2024 Pulse Quality Evaluation

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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2024 Chickpea Quality

This report evaluated **288** chickpea samples harvested from **six locations**, including Avonlea, Elrose, Goodale, Lucky Lake, Moose Jaw, and Swift Current, in **2024**. There were **sixteen varieties**, which included thirteen varieties of kabuli, one black desi variety, and two desi. Three replicates of each variety were cultivated in each location. **Table A** provides the samples' information and locations in detail.

The chickpea sampling locations and their corresponding crop regions are shown in **Figure A** and **Figure B**. **Figure A** also illustrates the soil zones across the province, while **Figure B** presents the cumulative rainfall during the 2024 growing season.

According to the 2024 Crop Reports by the Ministry of Agriculture, adequate rainfall in May improved topsoil moisture conditions across the province. However, subsequent moisture and cooler temperatures delayed seeding. Seeding progress has been fastest in the southwest and southeast, while the central regions have experienced slower progress due to higher spring snowfall accumulations. In June, cooler temperatures and excessive moisture further delayed overall crop development. By July and early August, reduced precipitation and rising temperatures depleted topsoil moisture reserves in many regions, accelerating crop advancement and maturity. The development of crops in the western regions was further ahead while the central and northern regions fell behind. Chickpea harvest began in southeast regions in early August and in southwest regions two weeks later. Harvest was completed by mid-September.

Table A. Description of 2024 chickpea samples tested for the Pulse Quality Program.

Crop	Type	Variety		Site	Number of samples
Chickpea	**Kabuli**	CDC Climax	3315-6	Avonlea Elrose Goodale Lucky Lake Moose Jaw Swift Current	288
		CDC Hardy	3584-4		
		CDC Lancer	3789-7		
		CDC Leader	3896-11		
		CDC Orkney	3867-4		
		CDC Pasqua	4231-2		
		CDC Pearl			
	Black desi	CDC Kala			
	Desi	CDC Sunset	4262-3		

- *Ten varieties that existed in 2022, 2023, and 2024, shown as black.*
- *Three varieties are in both 2023 and 2024, shown as blue.*
- *Four new varieties entered in 2024, shown in red.*

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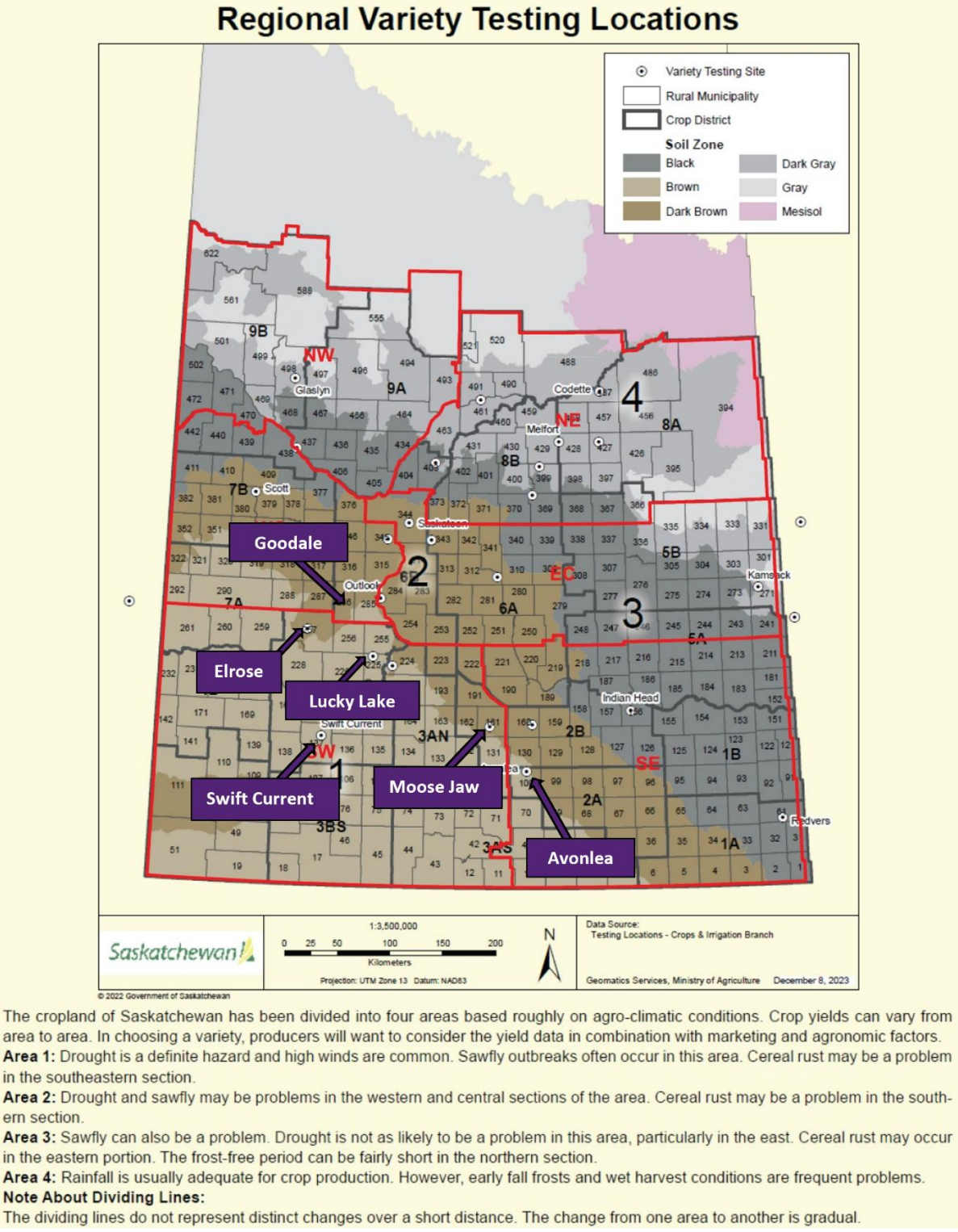

The cropland of Saskatchewan has been divided into four areas based roughly on agro-climatic conditions. Crop yields can vary from area to area. In choosing a variety, producers will want to consider the yield data in combination with marketing and agronomic factors.

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 chickpea quality testing in 2024 and the corresponding soil zones. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

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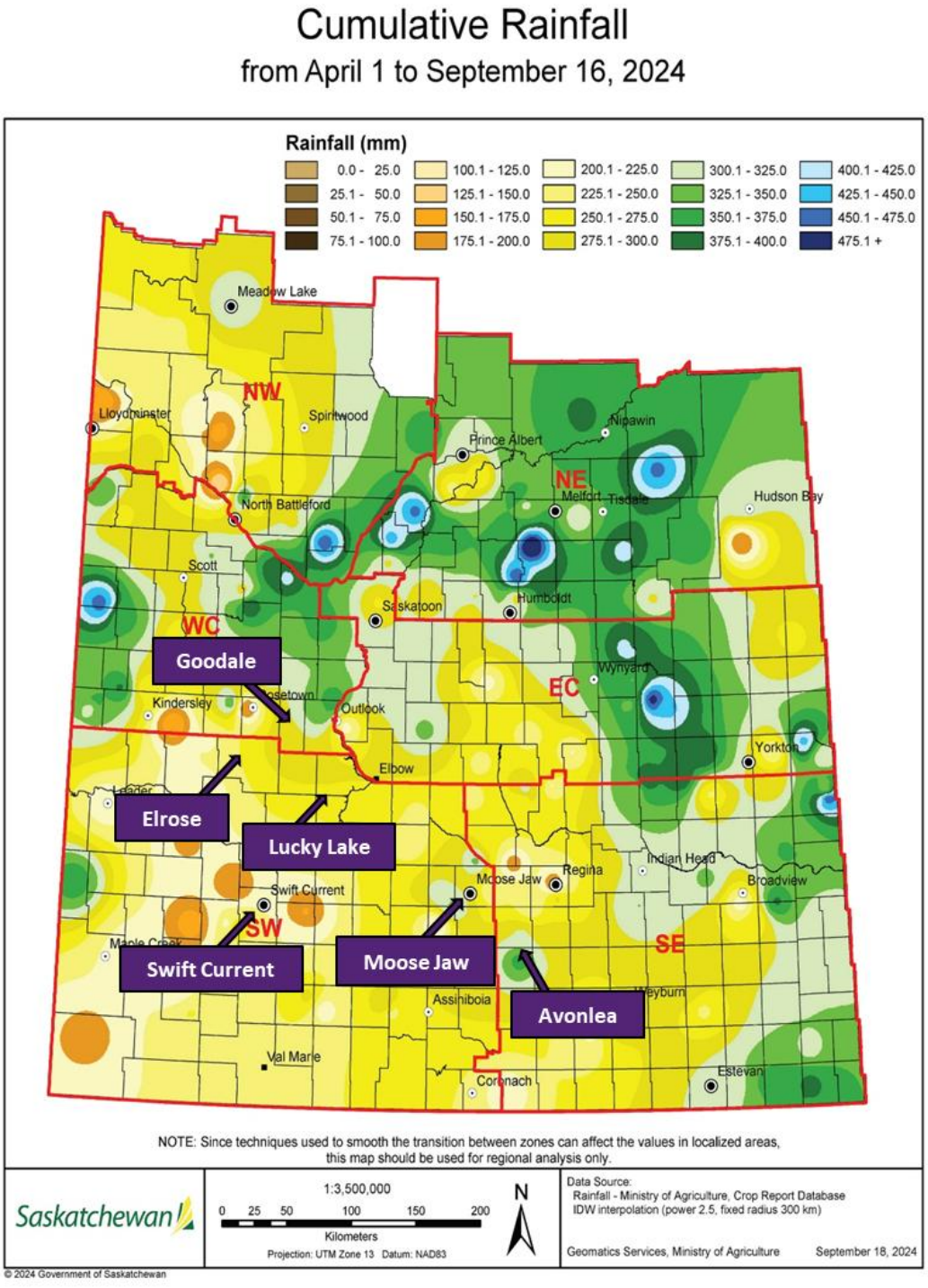


Figure B. Locations for Chickpea quality testing and cumulative rainfall from April 1 to September 16, 2024. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

This report includes two sections: **1)** 2024 kabuli chickpea varieties and **2)** 2024 black desi + desi varieties. Each section includes ten subsections for the results of the following quality parameters:

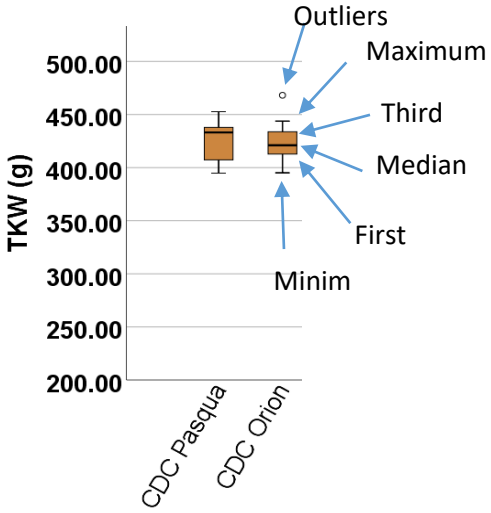
1. Yield
2. Thousand kernel weight (TKW)
3. Seed size distribution
4. Split amount
5. Other damage
6. Hardness of whole seed
7. Ash content
8. Protein content
9. Protein productivity
10. Colour (*L*, a*,* and *b**)

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 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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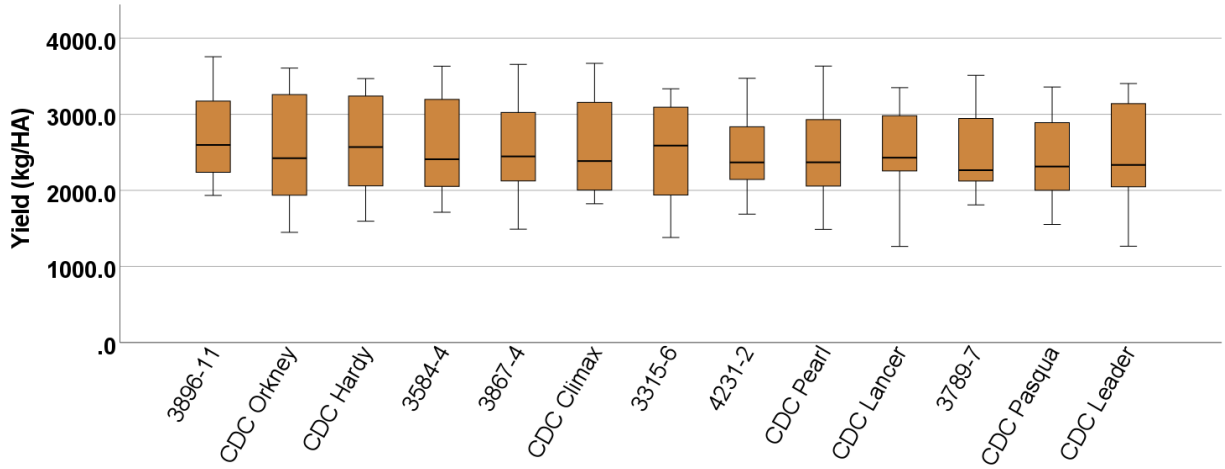
1) 2024 Kabuli Chickpea Quality

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. Box and Whisker plot of 2024 kabuli chickpeas for yield. Results were reported from highest to lowest.



- The variability was high for each variety.

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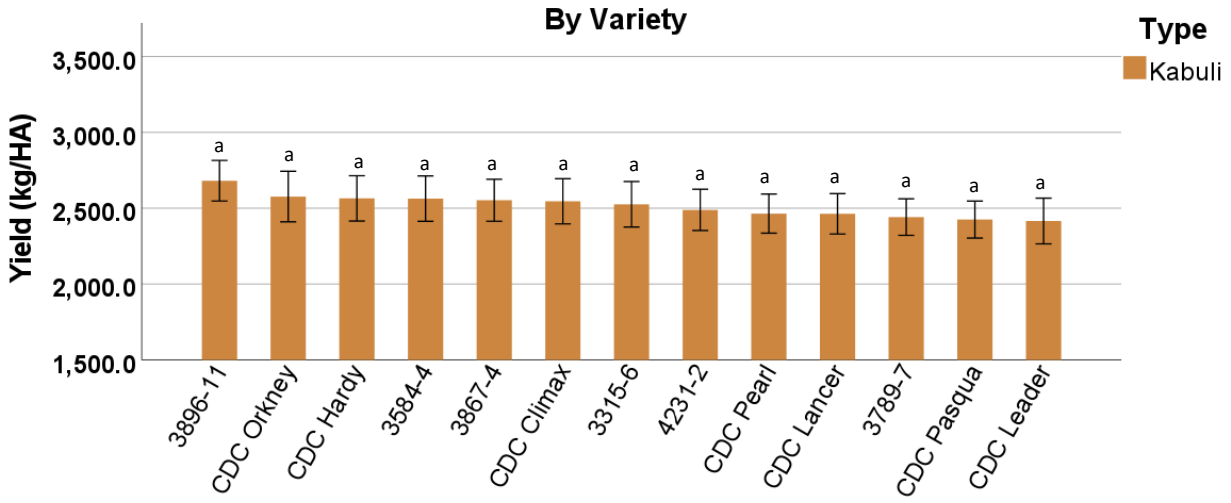
Figure 1.1.2. Mean yield of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



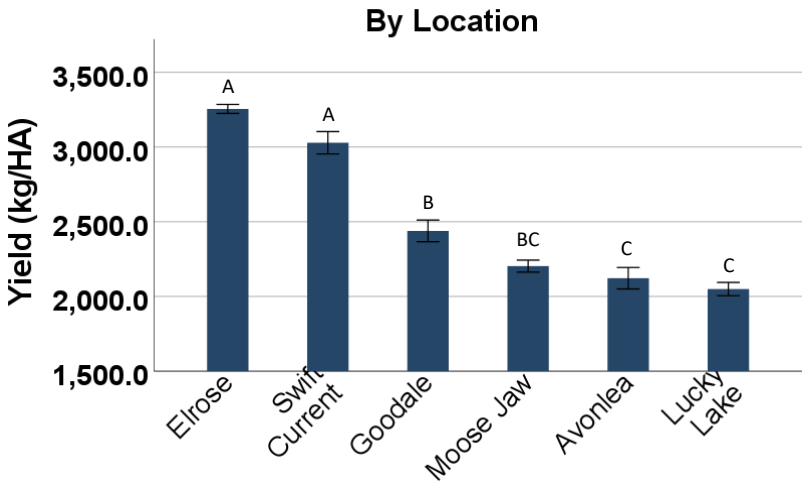


Table 1.1.1. Effects of variety and location in 2024.

	Sig.
Variety	*NS*
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:

- No significant difference.

By Location:

- A difference of 1000 kg/HA was observed from highest to lowest.

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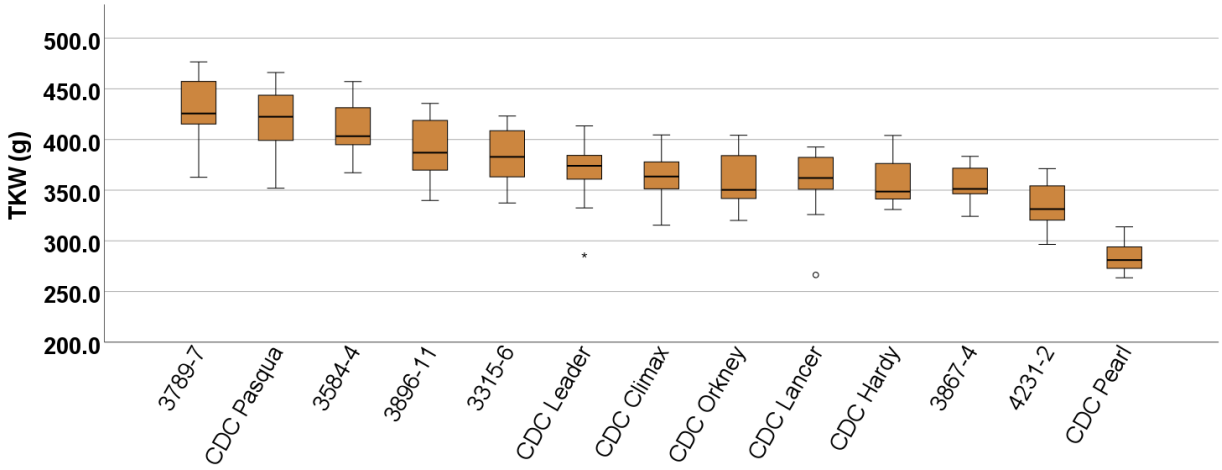
2. Thousand Kernel Weight

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. Box and Whisker plot of 2024 kabuli chickpeas for TKW. Results were reported from highest to lowest.



- CDC Pearl was the smallest in TKW.
- A few outliers were present.

Figure 1.2.2. Mean TKW of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

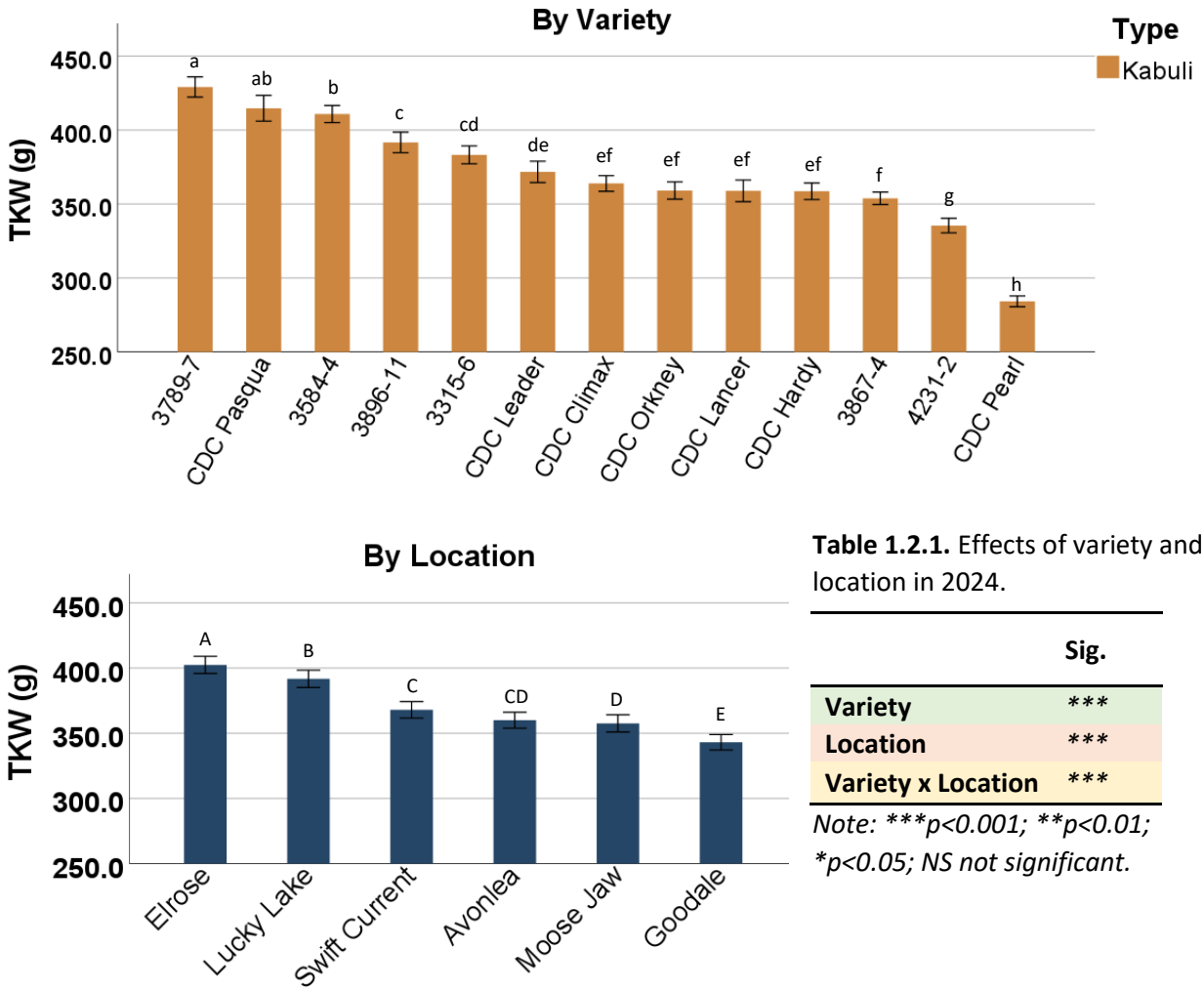


Table 1.2.1. Effects of variety and location in 2024.

	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:

- TKW was significantly different by variety, where a difference of 145 g was determined from the largest to the smallest.

By Location:

- A difference of 60 g was observed from highest to lowest.

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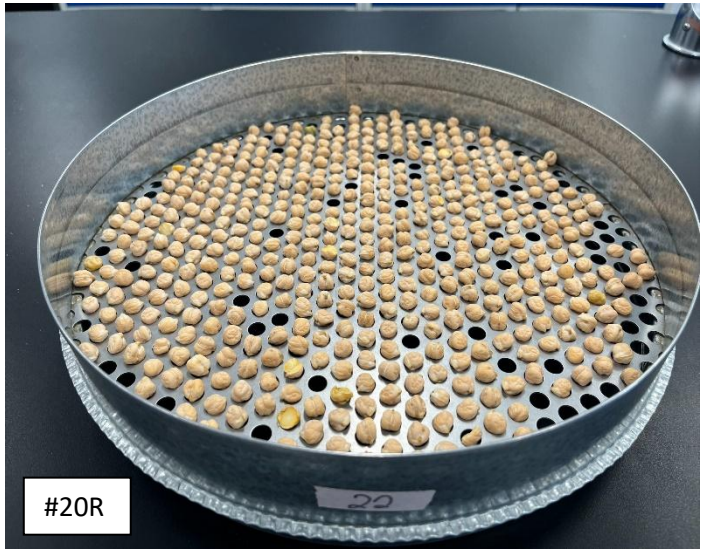
3. Seed Size Distribution

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 1.3.1 Seed size distribution (%) of each 2024 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	10.8 ± 7.1^{a}	54.2 ± 9.3^{a}	29.0 ± 9.4^{g}	4.5 ± 4.7^{g}	1.1 ± 1.6^{d}	0.6 ± 0.2^{b}
3584-4	6.9 ± 6.6^{b}	51.2 ± 10.6^{ab}	35.0 ± 13.7^{f}	5.2 ± 3.8^{fg}	3.0 ± 0.8^{d}	1.0 ± 0.3^{b}
CDC Pasqua	7.6 ± 5.3^{b}	46.2 ± 11.6^{bc}	37.6 ± 10.9^{f}	6.9 ± 5.9^{fg}	2.6 ± 0.5^{d}	0.9 ± 0.2^{b}
3315-6	3.6 ± 3.1^{c}	40.2 ± 12.9^{cd}	46.6 ± 12.6^{e}	8.1 ± 4.6^{fg}	1.9 ± 0.4^{d}	0.4 ± 0.1^{b}
3896-11	1.4 ± 1.2^{cd}	35.9 ± 13.9^{d}	52.1 ± 10.9^{de}	8.8 ± 5.8^{ef}	3.1 ± 0.8^{d}	0.9 ± 0.3^{b}
CDC Leader	1.0 ± 0.6^{d}	28.7 ± 9.8^{e}	54.2 ± 9.2^{cd}	12.8 ± 7.9^{de}	4.6 ± 0.9^{bcd}	1.5 ± 0.4^{b}
CDC Hardy	0.6 ± 0.8^{d}	22.4 ± 14.1^{ef}	60.9 ± 11.1^{ab}	14.5 ±7.3^{cd}	4.9 ± 1.0^{cd}	0.9 ± 0.2^{b}
CDC Climax	0.8 ± 1.1^{d}	20.6 ± 9.2^{fg}	58.1 ± 8.0^{abc}	17.8 ± 7.5^{c}	3.7 ± 0.8^{bcd}	0.9 ± 0.2^{b}
CDC Orkney	0.8 ± 1.0^{d}	19.6 ± 10.9^{fg}	63.1 ± 8.2^{a}	14.4 ± 6.8^{cd}	4.5 ± 0.8^{cd}	0.8 ± 0.1^{b}
3867-4	0.2 ± 0.3^{d}	18.2 ± 6.0^{fg}	63.3 ± 7.4^{a}	15.9 ± 5.7^{cd}	4.5 ± 0.8^{bcd}	0.8 ± 0.1^{b}
CDC Lancer	0.2 ± 0.2^{d}	15.2 ± 6.7^{gh}	62.6 ± 11.2^{ab}	18.3 ± 7.9^{c}	5.8 ± 1.0^{bc}	1.5 ± 0.4^{b}
4231-2	0.2 ± 0.4^{d}	10.8 ± 6.2^{h}	57.1 ± 8.0^{bcd}	27.8 ± 9.0^{b}	4.5 ± 0.8^{b}	0.8 ± 0.1^{b}
CDC Pearl	0.0 ± 0.0^{d}	0.7 ± 0.9^{i}	25.1 ± 11.8^{g}	58.4 ± 8.7^{a}	19.2 ± 2.4^{a}	3.4 ± 0.7^{a}

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

- Seed size distribution results corresponded to TKW.
- Line 3789-7 had the largest size, with over 10% of seeds larger than 9.52 mm.
- Line 3584-4 had the second largest size, followed by CDC Pasqua.
- In contrast, CDC Pearl was the smallest, with less than 1% of seed larger than 8.73 mm.

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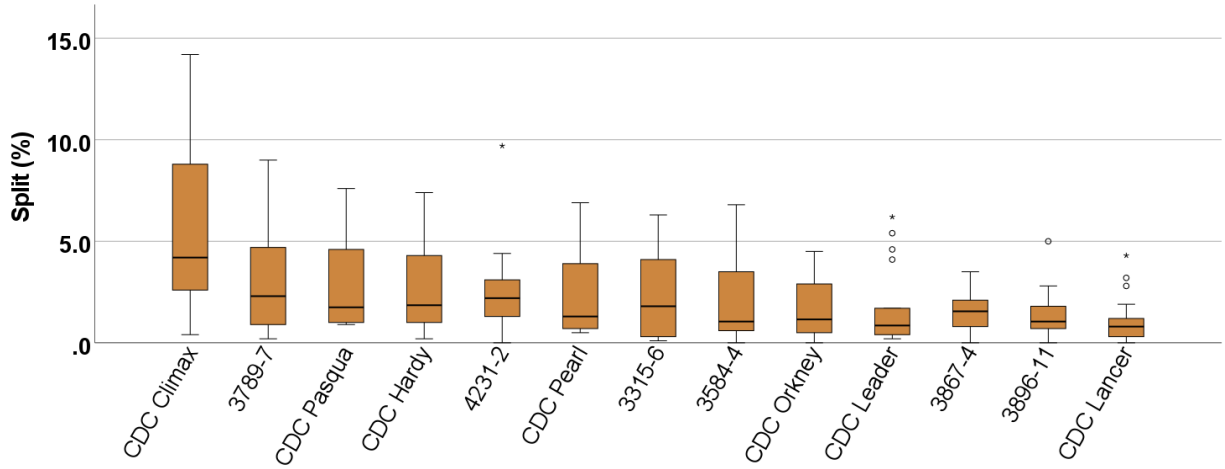
4. Split

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. Box and Whisker plot of 2024 kabuli chickpeas for the split. Results were reported from highest to lowest.



- CDC Climax had the highest split and cracked seed coat, with large variability.
- A large variability was observed in mopst varieties, and outliers and extreme outliers were present.

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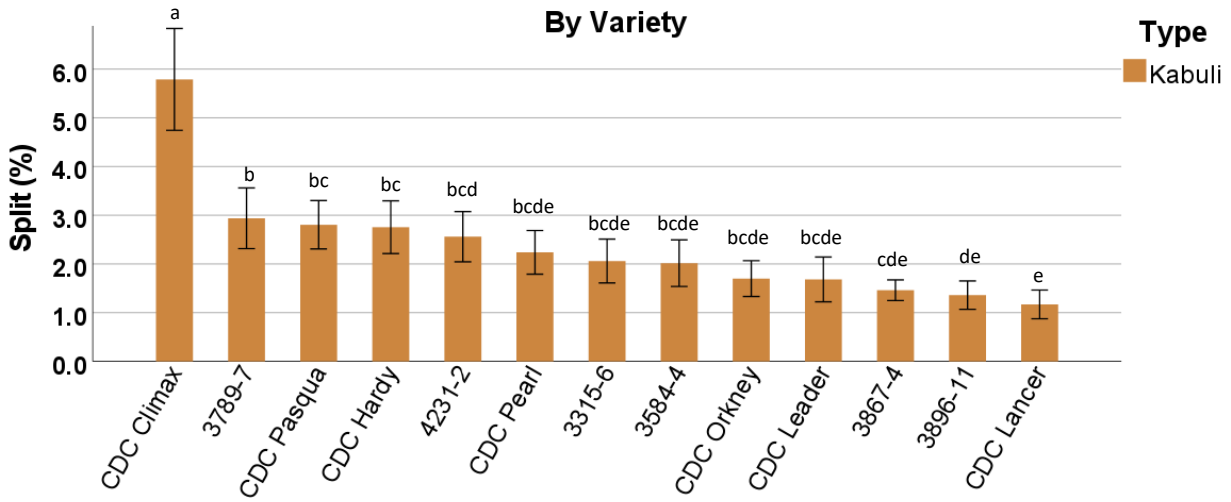
Figure 1.4.2. Mean split of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



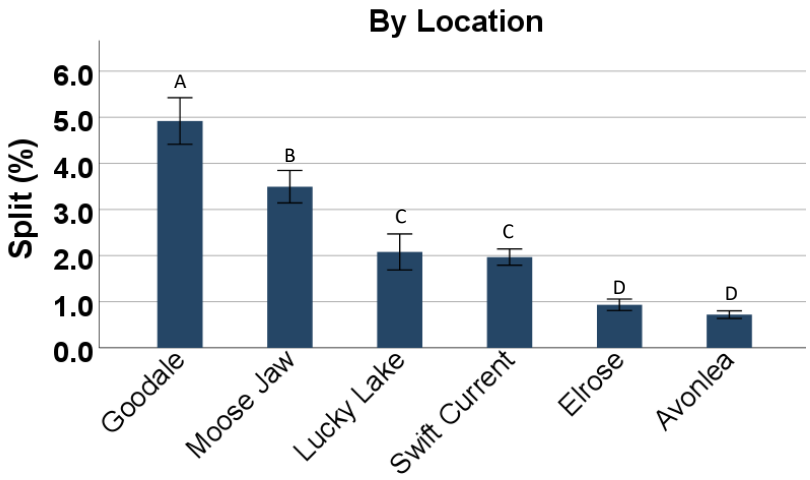


Table 1.4.1. Effects of variety and location in 2024.

	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 4% was observed from the largest to the smallest.
- **By Location:** A difference of 4% was observed from the largest to the smallest, indicating that seed harvest condition and processing play a role.

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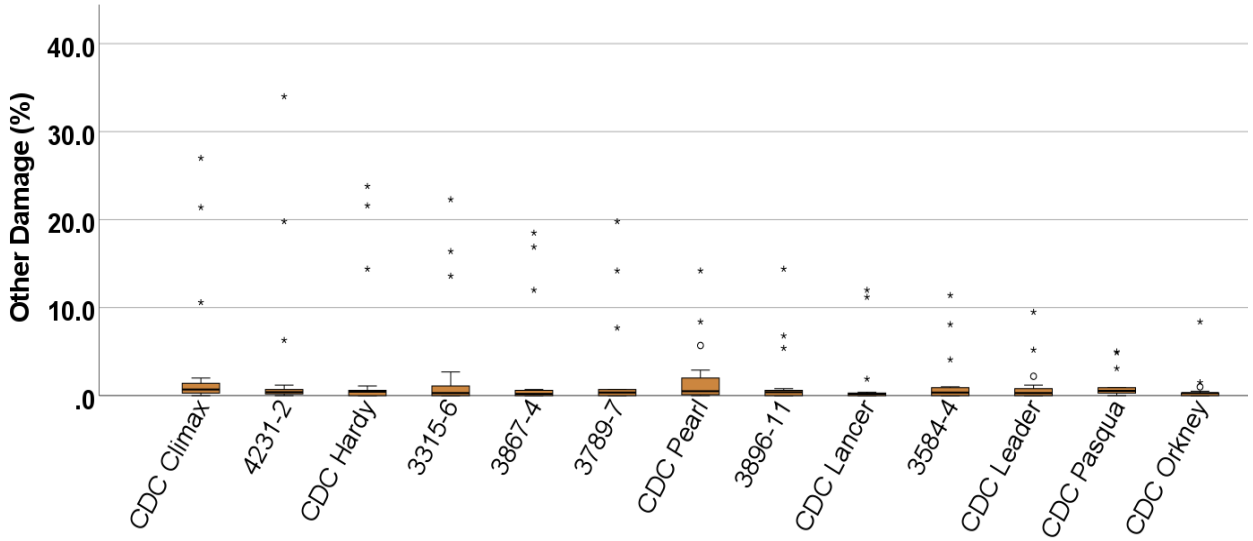
5. Other Damage

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. Box and Whisker plot of 2024 kabuli chickpeas for other damage. Results were reported from highest to lowest.



- Large viariability and extreme outliers were observed in each variety.

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Figure 1.5.2. Mean other damage of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

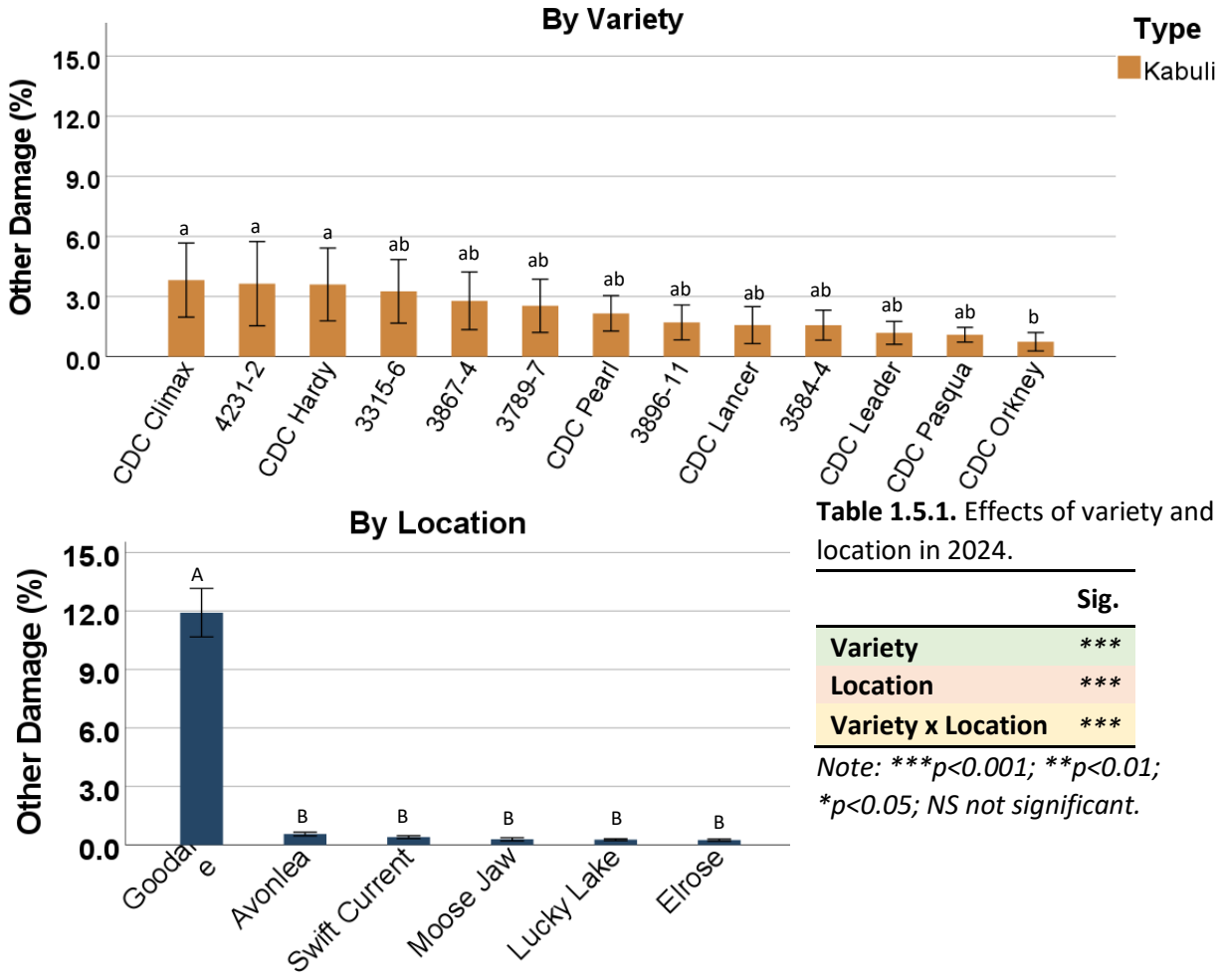

Table 1.5.1. Effects of variety and location in 2024.

	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:

- The average of the other damage ranged from 1% to 4% for all varieties.

By Location:

- Other damage varied significantly between locations.
- All locations, except Goodale, were below 1%
- At Goodale, a high amount of mouldy seeds, water damage, and sproutedseeds was observed (data not shown).

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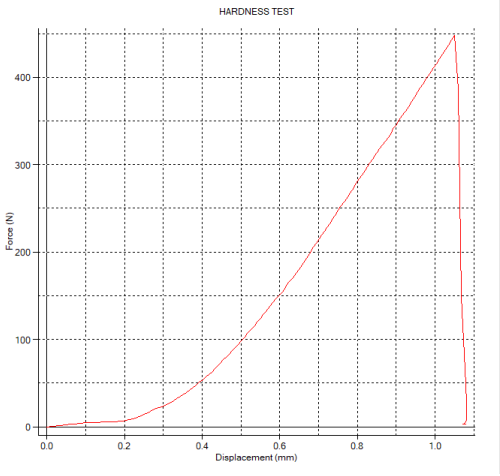
6. Hardness of Whole Seed

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

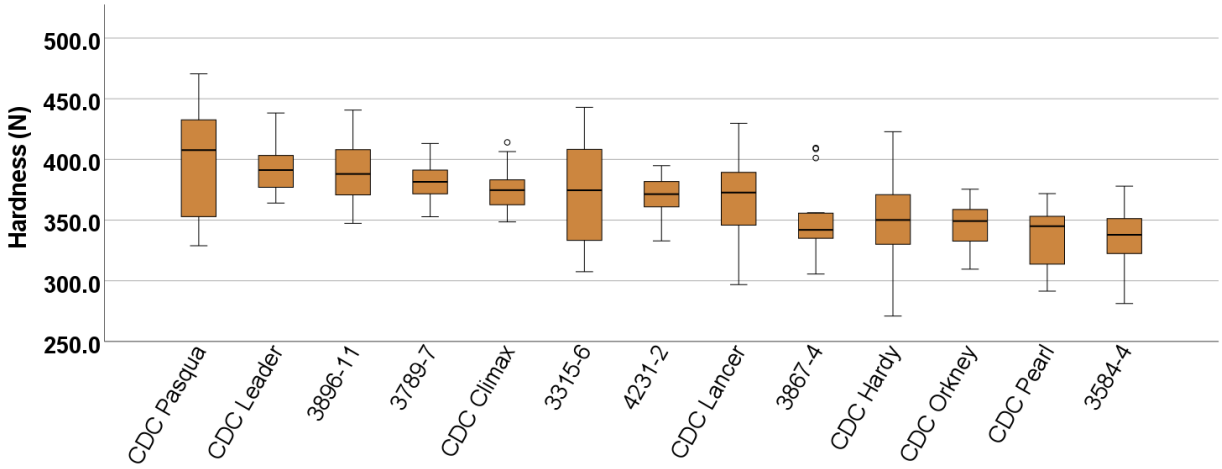
Method:

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.



Results: Figure 1.6.1. Box and Whisker plot of 2024 kabuli chickpeas for seed hardness (N). Results were reported from highest to lowest.



[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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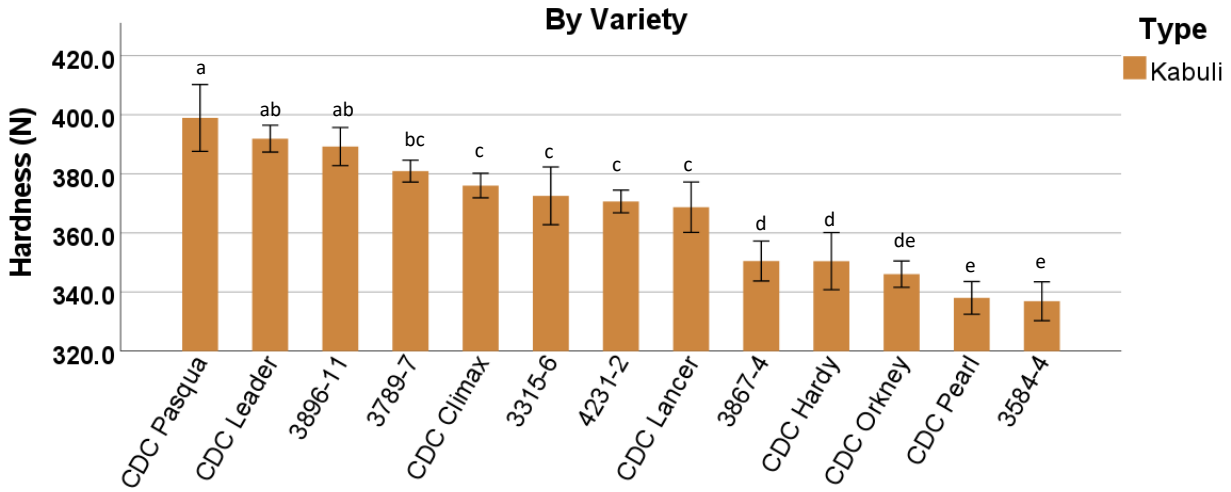
Figure 1.6.2. Mean seed hardness of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



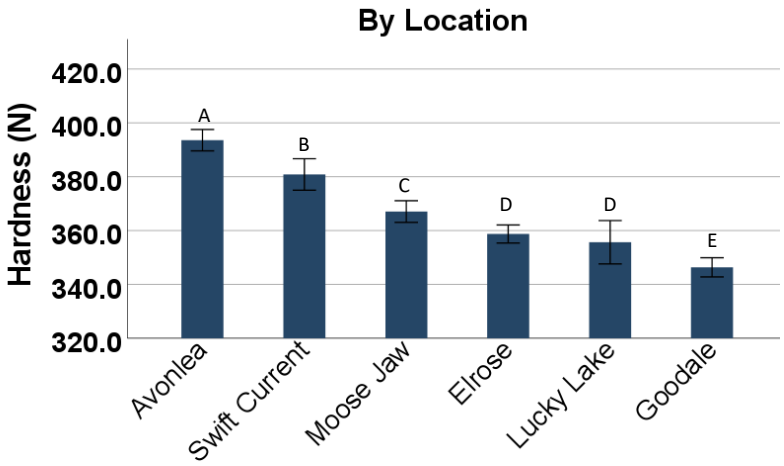


Table 1.6.1. Effects of variety and location in 2024.

	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 60 N difference in hardness was found from the largest to the lowest.
- **By Location:**Location effect also played a role, where seed hardness at Avonlea (largest) being 50 N higher than that at Goodale (lowest).
- A positive trend between TKW and seed hardness was observed (r=0.229, p<0.01).

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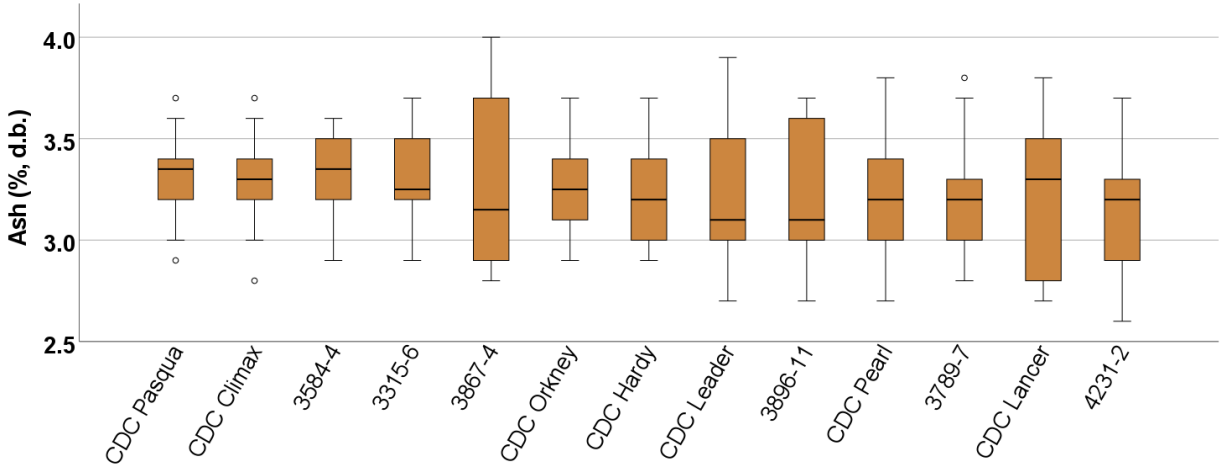
7. Ash Content

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. Box and Whisker plot of 2024 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.

Figure 1.7.2. Mean ash of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

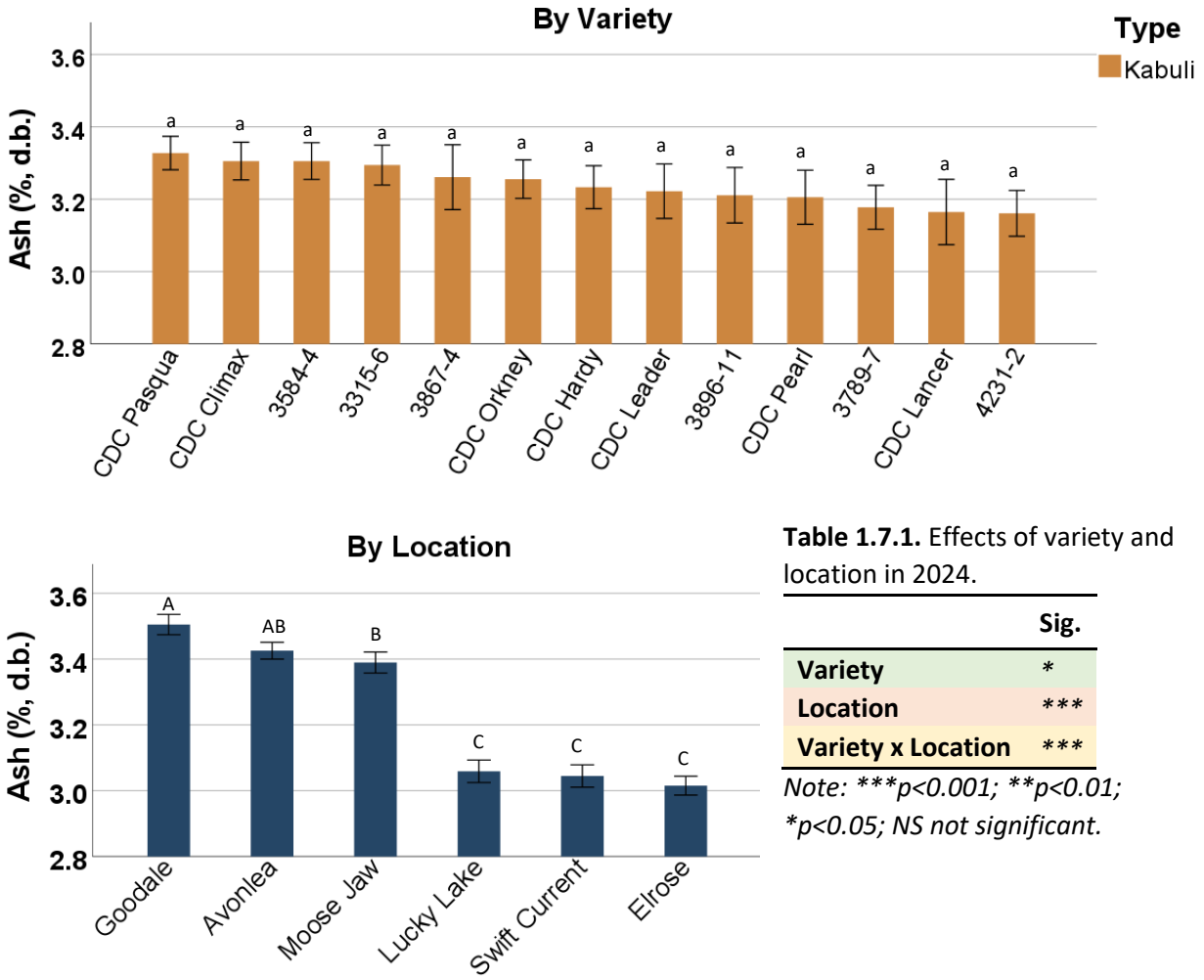


Table 1.7.1. Effects of variety and location in 2024.

	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:

- A difference of 0.5% was determined from the largest (Goodale) to the smallest (Elrose).
- A positive trend between ash content and other damge was observed (r=0.321, p<0.001).

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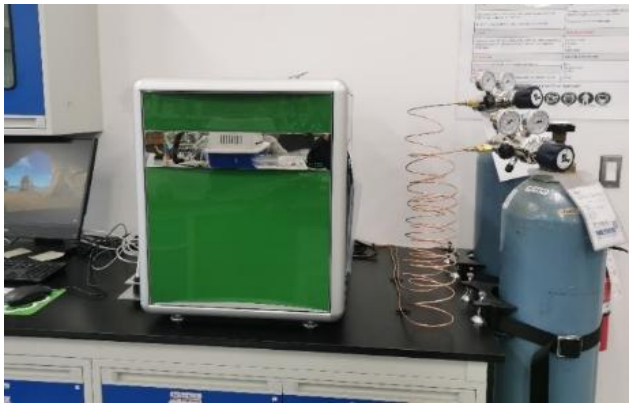
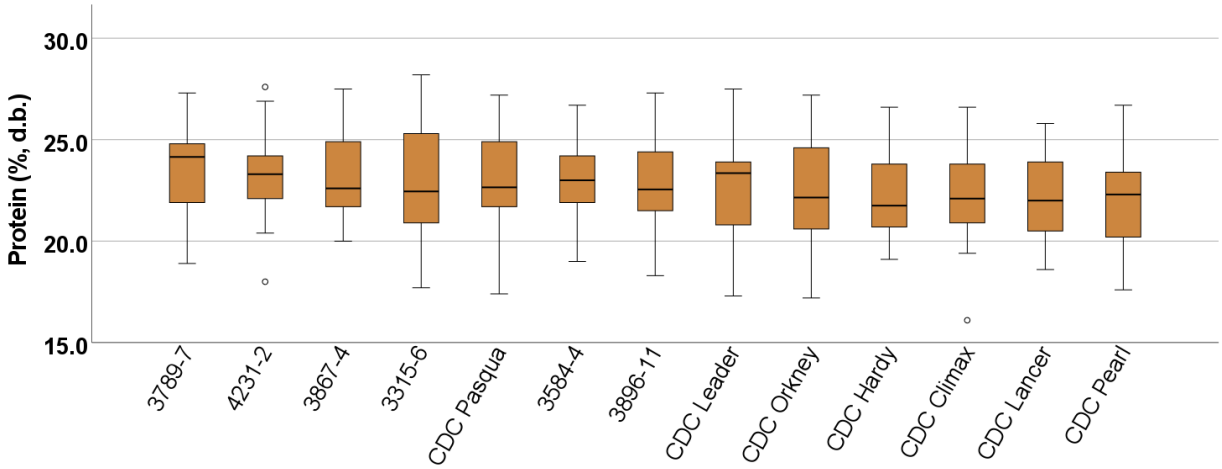
8. Protein Content

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. Box and Whisker plot of 2024 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.

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Figure 1.8.2. Mean protein of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

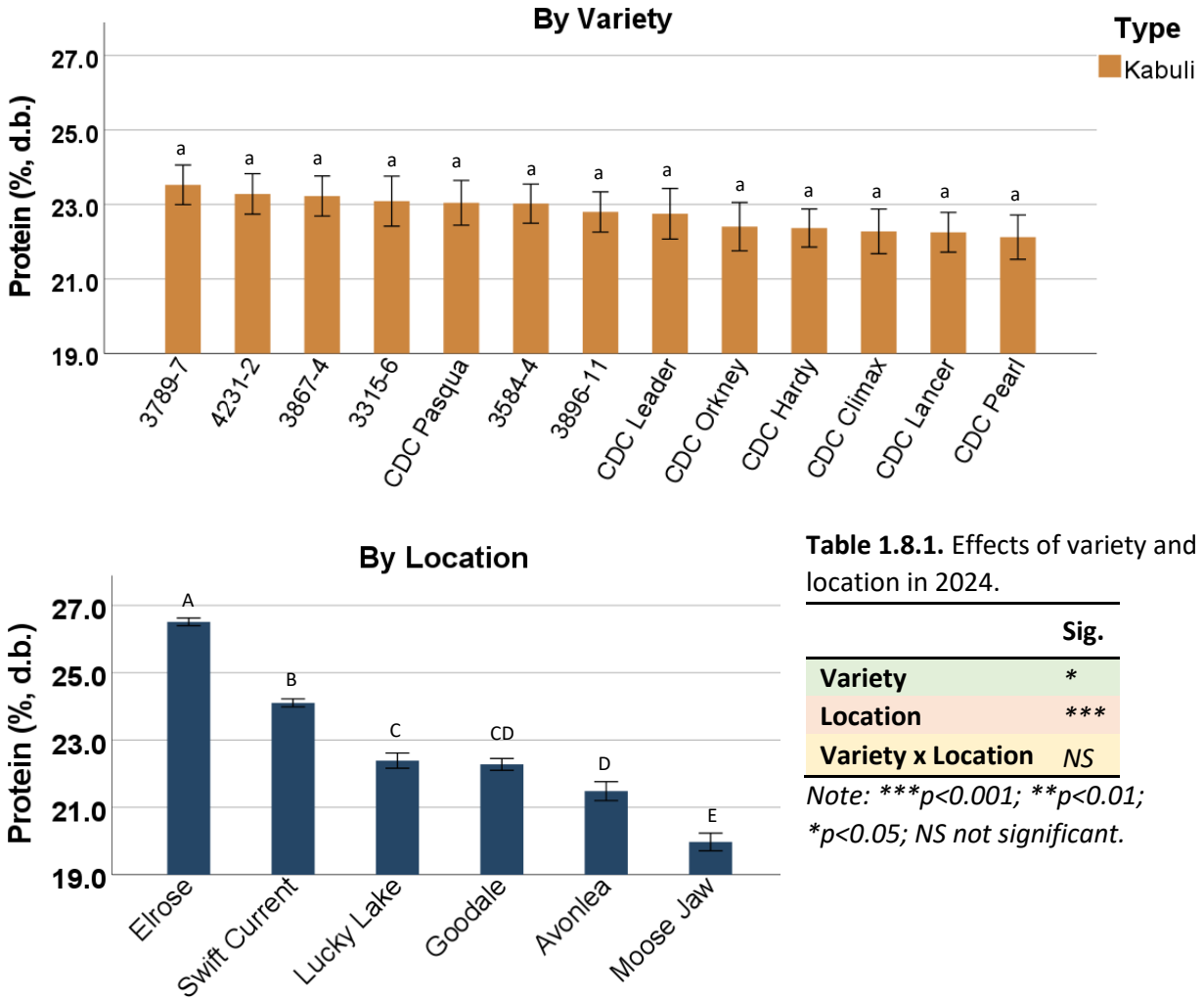

Table 1.8.1. Effects of variety and location in 2024.

	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 1.5% difference was found from highest to lowest.

By Location:

- Location effect played a significant role.
- Protein of Elrose was 6.5% higher than Moose Jaw.

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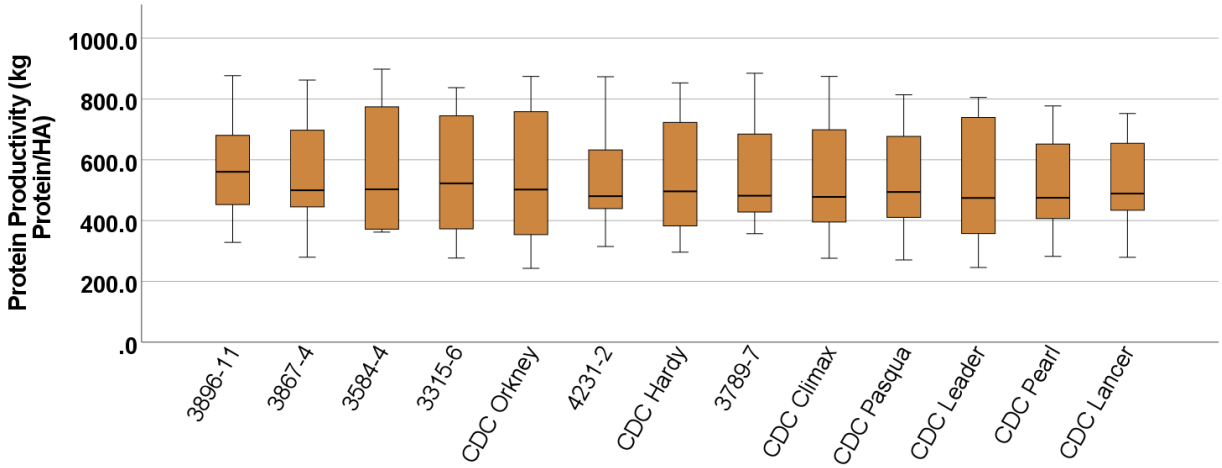
9. Protein Productivity

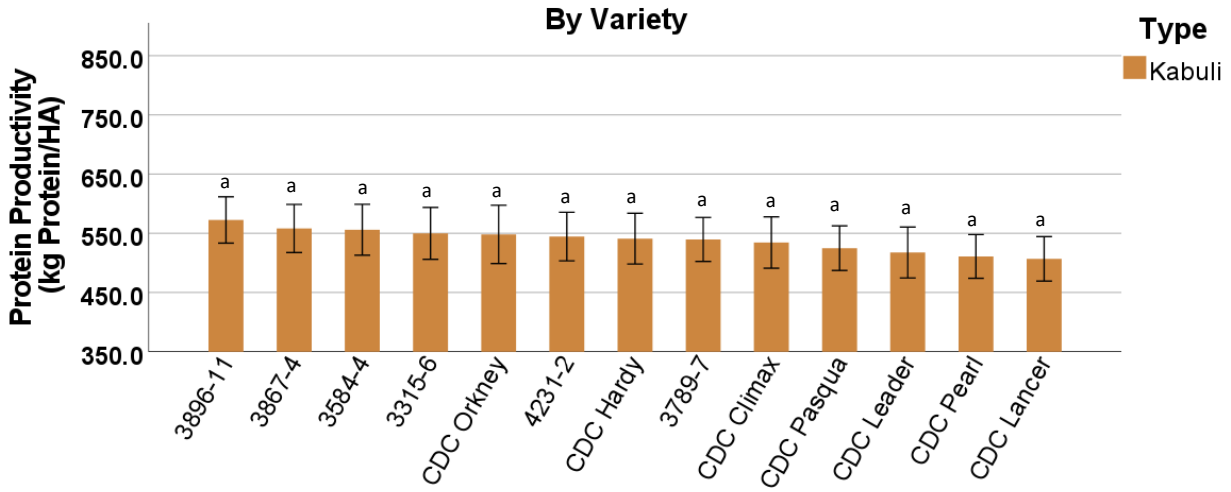
Method: Protein productivity (kg protein/HA), which is calculated using yield (kg/HA) multiplied by protein content (%), refers to the amount of protein produced per unit of land. It evaluates how much protein is being harvested from a given area.

Results: Figure 1.9.1. Box and Whisker plot of 2024 kabuli chickpeas for protein productivity. Results were reported from highest to lowest.



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

Figure 1.9.2. Mean protein productivity of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



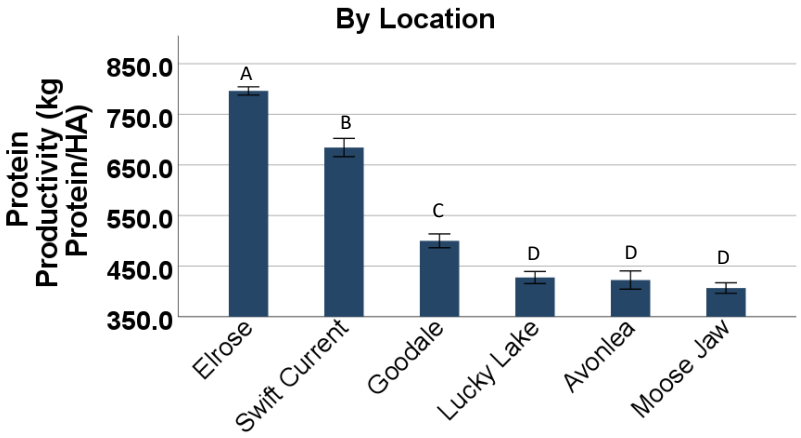


Table 1.9.1. Effects of variety and location in 2024.

	Sig.
Variety	*NS*
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:

- A 70 kg protein/HA difference was found from highest to lowest.

By Location:

- Location effect played a significant role.
- Protein productivity was high in Elrose, attributed to the high yield and high protein content (Figure 1.1.2 & 1.8.2).
- In contrast, the low yield of Moose Jaw, Avonlea, and Lucky Lake (Figure 1.1.2) resulted in the lowest protein productivity.
- A positive trend between protein productivity and yield was observed (r=0.967, p<0.001).

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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 (-)

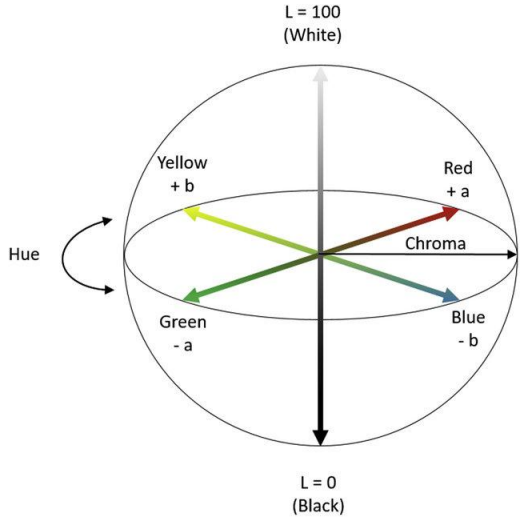
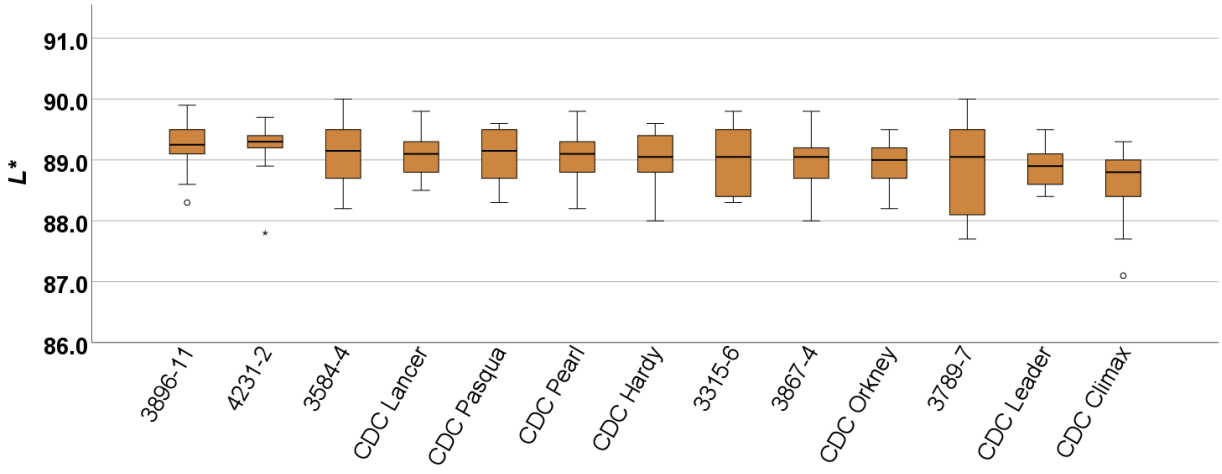


Figure 1.10.1. The CIELAB color spacediagram[3].

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

Results: Figure 1.10.2. Box and Whisker plot of 2024 kabuli chickpeas for lightness. Results were reported from highest to lowest.



[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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Figure 1.10.3. Mean lightness of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

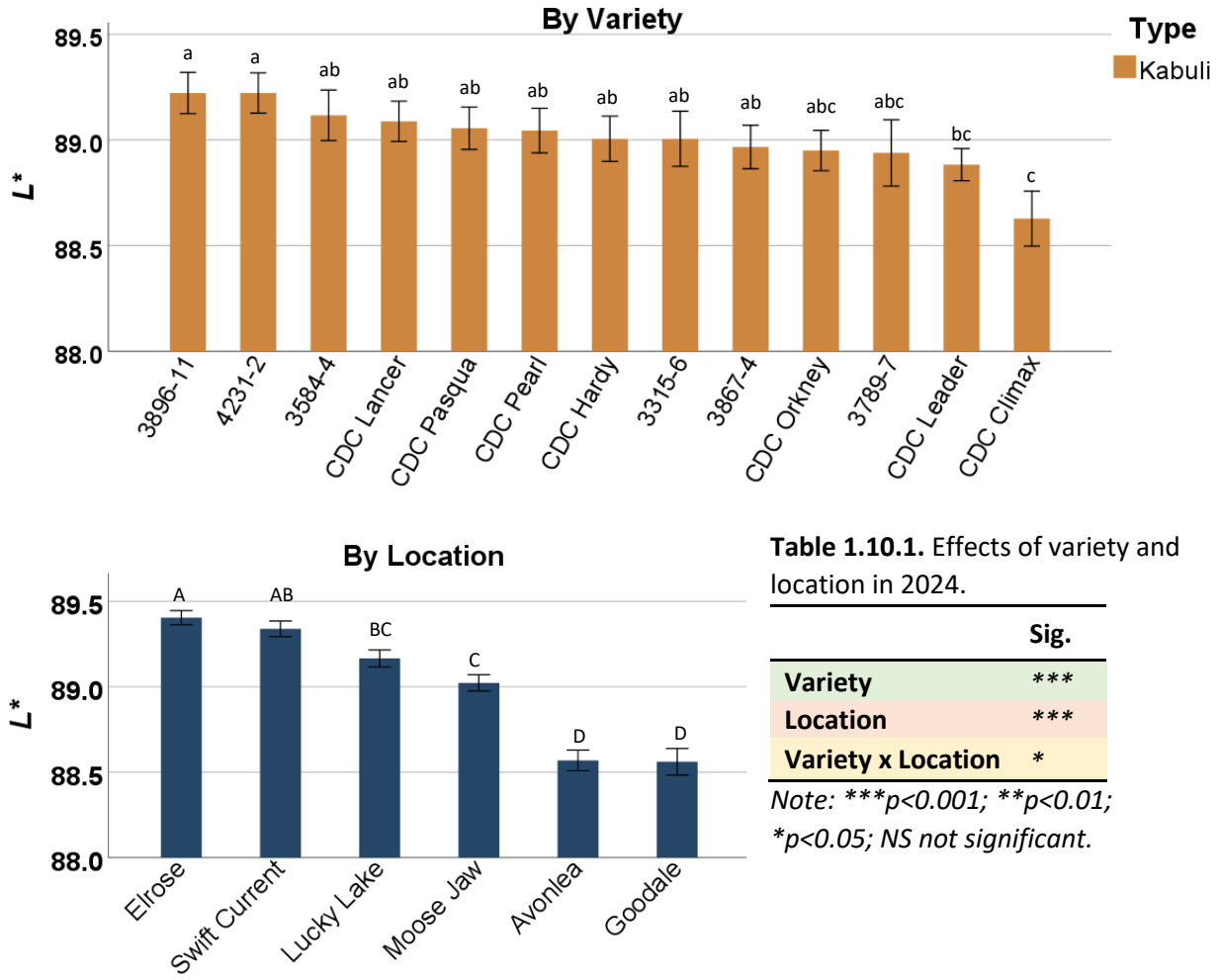


Table 1.10.1. Effects of variety and location in 2024.

	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 (-)

Results: Figure 1.10.4. Box and Whisker plot of 2024 kabuli chickpeas for *a** values. Results were reported from highest to lowest.

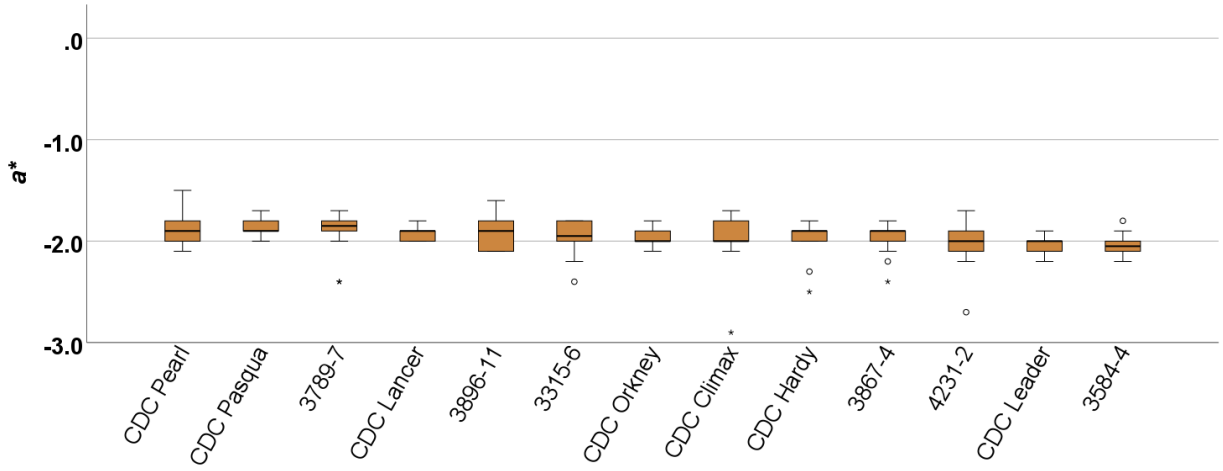
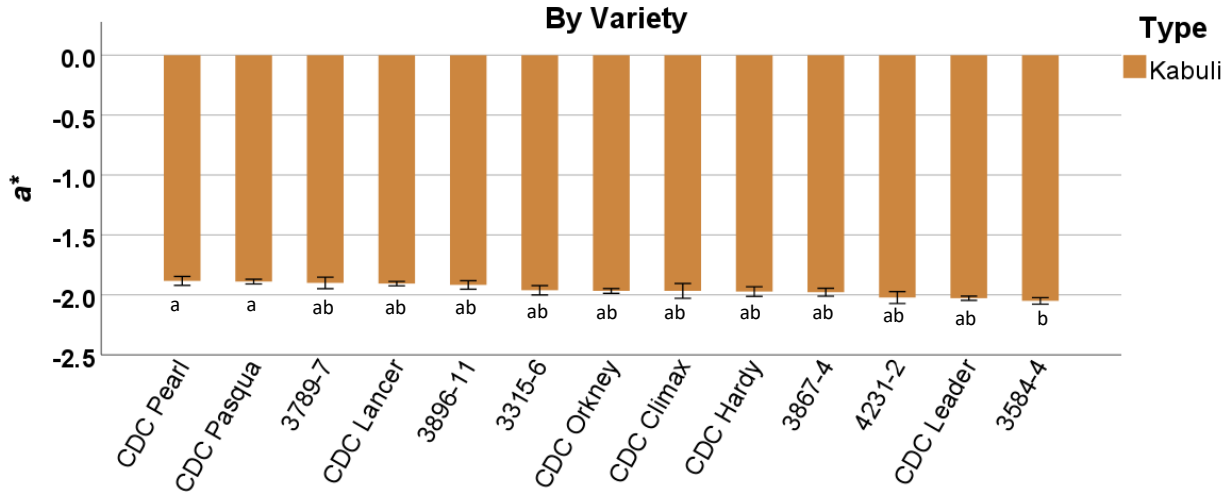


Figure 1.10.5. Mean *a** of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



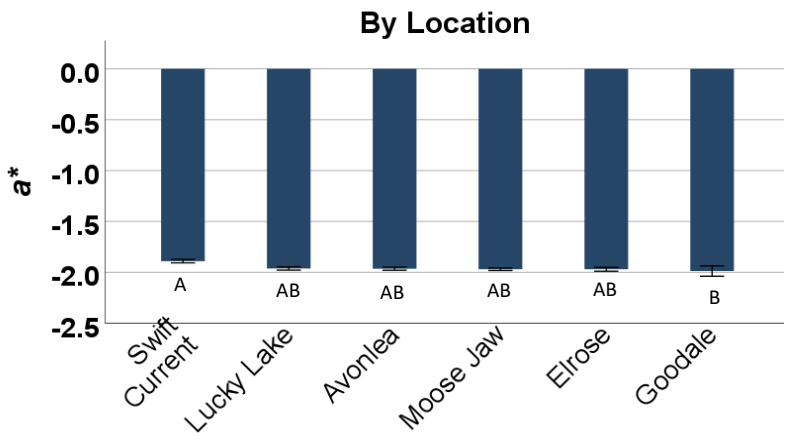


Table 1.10.2. Effects of variety and location in 2024.

	Sig.
Variety	**
Location	*
Variety x Location	***

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

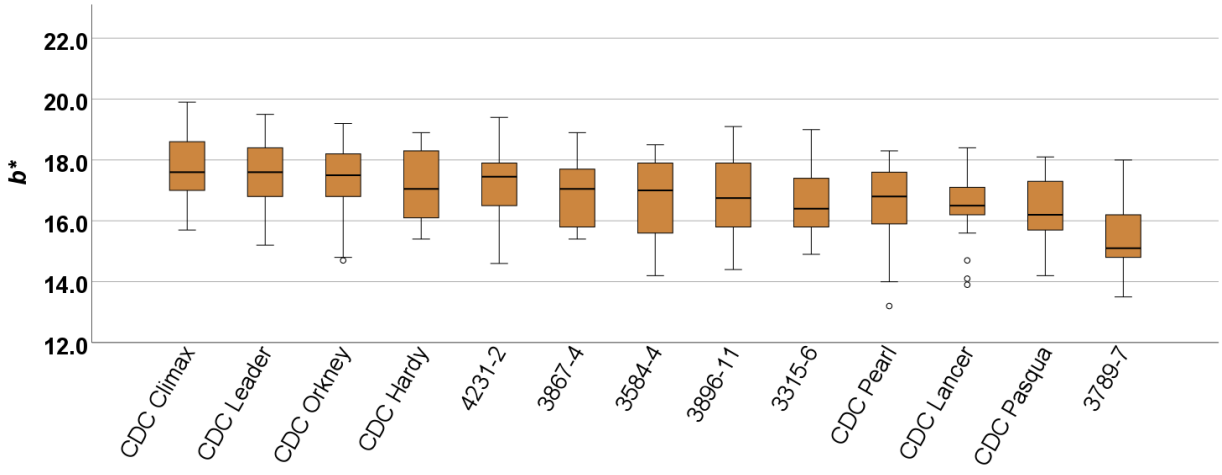
Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

By Variety: A difference of 0.2 unit only was determined from highest to lowest.

By Location: A difference of 0.1 unit was determined from highest to lowest.

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

Results: Figure 1.10.6. Box and Whisker plot of 2024 kabuli chickpeas for *b** resulting from 6 locations. Results were reported from highest to lowest.



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

Figure 1.10.7. Mean *b** of 2024 kabuli chickpeas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.

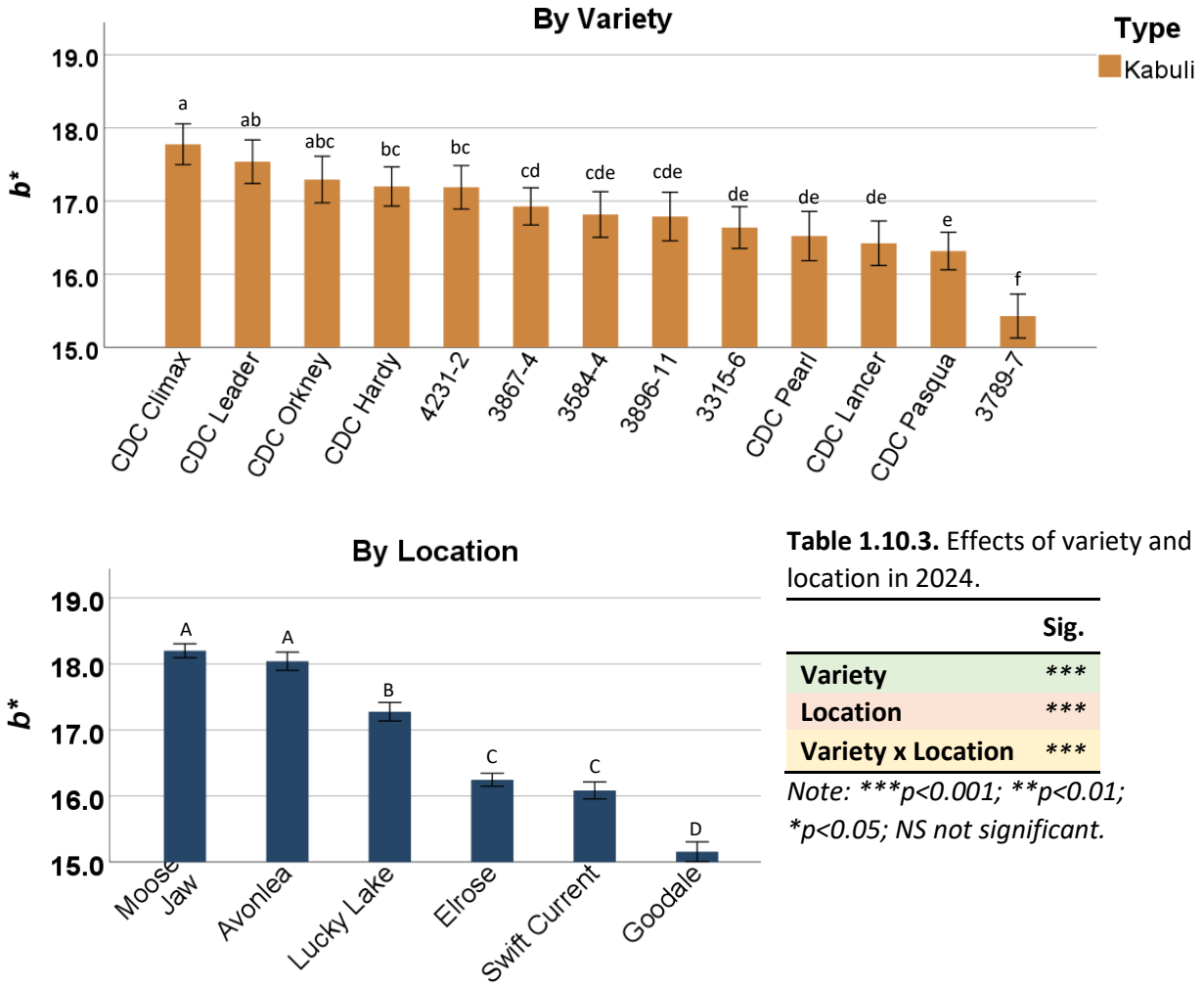


Table 1.10.3. Effects of variety and location in 2024.

	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 2.3 units higher than line 3789-7 (lowest).

By Location:

- Yellowness of chickpeas from Moose Jaw and Avonlea (highest) was 3 units higher than Goodale (lowest).

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2) Black Desi + Desi Chickpeas

This section included one variety of black desi (i.e. CDC Kala), two varieties of desi (i.e. CDC Sunset and line 4262-3), that presented in 2024 from six 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. An independent T-test was conducted to identify the differences in the quality parameters for the two desi varieties.

Results: Table 2.1. TKW, seed size distribution, different types of damage, and hardness for 2024 black desi + desi chickpeas.

Quality Attribute	Black Desi (CDC Kala)	Desi (4262-3)	Desi (CDC Sunset)
Yield (kg/HA)	2061.4 ± 582.7	2410.4 ± 587.5[a]	2356.0 ± 514.9[a]
TKW (g)	238.4 ± 27.4	277.2 ± 20.4[b]	296.9 ± 22.3[a]
Size distribution (%)			
> 9.52 mm	0.0 ± 0.0	0.0 ± 0.0[a]	0.0 ± 0.0[a]
> 8.73 mm	0.1 ± 0.2	0.7 ± 0.7[b]	1.9 ± 2.2[a]
> 7.94 mm	15.7 ± 13.3	27.9 ± 12.3[b]	41.0 ± 11.1[a]
> 7.14 mm	59.8 ± 9.7	56.4 ± 8.2[a]	46.8 ± 10.6[b]
> 6.35 mm	21.4 ± 10.0	13.8 ± 6.2[a]	9.9 ± 5.5[a]
Below 6.35 mm	2.9 ± 4.2	1.2 ± 1.3[a]	1.8 ± 2.1[a]
Split (%)	2.9 ± 3.4	2.5 ± 2.9[b]	6.2 ± 5.0[a]
Other damage (%)	0.3 ± 0.7	2.7 ± 3.9[a]	4.5 ± 8.5[a]
Hardness (N)	363.7 ± 46.4	366.6 ± 36.6[a]	334.6 ± 23.3[b]

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 > Line 4262-3 > CDC Kala.
- Over 90% of the seeds had the size between 6.35 mm and 7.94 mm.
- CDC Sunset had the highest split.
- Hardness of CDC Kala and line 4262-3 were similar.

Table 2.2. Ash, protein, protein productivity, and colour for 2024 black desi + desi chickpeas.

Quality Attribute	Black Desi (CDC Kala)	Desi (4262-3)	Desi (CDC Sunset)
Ash (d.b.; %)	3.4 ± 0.2	3.2 ± 0.2[a]	3.3 ± 0.3[a]
Protein (d.b.; %)	24.3 ± 2.7	21.9 ± 2.4[a]	23.6 ± 2.8[a]
Protein productivity (kg protein/HA)	472.5 ± 176.9	496.7 ± 166.9[a]	523.3 ± 161.8[a]
Colour			
L*	84.9 ± 0.6	87.3 ± 0.6[a]	87.2 ± 0.7[a]
a*	-2.6 ± 0.2	-1.4 ± 0.2[a]	-1.5 ± 0.1[a]
b*	12.6 ± 1.5	14.6 ± 1.1[a]	15.2 ± 1.3[a]

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

- Ash content, protein, and protein productivity showed no significant difference between CDC Sunset and line 4262-3.

- Color of the flour *(L*, a*, b*):*
  - *L** values: CDC Sunset = Line 4262-3 > CDC Kala.
  - *a** values (in terms of greenness): CDC Kala had greater greenness.
  - *b** values (in terms of yellowness): CDC Kala had lower yellowness.

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