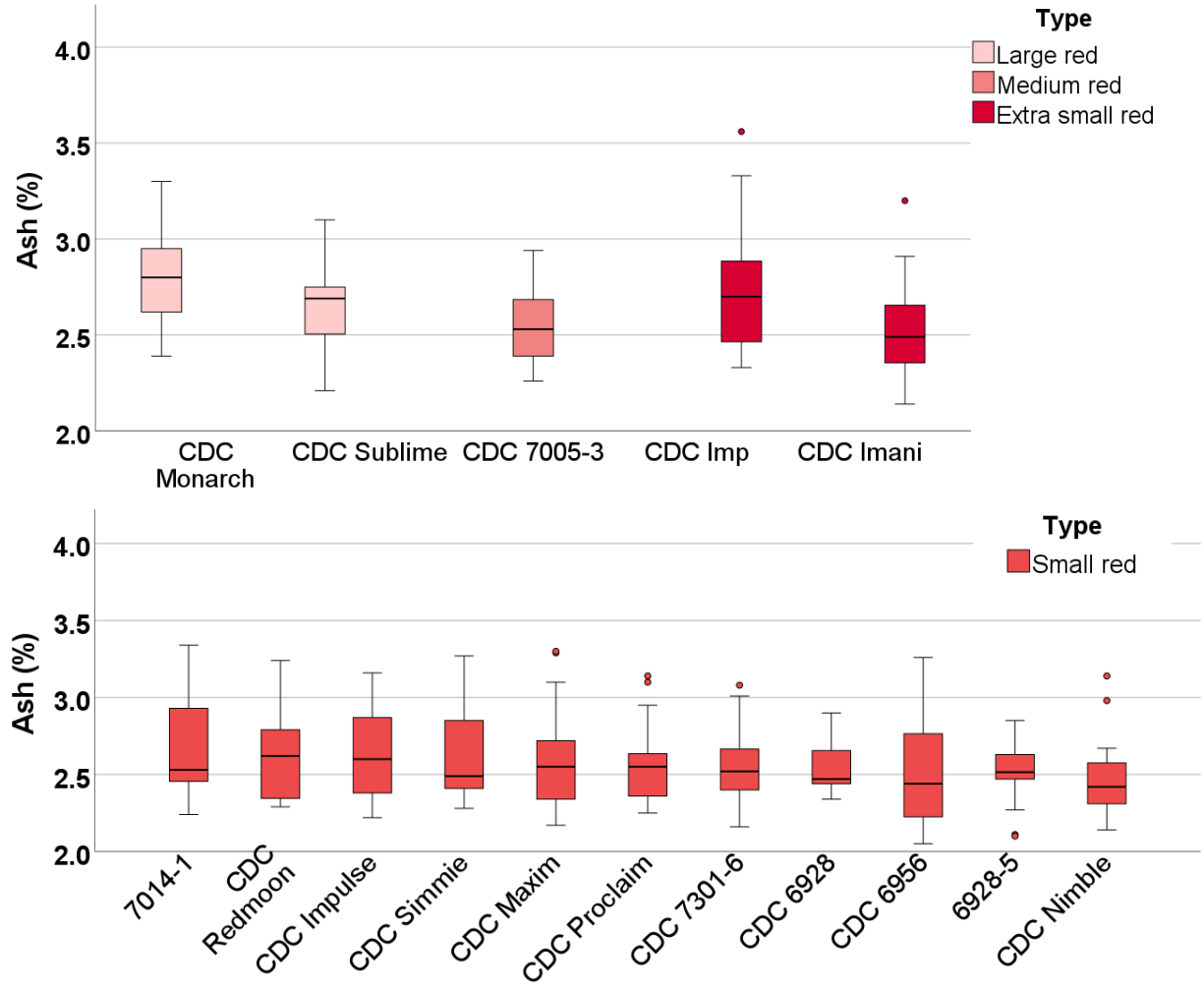
	Large red	Medium red	Small red	Extra small red
2022	2.7 ± 0.0[a]	2.6 ± 0.1[a]	2.6 ± 0.0[a]	2.7 ± 0.1[a]
2023	2.7 ± 0.0[a]	2.6 ± 0.1[a]	2.6 ± 0.0[a]	2.5 ± 0.1[a]

Note: different small letters within a column indicate significant differences.

- No statistical difference was found in ash for both years for all types of lentils.

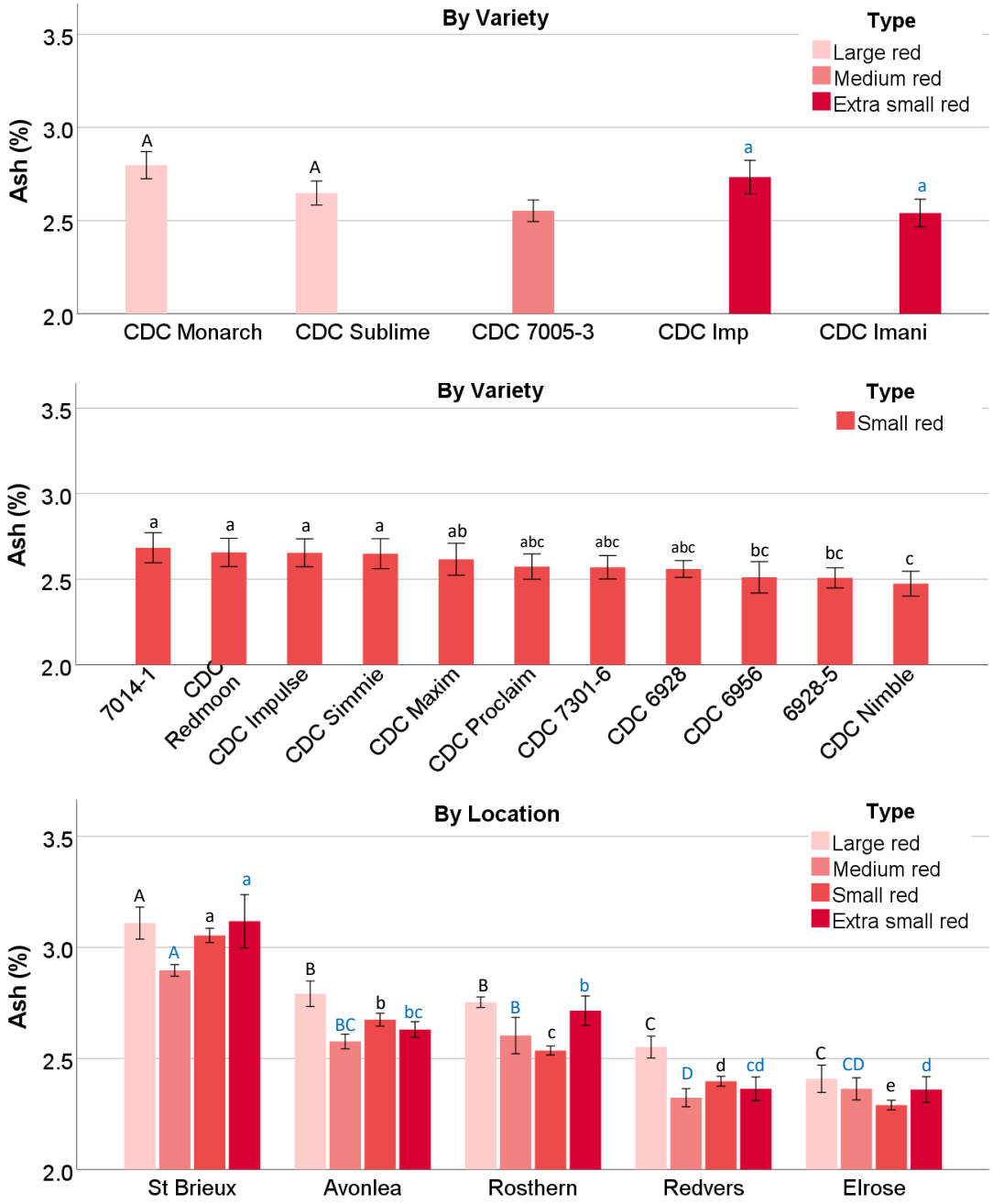
[4] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 2.7.2. Box and Whisker plot of 2023 red lentils for ash. Results by type were reported from highest to lowest.



- Ash levels were similar.

Figure 2.7.3. Mean ash of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No statistical difference.
- **Medium red:** Mean was 2.6%.
- **Small red:** Only a 0.2% difference was found from highest to lowest.
- **Extra small red:** No statistical difference.

By Location: Ash contents of red lentils from St Brieux were the highest for all types, while seeds from Redvers and Elrose were lowest. The difference from highest to lowest was over 0.5%.

Table 2.7.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	***	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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8. Protein Content

Method: The protein content (%) of each flour was determined through AACC 46-30[2] using the combustion method through a Rapid N Exceed (Elementar, USA). Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

Results: Figure 2.8.1. Box plot of protein content of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

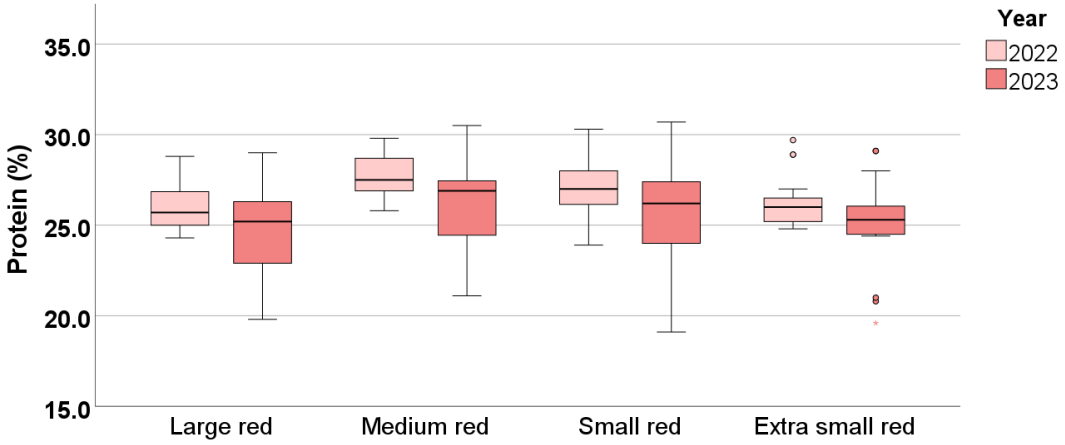


Table 2.8.1. Protein content of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

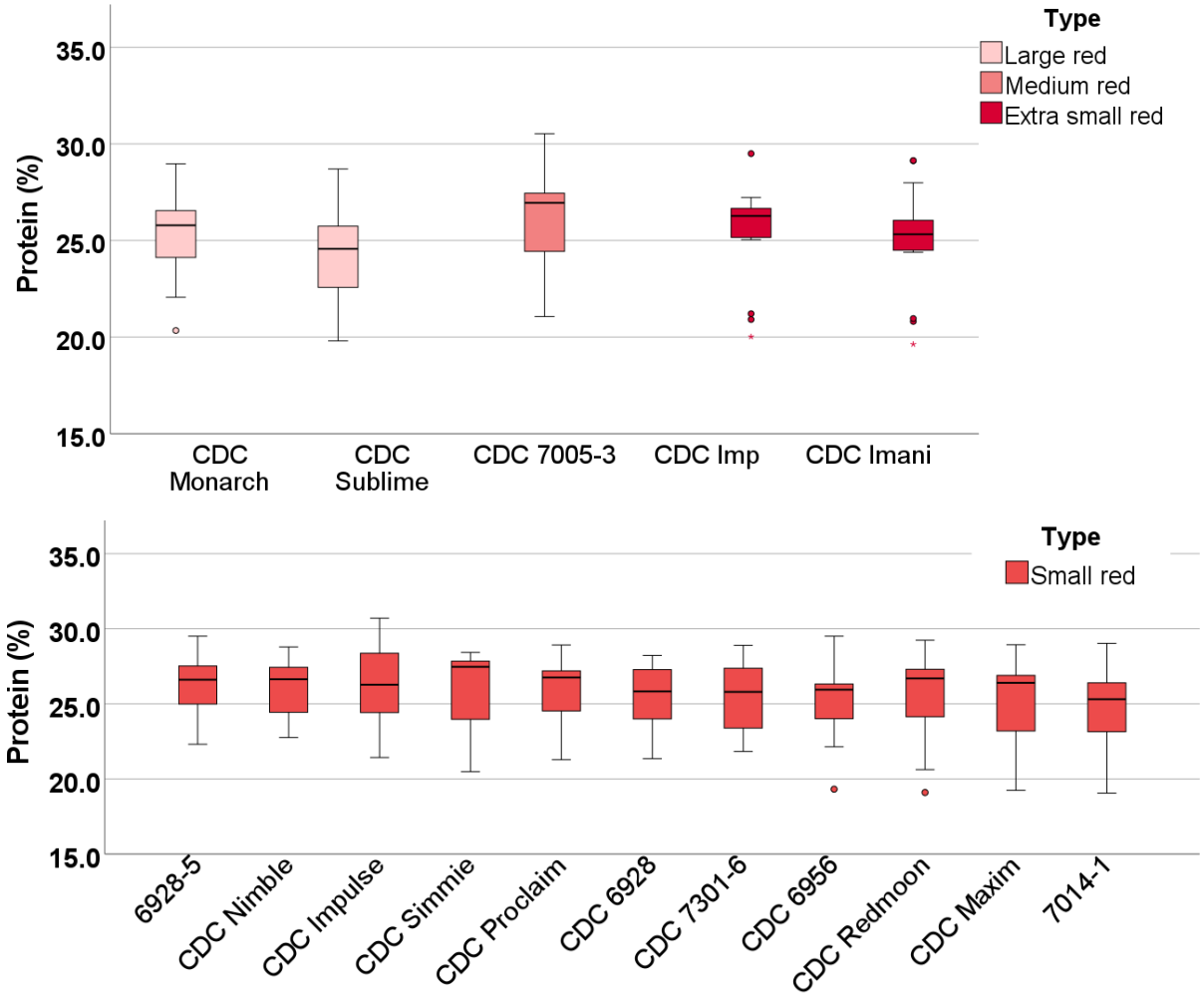
	Large red	Medium red	Small red	Extra small red
2022	26.0 ± 0.2[a]	27.7 ± 0.3[a]	27.1 ± 0.1[a]	26.3 ± 0.3[a]
2023	24.9 ± 0.4[b]	25.8 ± 0.7[b]	25.5 ± 0.2[b]	25.0 ± 0.7[a]

Note: different small letters within a column indicate significant differences.

- For all red lentil types, the 2023 protein was lower, and greater variability was seen in the 2023 samples.

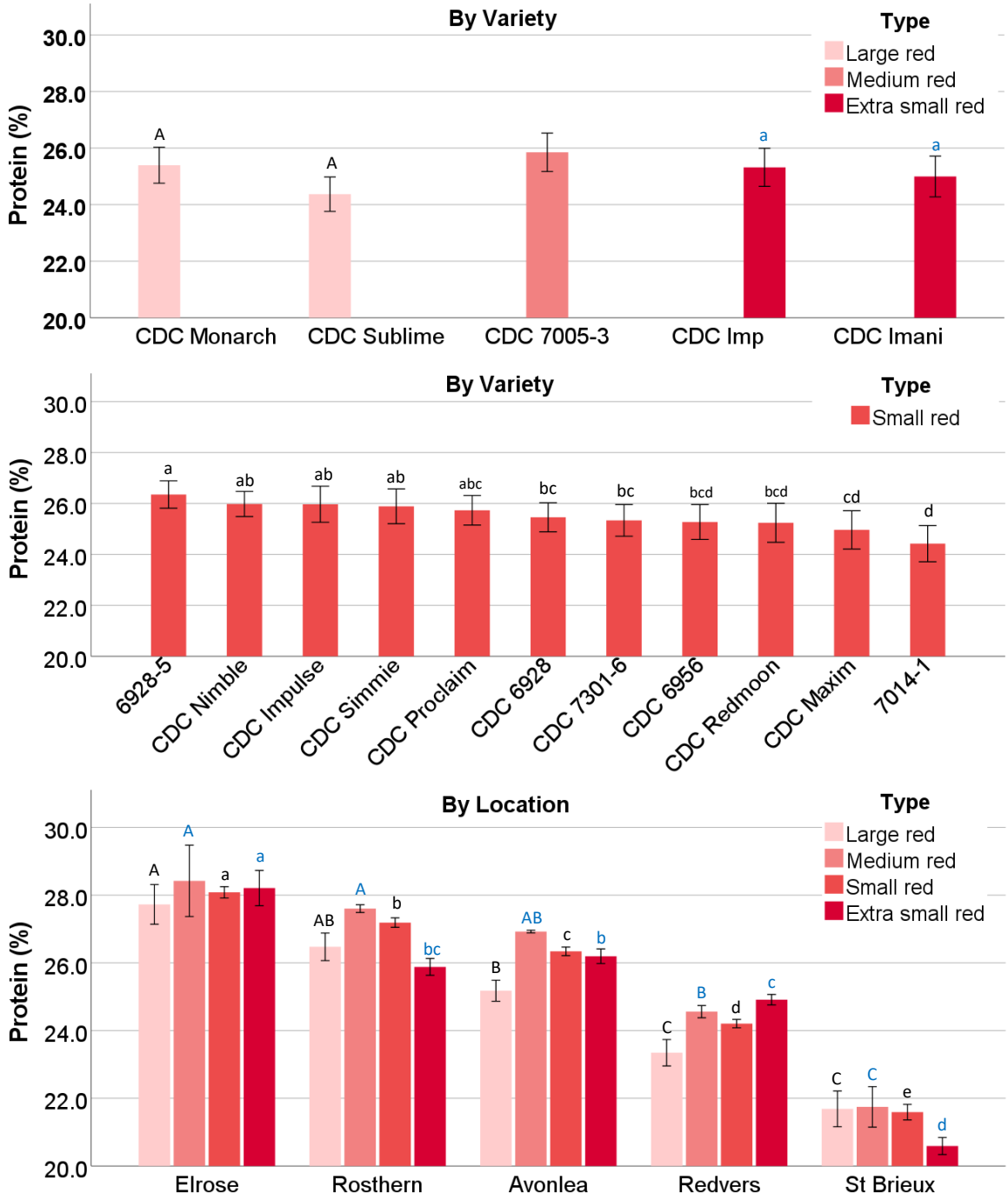
[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 2.8.2. Box and Whisker plot of 2023 red lentils for protein content. Results by type were reported from highest to lowest.



- Large variation was observed in each variety.
- Etreme outliers were present in the extra small varieties.

Figure 2.8.3. Mean protein of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No statistical difference.
- **Medium red:** Mean was 27.6%.
- **Small red:** A 2% difference was found from highest to lowest.
- **Extra small red:** No statistical difference.

By Location: Protein content varied significantly between locations, where Elrose had the highest protein for all types and St Brieux had the lowest protein.

- **Large red:** A 6% difference was observed from the highest to the lowest.
- **Medium red:** A 7% difference was observed from the highest to the lowest.
- **Small red:** A 6.5% difference was observed from the highest to the lowest.
- **Extra small red:** A 7.5% difference was observed from the highest to the lowest.

Table 2.8.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	**	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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9. Protein Productivity

Method: Protein productivity (kg protein/HA), which is calculated using yield (kg/HA) multiplied by protein content (%), refers to the amount of protein produced per unit of land. It evaluates how much protein is being harvested from a given area.

Results: Figure 2.9.1. Box plot of protein productivity of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

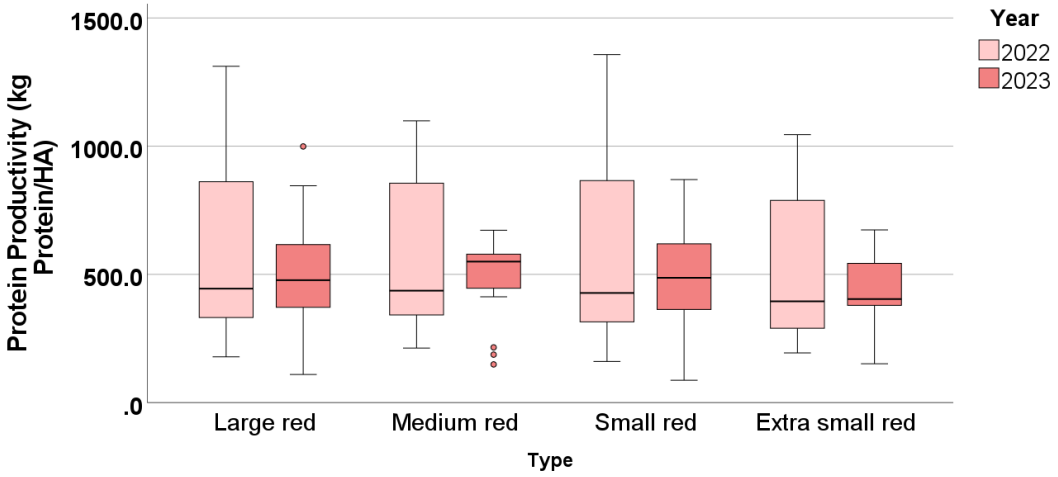


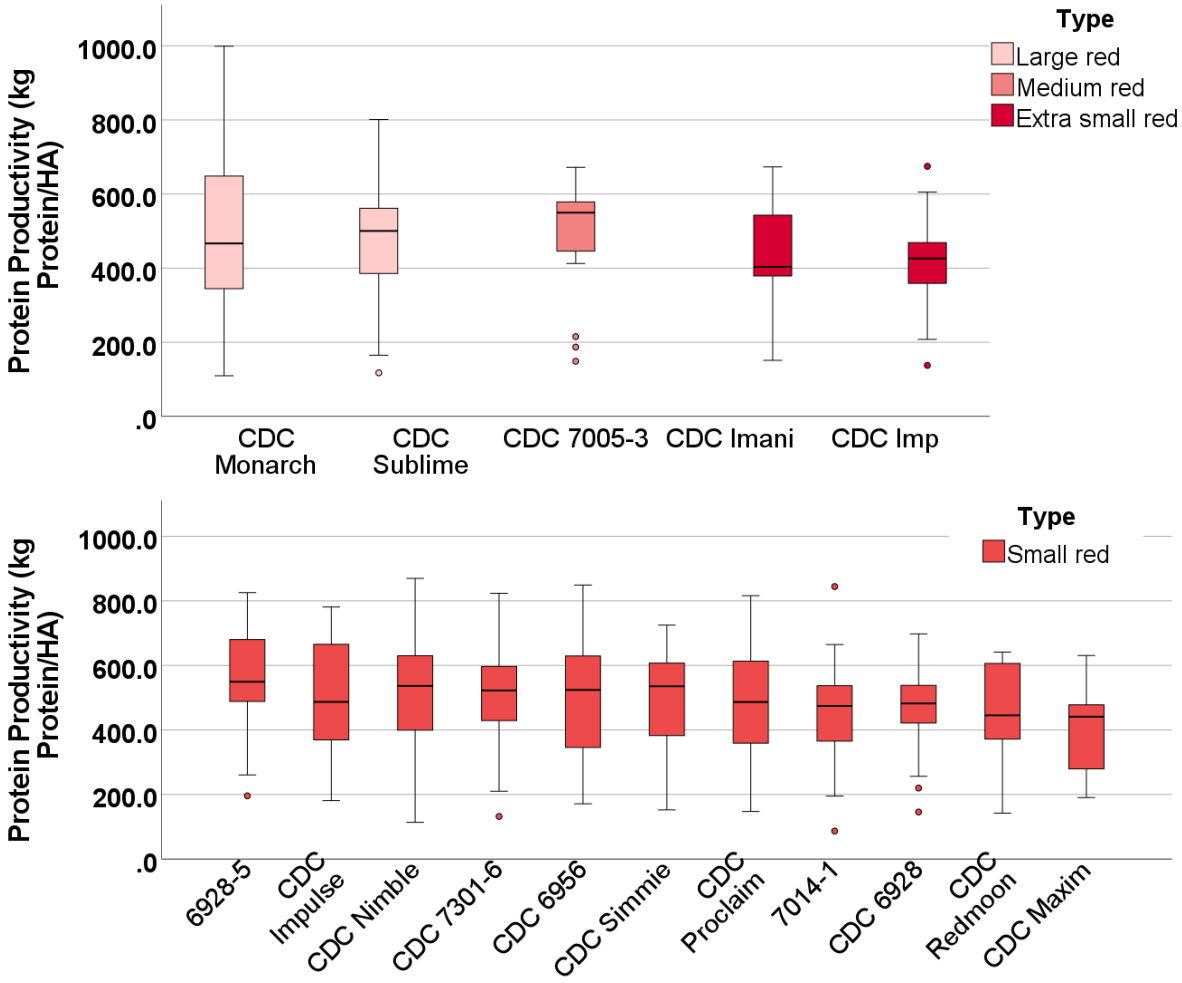
Table 2.9.1. Protein productivity of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	570.2 ± 54.7[a]	560.6 ± 72.2[a]	551.3 ± 23.4[a]	514.5 ± 66.8[a]
2023	494.4 ± 41.3[a]	486.5 ± 44.0[a]	476.0 ± 14.9[b]	420.6 ± 38.2[a]

Note: different small letters within a column indicate significant differences.

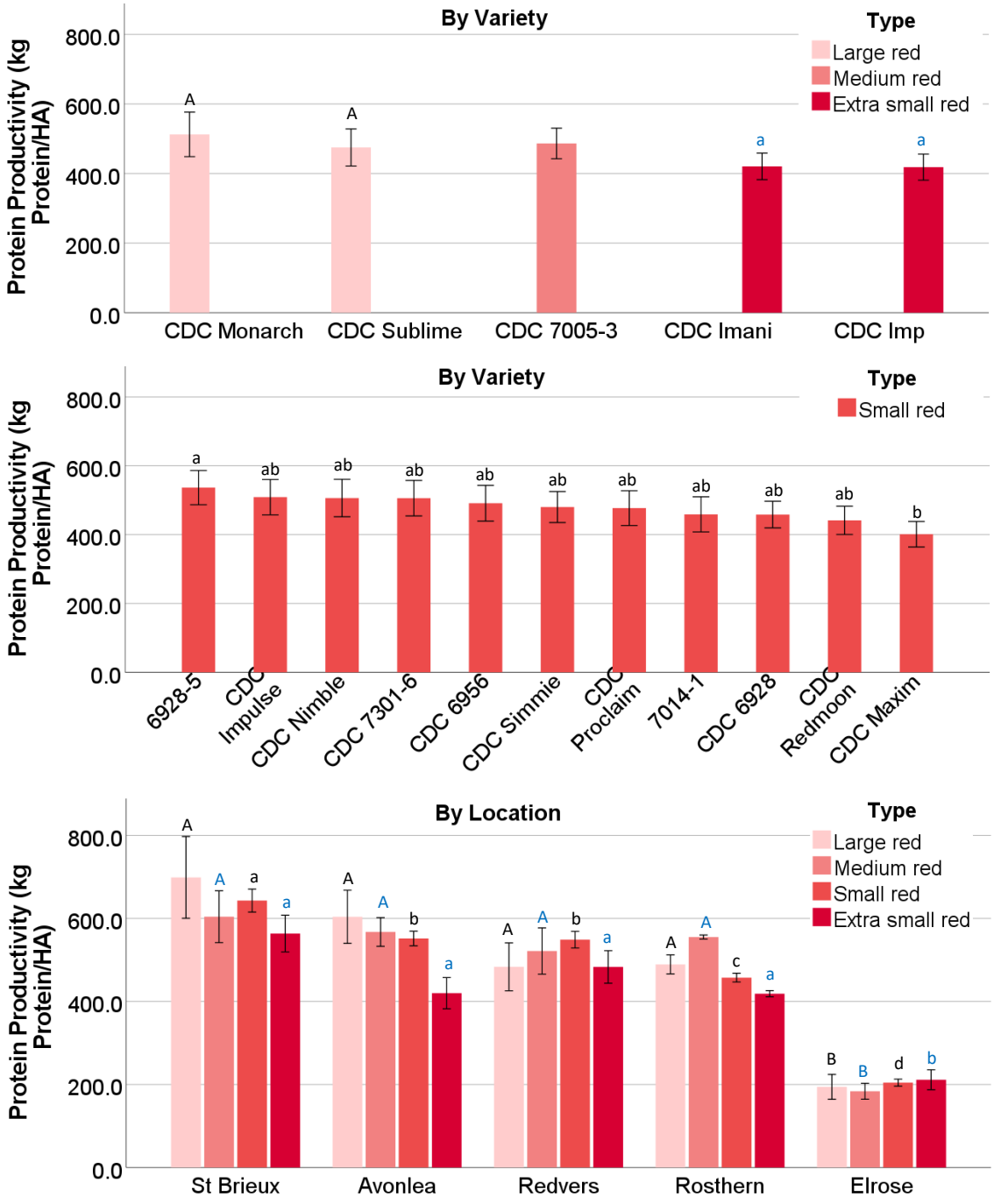
- For small red lentils, the protein productivity of the 2022 samples was higher than that of the 2023 samples.
- No differences were observed in the other types between the two years.

Figure 2.9.2. Box and Whisker plot of 2023 red lentils for protein productivity. Results by type were reported from highest to lowest.



- Large variation was observed in each variety.

Figure 2.9.3. Mean protein productivity of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No statistical difference.
- **Medium red:** Similar to CDC Sublime.
- **Small red:** A difference of 135 kg protein/HA was found from highest to lowest.
- **Extra small red:** No statistical difference.

By Location: Protein productivity varied significantly between locations, where Elrose was the lowest.

- **Large red:** The yield in St. Brieux was more than three times that of Elrose.
- **Medium red:** The yield in St. Brieux was more than three times that of Elrose.
- **Small red:** The yield in St. Brieux was more than three times that of Elrose.
- **Extra small red:** The yield in St. Brieux was two times that of Elrose.

Table 2.9.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant*

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10. Colour

Method: The absolute colour of each flour was determined using the Konica Minolta CR-400 Chroma meter, where *L*, a*,* and *b** values were reported. Three measurements were made for each sample, and the mean value was reported.

- ***L* (lightness):*** white (100) to black (0)
- ***a*:*** red (+) to green (-)
- ***b*:*** yellow (+) to blue (-)

a) ***L* (lightness):*** white (100) to black (0)

Results: Figure 2.10.1. Box plot of *L** values of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

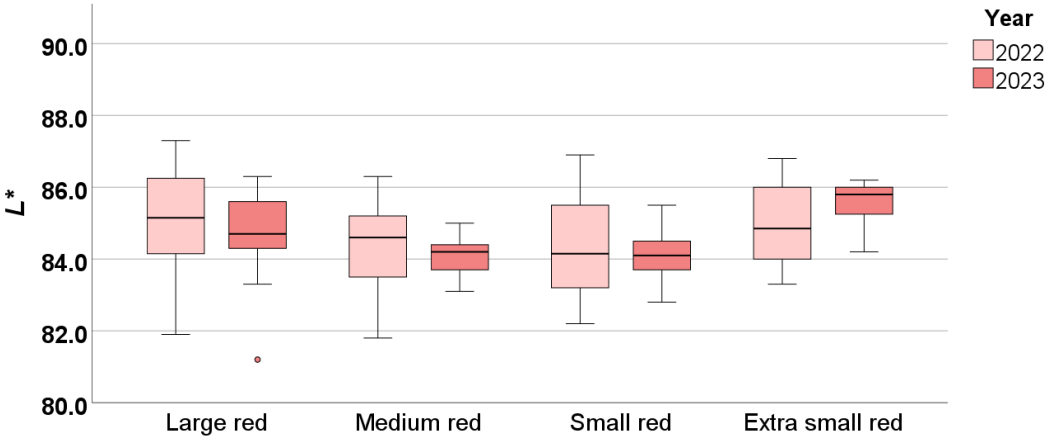

Table 2.10.1. *L** values of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	85.1 ± 0.2[a]	84.3 ± 0.3[a]	84.4 ± 0.1[a]	85.0 ± 0.3[a]
2023	84.8 ± 0.2[a]	84.1 ± 0.1[a]	84.1 ± 0.0[b]	85.5 ± 0.2[a]

Note: different small letters within a column indicate significant differences.

- Less variability in lightness was obversed in the 2023 samples.

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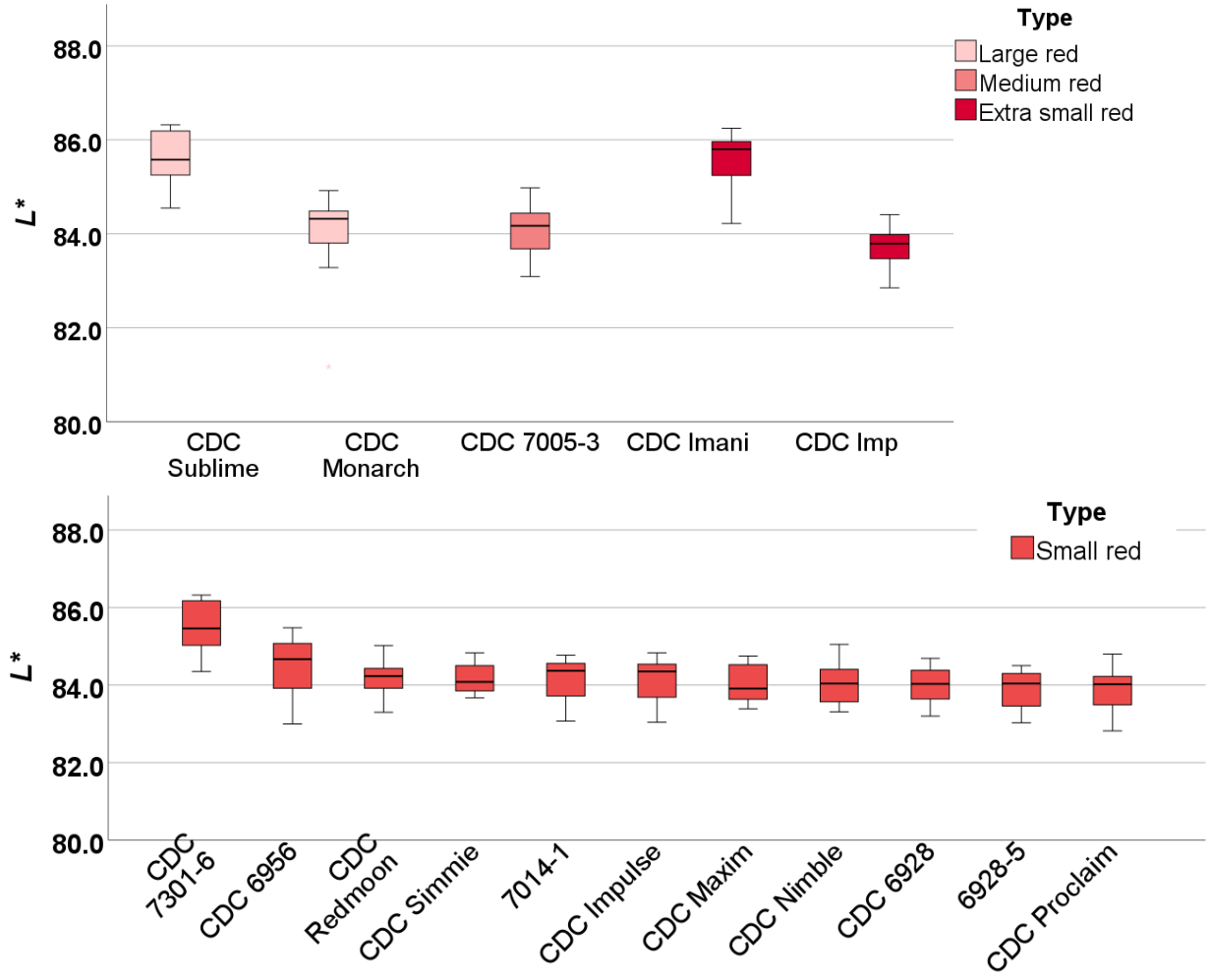
Results: Figure 2.10.2. Box and Whisker plot of 2023 red lentils for lightness. Results by type were reported from highest to lowest.



- **Large red:** Lightness of CDC Monarch was lower.
- **Medium red:** Lightness was similar to CDC Monarch.
- **Small red:** CDC 7301-6 had greater lightness.
- **Extra small red:** Lightness of CDC Imani was higher.

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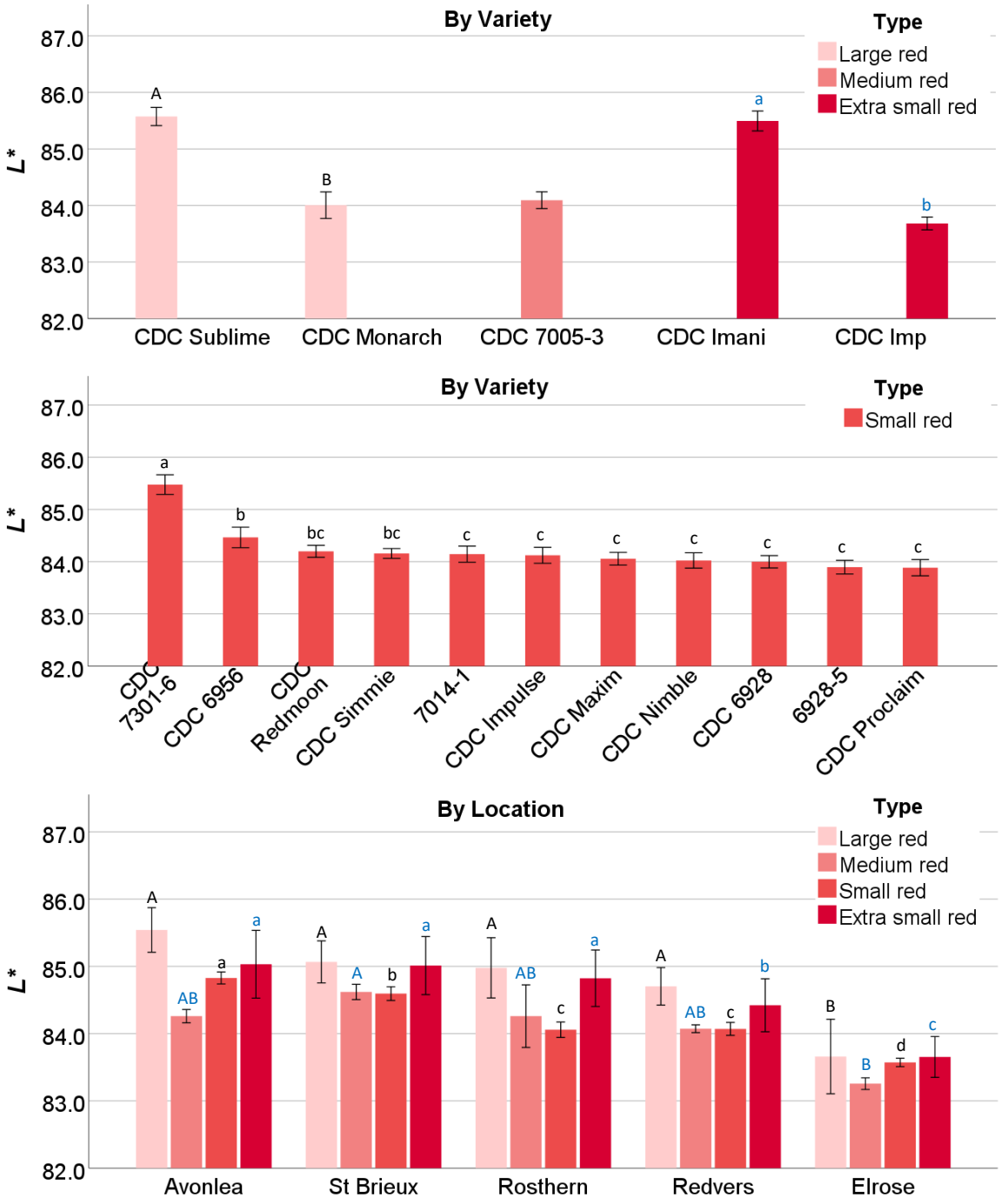
Figure 2.10.3. Mean lightness of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** A 1.6-unit difference was observed.
- **Medium red:** Lightness was 84.3.
- **Small red:** A 1.7-unit difference was observed from the highest to the lowest.
- **Extra small red:** A 1.7-unit difference was observed.

By Location: *L** values varied between locations, where Elrose had the lowest lightness for all types. The difference from highest to lowest within each type was less than 2 units.

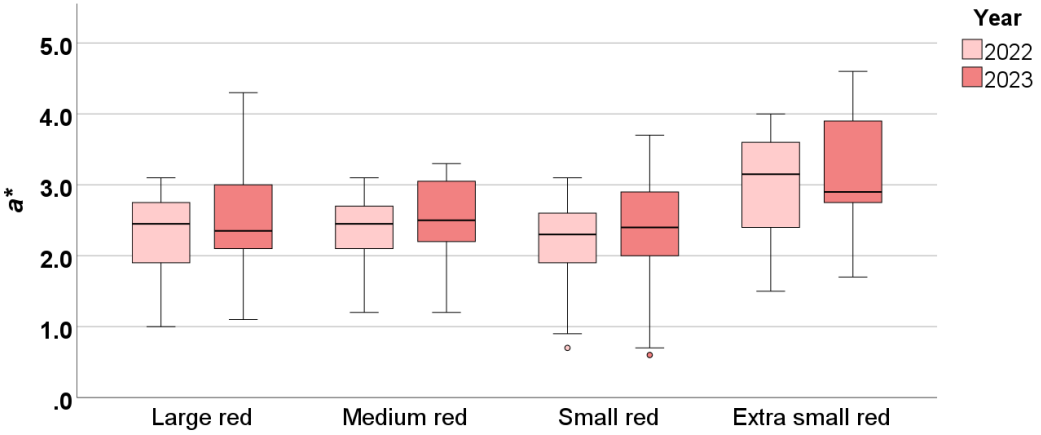
Table 2.10.2. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	***	*n.a.*	***	***
Location	***	*	***	***
Variety x Location	*NS*	*n.a.*	***	**

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

b) ***a*:*** red (+) to green (-)

Results: Figure 2.10.4. Box plot of *a** values of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).



- The 2023 samples in general had greater variability.

Table 2.10.3. *a** values of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	2.3 ± 0.1[a]	2.3 ± 0.1[a]	2.2 ± 0.0[a]	3.0 ± 0.2[a]
2023	2.5 ± 0.1[a]	2.5 ± 0.2[a]	2.3 ± 0.1[a]	3.2 ± 0.2[a]

Note: different small letters within a column indicate significant differences.

Figure 2.10.5. Box and Whisker plot of 2023 red lentils for *a** values. Results by type were reported from highest to lowest.

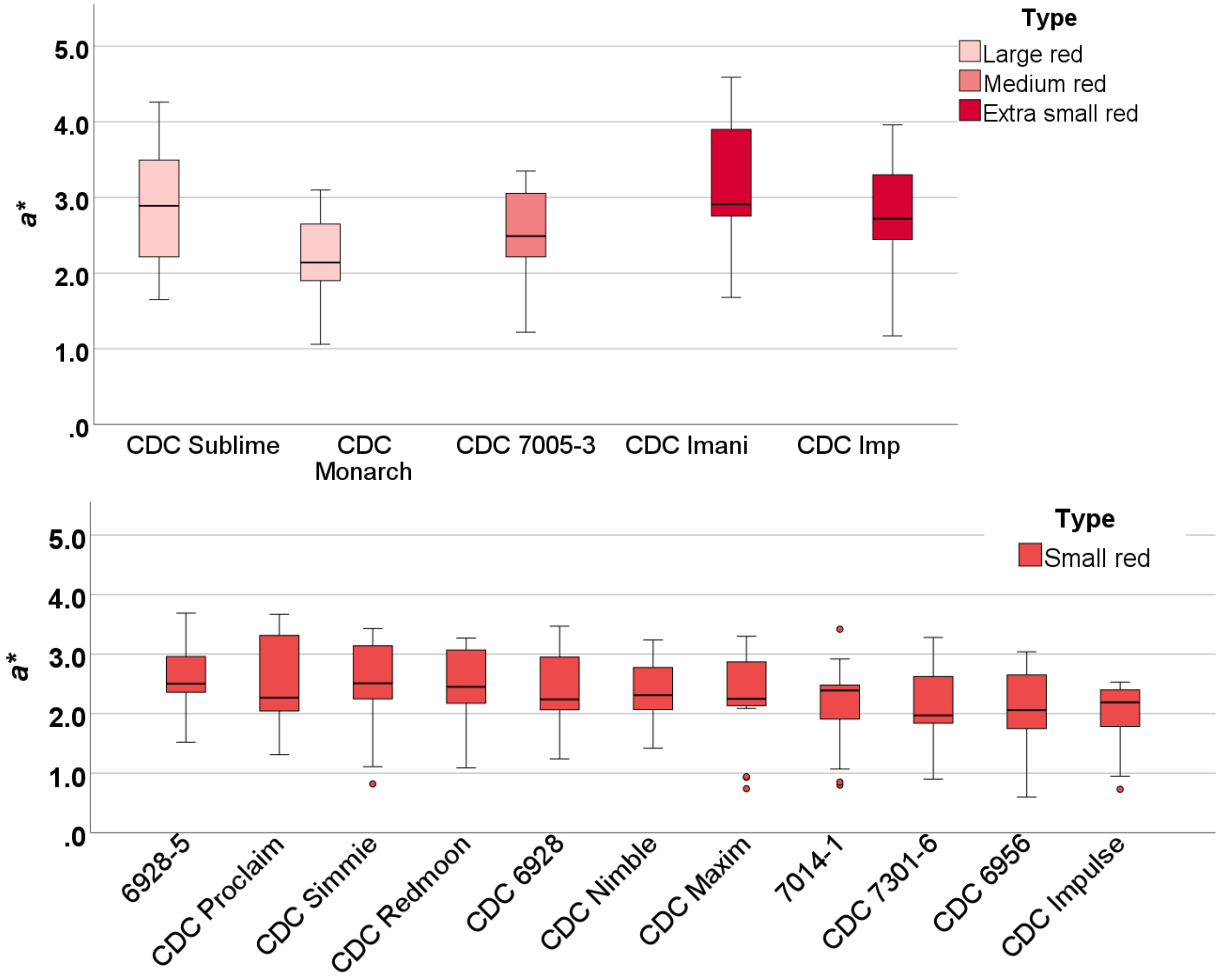
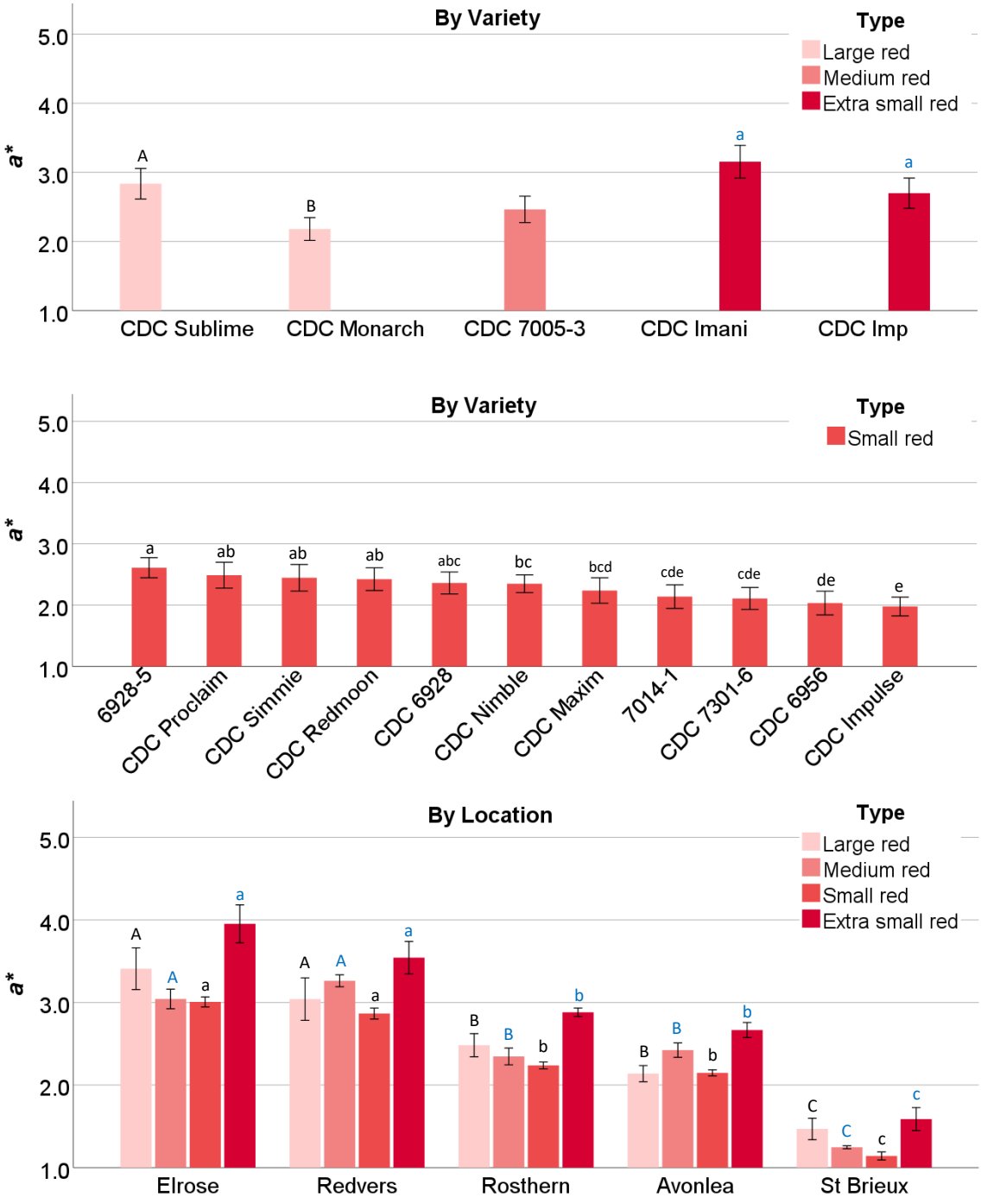


Figure 2.10.6. *a** values of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** A 0.6-unit difference was observed.
- **Small red:** A 0.6-unit difference was observed from highest to lowest.
- **Extra small red:** No difference (p>0.05).

By Location: All four types of samples from St Brieux had the lowest redness.

- **Large red:** A 1.5-unit difference was observed from the highest (Elrose and Redvers) to the lowest.
- **Medium red:** A 2-unit difference was observed from the highest (Redvers) to the lowest.
- **Small red:** A 1.8-unit difference was observed from the highest (Elrose and Redvers) to the lowest.
- **Extra small red:** A 2.4-unit difference was observed from the highest (Elrose and Redvers) to the lowest.

Table 2.10.4. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*	*n.a.*	***	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	**	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

c) ***b*:** yellow (+) to blue (-)

Results: Figure 2.10.7. Box plot of *b** values of red lentils in 2022 and 2023. The data in the figure include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

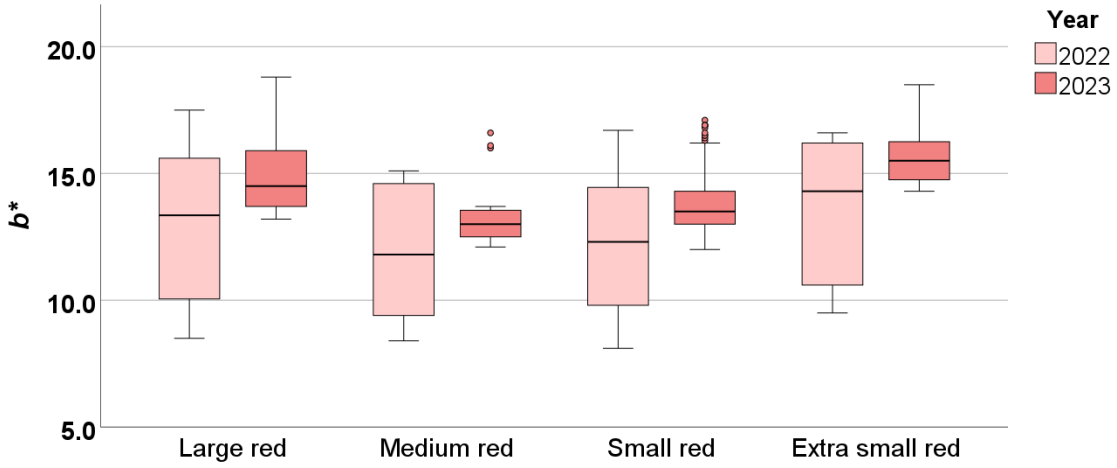


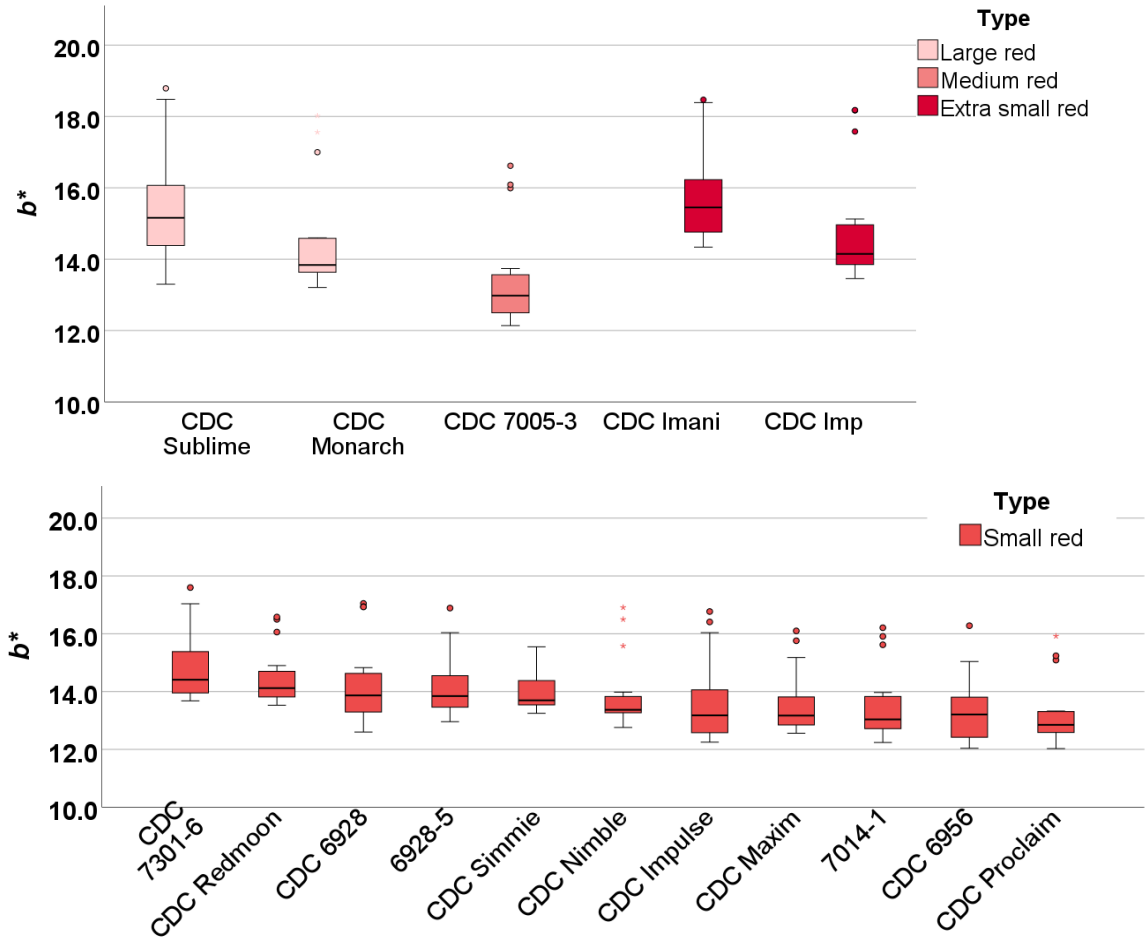
Table 2.10.5. *b** values of red lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

	Large red	Medium red	Small red	Extra small red
2022	13.0 ± 0.5[b]	11.9 ± 0.6[b]	12.2 ± 0.2[b]	13.6 ± 0.7[b]
2023	15.1 ± 0.3[a]	13.5 ± 0.4[a]	13.9 ± 0.1[a]	15.8 ± 0.4[a]

Note: different small letters within a column indicate significant differences.

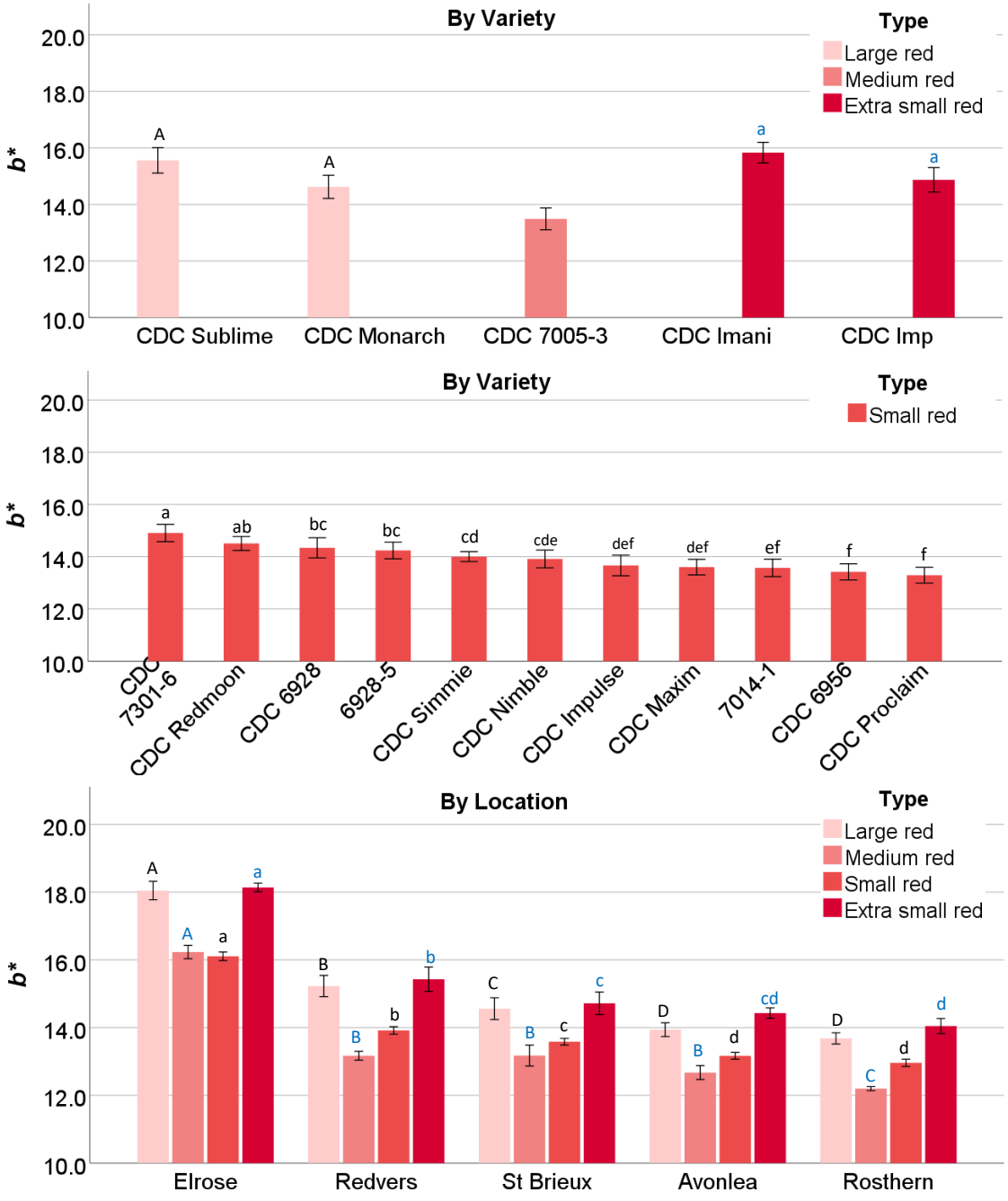
- Yellowness of the 2023 red lentil flours was higher than the 2022 samples.

Results: Figure 2.10.8. Box and Whisker plot of 2023 red lentils for *b**. Results by type were reported from highest to lowest.



- Outliers were present in all varieties.

Figure 2.10.9. Mean *b** of 2023 red lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by large red lentil. Capital letters in blue indicated significant differences (p<0.05) by medium red. Small letters in black indicated significant differences (p<0.05) by small red. Small letters in blue indicated significant differences (p<0.05) by extra small red.

By Variety:

- **Large red:** No difference (p>0.05).
- **Small red:** A 1.6-unit difference was observed from the highest to the lowest.
- **Extra small red:** No difference (p>0.05).

By Location: Yellowness of samples from Elrose was much higher. Rosthern and Avonlea had the lowest yellowness.

Table 2.10.6. Effects of variety and location.

	Large red	Medium red	Small red	Extra small red
Variety	*NS*	*n.a.*	***	*NS*
Location	***	***	***	***
Variety x Location	*NS*	*n.a.*	**	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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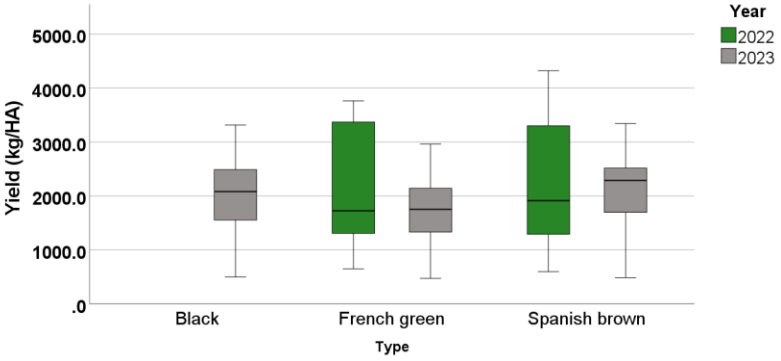
3) 2023 Specialty Lentil

1. Yield

Method: Yield refers to how much crops are produced and how efficiently land is used to produce food or agricultural commodities. The yield of each variety from each location is provided as kilogram per hectare (kg/HA).

Results: Figure 3.1.1. & **Table 3.1.1.** Yield of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).



	Black	French green	Spanish brown
2022	n.a.	2064.8 ± 255.5[a]	2203.5 ± 198.2[a]
2023	2015.1 ± 147.4	1721.2 ± 186.4[a]	2116.8 ± 151.6[a]

Note: different small letters within a column indicate significant differences.

- There was no statistical difference in yield between both years.

Figure 3.1.2. Box and Whisker plot of 2023 specialty lentils for yield. Results by type were reported from highest to lowest.

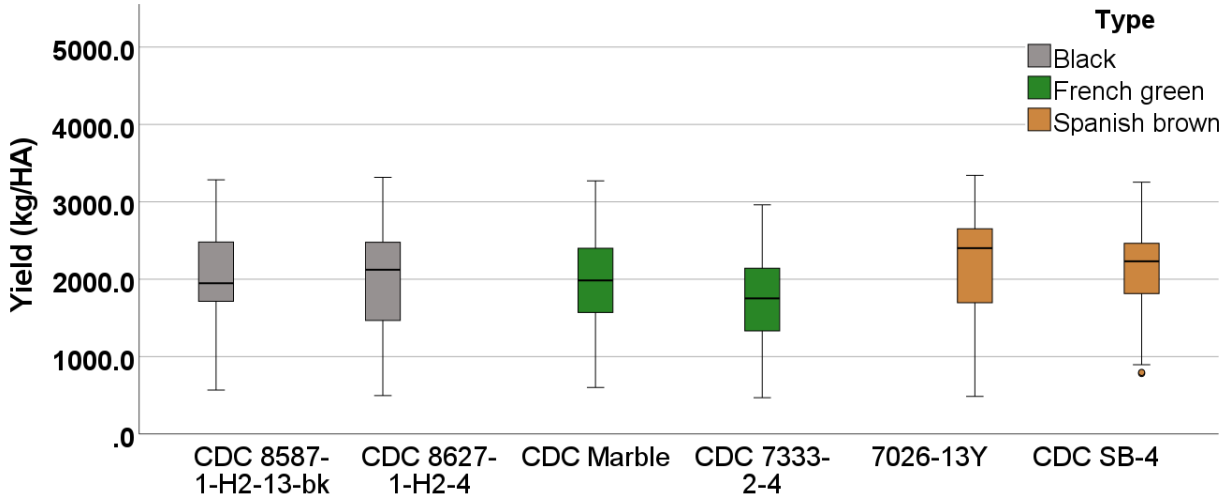
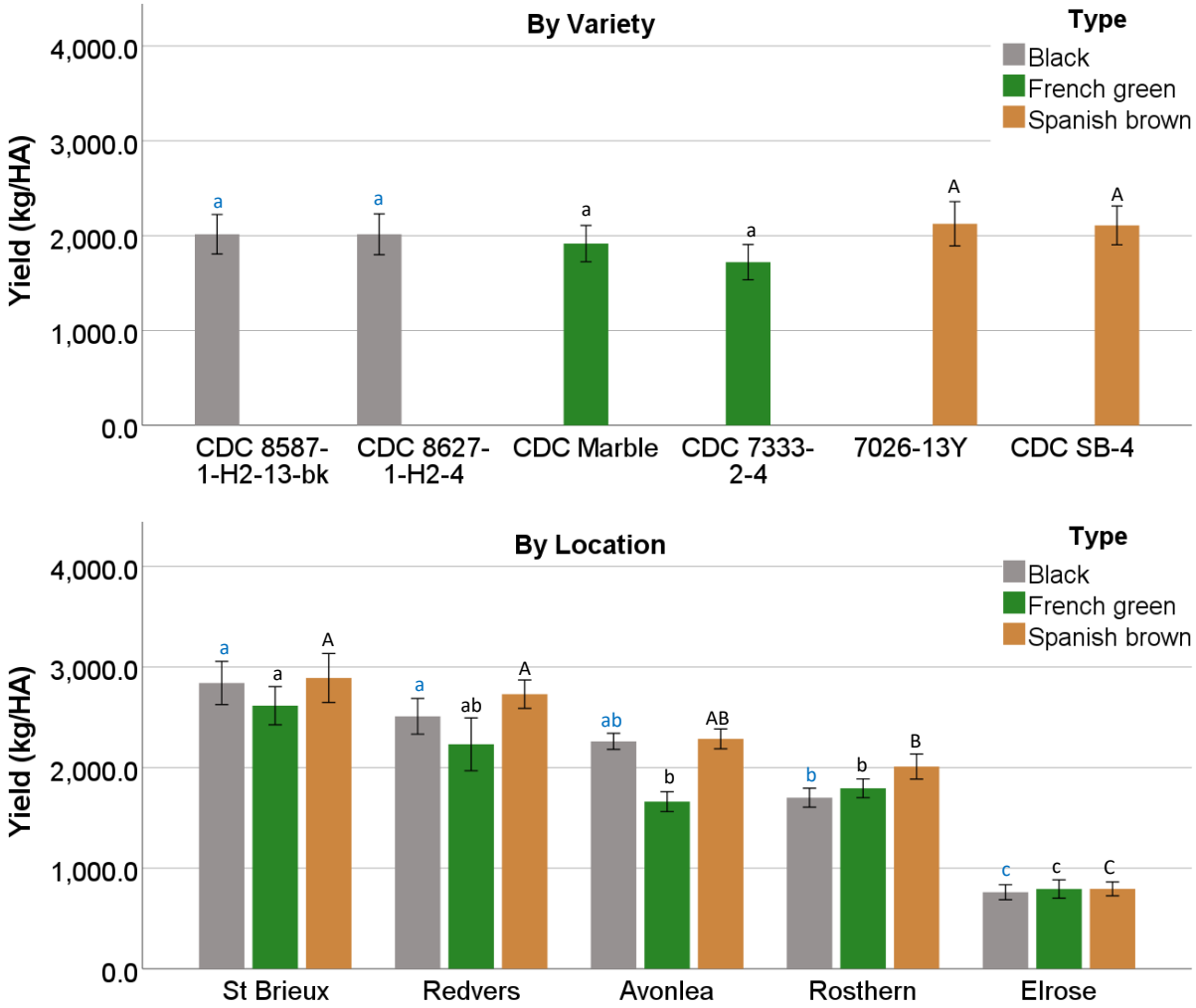


Figure 3.1.3. Mean yield of 2023 specialty lentils by variety (left) and location (right). Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety:

- No significant differences.

By Location:

- The yield of St Brieux and Redvers (highest) was over three times that of Elrose (lowest) for all three types.

Table 3.1.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	*NS*	*NS*	*NS*
Location	***	***	***
Variety x Location	*NS*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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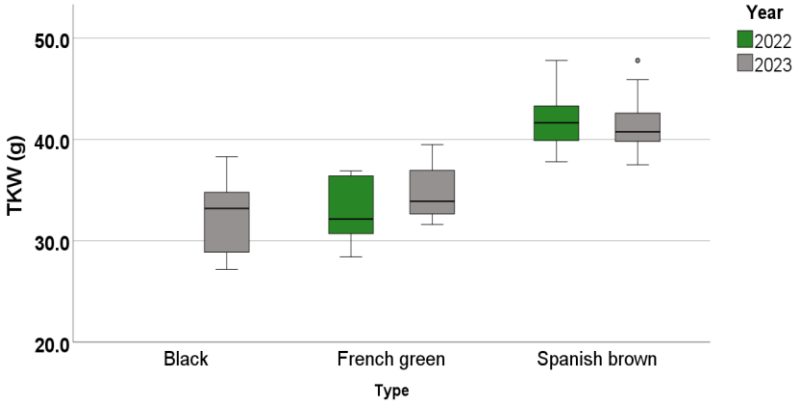
2. Thousand Kernel Weight

Method: Seed weight is important to indicate seed size and yield production. This test was conducted by weighing 300 seeds with duplicated measurements per sample. The thousand kernel weight (TKW) was reported.

Results: Figure 3.2.1. & **Table 3.2.1.** TKW of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).

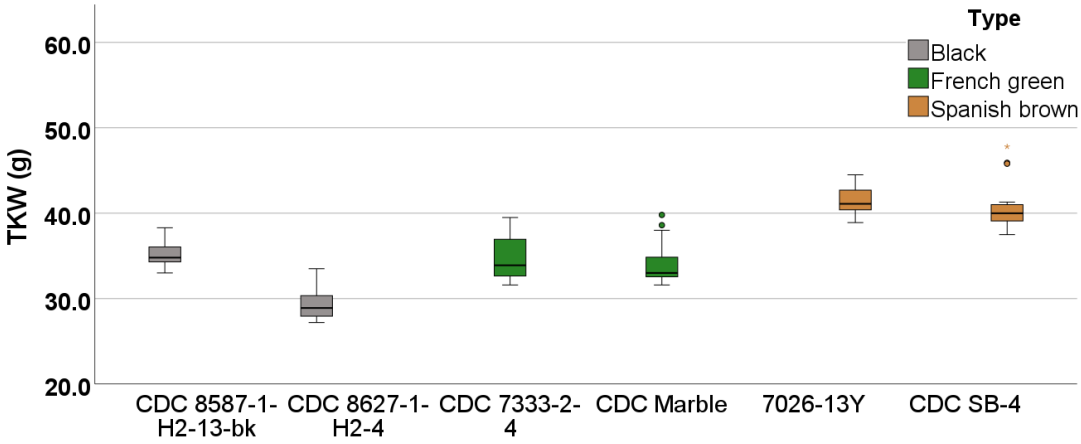


	Black	French green	Spanish brown
2022	n.a.	32.9 ± 0.7[a]	41.9 ± 0.4[a]
2023	32.3 ± 0.6	34.7 ± 0.7[a]	41.1 ± 0.4[a]

Note: different small letters within a column indicate significant differences.

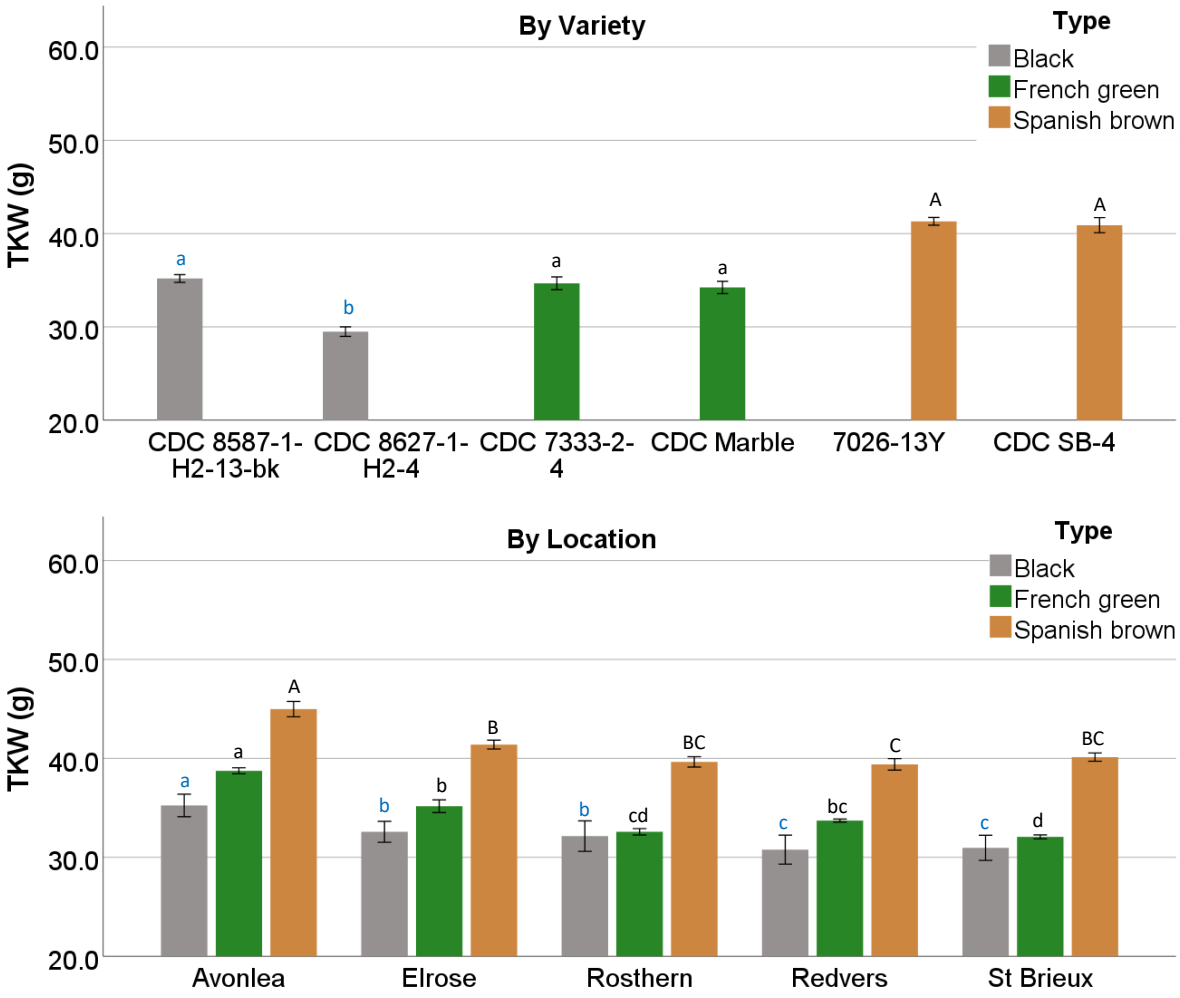
- There was no statistical difference in TKW between both years.

Figure 3.2.2. Box and Whisker plot of 2023 specialty lentils for TKW. Results by type were reported from highest to lowest.



- A few extreme high TKW values were observed in CDC SB-4.

Figure 3.2.3. Mean TKW of 2023 specialty lentils by variety (left) and location (right). Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety:

- Spanish brown > French green > Black
- Black: A 5.7 g difference between the varieties.

By Location:

- A 5 g difference was found from highest (Avonlea) to lowest for each lentil type.

Table 3.2.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	***	*NS*	*NS*
Location	***	***	***
Variety x Location	*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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3. Seed Size Distribution

Method: 250 g of seeds were placed on a series of round-hole opening sieves. The weight of seeds retained on each sieve was determined and reported as % of seeds retained. Duplicated measurements were performed.

Sieves used for evaluation:

a. #14R: 5.56 mm
b. #12R: 4.76 mm
c. #10R: 3.97 mm

Results:

Table 3.3. Seed size distribution (%) of each specialty lentil variety. Data represent mean ± one standard deviation.

Type	Variety	> 5.56 mm (%)	> 4.76 mm (%)	> 3.97 mm (%)	Below 3.97 mm (%)
Black	CDC 8587-1-H2-13-bk	0.1 ± 0.0[a]	33.4 ± 8.1[a]	62.9 ± 7.9[b]	3.6 ± 1.4[b]
	CDC 8627-1-H2-4	0.0 ± 0.0[b]	9.5 ± 5.3[b]	80.1 ± 3.0[a]	10.4 ± 3.9[a]
French green	CDC 7333-2-4	0.1 ± 0.2[a]	41.9 ± 10.6[a]	55.1 ± 10.5[a]	2.9 ± 1.8[a]
	CDC Marble	0.1 ± 0.1[a]	39.3 ± 13.0[a]	58.0 ± 13.0[a]	3.2 ± 1.8[a]
Spanish brown	CDC SB-4	0.8 ± 1.0[a]	67.5 ± 6.8[a]	30.1 ± 7.4[b]	1.5 ± 0.6[a]
	7026-13Y	0.3 ± 0.2[a]	59.8 ± 8.0[b]	37.8 ± 7.3[a]	2.2 ± 1.1[a]

Note: Different small letters within each type in a column indicated significant differences ($p<0.05$).

- The seed size distribution result corresponded to the TKW results, where Spanish brown > French green > Black.

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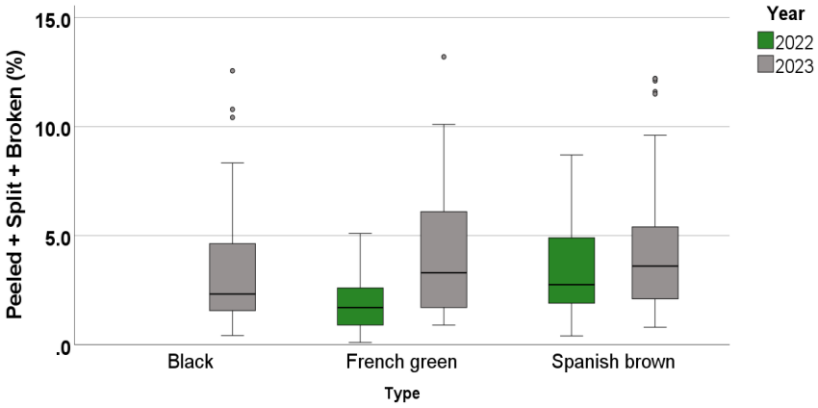
4. Peeled + Split + Broken

Method: 50 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Results included splits, cracks, seed coat damage, partially missing hull, and partially missing cotyledon.

Results: Figure 3.4.1. & **Table 3.4.1.** The peeled + split + broken specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).

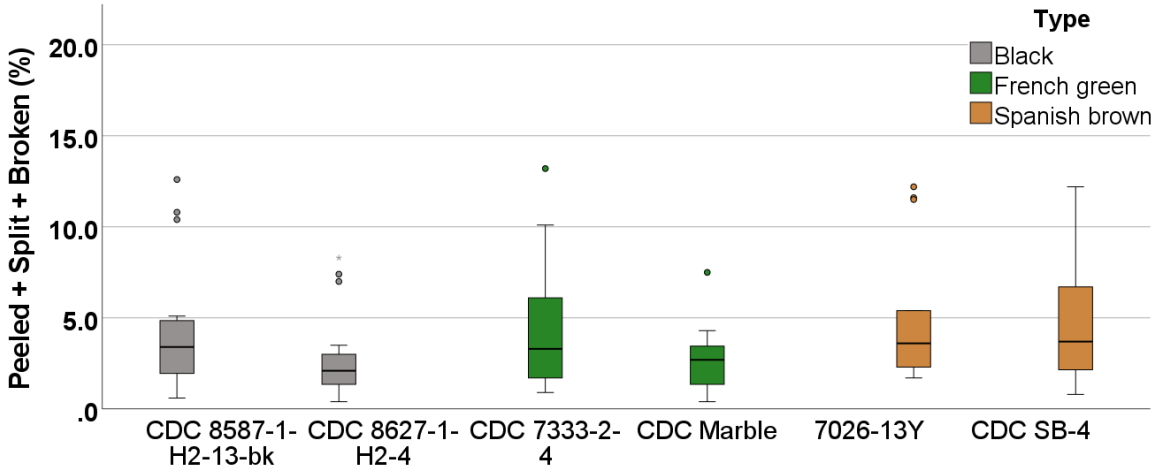


	Black	French green	Spanish brown
2022	n.a.	2.1 ± 0.4[b]	3.3 ± 0.4[b]
2023	3.7 ± 0.6	4.5 ± 1.0[a]	4.9 ± 0.7[a]

Note: different small letters within a column indicate significant differences.

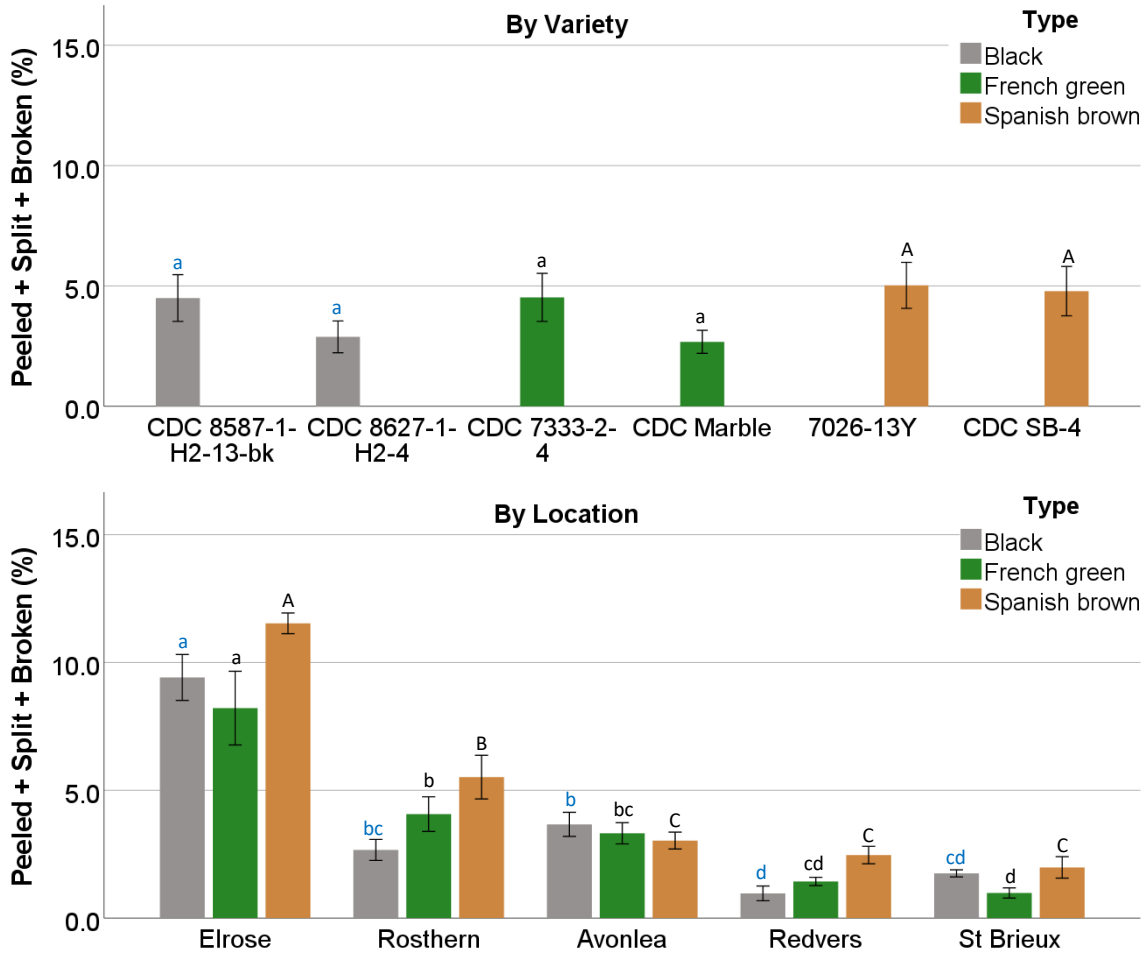
- Lentil seeds harvested in 2023 had a higher amount of mechanical damage ($p<0.05$).

Figure 3.4.2. Box and Whisker plot of peeled + split + broken specialty lentils in 2023. Results by type were reported from highest to lowest.



- Large variability with the presence of outliers and extreme outliers was observed in all varieties.

Figure 3.4.3. Mean peeled + split + broken seeds in 2023 by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: No significant difference was found within each type.

By Location: Location played a role. Lentils harvested from Redvers and St Brieux had low levels of broken seeds, while a high amount of damage was found in Elrose.

Table 3.4.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	*NS*	*NS*	*NS*
Location	***	***	***
Variety x Location	*NS*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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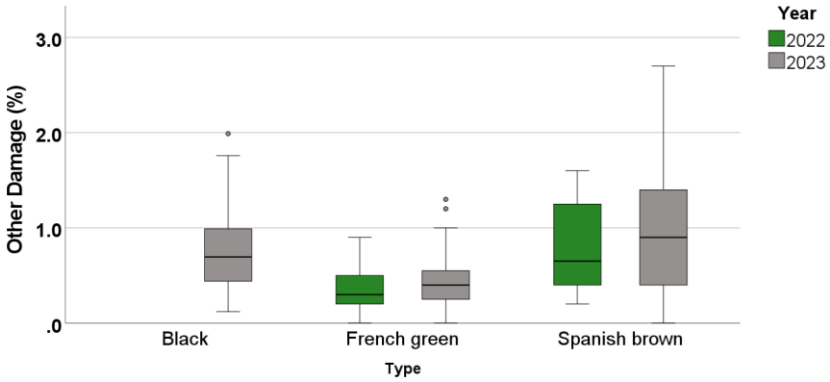
5. Other Damage

Method: 50 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included sprouting, distinct immaturity, distinct deterioration or discolouration by weather or disease, insect damage, heat damage, and any other damage that affects appearance.

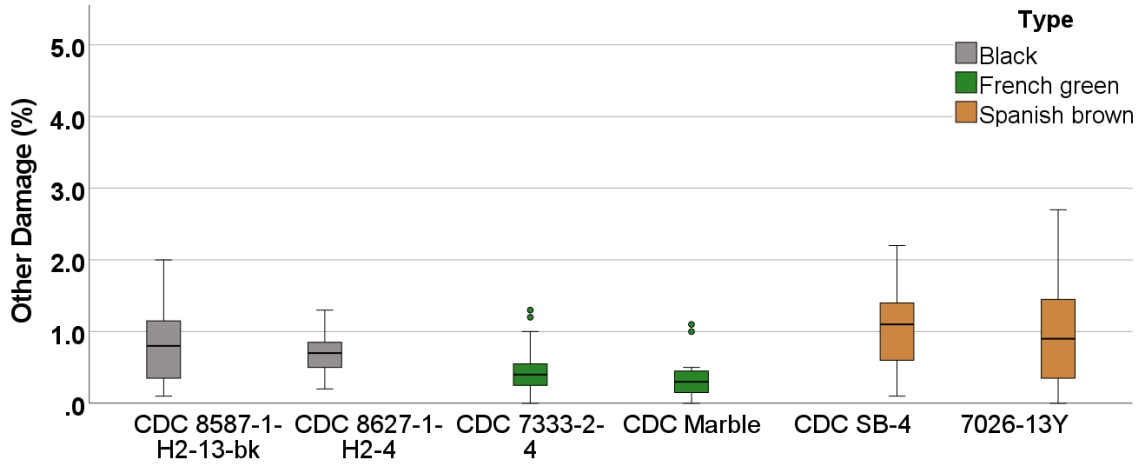
Results: Figure 3.5.1. & **Table 3.5.1.** Other damage of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties that were tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).



	Black	French green	Spanish brown
2022	n.a.	0.4 ± 0.1[a]	0.8 ± 0.1[a]
2023	0.8 ± 0.1	0.5 ± 0.1[a]	1.0 ± 0.1[a]

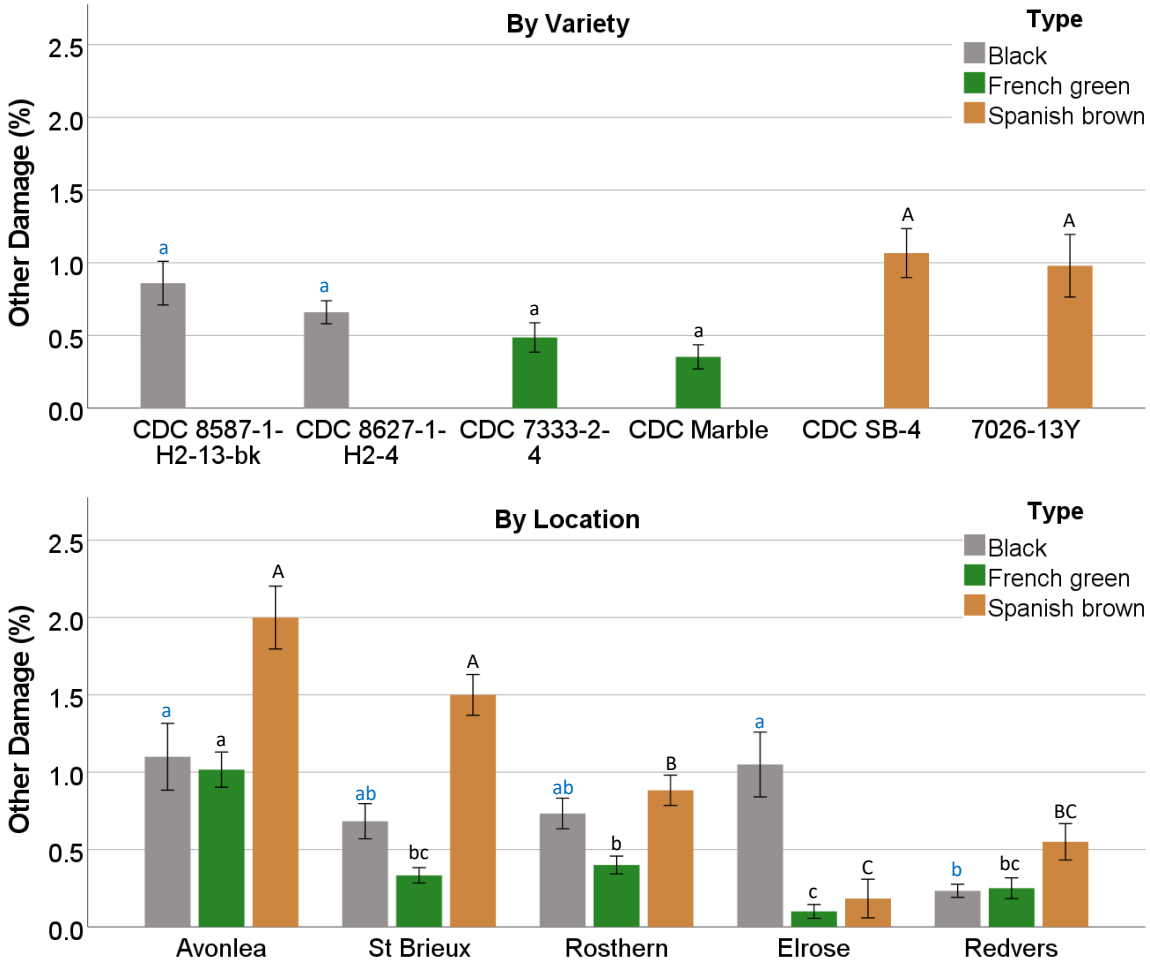
Note: different small letters within a column indicate significant differences.

Figure 3.5.2. Box and Whisker plot of other damage for 2023 specialty lentils. Results by type were reported from highest to lowest.



- Other damage in all 2023 samples was below 3%.

Figure 3.5.3. Mean other damage for 2023 specialty lentils by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: No significant difference was found within each type.

By Location: The other damage was low in samples from Redvers, with all mean values below 0.6%.

Table 3.5.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	*NS*	*NS*	*NS*
Location	***	***	***
Variety x Location	*NS*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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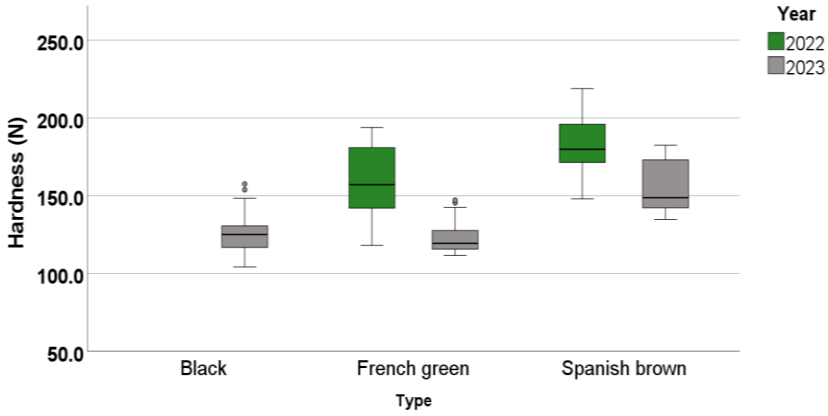
6. Hardness of Whole Seed

Method: Seed hardness is an important parameter to indicate milling yield and cooking quality. Seed hardness is affected by seed size, shape, density, composition, etc. Seed hardness was determined by measuring the force of breaking a seed using a texture analyzer (TMS-Pro, Food Technology Corporation, USA). The detailed procedure is outlined in the hardness section for green lentils (pg. 15).

Results: Figure 3.6.1. & **Table 3.6.1.** Hardness of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).

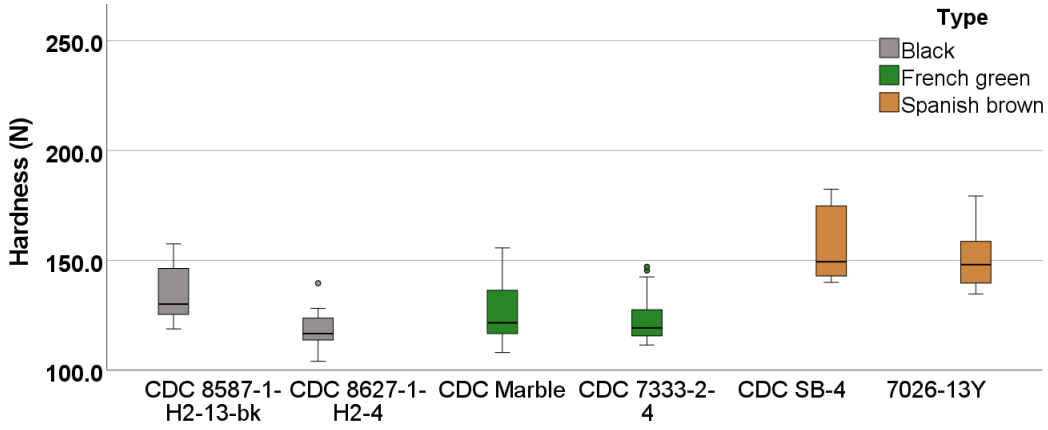


	Black	French green	Spanish brown
2022	n.a.	160.1 ± 5.3[a]	182.6 ± 2.9[a]
2023	126.9 ± 2.4	124.0 ± 3.1[b]	155.1 ± 3.0[b]

Note: different small letters within a column indicate significant differences.

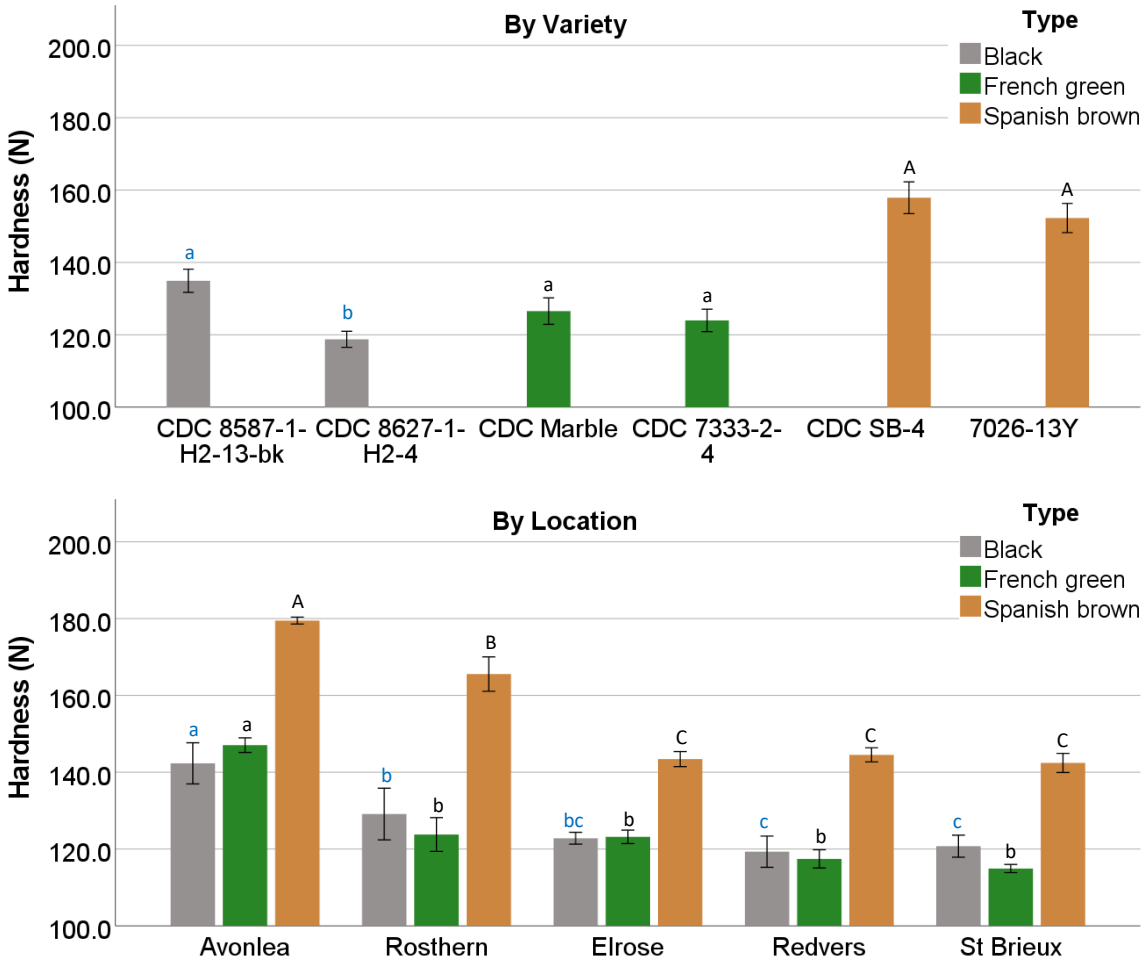
- The 2022 lentils had greater hardness than the 2023 samples ($p<0.05$).

Figure 3.6.2. Box and Whisker plot of specialty lentils hardness in 2023. Results by type were reported from highest to lowest.



- The Spanish brown varieties were higher than the French green and black lentils.

Figure 3.6.3. Mean hardness of 2023 specialty lentils by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: A 16 N difference was found between the black varieties.

By Location:

- Seed hardness from Elrose, Redvers, and St Brieux were similar for all types.
- Avonlea was significantly larger.

Table 3.6.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	***	*NS*	**
Location	***	***	***
Variety x Location	***	*NS*	*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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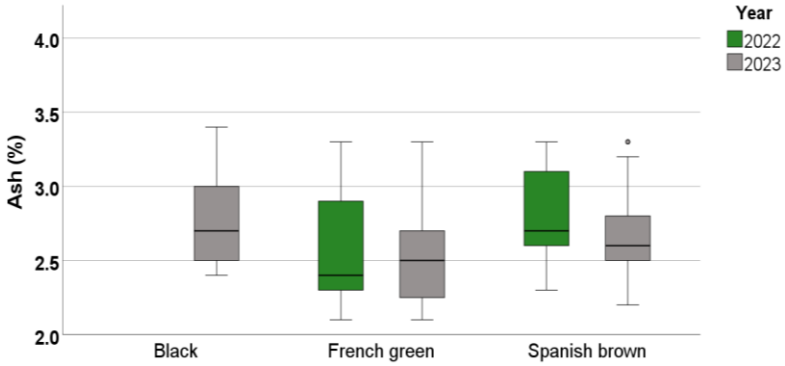
7. Ash Content

Method: Ash content (%) was determined using AACC 08-01.01[5] with modification. Samples were heated at 560°C till they turned white. Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

Results: Figure 3.7.1. & **Table 3.7.1.** Ash of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).

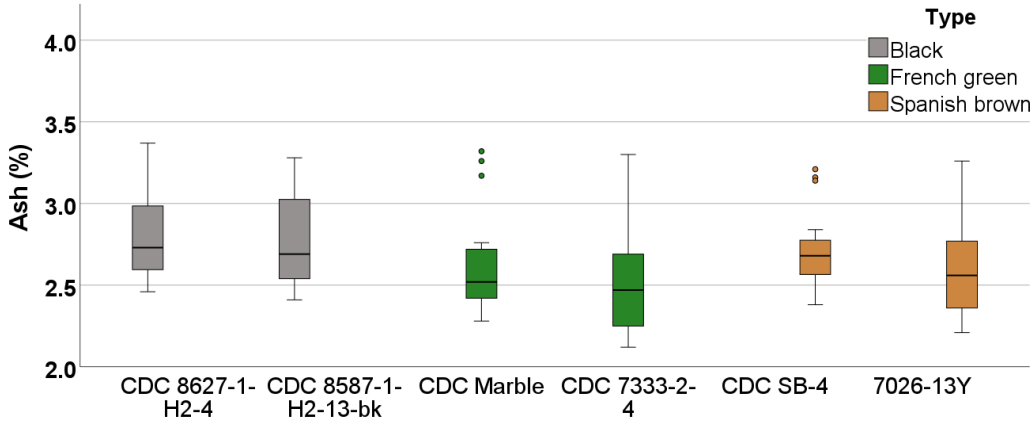


	Black	French green	Spanish brown
2022	n.a.	2.6 ± 0.1[a]	2.8 ± 0.0[a]
2023	2.8 ± 0.1	2.5 ± 0.1[a]	2.7 ± 0.1[a]

Note: different small letters within a column indicate significant differences.

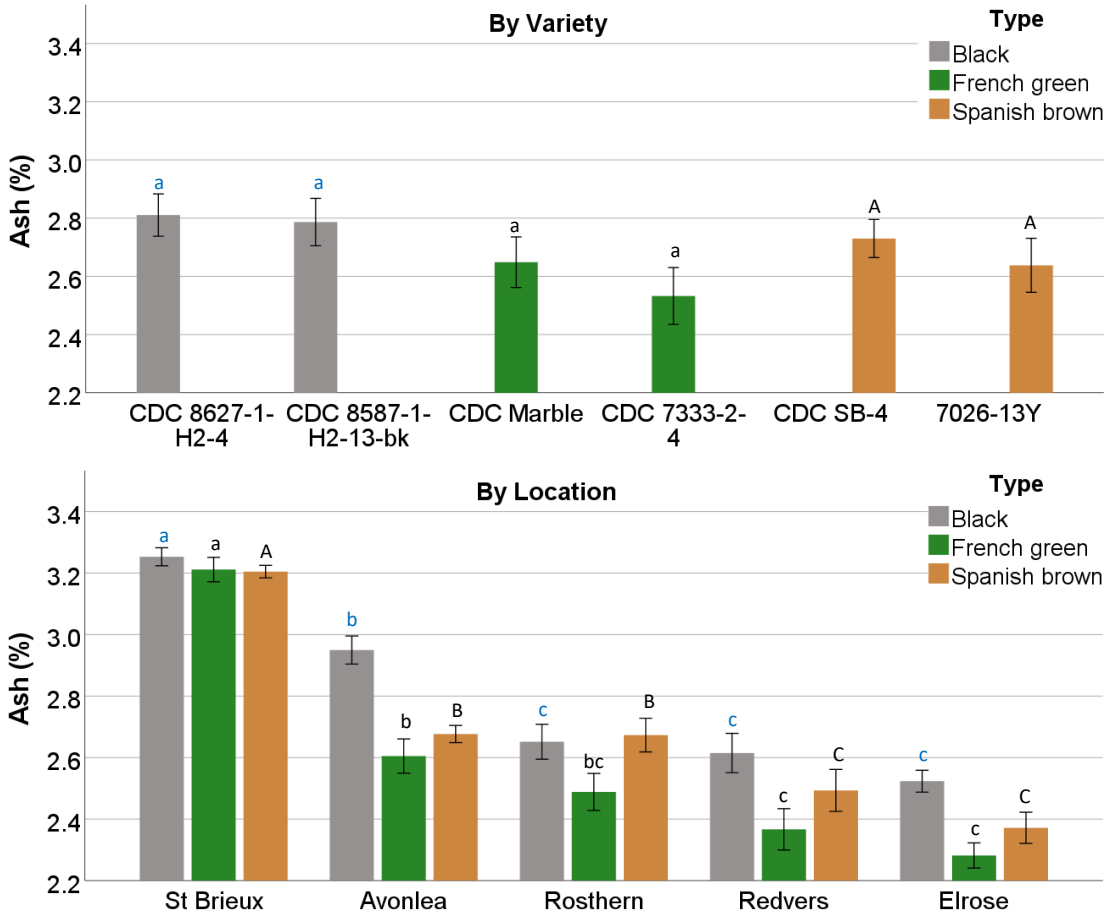
- Ash content was similar for all samples.

Figure 3.7.2. Box and Whisker plot of 2023 specialty lentils for ash content. Results by type were reported from highest to lowest.



[5] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 3.7.3. Mean ash content of 2023 specialty lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil

By Variety: No significant difference was found within each type.

By Location: Ash content was in general low except for those from St Brieux.

Table 3.7.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	*NS*	*NS*	*NS*
Location	***	***	***
Variety x Location	*NS*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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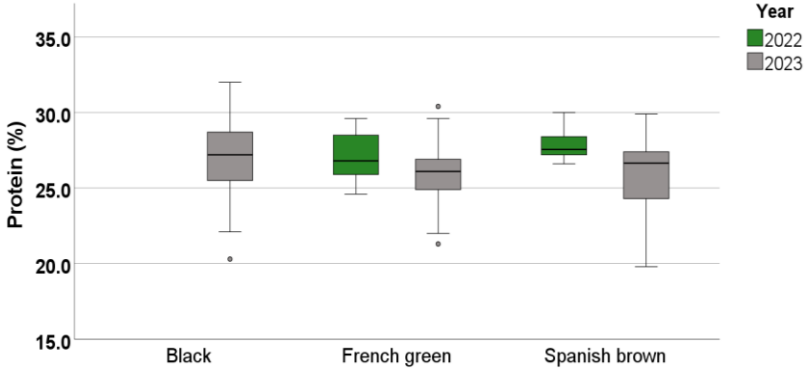
8. Protein Content

Method: The protein content (%) of each flour was determined through AACC 46-30[2] using the combustion method through a Rapid N Exceed (Elementar, USA). Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

Results: Figure 3.8.1. & **Table 3.8.1.** Protein of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).

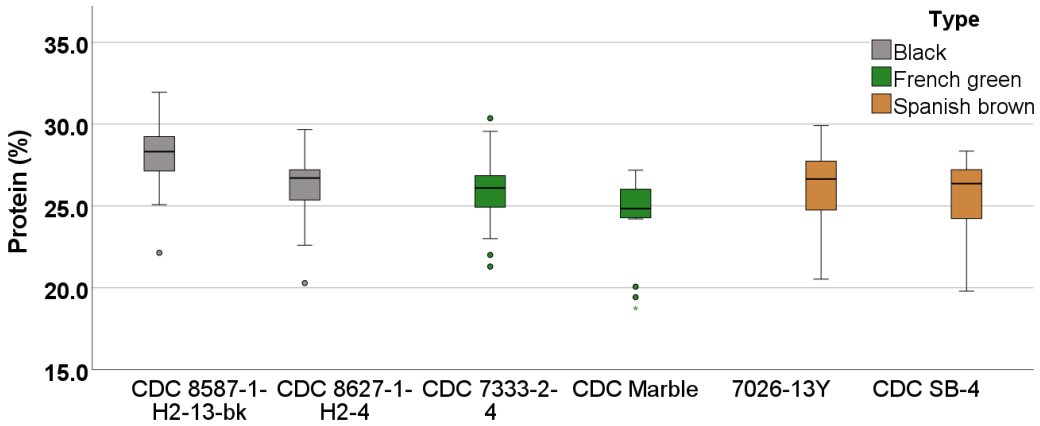


	Black	French green	Spanish brown
2022	n.a.	27.2 ± 0.4[a]	27.9 ± 0.2[a]
2023	26.9 ± 0.5	25.8 ± 0.6[a]	25.6 ± 0.5[b]

Note: different small letters within a column indicate significant differences.

- The 2023 lentils had lower protein contents and greater variability.

Figure 3.8.2. Box and Whisker plot of 2023 specialty lentils for protein content. Results by type were reported from highest to lowest.



- There were some outliers and extreme outliers.

[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

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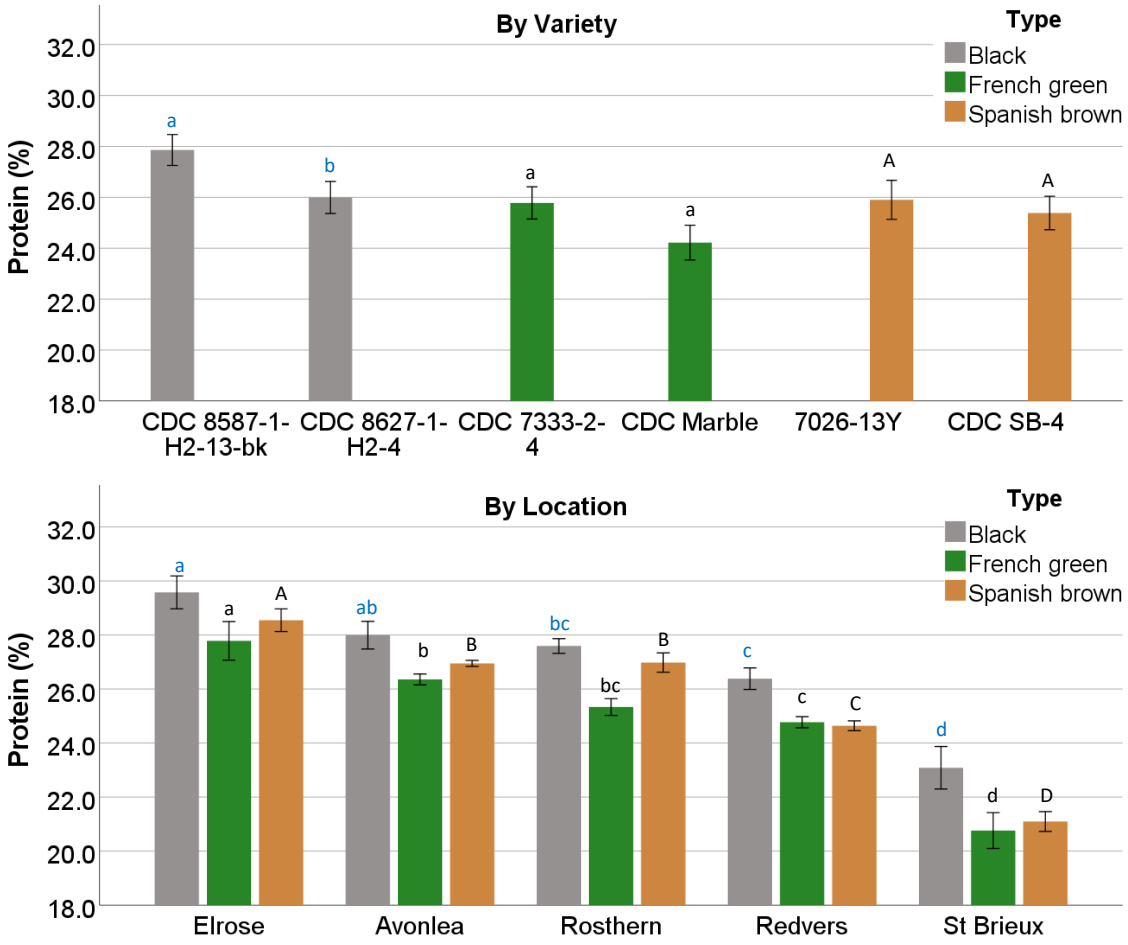
Figure 3.8.3. Mean protein of 2023 specialty lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: There was less than a 2% difference between the black varieties.

By Location: Protein varied significantly.

- **Black:** A 6.5% difference from highest to lowest.
- **French green:** A 7% difference from highest to lowest.
- **Spanish brown:** A 7.5% difference from highest to lowest.

Table 3.8.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	***	*NS*	*NS*
Location	***	***	***
Variety x Location	*NS*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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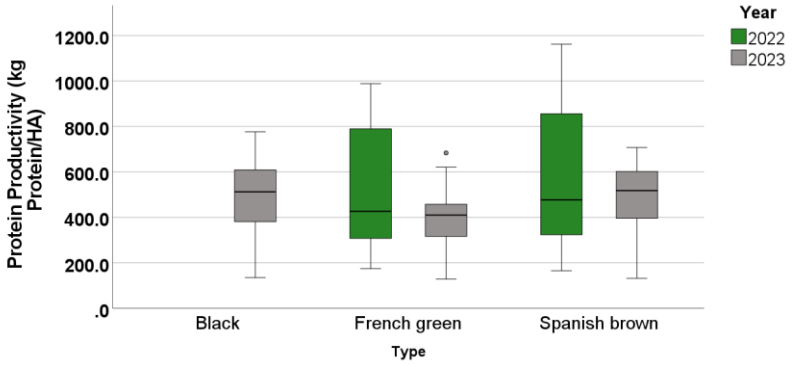
9. Protein Productivity

Method: Protein productivity (kg protein/HA), which is calculated using yield (kg/HA) multiplied by protein content (%), refers to the amount of protein produced per unit of land. It evaluates how much protein is being harvested from a given area.

Results: Figure 3.9.1. & **Table 3.9.1.** Protein productivity of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).



	Black	French green	Spanish brown
2022	n.a.	512.6 ± 64.5[a]	562.0 ± 50.9[a]
2023	486.5 ± 32.4	397.6 ± 37.7[a]	488.0 ± 31.3[a]

Note: different small letters within a column indicate significant differences.

- No significant differences in protein productivity

Figure 3.9.2. Box and Whisker plot of 2023 specialty lentils for protein productivity. Results by type were reported from highest to lowest.

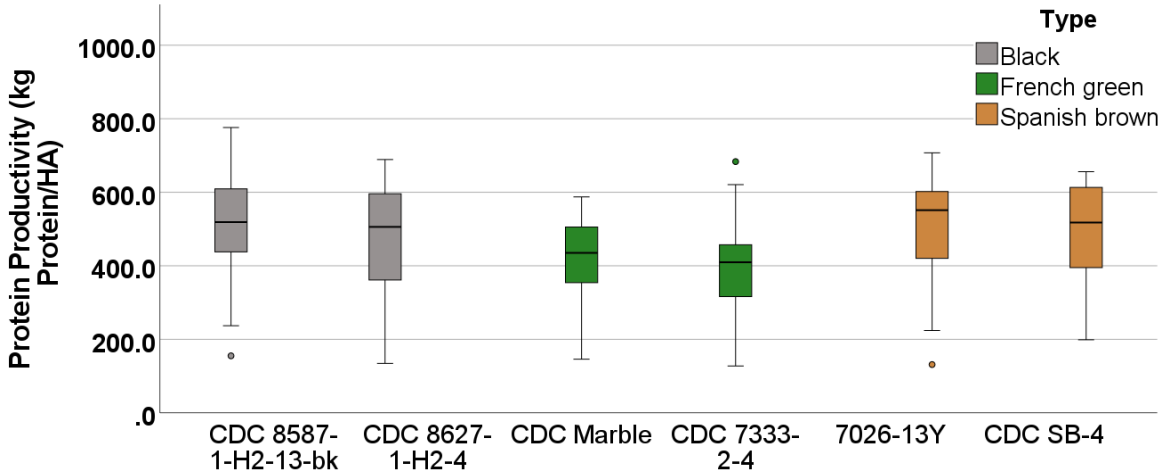
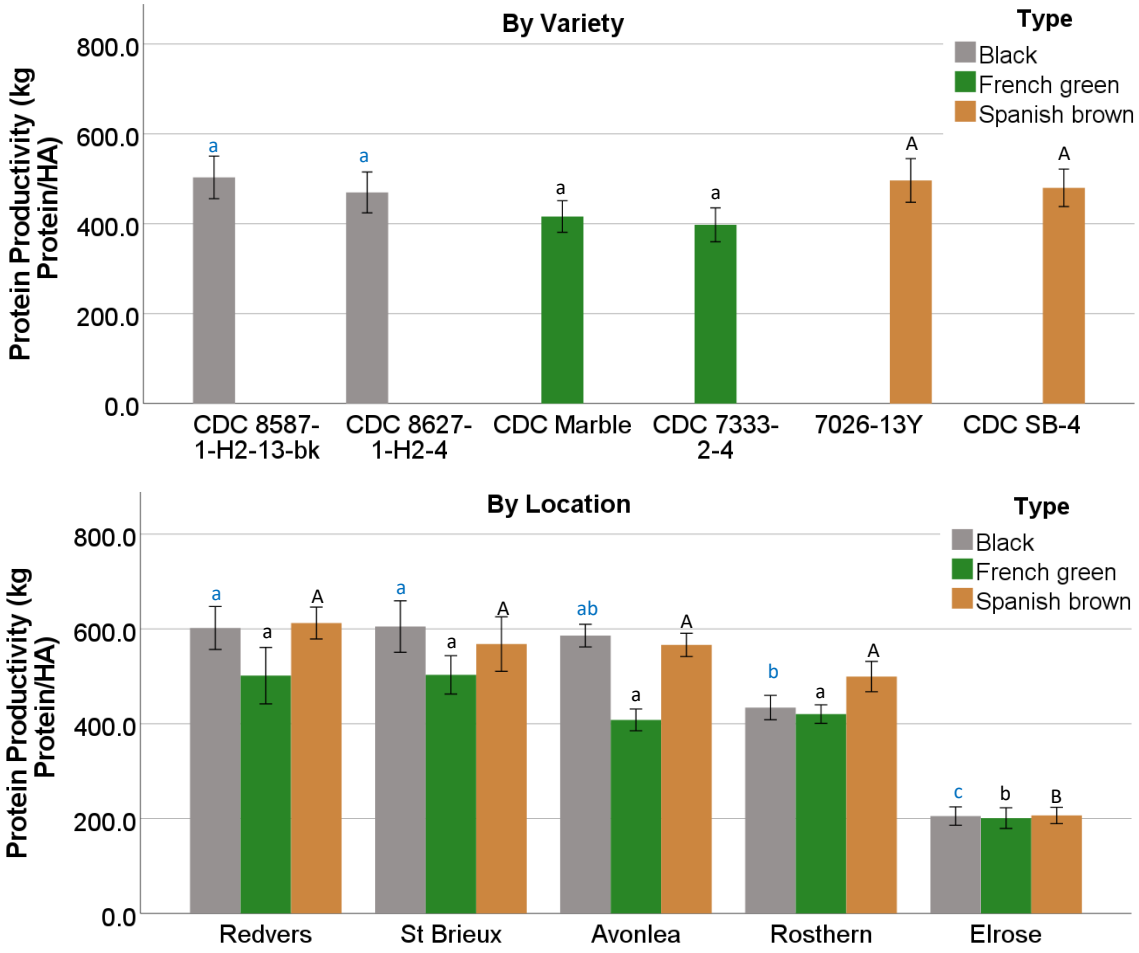


Figure 3.9.3. Mean protein productivity of 2023 specialty lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: There were no differences within each lentil type.

By Location:

- Redvers and St Brieux were similar (highest).
- Elrose was the lowest, approximately one-third that of Redver and St Brieux.

Table 3.9.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	*NS*	*NS*	*NS*
Location	***	***	***
Variety x Location	*NS*	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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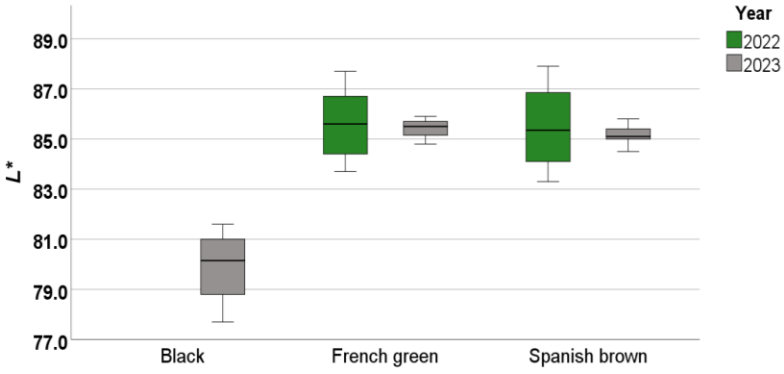
10. Colour

Method: The absolute colour of each flour was determined using the Konica Minolta CR-400 Chroma meter, where *L*, a*,* and *b** values were reported.

- ***L* (lightness):*** white (100) to black (0)
- ***a*:*** red (+) to green (-)
- ***b*:*** yellow (+) to blue (-)

a) ***L* (lightness):*** white (100) to black (0)

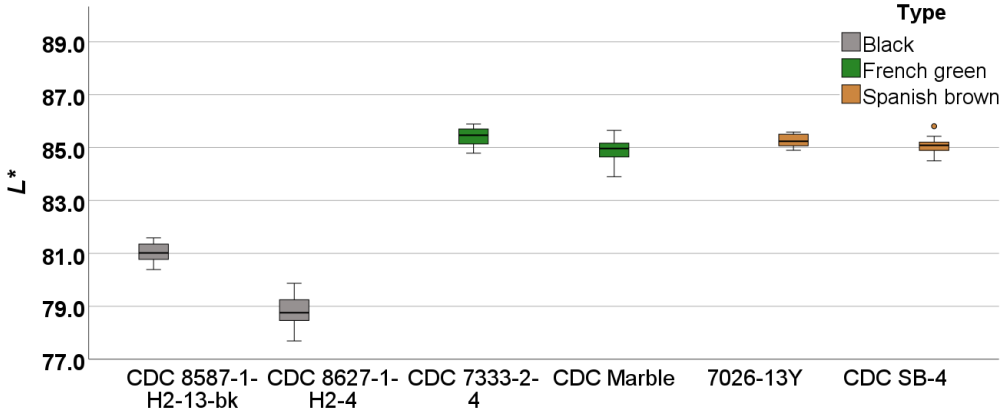
Results: Figure 3.10.1. & **Table 3.10.1.** Lightness of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).



	Black	French green	Spanish brown
2022	n.a.	85.6 ± 0.3[a]	85.4 ± 0.2[a]
2023	79.9 ± 0.2	85.4 ± 0.1[a]	85.2 ± 0.1[a]

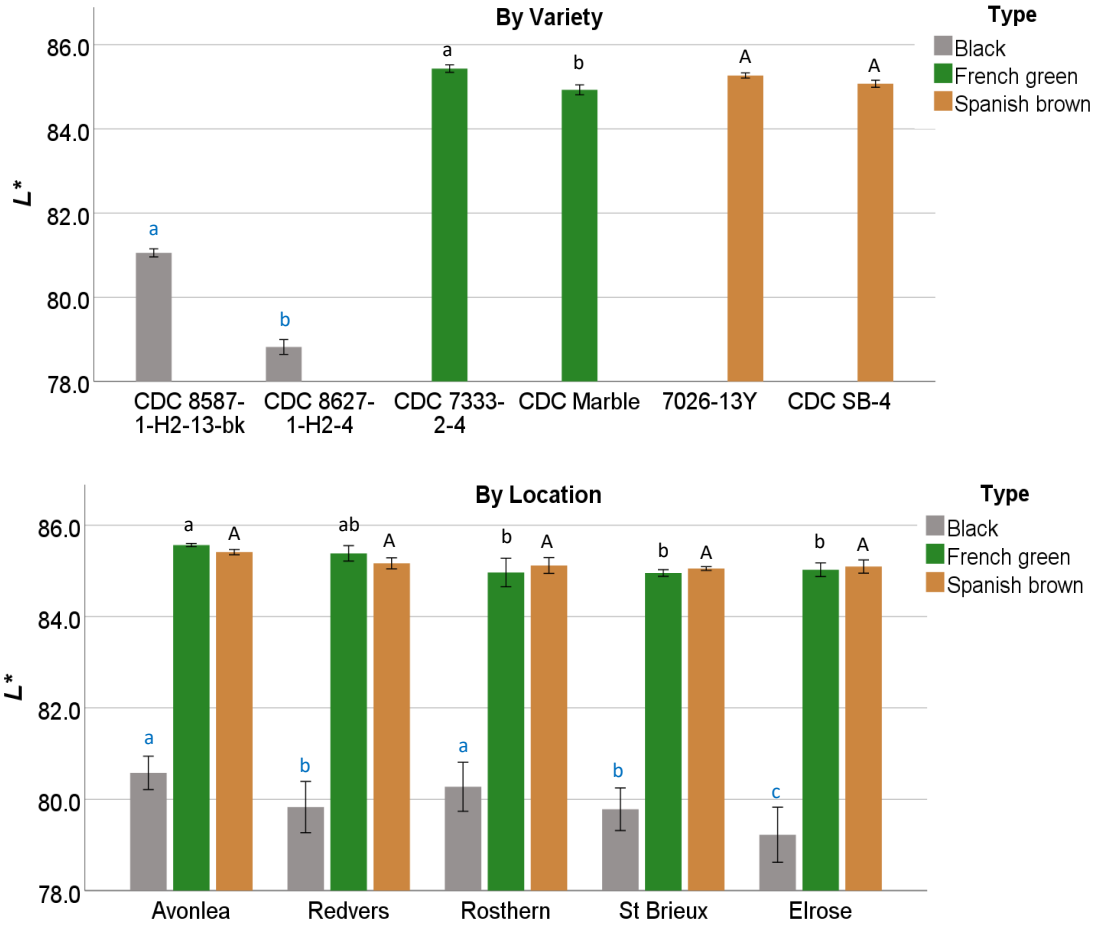
Note: different small letters within a column indicate significant differences.

Figure 3.10.2. The Box and Whisker plot of 2023 specialty lentils for *L** values. Results by type were reported from highest to lowest.



- Lightness varied between the two black types.

Figure 3.10.3. Mean *L** value of 2023 specialty lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: Lightness of the black lentil flours was much lower, which was associated with the black seed coat.

By Location: The location effect was minor.

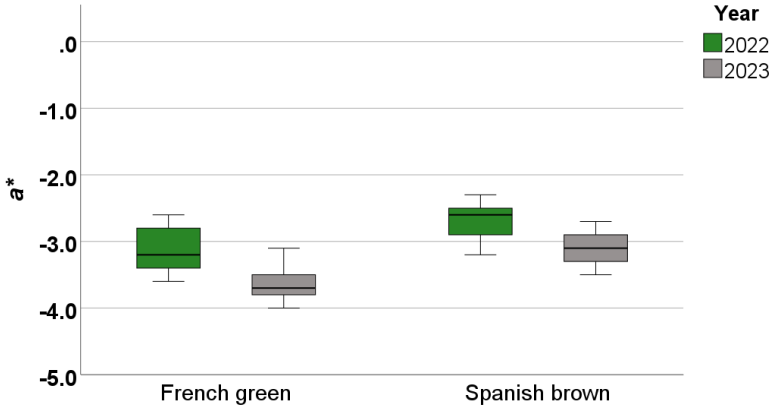
Table 3.10.2. Effects of variety and location.

	Black	French green	Spanish brown
Variety	***	***	*NS*
Location	***	**	*NS*
Variety x Location	**	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

b) ***a**:*** red (+) to green (-)

Results: Figure 3.10.4. & **Table 3.10.3.** *a** values of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties that were tested in both years; see the varieties shown in black in Table A (p. 2).

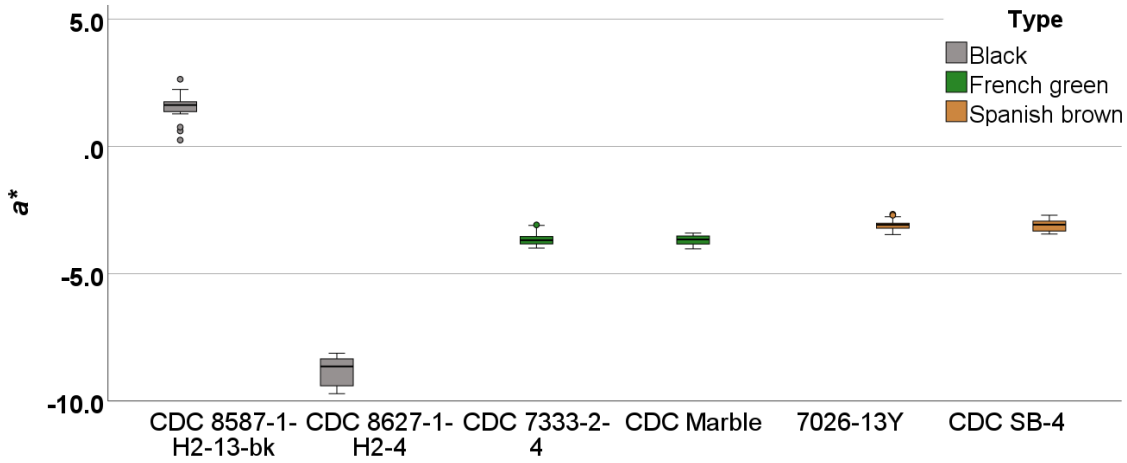


	Black	French green	Spanish brown
2022	n.a.	-3.1 ± 0.1[a]	-2.7 ± 0.0[a]
2023	-3.7 ± 1.0	-3.6 ± 0.1[b]	-3.1 ± 0.0[b]

Note: different small letters within a column indicate significant differences.

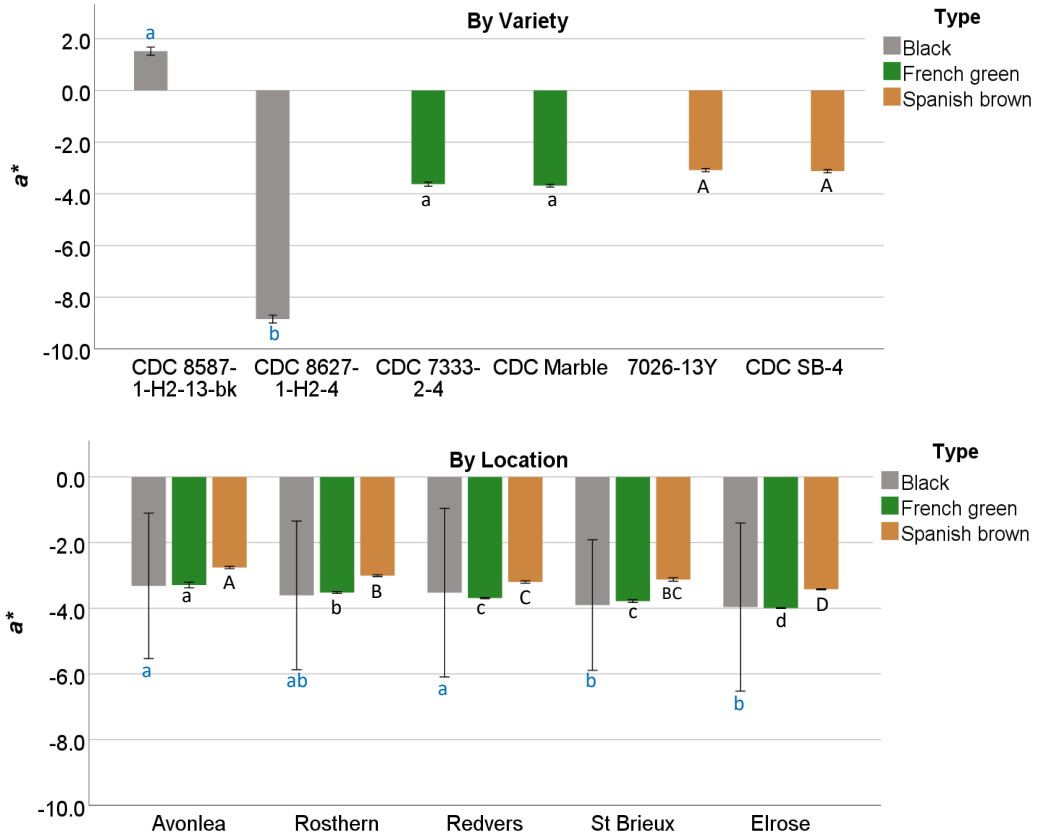
- Stronger greenness (more negative values) was observed in 2023 samples.

Figure 3.10.5. Box and Whisker plot of 2023 specialty lentils for *a** values. Results by type were reported from highest to lowest.



- **Black:** CDC 8587-1-H2-13-bk had a red cotyledon and thus positive *a** values, while CDC 8627-1-H2-4 had a green cotyledon and thus negative *a** values.
- In addition, CDC 8627-1-H2-4 displayed stronger greenness than the French green and Spanish brown samples.

Figure 3.10.6. Mean *a** value of 2023 specialty lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: Except for the black varieties, there was no significant difference within the French green and the Spanish brown.

By Location: The difference between locations was less than 1 unit.

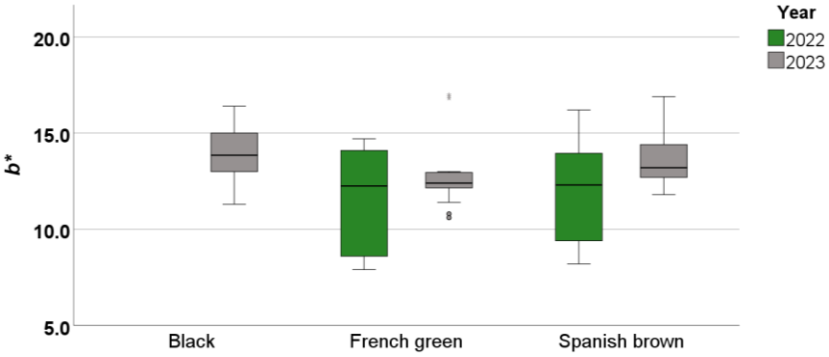
Table 3.10.4. Effects of variety and location.

	Black	French green	Spanish brown
Variety	***	*NS*	*NS*
Location	***	***	***
Variety x Location	***	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

c) ***b*:*** yellow (+) to blue (-)

Results: Figure 3.10.7. & **Table 3.10.5.** *b** values of specialty lentils in 2022 and 2023. Data in the table represent mean ± one standard error. The data of French green and Spanish brown lentils in the figure and table include only the varieties tested in both years, and there was no black lentil in 2022; see the varieties shown in black in Table A (p. 2).

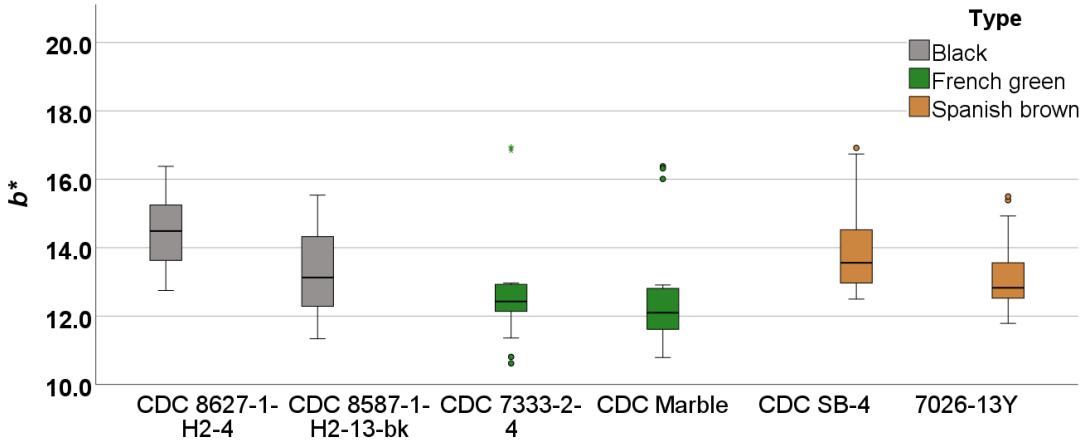


	Black	French green	Spanish brown
2022	n.a.	11.5 ± 0.6[a]	12.1 ± 0.4[b]
2023	13.9 ± 0.2	13.1 ± 0.5[a]	13.6 ± 0.3[a]

Note: different small letters within a column indicate significant differences.

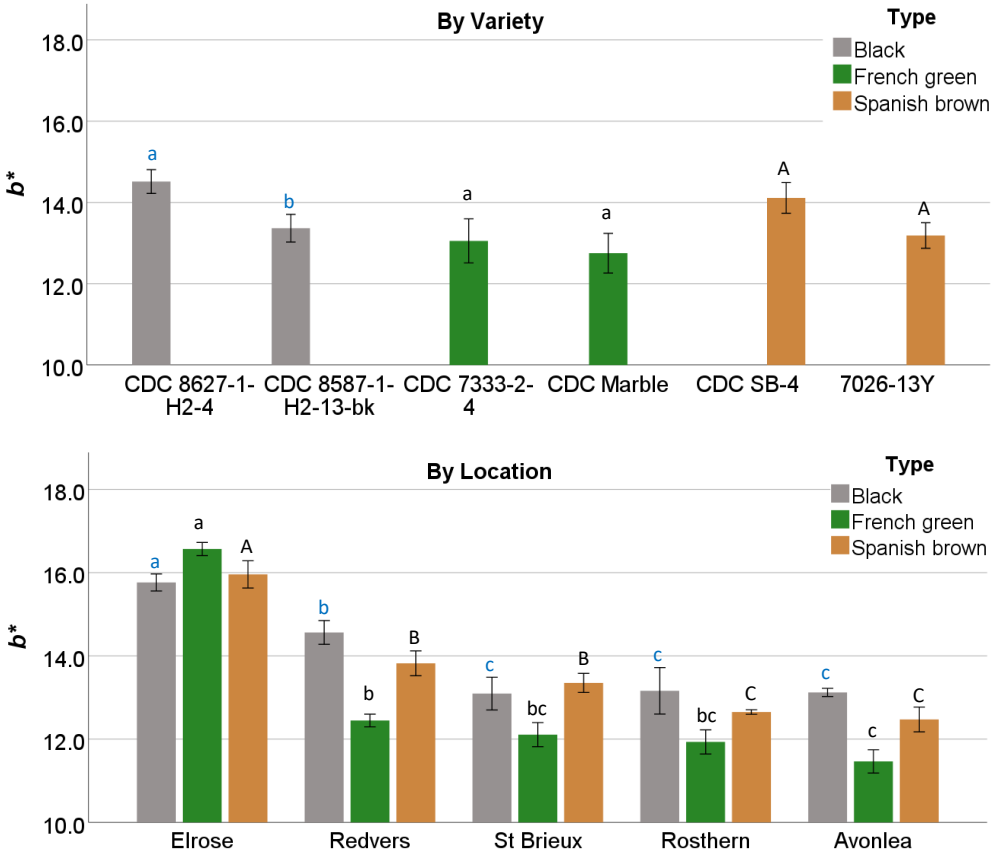
- Overall, the 2023 samples had greater yellowness.

Figure 3.10.8. Box and Whisker plot of 2023 specialty lentils for *b** values. Results by type were reported from highest to lowest.



- Each variety had great variability.

Figure 3.10.9. Mean *b** value of 2023 specialty lentils by variety and by location. Each bar represents mean ± one standard error.



Note: Capital letters in black indicated significant differences (p<0.05) by Spanish brown. Small letters in black indicated significant differences (p<0.05) by French green. Small letters in blue indicated significant differences (p<0.05) by black lentil.

By Variety: A 1.2 unit difference was found between the black varieties.

By Location: Sample from Elrose had significantly higher yellowness. The difference for other locations was less noticeable.

Table 3.10.6. Effects of variety and location.

	Black	French green	Spanish brown
Variety	***	*NS*	*NS*
Location	***	***	***
Variety x Location	***	*NS*	*NS*

*Note: ***p<0.001; **p<0.01; *p<0.05; NS not significant.*

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