# *2023 Pulse Quality Evaluation*

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## Chickpea

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, lentils, chickpeas, faba beans, 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 Chickpea Quality

This report evaluated **357** chickpea samples harvested from **seven locations**, including Avonlea, Elrose, Goodale, Lucky Lake, Moose Jaw, Redvers, and Swift Current, in **2023**. There were **seventeen varieties**, which included fourteen varieties of kabuli, one black desi variety, one desi, and one white desi. Three replicates of each variety were cultivated in each location. **Table A** and **Figure A** provide the samples' information and locations in detail.

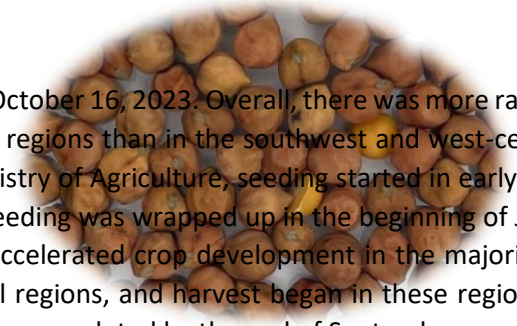

**Figure B** provides the cumulative rainfall from April 1 to October 16, 2023. Overall, there was more rainfall in the southeast, east-central, northeast and northwest regions than in the southwest and west-central regions. According to the 2023 Crop Reports by the Ministry of Agriculture, seeding started 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 peas, lentils, and chickpeas was completed by the end of September.

**Table A.** Description of 2023 chickpea samples tested for the Pulse Quality Program. Varieties presented in both 2022 and 2023 are shown in black, and new varieties that entered in 2023 are shown in red.

| Crop | Type | Variety | | Site | Number of samples |
|---|---|---|---|---|---|
| **Chickpea** | **Kabuli** | CDC Climax | Kasin | Avonlea<br>Elrose<br>Goodale<br>Lucky Lake<br>Moose Jaw<br>Redvers<br>Swift Current | 357 |
| | | CDC Hardy | 3315-6 | | |
| | | CDC Lancer | 3584-4 | | |
| | | CDC Leader | 3789-7 | | |
| | | CDC Orkney | 3869-11 | | |
| | | CDC Pasqua | 3884-2 | | |
| | | CDC Pearl | 3896-11 | | |
| | **Black desi** | CDC Kala | | | |
| | **Desi** | CDC Sunset | | | |
| | **White desi** | 3627-7 | | | |

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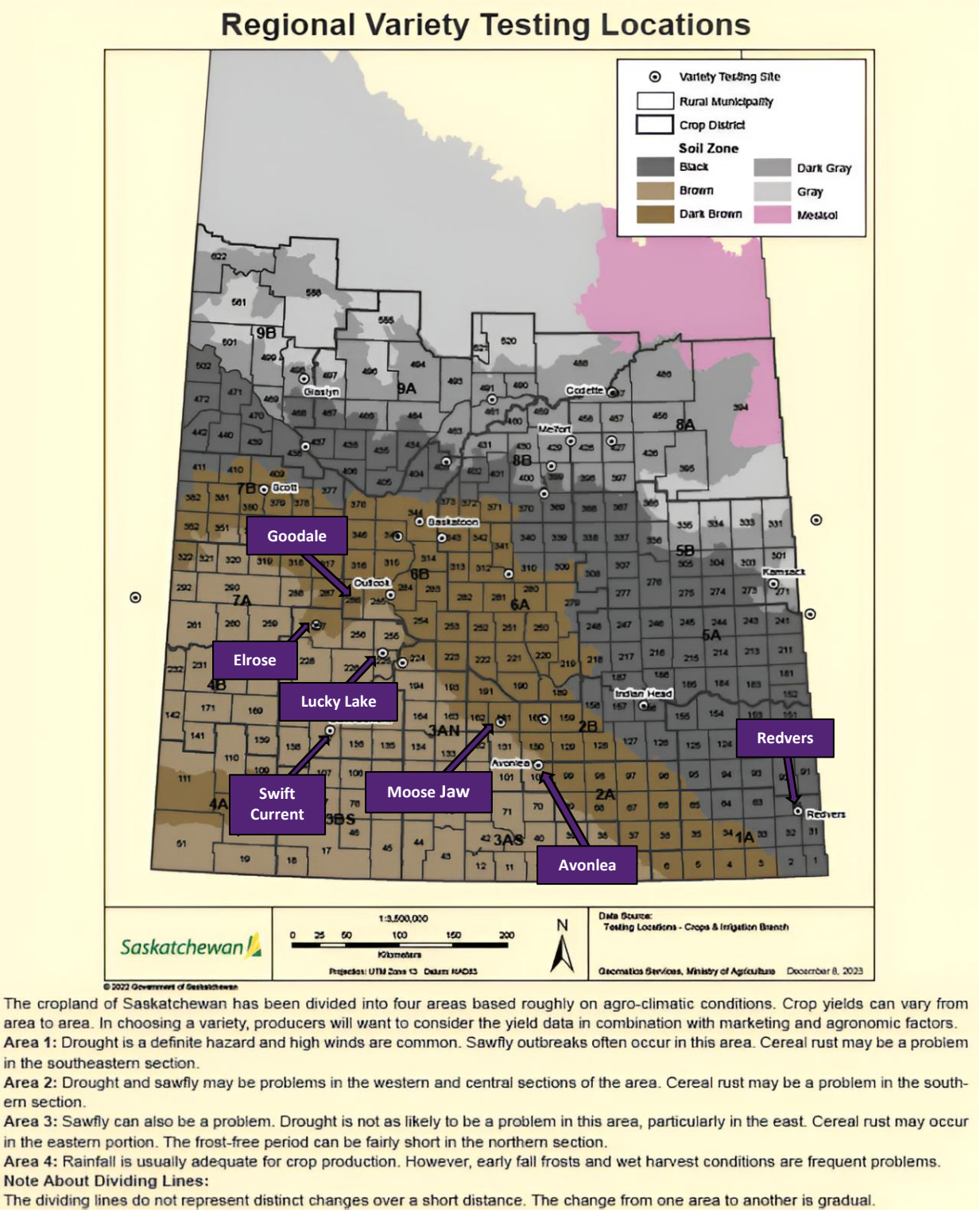


**Figure A.** Locations for chickpea quality testing in 2023 and the corresponding soil zones. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

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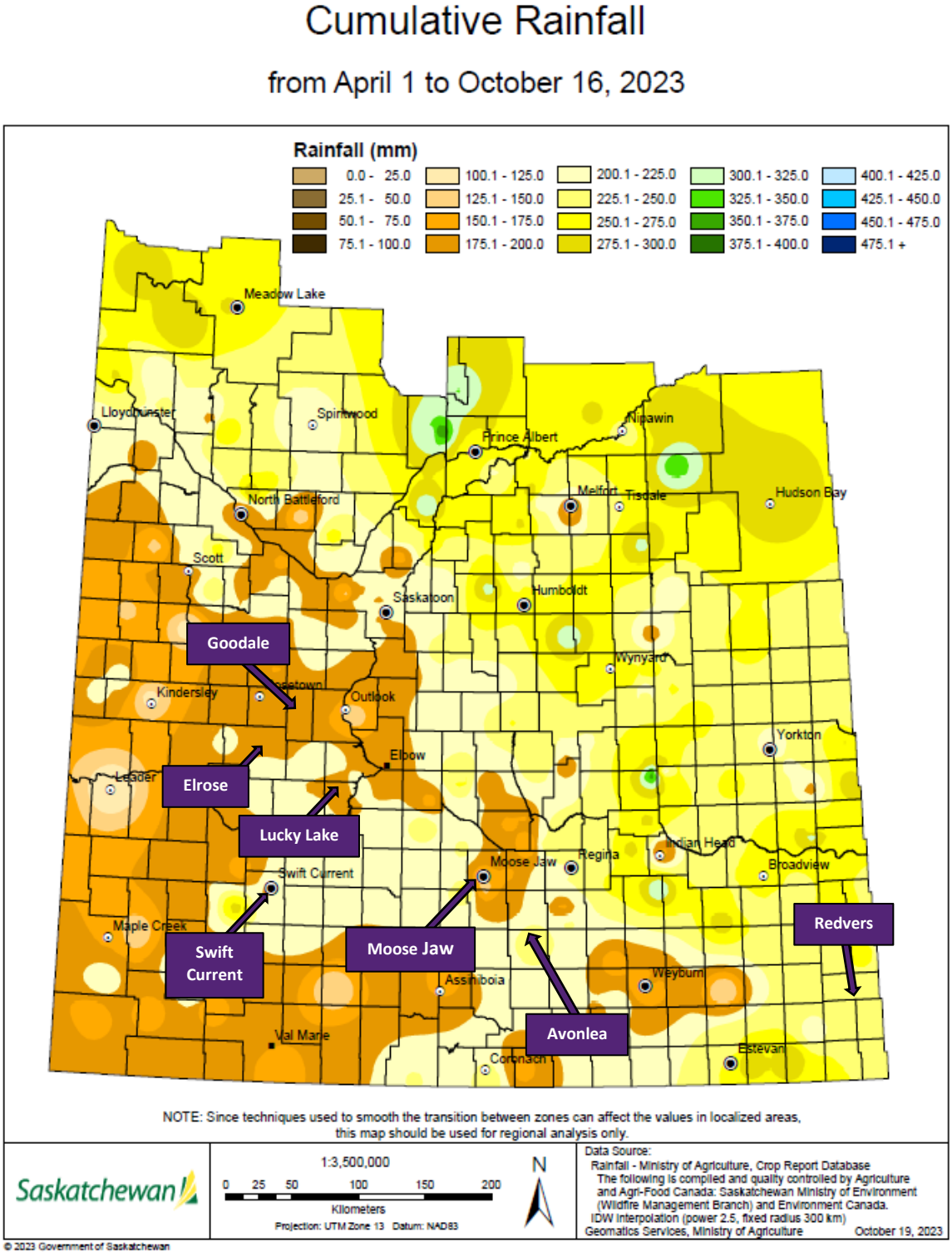



**Figure B.** Locations for Chickpea quality testing and cumulative rainfall from April 1 to October 16, 2023. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

This report includes two sections: **1)** 2023 kabuli chickpea varieties and **2)** 2023 black desi + desi + white desi varieties. Each section includes ten subsections for the results of the following quality parameters:

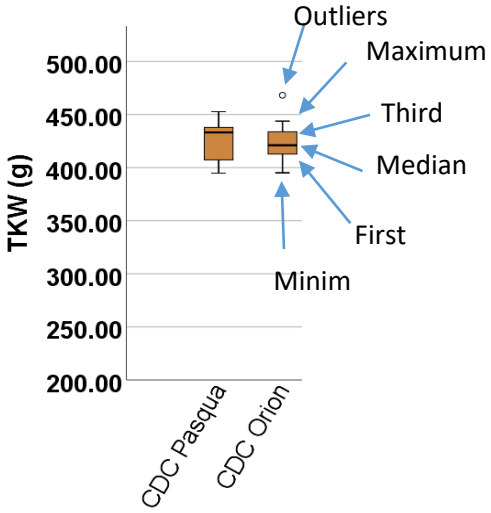
1. Yield
2. Thousand kernel weight (TKW)
3. Seed size distribution
4. Split amount
5. Other damage
6. Hardness of whole seed
7. Ash content
8. Protein content
9. Protein productivity
10. Colour (*L*, a*,* and *b**)

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 average value 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, other damage, protein, protein productivity, ash, and colour, by location for kabuli, desi, white desi, and black desi chickpeas and by variety for kabuli chickpeas.

An independent T-test was conducted to identify the differences in the quality parameters for desi chickpeas by variety. A two-way analysis of variance (ANOVA) was conducted to determine the effects of variety, location, and their interaction on each parameter for kabuli chickpeas. The Pearson Product Moment Correlation was performed to measure the correlation between quality parameters.

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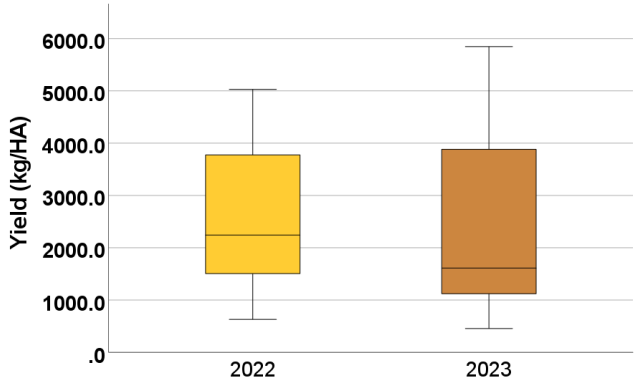
# 1) 2023 Kabuli Chickpea Quality

## 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 kabuli chickpeas 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).

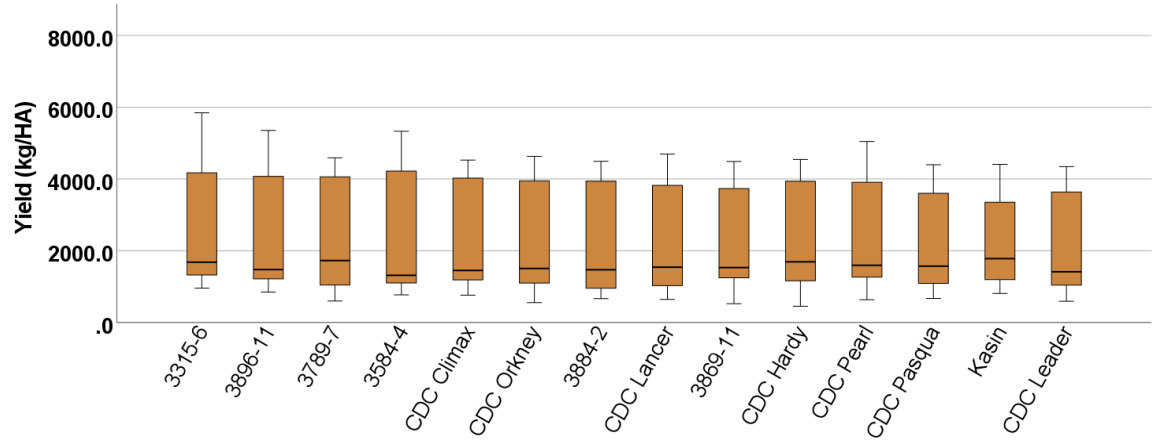



| | Kabuli Chickpea |
|---|---|
| **2022** | 2635.0 ± 98.7[a] |
| **2023** | 2369.7 ± 104.1[a] |

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

- No significant differences in yield were found between the two years.

**Figure 1.1.2.** Box and Whisker plot of 2023 kabuli chickpeas for yield. Results were reported from highest to lowest.




- The variability was high for each variety.

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

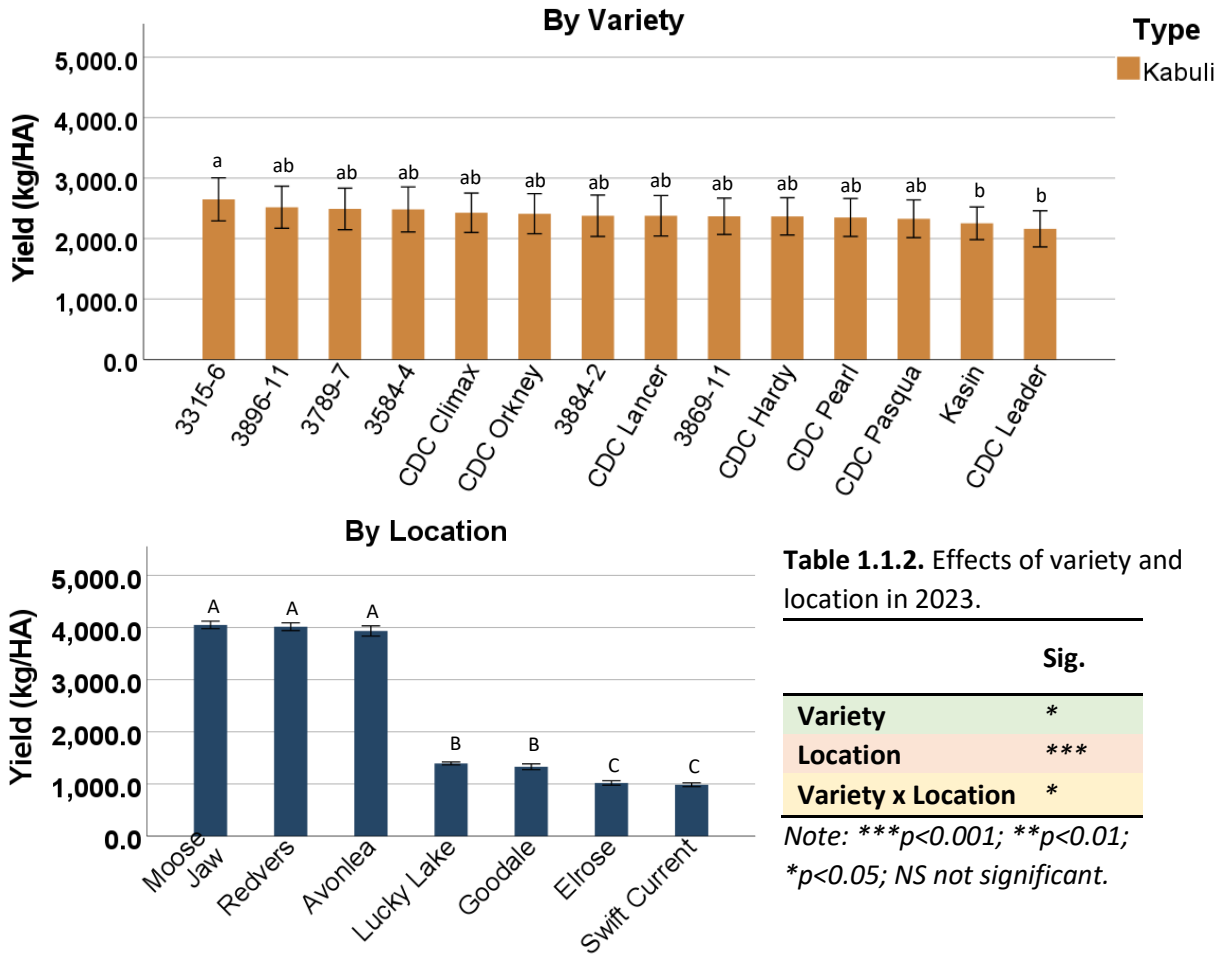


**Table 1.1.2.** Effects of variety and location in 2023.

| | Sig. |
|---|---|
| **Variety** | * |
| **Location** | *** |
| **Variety x Location** | * |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- A difference of 488 kg/HA was determined from the largest (line 3315-6) to the smallest (Kasin, CDC Leader).

**By Location:**

- Three very high lications with yield about 4000 kg/HA were observed.
- In contrast, the yield of other four locations was very ow, all below 1400 kg/HA.

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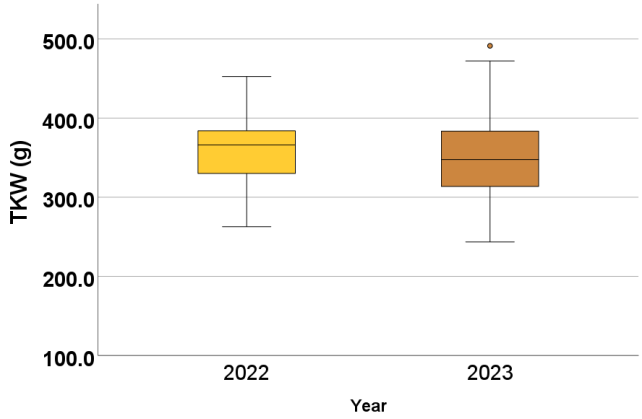
## 2. Thousand Kernel Weight

**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 kabuli chickpeas 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).

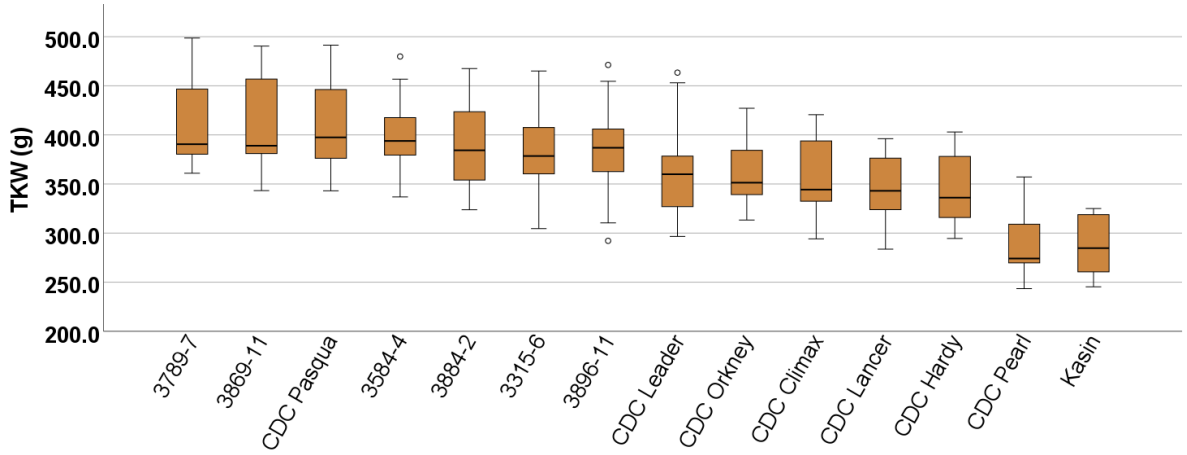



| | Kabuli Chickpea |
|---|---|
| **2022** | 356.9 ± 3.4[a] |
| **2023** | 349.4 ± 3.9[a] |

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

- No significant differences in TKW were found between the two years.

**Figure 1.2.2.** Box and Whisker plot of 2023 kabuli chickpeas for TKW. Results were reported from highest to lowest.




- Lines 3789-7, 3869-11, and CDC Pasqua were larger in size.
- Kasin and CDC Pearl were the smallest in TKW.

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

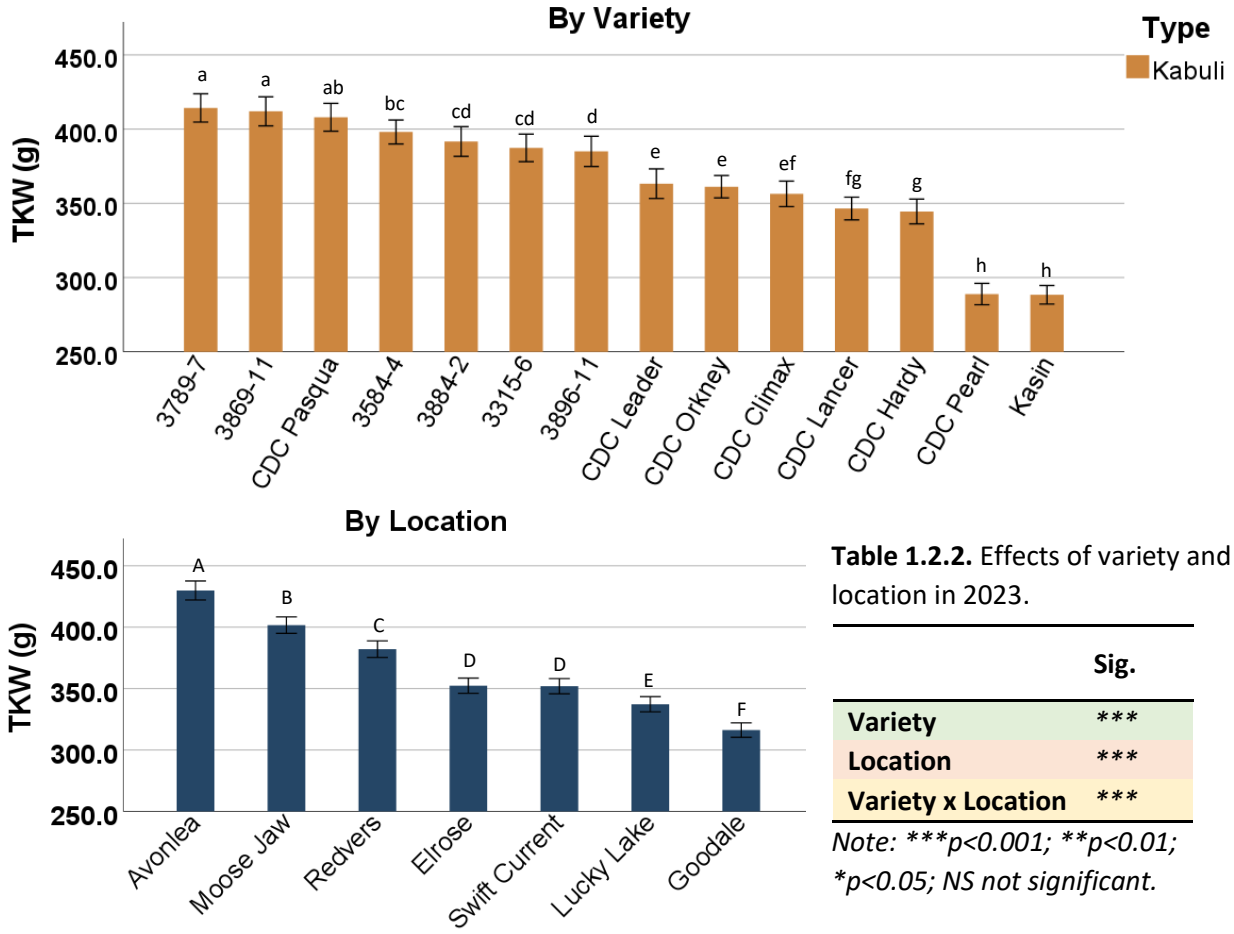



**Table 1.2.2.** Effects of variety and location in 2023.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- A difference of ~125 g was determined from the largest (lines 3789-7 and 3869-11) to the smallest (CDC Pearl and Kasin).

**By Location:**

- TKW was significantly different in each location, where a difference of 113 g was observed from highest to lowest.

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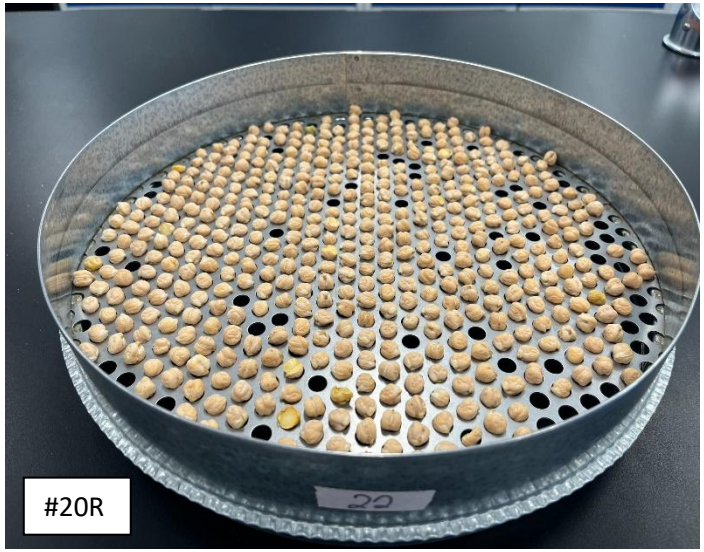
## 3. Seed Size Distribution

**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 chickpeas:

a. #24R: 9.52 mm
b. #22R: 8.73 mm
c. #20R: 7.94 mm
d. #18R: 7.14 mm
e. #16R: 6.35 mm

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**Results: Table 1.3.** Seed size distribution (%) of each 2023 kabuli chickpea variety. Data represent mean ± one standard error.

| Variety | > 9.52 mm (%) | > 8.73 mm (%) | > 7.94 mm (%) | > 7.14 mm (%) | > 6.35 mm (%) | Below 6.35 mm (%) |
|---|---|---|---|---|---|---|
| 3789-7 | 12.6 ± 2.4$^{a}$ | 42.7 ± 3.2$^{a}$ | 32.8 ± 3.4$^{fg}$ | 9.3 ± 1.4$^{h}$ | 1.9 ± 0.4$^{g}$ | 0.6 ± 0.2$^{ef}$ |
| 3869-11 | 11.2 ± 2.1$^{a}$ | 43.1 ± 3.5$^{a}$ | 34.2 ± 3.6$^{ef}$ | 9.6 ± 1.6$^{h}$ | 1.9 ± 0.4$^{g}$ | 0.5 ± 0.1$^{f}$ |
| CDC Pasqua | 8.4 ± 1.7$^{b}$ | 40.8 ± 3.3$^{ab}$ | 34.9 ± 2.7$^{ef}$ | 11.8 ± 1.7$^{gh}$ | 3.0 ± 0.8$^{efg}$ | 1.0 ± 0.3$^{cdef}$ |
| 3584-4 | 6.6 ± 1.8$^{b}$ | 42.1 ± 2.6$^{ab}$ | 37.4 ± 2.5$^{de}$ | 10.4 ± 1.5$^{h}$ | 2.6 ± 0.5$^{fg}$ | 0.9 ± 0.2$^{def}$ |
| 3315-6 | 6.7 ± 1.8$^{b}$ | 38.9 ± 3.7$^{b}$ | 40.7 ± 3.4$^{cd}$ | 11.4 ± 1.9$^{gh}$ | 1.9 ± 0.4$^{g}$ | 0.4 ± 0.1$^{f}$ |
| 3884-2 | 6.3 ± 1.3$^{b}$ | 38.5 ± 3.4$^{b}$ | 37.1 ± 2.4$^{de}$ | 13.6 ± 2.0$^{g}$ | 3.4 ± 0.7$^{defg}$ | 1.2 ± 0.4$^{cde}$ |
| 3896-11 | 3.0 ± 0.9$^{c}$ | 33.8 ± 4.0$^{c}$ | 45.3 ± 2.8$^{b}$ | 13.9 ± 2.2$^{g}$ | 3.1 ± 0.8$^{efg}$ | 0.9 ± 0.3$^{cdef}$ |
| CDC Leader | 3.5 ± 1.2$^{c}$ | 25.7 ± 3.5$^{d}$ | 44.5 ± 2.7$^{bc}$ | 20.2 ± 2.3$^{e}$ | 4.6 ± 0.9$^{cde}$ | 1.5 ± 0.4$^{c}$ |
| CDC Climax | 1.9 ± 0.4$^{cd}$ | 24.0 ± 3.7$^{d}$ | 45.9 ± 1.5$^{b}$ | 22.3 ±3.1$^{de}$ | 4.9 ± 1.0$^{cd}$ | 0.9 ± 0.2$^{def}$ |
| CDC Orkney | 1.5 ± 0.5$^{cd}$ | 25.7 ± 3.2$^{d}$ | 50.9 ± 2.1$^{a}$ | 17.3 ± 2.2$^{f}$ | 3.7 ± 0.8$^{def}$ | 0.9 ± 0.2$^{cdef}$ |
| CDC Hardy | 0.6 ± 0.1$^{d}$ | 22.0 ± 3.6$^{d}$ | 48.1 ± 1.4$^{ab}$ | 24.0 ± 3.4$^{cd}$ | 4.5 ± 0.8$^{cde}$ | 0.8 ± 0.1$^{ef}$ |
| CDC Lancer | 0.6 ± 0.1$^{d}$ | 15.6 ± 2.2$^{e}$ | 50.4 ± 2.2$^{a}$ | 26.0 ± 2.9$^{c}$ | 5.8 ± 1.0$^{c}$ | 1.5 ± 0.4$^{cd}$ |
| CDC Pearl | 0.0 ± 0.0$^{d}$ | 2.4 ± 0.9$^{f}$ | 28.3 ± 3.8$^{g}$ | 46.6 ± 2.3$^{b}$ | 19.2 ± 2.4$^{b}$ | 3.4 ± 0.7$^{a}$ |
| Kasin | 0.0 ± 0.0$^{d}$ | 0.4 ± 0.1$^{f}$ | 23.6 ± 3.4$^{h}$ | 51.2 ± 1.1$^{a}$ | 22.1 ± 3.2$^{a}$ | 2.7 ± 0.5$^{b}$ |

*Note: Means within a column followed by different lowercase letters are significantly different ($p<0.05$).*

- Seed size distribution results corresponded to TKW.
- The new lines 3789-7 and 3869-11 had the largest size, with over 10% of seeds larger than 9.52 mm.
- CDC Pasqua and lines 3315-6, 3584-4, 3884-2 had similar size.
- In contrast, Kasin and CDC Pearl, with the most seeds ranging between 8.73 mm to 6.35 mm.

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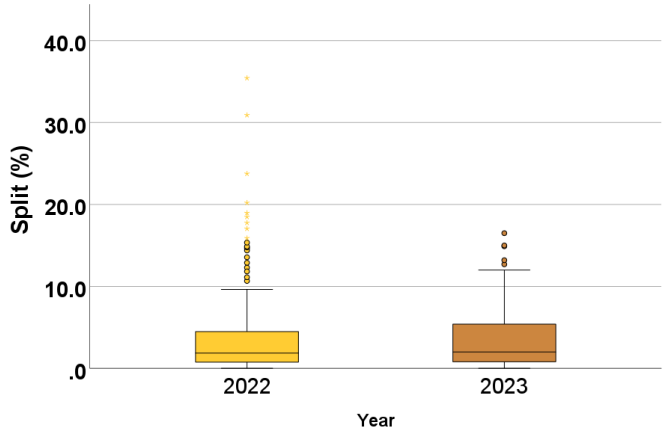
## 4. Split

**Method:** 100 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.** Split of kabuli chickpeas 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).

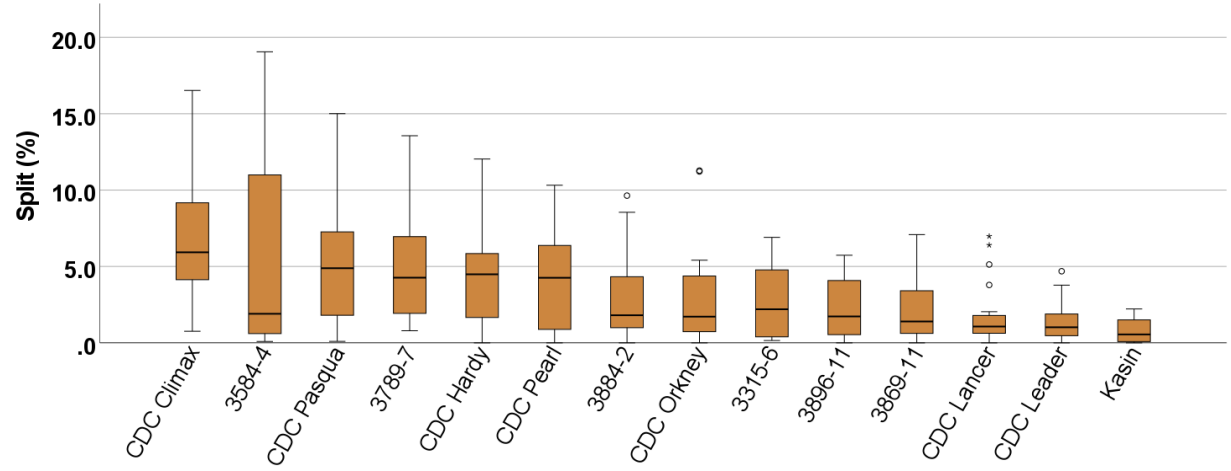



| | Kabuli Chickpea |
|---|---|
| **2022** | 4.2 ± 0.5[a] |
| **2023** | 3.3 ± 0.3[a] |

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

- No significant differences in split amount were found between the two years.

**Figure 1.4.2.** Box and Whisker plot of 2023 kabuli chickpeas for the split. Results were reported from highest to lowest.




- Kasin had the lowest amount of split and small variability.
- CDC Climax and line 3584-4 had the highest split and cracked seed coat with large variability.

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**Figure 1.4.3.** Mean split of 2023 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

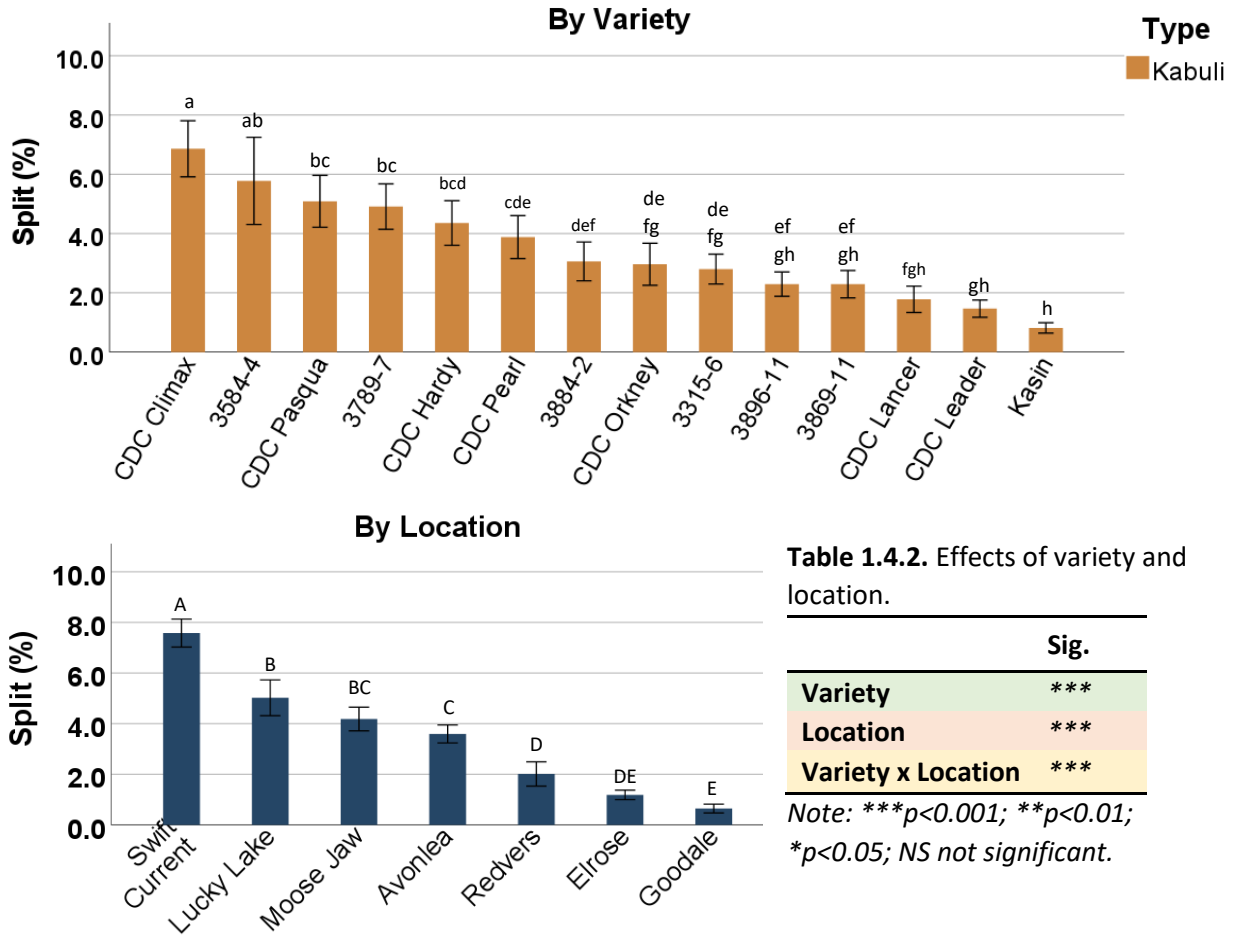


**Table 1.4.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

Split amount varied significantly between varieties and locations.

- **By Variety:** A difference of 6% was determined from the largest to the smallest.
- **By Location:** The amount of split + cracked seed coat was extremely high in Swift Current bu tlow in Goodale and Elrose, which was opposite to last year, indicating seed harvest condition and processing playing a role.

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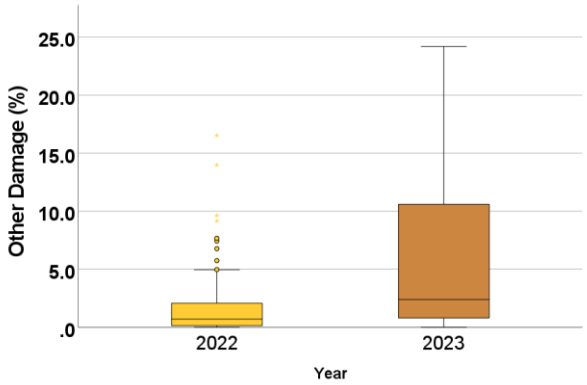
## 5. Other Damage

**Method:** 100 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included chickpeas that are sprouted, shrivelled, heated, frost, and insect damage.

**Results: Figure 1.5.1.** & **Table 1.5.1.** Other damage of kabuli chickpeas 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).

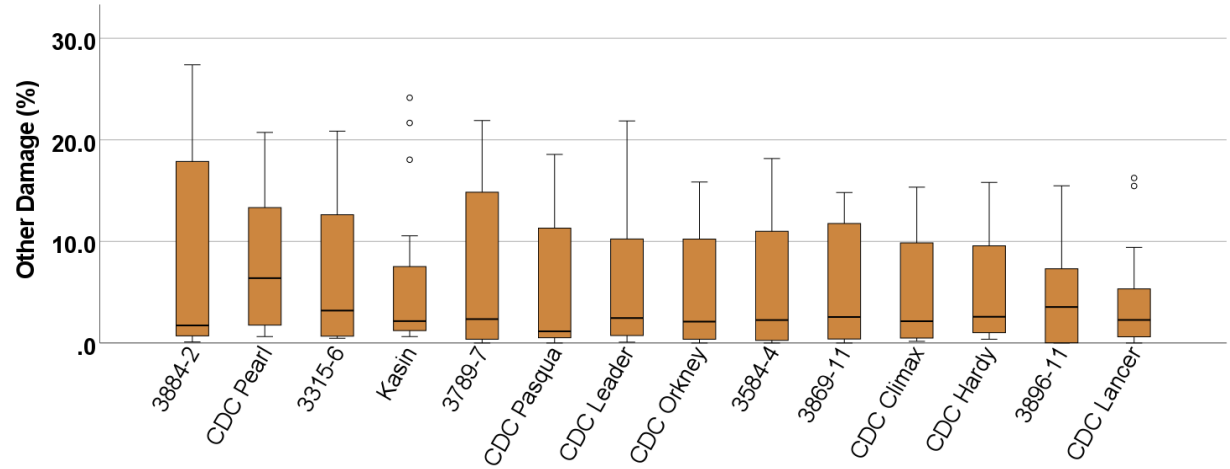



| | Kabuli Chickpea |
|---|---|
| **2022** | 1.5 ± 0.2[b] |
| **2023** | 5.7 ± 0.4[a] |

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

- The other damage for 2023 kabuli chickpeas was significantly higher than the 2022 samples.

**Figure 1.5.2.** Box and Whisker plot of 2023 kabuli chickpeas for other damage. Results were reported from highest to lowest.




- Large viariability was seen in each variety.

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

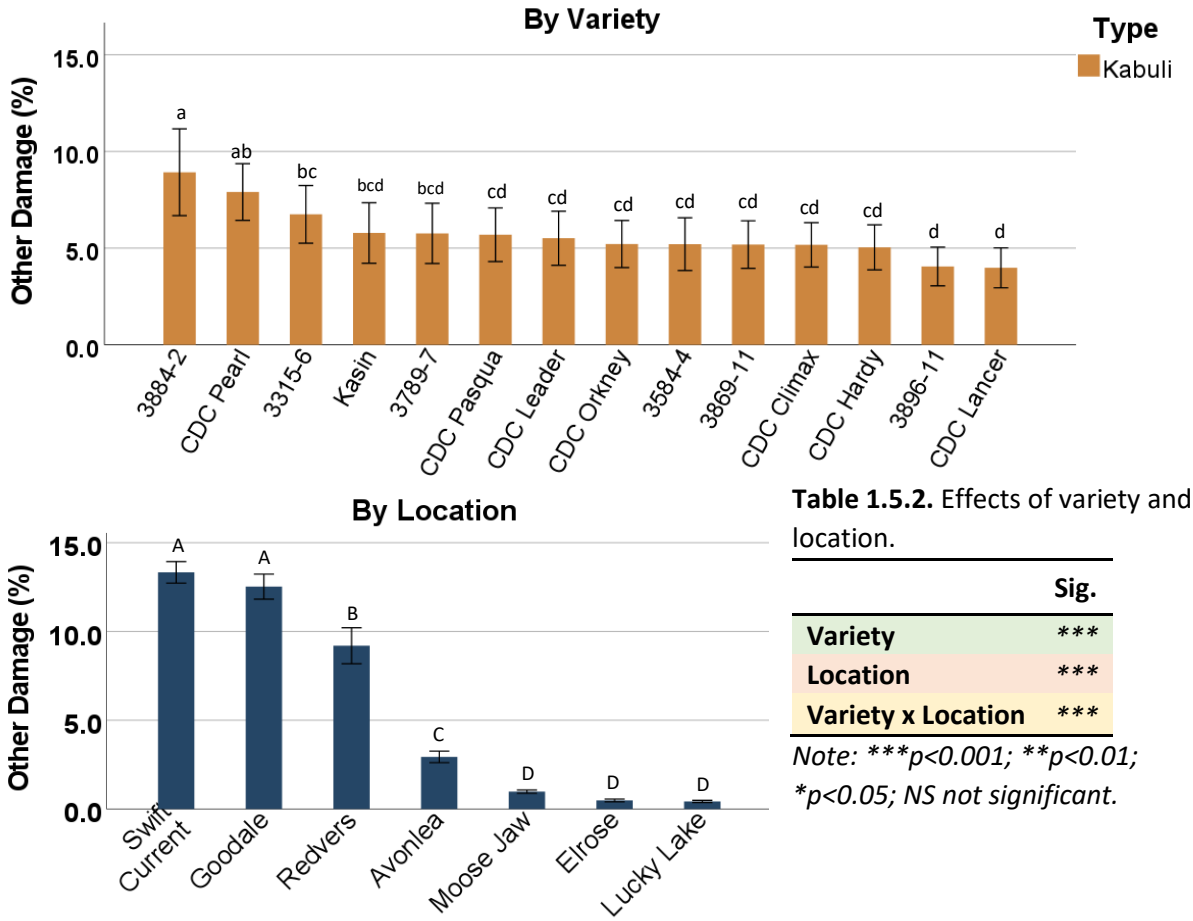


**Table 1.5.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- Other damage ranged from 4% to 9% for all varieties.

**By Location:**

- Other damage varied significantly between locations, where Lucky Lake, Elrose, and Moose Jaw were below 1%.
- In contrast, Swift Current had high amount of green and frost-damage, and mouldy seeds (data not shown). Goodale had high amount of water damage, and lots of seeds are sprouted or mouldy in Redvers (data not shown).

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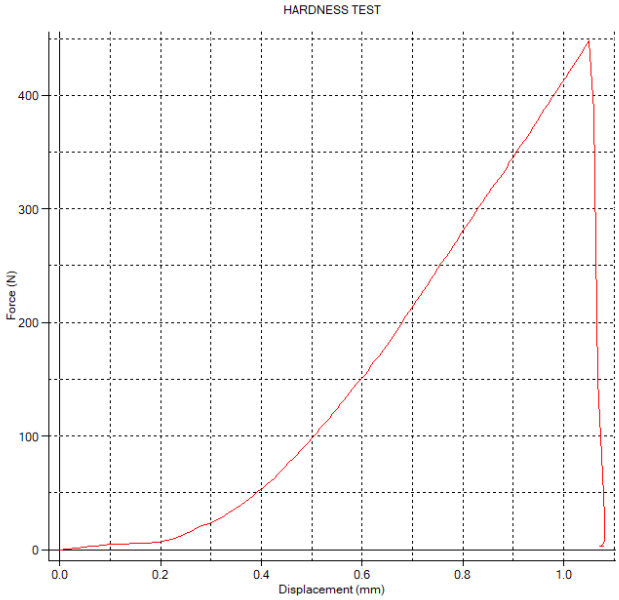
## 6. Hardness of Whole Seed

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.

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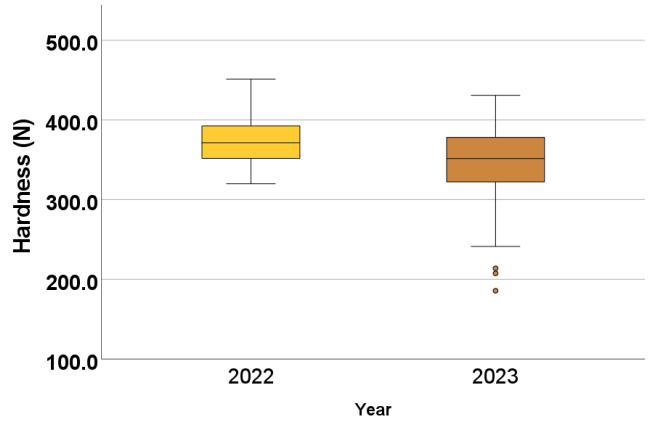
**Results: Figure 1.6.1.** & **Table 1.6.1.** Hardness of kabuli chickpeas in 2022 and 2023. Data in the table represent mean ± one standard error. The data in the figure and table include only the varieties tested in both years; see the varieties shown in black in Table A (p. 2).

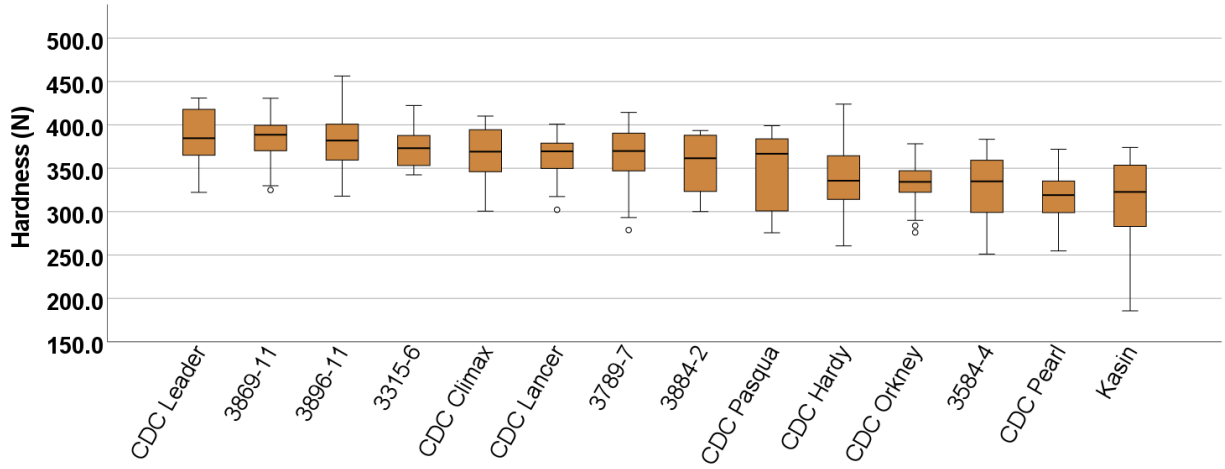



| | Kabuli Chickpea |
|---|---|
| **2022** | 374.1 ± 2.3[a] |
| **2023** | 363.4 ± 2.8[b] |

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

- The hardness of 2023 kabuli chickpeas was significantly lower than the 2022 samples.

**Figure 1.6.2.** Box and Whisker plot of 2023 kabuli chickpeas for seed hardness (N). Results were reported from highest to lowest.




- Kasin had the smallest seed hardness and the largest variability.

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

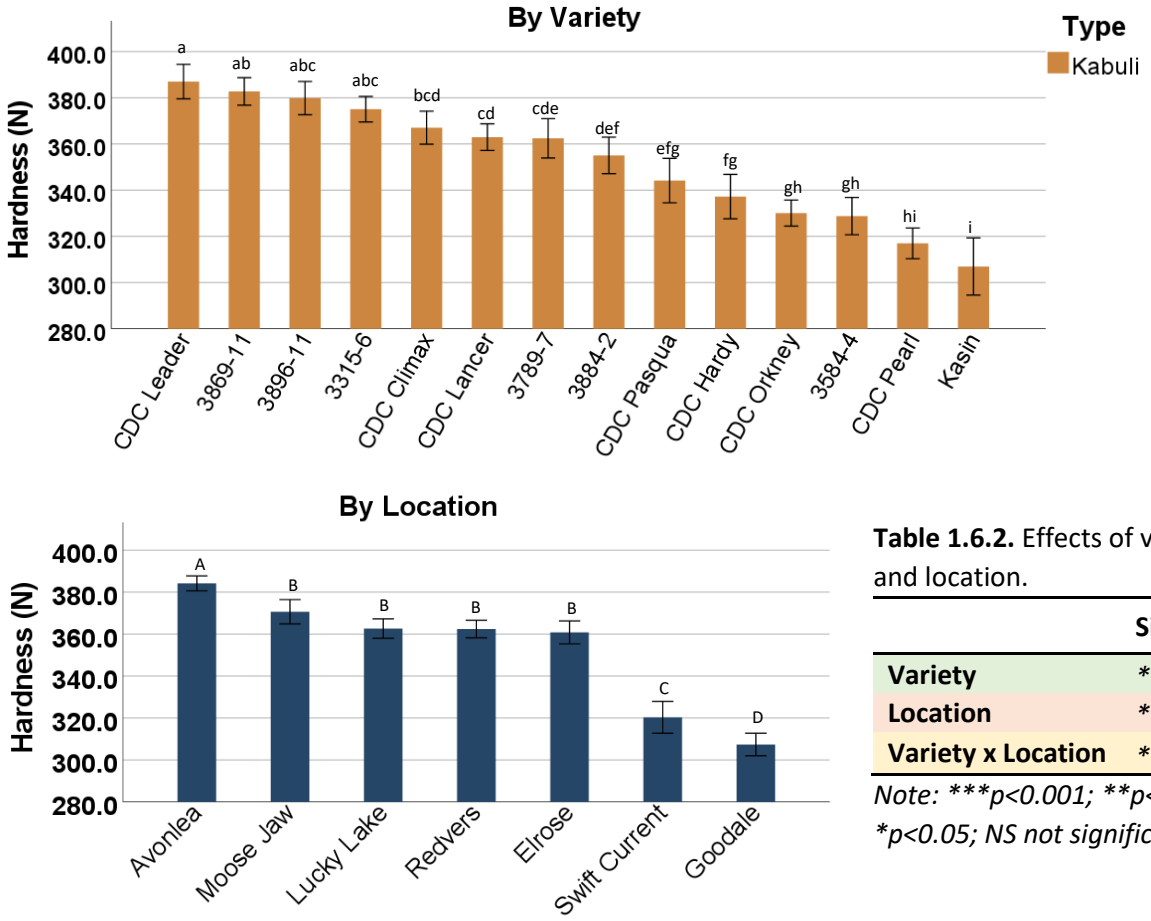



**Table 1.6.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

- **By Variety:** An 80 N difference in hardness was found from the largest (CDC Leader) to the lowest (Kasin).
- **By Location:**Location effect also played a role, where seed hardness of Avonlea (largest) being 77 N higher than that of Goodale (lowest).
- A positive trend between TKW and seed hardness was observed (r=0.557, p<0.001).
- A positive trend between yield and seed hardness was observed (r=0.393, p<0.001).

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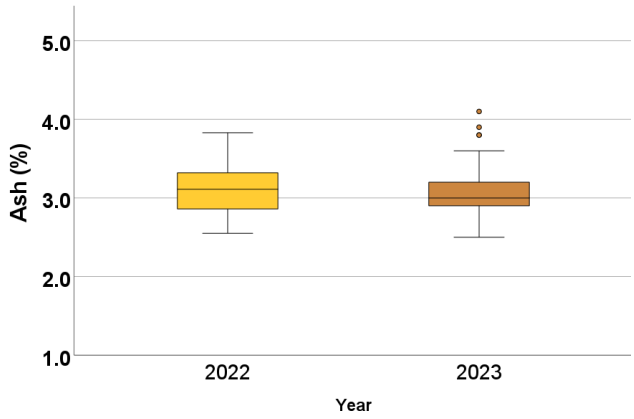
# 7. Ash Content

**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 kabuli chickpeas 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).

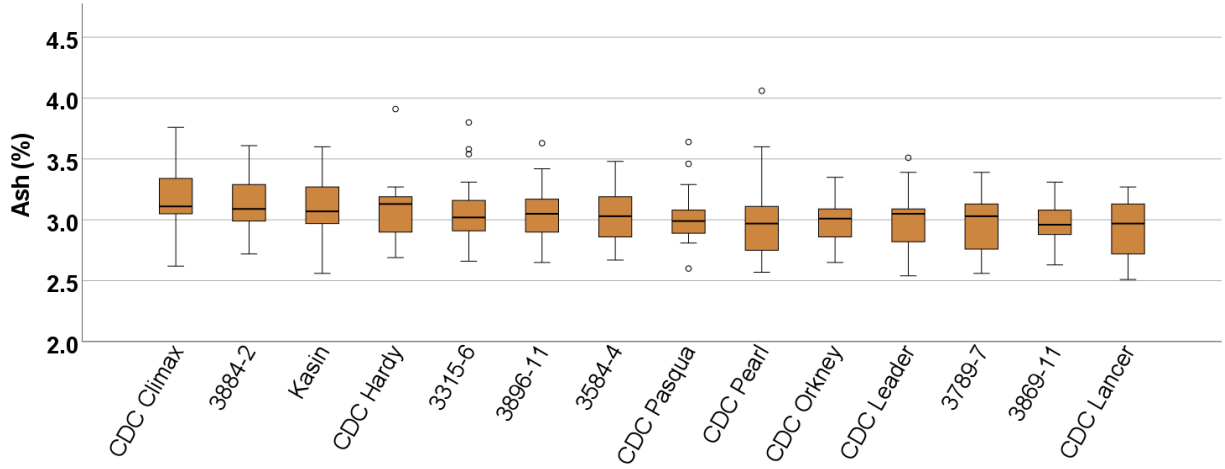



| | Kabuli Chickpea |
|---|---|
| **2022** | 3.1 ± 0.0[a] |
| **2023** | 3.0 ± 0.0[b] |

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

- Ash for 2023 sample was higher than the 2022 samples ($p<0.05$).

**Figure 1.7.2.** Box and Whisker plot of 2023 kabuli chickpeas for ash content. Results were reported from highest to lowest.




- Ash content ranged from 2.5% to 4%.

[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 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

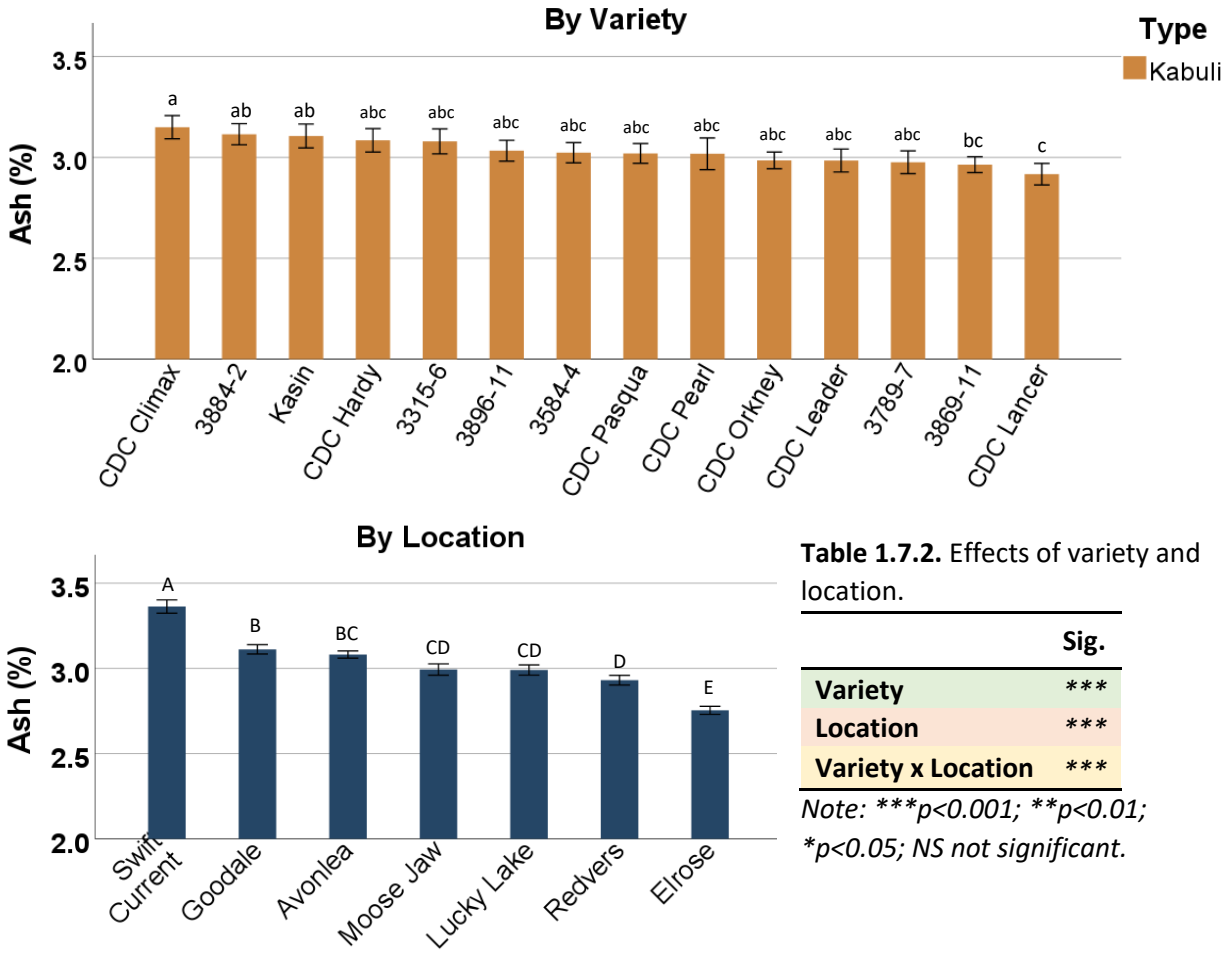


**Table 1.7.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- Only 0.2% difference was found from highest to lowest.

**By Location:**

- Location effect played a role.
- A difference of 0.6% was determined from the largest (Swift Current) to the smallest (Elrose).
- A positive trend between ash content and other damge was observed (r=0.425, p<0.001).

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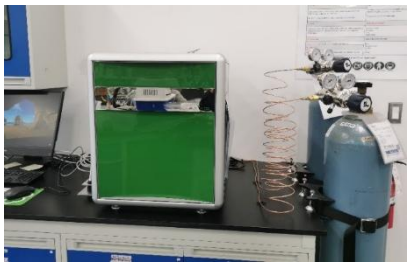
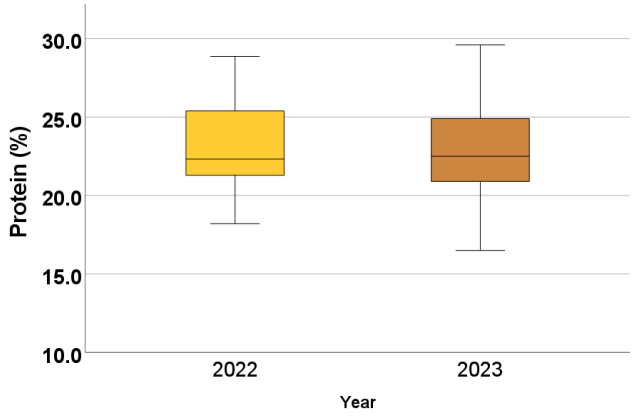
## 8. Protein Content



**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 content of kabuli chickpeas 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).

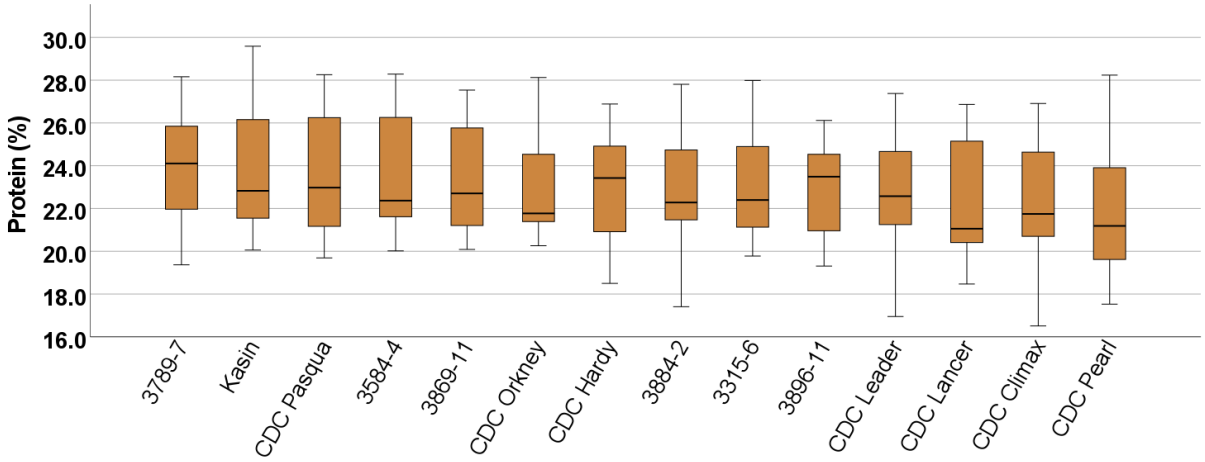



| | Kabuli Chickpea |
|---|---|
| **2022** | 23.1 ± 0.2[a] |
| **2023** | 22.9 ± 0.2[a] |

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

- No significant differences in protein content were found between the two years.

**Figure 1.8.2.** Box and Whisker plot of 2023 kabuli chickpeas for protein content. Results 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.

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

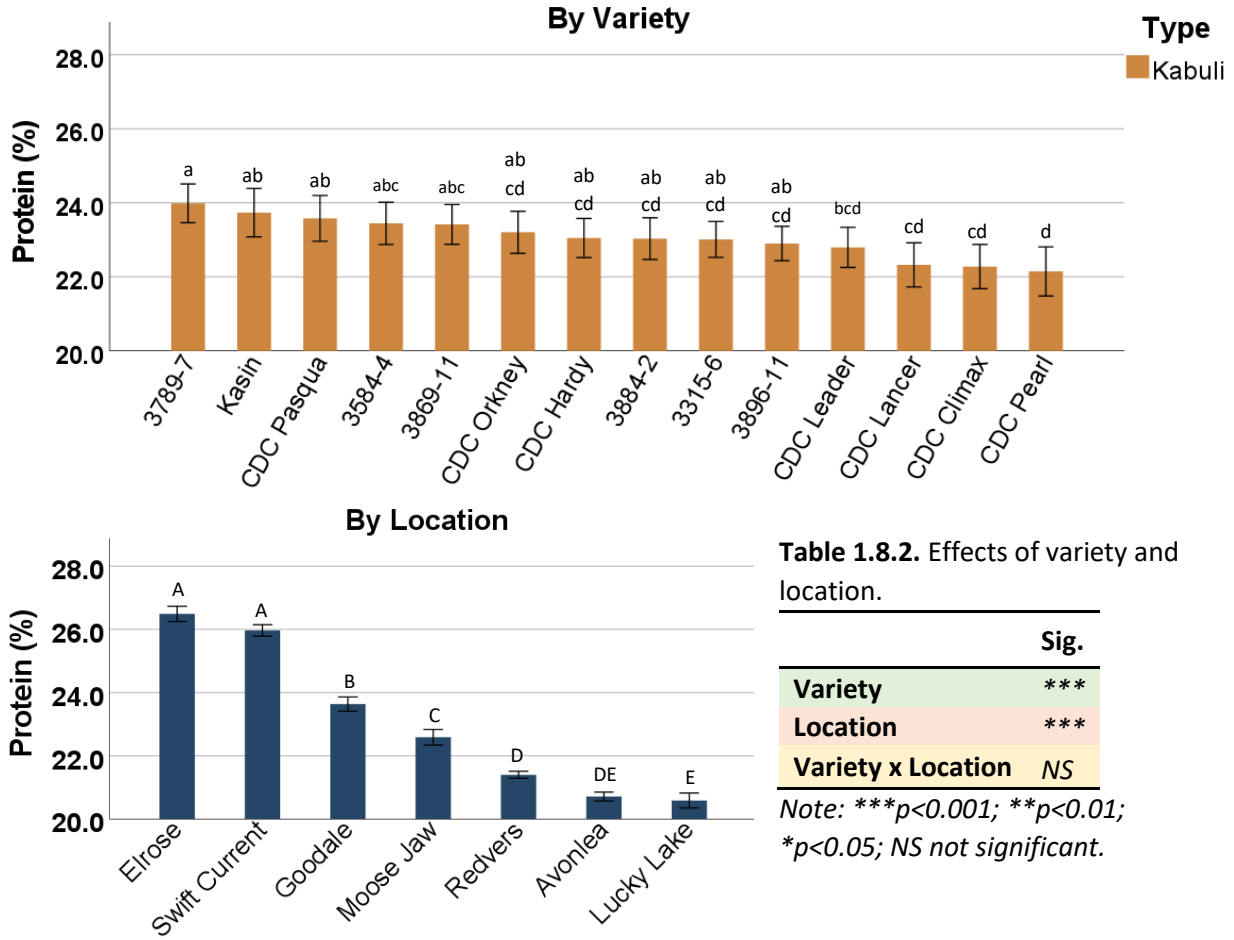



**Table 1.8.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *NS* |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- Less than 2% difference was found from highest to lowest.

**By Location:**

- Location effect played a significant role.
- Protein of Elrose and Swift Current was over 5% higher than Avonlea and Lucky Lake.

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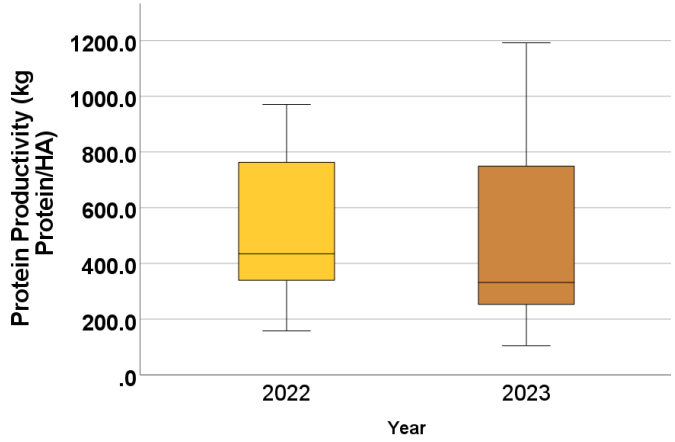
# 9. Protein Productivity

**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.** TKW of kabuli chickpeas 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).

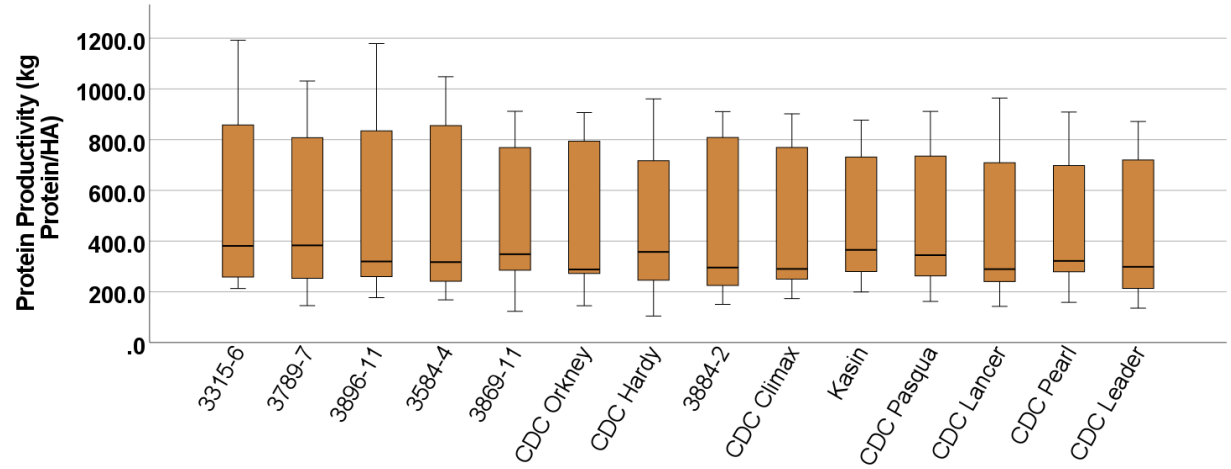



| | Kabuli Chickpea |
|---|---|
| **2022** | 538.9 ± 18.0[a] |
| **2023** | 479.0 ± 19.6[a] |

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

- Protein productivity of the 2023 samples were lower than the 2022 samples.

**Figure 1.9.2.** Box and Whisker plot of 2023 kabuli chickpeas for protein productivity. Results were reported from highest to lowest.




- Large variability of protein productivity was found in all varieties.

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

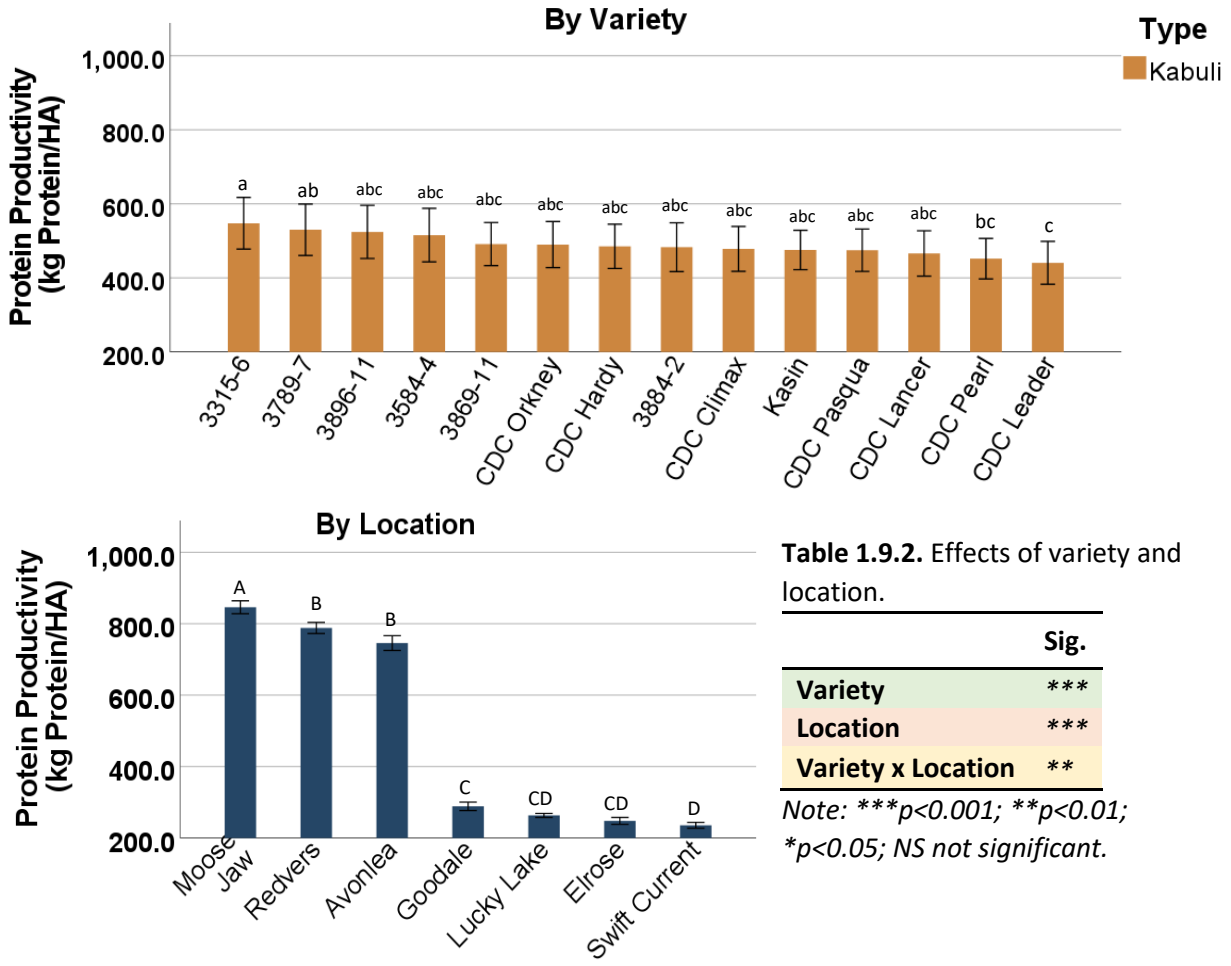


**Table 1.9.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | ** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- A 107kg protein/HA difference was found from highest to lowest.

**By Location:**

- Location effect played a significant role.
- Protein productivity was high in Moose Jaw, Redvers, and Avonlea, attributing to the high yield (Figure 1.1.3).
- In contrast, the very low yield of Elrose, Swift Current, Lucky Lake, and Goodale (Figure 1.1.2) resulted in the lowest protein productivity even though the protein content was high in Elrose and Swift Current.

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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 (-)

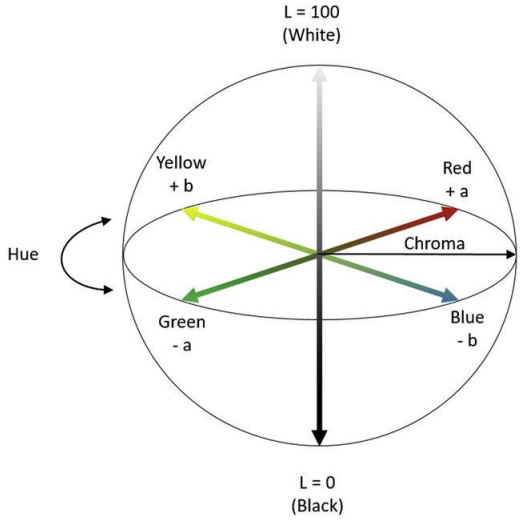
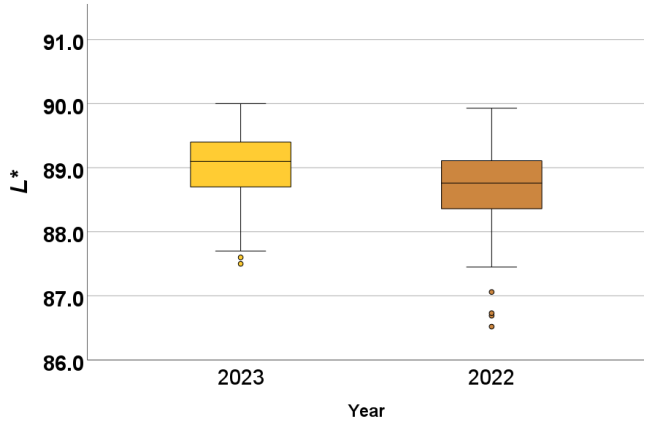



**Figure 1.10.1.** The CIELAB color spacediagram[3].

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

**Results: Figure 1.10.2.** & **Table 1.10.1.** Lightness of kabuli chickpeas 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).




| | Kabuli Chickpea |
|---|---|
| **2022** | 88.7 ± 0.1[b] |
| **2023** | 89.0 ± 0.0[a] |

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

- The 2023 kabuli chickpea flours were significantly lighter than the 2022 samples.

[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.

**Figure 1.10.3.** Box and Whisker plot of 2023 kabuli chickpeas for lightness. Results were reported from highest to lowest.

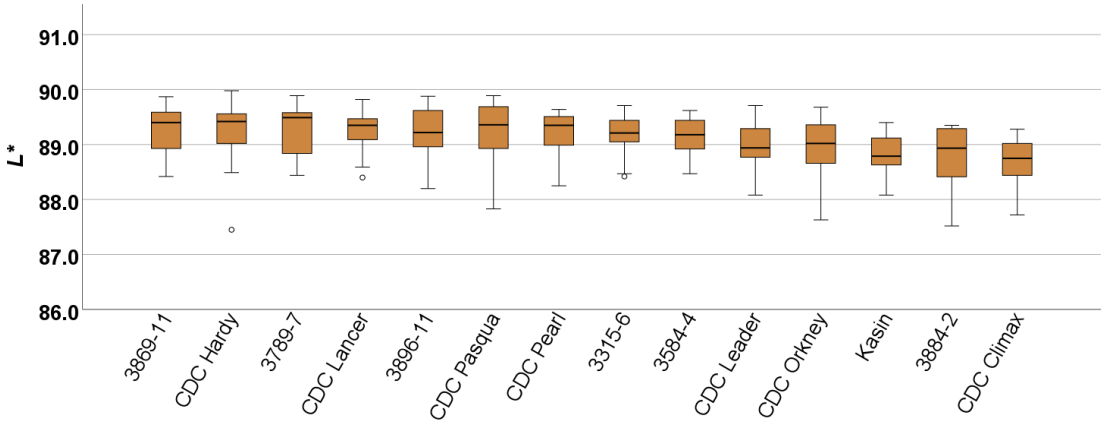
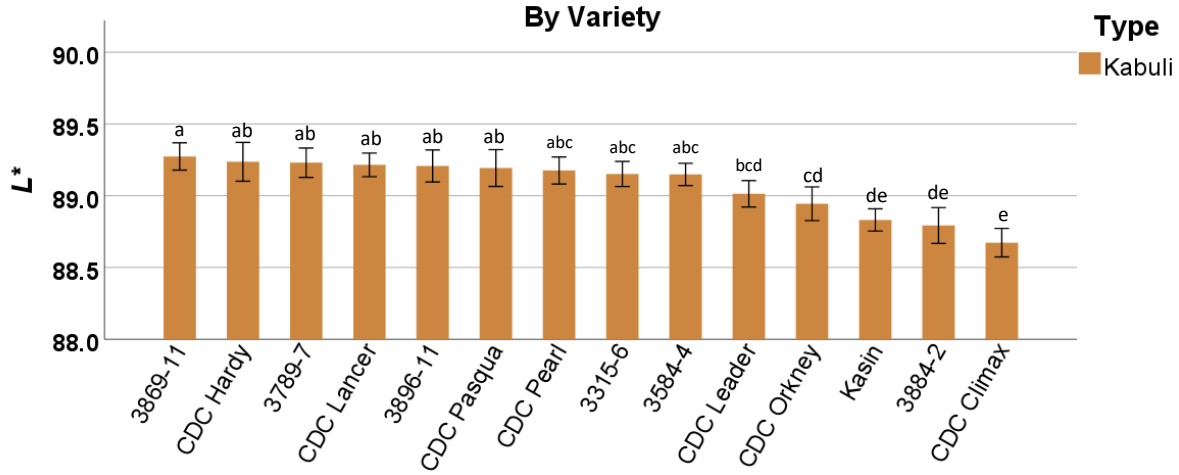



**Figure 1.10.4.** Mean lightness of 2023 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



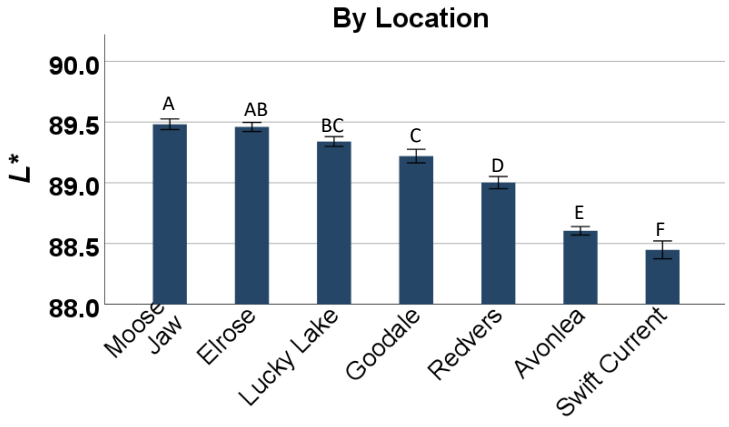




**Table 1.10.2.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

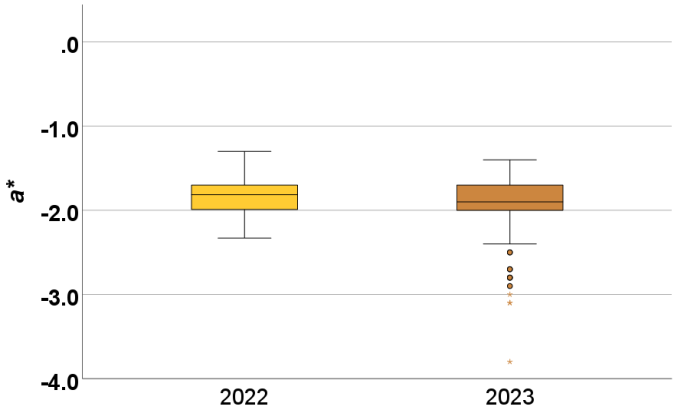
- Lightness from highest to lowest was only 0.6 unit in difference.

**By Location:**

- A difference of 1 unit was determined from highest to lowest.

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

**Figure 1.10.5.** & **Table 1.10.3.** *a** of kabuli chickpeas 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).

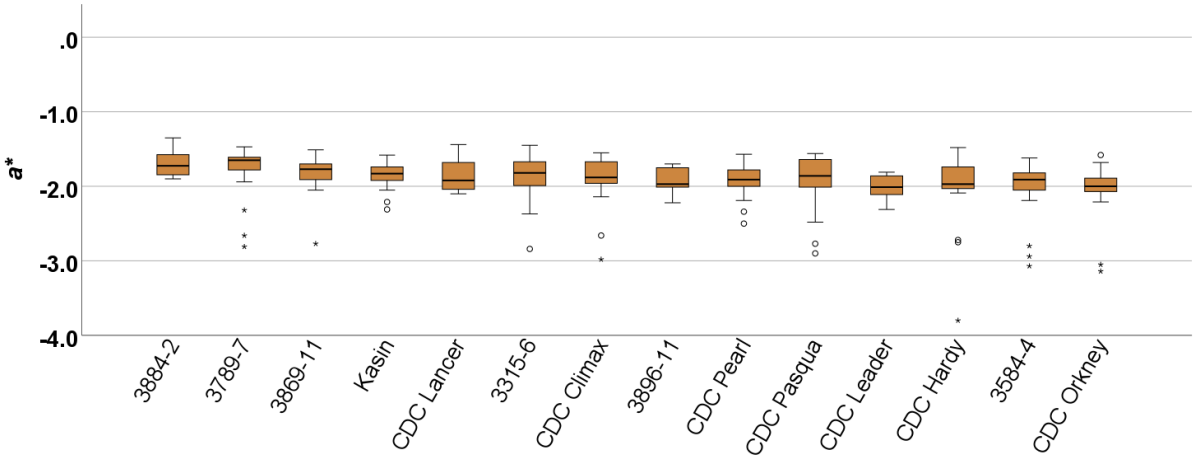



| | Kabuli Chickpea |
|---|---|
| **2022** | -1.8 ± 0.0[a] |
| **2023** | -1.9 ± 0.0[b] |

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

- The 2023 kabuli chickpea flours showed more greenness.

**Figure 1.10.6.** Box and Whisker plot of 2023 kabuli chickpeas for *a** values. Results were reported from highest to lowest.




- Line 3884-2 had the least greenness with small variability.

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

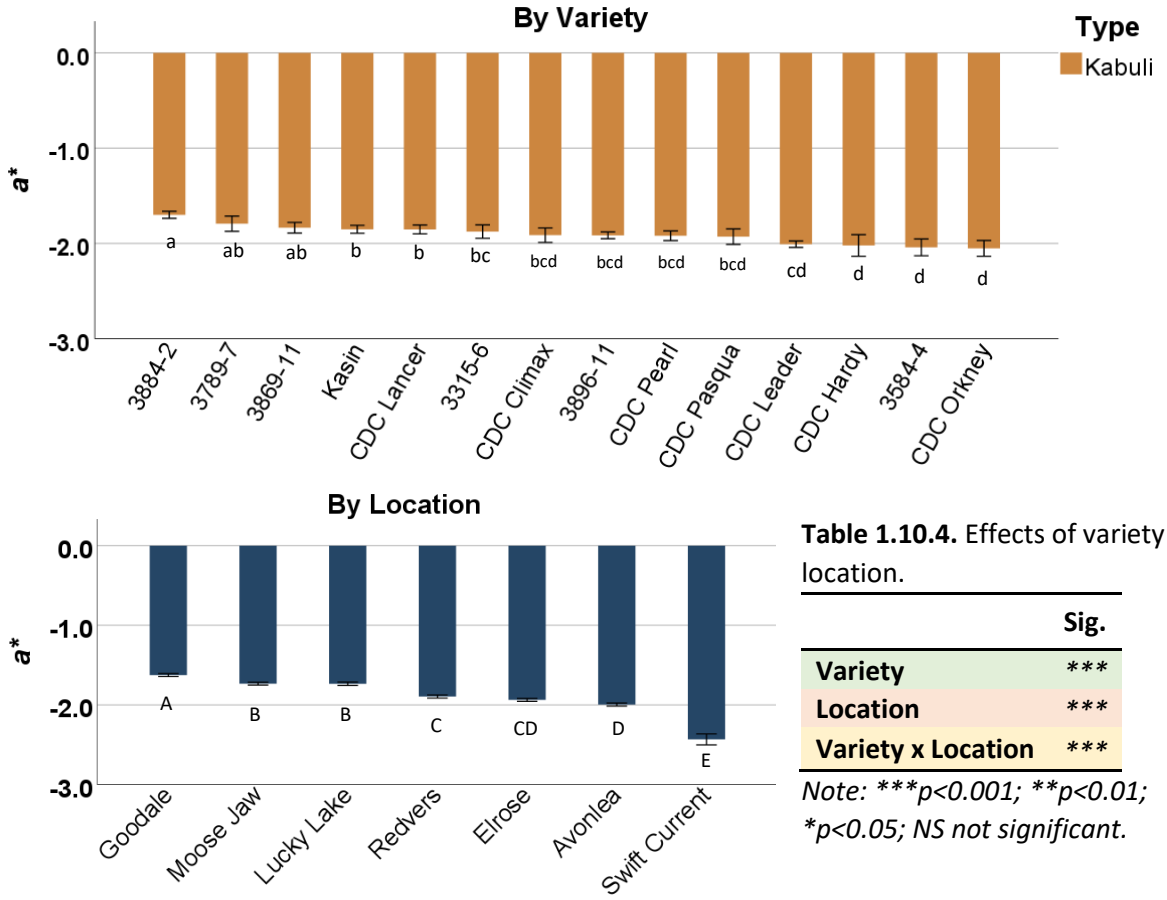



**Table 1.10.4.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

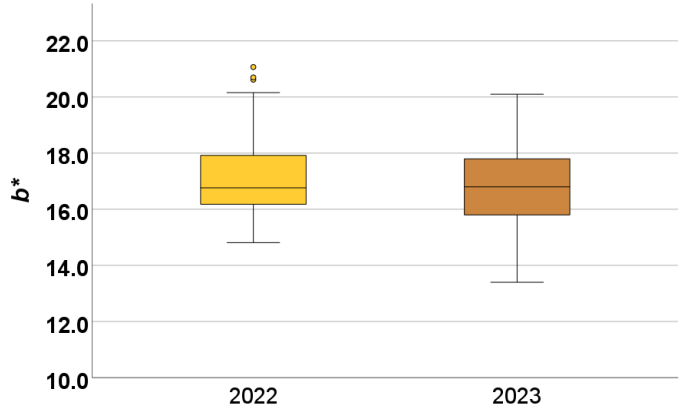
*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:** A difference of 0.3 unit only was determined from highest to lowest.

**By Location:** A difference of 0.8 unit was determined from highest to lowest.

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

**Figure 1.10.8.** & **Table 1.10.5.** $b^*$ of kabuli chickpeas 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).

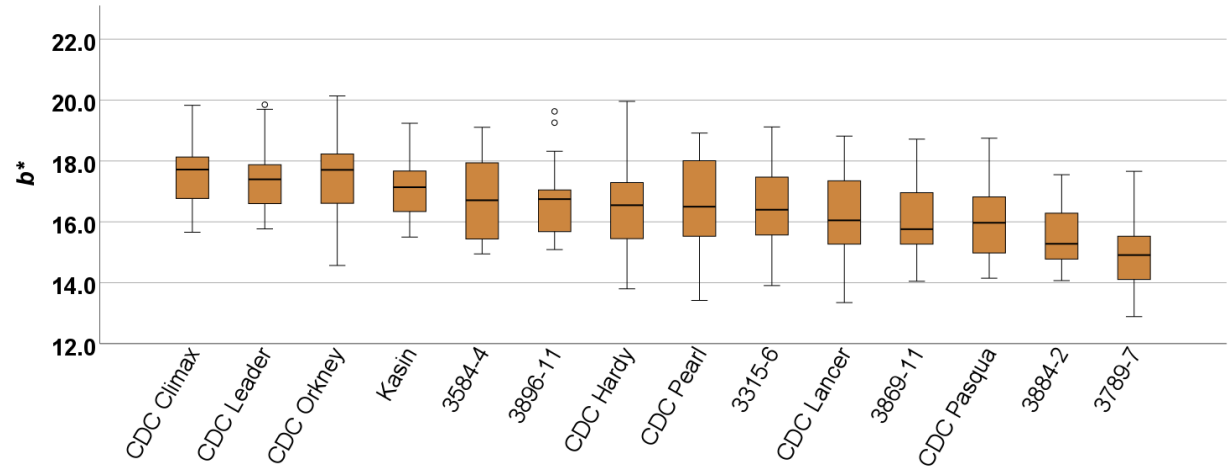



| | Kabuli Chickpea |
|---|---|
| **2022** | 17.1 ± 0.1[a] |
| **2023** | 16.8 ± 0.1[a] |

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

- No significant differences in yield were found between the two years.

**Figure 1.10.9.** Box and Whisker plot of 2023 kabuli chickpeas for *b** resulting from 6 locations. Results were reported from highest to lowest.




- Line 3789-7 had the lowest *b** value.

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

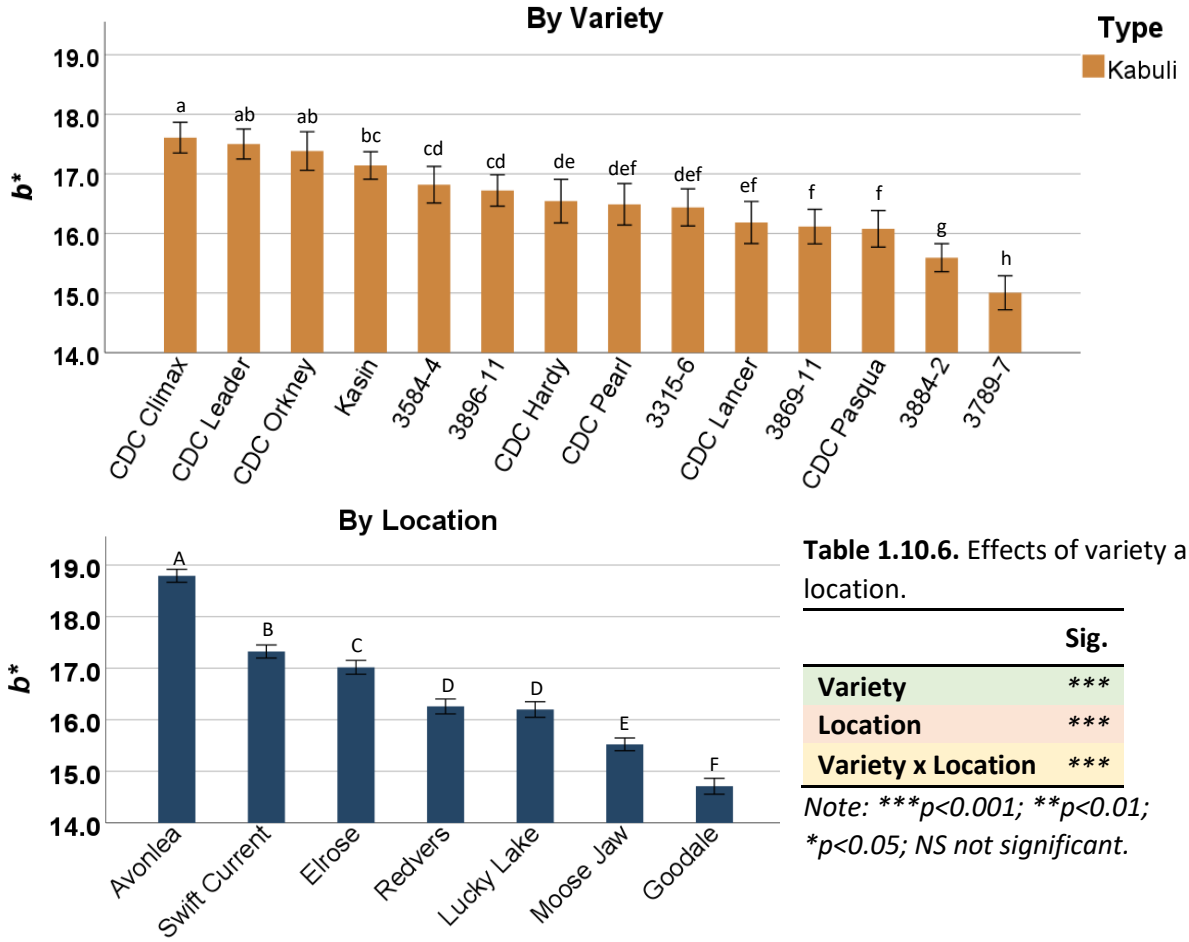


**Table 1.10.6.** Effects of variety and location.

| | Sig. |
|---|---|
| **Variety** | *** |
| **Location** | *** |
| **Variety x Location** | *** |

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

*Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.*

**By Variety:**

- Yellowness of chickpeas from CDC Climax (highest) was 2.6 units higher than line 3789-7 (lowest).

**By Location:**

- Yellowness of chickpeas from Avonlea (highest) was 4 units higher than Goodale (lowest).

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# 2) Black Desi + Desi + White Desi Chickpeas

This section included one variety of black desi (i.e. CDC Kala), one variety of desi (i.e. CDC Sunset), and one variety of white desi (i.e. 3627-7) that presented in 2023 from seven locations. The methods used for evaluation were the same as in previous sections. The quality results for each characteristic are provided in Table 2.1 and 2.2. Data represent mean ± one standard error.

**Results: Table 2.1.** TKW, seed size distribution, different types of damage, and hardness for 2023 black desi + desi + white desi chickpeas.

| Quality Attribute | Black Desi (CDC Kala) | Desi (CDC Sunset) | White Desi (Line 3627-7) |
|---|---|---|---|
| **Yield (kg/HA)** | 2058.1 ± 233.6 | 2353.8 ± 309.2 | 2315.6 ± 294.1 |
| **TKW (g)** | 235.8 ± 5.6 | 296.4 ± 5.4 | 205.3 ± 5.3 |
| **Size distribution (%)** | | | |
| > 9.52 mm | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| > 8.73 mm | 0.4 ± 0.1 | 3.6 ± 0.7 | 0.8 ± 0.2 |
| > 7.94 mm | 23.6 ± 2.7 | 39.9 ± 3.1 | 15.7 ± 1.9 |
| > 7.14 mm | 51.9 ± 1.4 | 40.4 ± 1.7 | 46.6 ± 1.4 |
| > 6.35 mm | 20.8 ± 2.3 | 13.9 ± 1.8 | 31.3 ± 2.2 |
| Below 6.35 mm | 3.3 ± 0.7 | 2.3 ± 0.4 | 5.7 ± 0.9 |
| **Split (%)** | 1.9 ± 0.4 | 7.8 ± 1.8 | 4.3 ± 0.7 |
| **Other damage (%)** | 0.9 ± 0.2 | 3.2 ± 0.6 | 6.0 ± 1.6 |
| **Hardness (N)** | 335.5 ± 8.1 | 293.2 ± 7.6 | 225.1 ± 13.2 |

*Note: Means within a row followed by different lowercase letters are significantly different (p<0.05).*

- The yield ranged from 2000 to 2400 kg/HA.
- TKW: CDC Sunset > CDC Kala > Line 3627-7.
- Over 90% of the seeds had the size between 6.35 mm and 8.73 mm.
- CDC Kala had the lowest split amount, while CDC Sunset had the highest split.
- CDC Kala had the greatest hardness, followed by CDC Sunset. Line 3627-7 had the lowest hardness.

**Table 3.2.** Ash, protein, protein productivity, colour, Hausner ratio, and the flour particle size for 2023 black desi + desi + white desi chickpeas.

| Quality Attribute | Black Desi (CDC Kala) | Desi (CDC Sunset) | White Desi (Line 3627-7) |
|---|---|---|---|
| **Ash (d.b.; %)** | 3.3 ± 0.1 | 3.2 ± 0.1 | 2.9±0.0 |
| **Protein (d.b.;%)** | 24.9 ± 0.6 | 24.2 ± 0.6 | 22.3±0.6 |
| **Protein productivity (kg protein/HA)** | 457.5 ± 48.6 | 529.0 ± 61.3 | 456.5±54.2 |
| **Colour** | | | |
| ***L**** | 84.5 ± 0.1 | 86.9 ± 0.1 | 88.8±0.1 |
| ***a**** | -2.5 ± 0.1 | -1.5 ± 0.1 | -1.8±0.1 |
| ***b**** | 12.1 ± 0.3 | 15.3 ± 0.3 | 16.6±0.4 |

*Note: Means within a row followed by different lowercase letters are significantly different ($p<0.05$).*

- Ash ranged from 2.9% to 3.3%.
- Protein contents of CDC Kala and CDC Sunset were higher than line 3627-7.
- Protein productivity of CDC Sunset was the highest due to higher protein content and greater yield. Protein productivity of CDC Kala and line 3627-7 was similar, where CDC Kala had a higher protein content with a lower yield and line 3627-7 had a greater yield with lower protein content.
- Color of the flour *(L*, a*, b*):*
  - *L** values: white desi > desi > black desi.
  - *a** values (in terms of greenness): CDC Kala had the greatest greenness.
  - *b** values (in terms of yellowness): Line 3627-7 had the greatest yellowness.

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