

Evaluation of varieties of Chinese cabbage (Japanese varieties) at ARDC, Bajo and ARDSC, Tsirang.

1. Introduction

Chinese cabbage (*Brassica rapa* var. *pekinensis*) is a cole crop, sharing family ties with cabbage, cauliflower, and broccoli. Originating in Northeast China (Tomiyasu, 2018), it is more closely related to turnips and rutabagas than to common cabbages (Andersen, 1914). This versatile vegetable is consumed in various forms, including salads, curries, and kimchi (Andersen, 1914). Research indicates that Chinese cabbage is a valuable source of Vitamin A, Vitamin C, protein, iron, and niacin (SAP. 2005). Furthermore, its nutritional composition includes approximately 5% dry matter, 10 g/kg of dietary fiber, 2,520 mg/kg of potassium, 1,050 mg/kg of calcium, 190 mg/kg of magnesium, 650 mg/kg of sodium, and 450 mg/kg of vitamin C in its fresh state (R. Pokluda, 2008).

The growing consumption of Chinese cabbage among some Bhutanese, evidenced by its market presence and shifting dietary patterns, signals a clear requirement for increased domestic production of this crop. Despite this, there is no record of the crops production and import figures and there is only one variety i.e. Kyoto-1 available with the farmers (Ngawang, 2018). The need to carry out the trial for the new variety is found crucial to help the farmers before the old one is de notified.

This trial is done to study the yield performance of four Japanese open-pollinated Chinese cabbage varieties (Kaga, Nozaki, Neo Kyoto 3, and Ousho) in Bajo and Tsirang, comparing them to the established local variety, Kyoto-1 as check. The study also will help to address the issue of crop degeneration resulting from the prolonged use of limited variety of the crop.

2. Materials and Methods

2.1. Trial location

ARDC-Bajo and ARDSC, Tsirang having an altitude of 1284 masl and 1500 masl respectively.

2.2. Trial design and layout

2.2.1. Trial layout.

Randomized Complete Block Design (RCBD) with each varieties having four replications.

Table 1. Experimental trial design layout

Plot	Replication-1	Replication-2	Replication-3	Replication 4
	Border plot (2 rows)	Border plot (2 rows)	Border plot (2 rows)	Border plot (2 rows)
1	R1T1	R1T5	R1T4	R1T2
2	R1T2	R1T3	R1T1	R1T5
3	R1T3	R1T4	R1T2	R1T3
4	R1T4	R1T1	R1T5	R1T4
5	R1T5	R1T2	R1T3	R1T1
	Border plot (2 rows)	Border plot (2 rows)	Border plot (2 rows)	Border plot (2 rows)

T1= Kaga, T2= Nozaki, T3=Neo Kyoto 3, T4=Ousho, T5= Kyoto-1 (check)

2.2.2. Plot design.

Plot size: 3.3 m x 1m (3.3 m²). No. of rows/plot: 2. No. of plants/row: 10. No. of plants/plot: 20

2.2.3. Plant spacing.

45cm x 30 cm (Row x Plant).

2.2.4. Fertiliser and manure application

FYM was used during field preparation and incorporated with soil. NPK: 64:32:72 kg/acre was applied as a basal dose before transplanting. Top dress with 500 gm suphala per decimal after one month from transplanting.

2.3. Sampling Method

Systematic; 10 plants each per plot from the total plants will be evaluated

3. Result

R-statistics ver.4.4.3 was used to analyse and interpret the results and findings of this trial.

3.1. Findings from field experiments.

3.1.1. Fruit quality parameters among different Chinese Cabbage varieties at Bajo.

At ARDC, Bajo, the analysis of fruit quality parameters revealed significant differences among the Chinese cabbage varieties for fruit girth and fruit length. Given the non-normal distribution of the data, Kruskal-Wallis test was employed to assess the differences. For fruit girth (P-value = 0.03), Kaga (133.29 mm) had a significantly greater average fruit girth than Kyoto-1 (116.36 mm), as indicated by the letters "a" and "b" respectively, where different letters denote significant differences based on Dunn's test used for post-hoc analysis. Nozaki (119.79 mm, denoted by "ab") and Neo Kyoto-3 (118.71 mm, denoted by "ab") did not show significant differences from either Kaga or Kyoto-1. Fruit weight, however, did not show significant differences among the varieties (P-value = 0.71). In contrast, fruit length showed a highly significant difference (**P-value = 2.55e-07**). Kaga (243.84 mm, denoted by "a") exhibited the greatest fruit length, significantly exceeding both Kyoto-1 (195.90 mm, denoted by "b") and Neo Kyoto-3 (221.02 mm, denoted by "c"). Nozaki (229.94 mm, denoted by "ac") was also significantly longer than Neo Kyoto-3 but not significantly different from Kaga.

Due to the highly skewed distribution of the 'Total Heads Formed' data, the median, rather than the mean, was used to accurately represent the data of this variable across all the treatments. It should be noted that data for the Ousho variety is not available for Bajo, as this variety was not included in the trial.

Table 2. Comparison of fruit quality parameters among five Chinese cabbage varieties
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Treatment	Fruit girth (mm)	Fruit weight (g)	Fruit length(mm)	Total Heads formed
Kaga	133.29(21.97) ^a	1075.64(553)	243.84(28.40) ^a	0.00
Nozaki	119.79(23.55) ^{ab}	1152.85(594)	229.94(34.81) ^{ac}	0.00
Neo Kyoto-3	118.71(19.68) ^{ab}	1082.58(468)	221.02(22.50) ^c	0.00
Ousho	NA	NA	NA	NA
Kyoto-1	116.36(40.38) ^b	983.12(451.2)	195.90(23.68) ^b	0.00
<i>P-Value</i>	0.03	0.71	2.55e-07	0.88

3.1.2. Fruit quality parameters among different Chinese Cabbage varieties at Tsirang.

At ARDSC, Tsirang, the analysis revealed significant differences in fruit weight and fruit length among the Chinese cabbage varieties. Given the non-normal distribution of the data, Kruskal-Wallis test was employed to assess the differences. For fruit weight (P-value = 0.03), Kaga (931.03 g), Neo Kyoto-3 (818.57 g), and Kyoto-1 (827.33 g) were found to have statistically similar average fruit weights (denoted by "a"), while Nozaki (629.36 g, denoted by "ab") and Ousho (655.14 g, denoted by "b") had significantly lower fruit weights. The different letters indicate statistically significant differences based on Dunn's test used for post-hoc analysis. The most pronounced significant difference was observed in fruit length (P-value = 0.001), where Kaga (250.25 mm, denoted by "a"), Neo Kyoto-3 (229.17 mm, denoted by "a"), and Kyoto-1 (268.33 mm, denoted by "a") demonstrated greater fruit length compared to Nozaki (213.14 mm, denoted by "b") and Ousho (196.68 mm, denoted by "c"), highlighting a clear distinction in this trait across the varieties. In contrast, fruit girth did not vary significantly among the varieties (P-value = 0.07), and consistent with the Bajo results, none of the plants formed heads at Tsirang.

Like Bajo, due to the highly skewed distribution of the 'Total Heads Formed' data, the median, rather than the mean, was used to accurately represent the data of this variable across the all the treatments.

Table 3 Comparison of fruit quality parameters among five Chinese cabbage varieties evaluated at ARDSC, Tsirang.

Treatment	Fruit girth (mm)	Fruit weight (g)	Fruit length(mm)	Total Heads formed
Kaga	102.52(28)	931.03(490.43) ^a	250.25(43.03) ^a	0.00
Nozaki	84.21(24.62)	629.36(304) ^{ab}	213.14(30.5) ^b	0.00
Neo Kyoto-3	97.88(28.19)	818.57(438.6) ^a	229.17(438) ^a	0.00
Ousho	93.70(21.45)	655.14(288) ^b	196.68(47.20) ^c	0.00
Kyoto-1	93.81(21.21)	827.33(137.18) ^a	268.33(113.14) ^a	0.00
<i>P-Value</i>	0.07	0.03	0.001	0.7

3.1.3. Comparison of fruit quality parameters among different Chinese Cabbage varieties in two study sites.

The analysis of fruit quality parameters across Bajo and Tsirang revealed significant interactions between location and variety for the traits. These interactions were primarily assessed through box plot visualization due to the non-normal distribution of the data, which rendered traditional parametric tests (like ANOVA) inappropriate.

Box plots allowed for a robust comparison of the median, spread, and range of each trait across locations and varieties, without relying on assumptions of normality. For fruit girth (Figure 1), Kaga exhibited a larger median girth in Bajo, while differences among varieties were less pronounced in Tsirang, suggesting that Kaga's girth performance is location-dependent. Fruit weight (figure 2) displayed a strong interaction, with a general trend of higher weights in Bajo but significant variety-specific differences emerging only in Tsirang. Fruit length (Figure 3) also showed interactive effects, with varieties like Kyoto-1 demonstrating increased length in Tsirang, while others like Nozaki showed the opposite trend. Finally, total head formation (Figure 4), while uniformly absent in the table data, showed variation in the boxplots, with varieties like Kyoto-1 and Ousho showing a higher head formation in Tsirang, further supporting the influence of location on varietal performance. girth, fruit weight, fruit length, and total head formation is significantly influenced by the growing location.

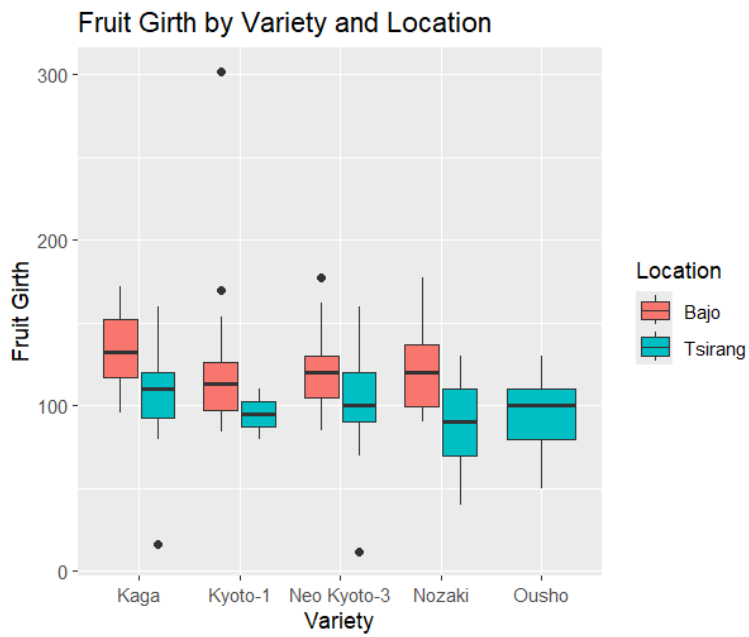


Figure 1 Fruit Girth by Variety and Location

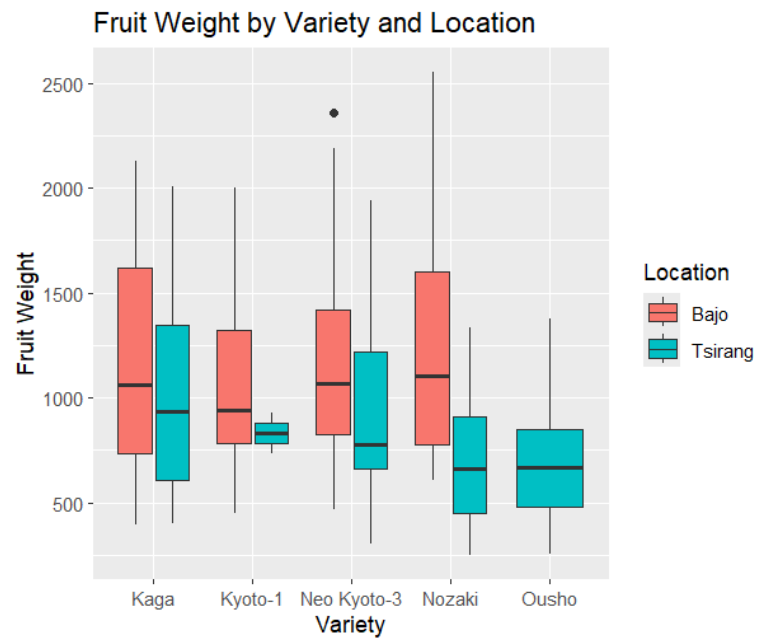


Figure 2 Fruit weight by Variety and Location

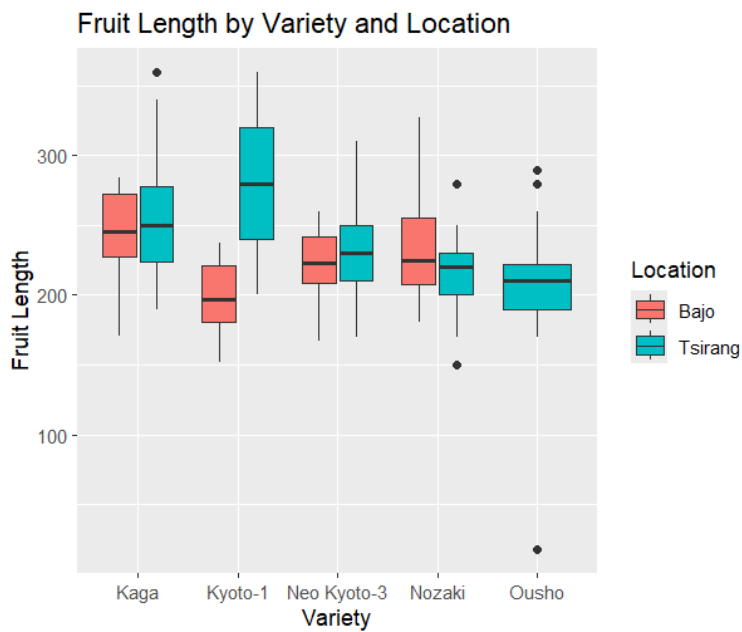


Figure 3 Fruit Length by Variety and Location

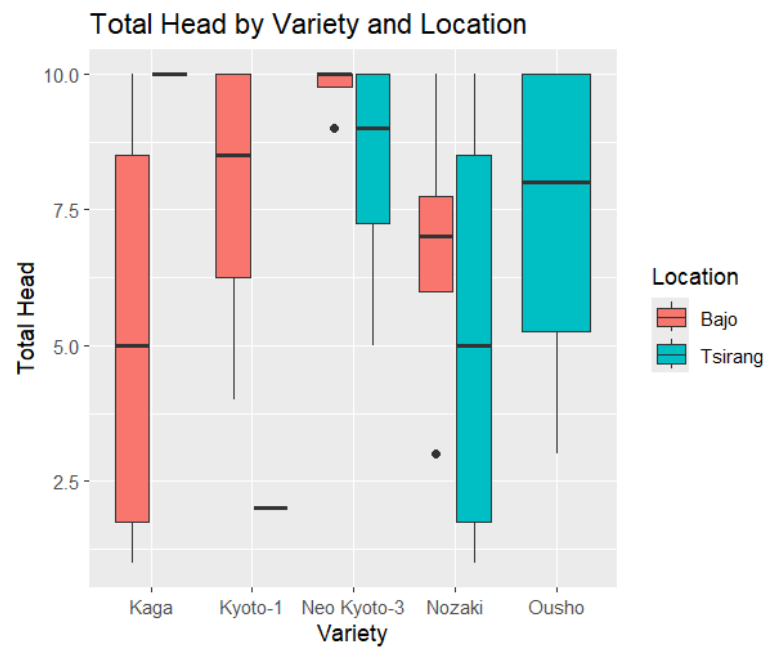


Figure 4 Total Head Formed by Variety and Location

4. Discussion

This study evaluated the yield performance of four Japanese open-pollinated Chinese cabbage varieties (Kaga, Nozaki, Neo Kyoto 3, and Ousho) in comparison to the local variety, Kyoto-1, at ARDC, Bajo and ARDSC, Tsirang. The results demonstrated significant location-specific performance differences among the varieties, highlighting the critical role of environmental factors in trait expression. The non-normal distribution of the data necessitated the use of the Kruskal-Wallis test, with Dunn's test used for post-hoc analysis, and box plots for visualization. The weather data (Mean Maximum temperature, Mean Minimum Temperature and Mean Relative Humidity) were requested and sourced from National Center for Hydrology and Meteorology (NCHM), Bhutan.

At Bajo, seed sowing was conducted on 16 September 2024, followed by transplantation on 17 October 2024, and harvesting on 10 January 2025. During this time, the crop experienced relatively high temperatures, particularly during its early growth stages. In September, the mean maximum temperature was 30.8°C, with a minimum temperature of 20.3°C, and a relative humidity of 79%. By October, temperatures slightly declined, with a mean maximum of 27.5°C, a minimum of 18°C, and a relative humidity of 81%. During the harvest period in January 2025, the mean maximum temperature further dropped to 21.3°C, with a minimum of 7.3°C, and a relative humidity of 77%. These conditions were substantially above the optimal range for Chinese cabbage cultivation; a cool season crop which typically prefers mean temperatures around 15–16°C for optimal head formation and quality development according to Opena and Ho, (1979).

Elevated temperatures, especially beyond 25°C, have been shown to impair head development, reduce leaf expansion, and predispose plants to physiological disorders such as tip burn, internal browning, and soft rot (Son, (2015); Lee (2016)). These adverse effects were evident at Bajo as none of the varieties succeeded in forming heads, and fruit quality parameters such as girth, length, and weigh were all considerably lower than would be expected under more favourable conditions. However, Kaga performed relatively better in girth and length, suggesting a degree of heat tolerance, aligning with previous finding from Yuan et al, (2024) that certain genotypes can maintain better vegetative growth under moderate thermal stress. Importantly, pest and disease incidences were not monitored during the trial. This introduces a degree of uncertainty, as some of the reduced growth and quality outcomes might partially be attributed to biotic stresses.

Similarly, at Tsirang, seed sowing took place earlier on 23 August 2024, transplantation was done on 11 September 2024, and harvesting occurred on 14 January 2025. Climatic data from the NCHM indicated that in August, the mean maximum temperature was 24.8°C, the minimum was 19.5°C, and the relative humidity was notably high at 90%. In September, conditions remained warm, with a mean maximum temperature of 25.6°C, a minimum of 18.9°C, and a relative humidity of 87%. By January 2025, temperatures at Tsirang had decreased considerably, with a mean maximum of 16.6°C, a minimum of 6.1°C, and a relative humidity of 8.2%.

Although temperatures during the early vegetative stage were slightly cooler compared to Bajo, they still exceeded the optimal range for Chinese cabbage. High humidity levels, particularly in August and September, can aggravate stress on plants by facilitating the proliferation of pathogens and increasing the risk of diseases such as downy mildew and bacterial soft rot (Golian et al., 2023). Despite these suboptimal conditions, significant varietal differences were observed at Tsirang, especially in fruit length. Varieties such as Kaga, Neo Kyoto-3, and Kyoto-1 demonstrated superior performance in fruit length, suggesting they may possess better adaptability to moderately warm and humid environments which is supported by a study conducted by Kerry Porter, (2023), where he noticed varieties of Chinese cabbage performing better in warm and humid condition rather than in cold environment. Nevertheless, similar to Bajo, none of the varieties successfully formed heads, highlighting the critical role of temperature and humidity stresses during early developmental stages. Though the data and result showed that location specific effect and environmental factors did play a role in fruit weight performance, further data validation is needed to confirm the exact cause.

The data revealed strong location-by-variety interactions across all fruit quality parameters. Boxplot analyses indicated that Kaga displayed a larger median girth at Bajo compared to other varieties, demonstrating its relative resilience to high-temperature stress. In Tsirang, however, varietal differences were less distinct for girth but more pronounced for fruit length and weight, where Kyoto-1 and Neo Kyoto-3 performed notably well. Such genotype-by-environment interactions are well-documented in Brassica species, where thermal stress, photoperiod, humidity, and soil conditions interact with varietal traits to influence agronomic outcomes (Palta, 1996; Dixon, 2007; Park et al., 2016). The results align with existing literature that stresses the need for site-specific cultivar selection and adaptive management practices to

optimize productivity under changing climates (Dixon, 2007; Frontiers in Sustainable Food Systems, 2024; World Bank, 2019).

The complete absence of head formation at both locations, despite genetic differences among varieties, indicates that environmental stressors overrode genetic potential. This supports earlier findings that temperatures consistently above 20–22°C during the rosette or early heading stages can inhibit proper head development in Chinese cabbage (Palta, 1996; UNECE, 2014; CIRAD, 2010). It may also reflect suboptimal nutrient ratios. Studies have demonstrated that nitrogen-potassium balances directly influence head development in Chinese cabbage (Siahaan et al., 2024). The lack of soil analysis made it hard to determine the existing nutrient profiles and therefore made it difficult to confirm or contradict the role of nutrient ratios in the observed lack of head formation.

Other potential contributing factors include temperature fluctuations or photoperiodic effects, which warrant further investigation as those parameters weren't regarded during data collection.

5. Conclusion and Recommendations

This study demonstrated significant location-specific differences in the performance of Chinese cabbage varieties in Bhutan. At ARDC, Bajo, Kaga exhibited superior fruit girth and length compared to the local check variety, Kyoto-1, likely due to favorable cooler temperatures for vegetative growth. In contrast, at ARDSC, Tsirang, Kaga, Neo Kyoto-3, and Kyoto-1 showed comparable and higher fruit weight, while Kyoto-1 displayed improved fruit length performance, indicating a shift in relative performance depending on the environment.

Overall, Kaga demonstrated relatively consistent and strong performance across both locations, particularly for fruit length. However, the optimal variety selection depends on the specific location and desired traits.

The strong Location and Variety interactions were observed for fruit girth, fruit weight, and fruit length, highlighting the importance of environmental adaptation for optimal yield. The absence of head formation across all varieties, despite adequate growing seasons, warrants further investigation to optimize cultivation practices.

Based on this study, recommendations are as follows:

- Soil testing should be done before and after the trial.
- Increasing cropping cycle for validation of the data
- Pest and Disease monitoring

Reference

- Agriculture Survey Report national statistics bureau*. (2021). www.nsb.gov.bt
- Andersen, C. (1914). Chinese cabbage, home gardening series. Division of Agriculture. Research and Extension. University of Arkansas system.
- Chhetri, R. B. (2014). Effect of Organic Nutrients on the Yield of Cabbage. *Bhutan Journal of Natural Resources & Development*, 1(2), 32–36. <https://doi.org/10.17102/cnr.2014.05>
- CIRAD. (2010). *Vegetable crop production under tropical conditions*. https://agritrop.cirad.fr/559774/1/document_559774.pdf
- Dixon, J. M. (2007). *Climate change and sustainable food systems*. Retrieved from <https://documents1.worldbank.org/curated/en/367871546582390434>
- Frontiers in Sustainable Food Systems. (2024). *Genotype-environment interactions in vegetable crop adaptation*. <https://www.frontiersin.org/articles/10.3389/fsufs.2024.1433701/full>
- Integrated Agriculture Technical Guide Book. Thimphu, Bhutan: CoRRB, MoA Tomiyasu, Y. (2018). Guidebook on vegetable cultivation. Integrated Horticulture Promotion Project, IHPP/JICA, ARDC, Bajo.
- Jingjuan Li, Minghui Qiu, Faujiah Nurhasanah Ritonga, Fengde Wang, Dandan Zhou, Cheng Li, Huayin Li, Yihui Zhang, Jianwei Gao. Metabolite Profiling and Comparative Metabolomics Analysis of Jiaozhou Chinese Cabbage (*Brassica rapa* L. ssp. *pekinensis*) Planted in Different Areas. *Front. Biosci. (Landmark Ed)* **2023**, 28(12), 345. <https://doi.org/10.31083/j.fbl2812345>
- Lee, S. G., Kim, S. K., Lee, H. J., Choi, C. S., & Park, S. T. (2016). Impacts of climate change on the growth, morphological and physiological responses, and yield of Kimchi cabbage leaves. *Horticulture, Environment, and Biotechnology*, 57, 470-477.

- Lee, S. G., Lee, H. J., Kim, S. K., Choi, C. S., Park, S. T., Jang, Y. A., & Do, K. R. (2015). Effects of vernalization, temperature, and soil drying periods on the growth and yield of Chinese cabbage. *Horticultural Science and Technology*, 33(6), 820-828.
- Li, J., Qiu, M., Ritonga, F. N., Wang, F., Zhou, D., Li, C., Li, H., Zhang, Y., & Gao, J. (2023). Metabolite Profiling and Comparative Metabolomics Analysis of Jiaozhou Chinese Cabbage (*Brassica rapa* L. ssp. *pekinensis*) Planted in Different Areas. *Frontiers in Bioscience (Landmark Edition)*, 28(12), 345. <https://doi.org/10.31083/j.fbl2812345>
- Ngawang. (2018). Inventory of Released and De-notified Crops in Bhutan (1988-2017) DEPARTMENT OF AGRICULTURE Ministry of Agriculture and Forests Ngawang.
- Opena, R. T., & Lo, S. H. (1979). Genetics of Heat Tolerance in Heading Chinese Cabbage. *HortScience*, 14(1), 33-34.
- Palta, J. A. (1996). *Physiological responses of Chinese cabbage to high temperature stress*. Retrieved from <https://digital.library.adelaide.edu.au/dspace/bitstream/2440/22065/2/02whole.pdf>
- Park, H. J., Kim, H. J., & Lee, J. S. (2016). *Heat-tolerant Chinese cabbage variety and method for cultivation*. Korea Patent KR20160103312A. <https://patents.google.com/patent/KR20160103312A/en>
- Pokluda, R. "Nutritional Quality of Chinese Cabbage from Integrated Culture." *Horticultural Science* 35, no. 4 (December 31, 2008): 145–50. <https://doi.org/10.17221/19/2008-HORTSCI>. SAP. (2005).
- Siahaan, F. R., Tampubolon, K., & Pardede, E. (2024). Agrophysiology, biochemical, and yielding characteristics of Chinese cabbage due to formulations and concentrations of nutrient in hydroponic. *Comunicata Scientiae*, 15. <https://doi.org/10.14295/CS.v15.4192>
- UNECE. (2014). *UNECE Standard FFV-44 concerning the marketing and commercial quality control of Chinese cabbage*. https://unece.org/fileadmin/DAM/trade/agr/standard/standard/fresh/FFV-Std/English/44_ChineseCabbage.pdf

World Bank. (2019). *Strengthening agro-meteorological services in Bhutan: Final report*.
<https://documents1.worldbank.org/curated/en/367871546582390434/txt/Final-Report-Strengthening-Agro-Met-Services-in-Bhutan.txt>

Yuan, X., Yu, H., Geng, T., Ma, R., & Li, P. (2024). Enhancing sustainable Chinese cabbage production: a comparative analysis of multispectral image instance segmentation techniques. *Frontiers in Sustainable Food Systems*, 8.
<https://doi.org/10.3389/fsufs.2024.1433701>

ANNEXTURE I

Trial Pictures

