

Agro-Morphological Diversity and Yield Performance of Pak Choi (*Brassica Rapa* L. Var. *Chinensis*) under the Winter Conditions of Peshawar.

Rahamdad*¹, Neelam Ara¹, Masood Ahmad*¹, Muhammad Abbas¹, Zakir Khan¹, Adil Iqbal¹, Asfand Yar¹, Abu Sufyan¹ Fahad Ali²

¹ Department of Horticulture, Faculty of Crop Production Sciences, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan

² Department of Agricultural Extension Education and Communication, The University of Agriculture Peshawar, Khyber Pakhtunkhwa- Pakistan

*Corresponding Author's email: Rahamdadtony@gmail.com; zakirbangash@aup.edu.pk

DOI: <https://doi.org/10.63163/jpehss.v4i1.1022>

Abstract

Pak Choi (*Brassica rapa* L. var. *chinensis*), a highly nutritious green vegetable, is well-known for its soft leaves and rich vitamins, minerals. While commonly grown in Asia, Europe, and North America, its adaptation to cold winter temperatures in Peshawar, Pakistan, is now largely unknown. The purpose of this study was to evaluate Pak Choi's agro-morphological features, growth habits, vegetation placement, and productivity potential during the winter season of 2022-2023 at the University of Agriculture in Peshawar. Morphological aspects such as plant height, girth, root length, and leaf length and dimensions were measured, as well as yield aspects such as edible green weight, root weight, total biological weight, and leaf number were recorded. The results revealed that Pak Choi is very adaptive to local winter environments, with a highest plant height of 33.97 cm, girth of 31.5 cm, leaf length of 21.1 cm, and leaf width of 12.3 cm. The vegetative weight of each plant averaged between 291 and 322.3 g, with edible green biomass comprising for 155 and 169.7 g. The predicted production per hectare ranged from 26.3 to 30.7 tons, demonstrating high productivity potential. The results obtained indicate that Pak Choi may be effectively incorporated into Peshawar's winter growing practices, delivering nutritional and economic advantages to farmers while also serving as a foundation for further study and crop enhancement projects.

Key Words: Pak Choi, Bok Choi, *Brassica rapa* var. *chinensis*, agro-morphological diversity, winter cultivation, leafy vegetable, cold-season crop

Introduction

Pak Choi (*Brassica rapa* L. var. *chinensis*), commonly known as Bok Choy, is a commonly grown leafy vegetable from the Brassicaceae family, that contains cabbage, mustard, broccoli, and cauliflower. It is identified by its thin white petioles and light green leaves, that are full of vitamins A and C, as well as K, folic acid, minerals such as potassium and calcium (Self Nutrition Data, 2014). The leafy green vegetable is abundant in moisture and low in calories, making it suitable for many kinds of cooking uses such as stir-frying, salads and soups, and cooked meals. Daily use of Pak Choi was related with a lower risk for long-lasting diseases, such as prostate cancer, heart diseases, and osteoporosis abnormalities (Tuquero et al., 2018).

Pak Choi originated in south China more than 1,000 years ago and became popular throughout the Asian continent, especially Japan, Malaysia, Indonesia, and Philippines. It was further introduced to Europe and America (Lu and Yan, 2018). Pak Choi was brought to Europe by Osbeck in the eighteenth century, and Chinese immigrants planted it in Malaysia with the Canton

region seedlings. Throughout the years, massive hybridization has produced various cultivars that ranged in leaf shape, color, and plant dimension (Teixeira da Silva, 2019).

Its flexibility, brief life period, and excellent nutritional content make it a viable crop for cold-season production. Cold-season vegetables for example lettuce, spinach, coriander, and cauliflower contribute to almost all of production in Pakistan. Considering its potential to enhance nutrition and generate revenue, Pak Choi is ignored. The Peshawar winter conditions, with mild temperatures from 4 to 20°C, minimal freezing probability, & a moderate amount of moisture (55-70%), is ideal for cool-season crops like Pak Choi production. However, detailed research on its physiological characteristics, productivity prospects and adaptation to regional winter seasons is limited.

The current research planned to address this information gap by analyzing growing patterns, character traits, and production outcomes of Pak Choi in Peshawar. Important goals were:

- Study the crop-morphological growing pattern of Pak Choi.
- Find out production and generation of biomass capacity under winter conditions.
- To evaluate adaptation and recommend techniques for local cultivation.

By giving this basic data, the research expects to promote the introduction of Pak Choi into local winter agricultural practices, thus adding to crop variety, adequate nutrition, and economic prospects for local farmers.

Materials and Methods

Experimental Site and Climate

The research study was performed at the University of Agriculture's Horticulture Research Farm in Peshawar during the winter of 2022-2023. Peshawar has a subtropical Mediterranean climate, with normal cold temperatures of 4-7°C and highs of 16-20°C. Cold occurs rarely, and relative humidity ranges between 55-70%, making it ideal for growing cool-season green crops like Pak Choi.

Soil Characteristics

The location for the experiment contained well-draining loamy soil with a pH range of 6.5 to 7.2. To increase crop growth, manure was added to the soil ahead of the transplanting process. Growing beds have been developed to enhance irrigation and airflow, which are necessary for good sprouting of roots and vegetative growth of green crops.

Seedling Preparation and Transplanting

Pak Choi seeds have been brought from China and then planted in high in nutrients containers. The sprouts were watered on a regular basis and transferred into ready fields about two weeks' later. Planting was done in three rows each plot, having 20 plants in each row. Plants were spaced 25 cm apart, with 45 cm between rows. The transplantation was scheduled to make sure that seeds emerged earlier than the cold winter season.

Experimental Design and Crop Management

The research implemented a CRD (completely randomized design) with 3 replications. Regular agricultural steps, such as hand weeding and frequent irrigation were used. No extra fertilizers or growth promoters were added, which allowed a study of the crop's natural resistance to winter conditions.

Data Collection

A total of ten plants per plot were randomly chosen to test the following attributes:

Morphological Parameters:

- Plant height (cm) — is measured from the soil surface to the tallest leaf tip.
- Plant girth (cm) — refers to the diameter of the stem at its thickest point.
- Root length (cm) — primary root length.
- Leaf length and width (cm) — Fully inflated leaf dimensions.

Yield and Biomass Parameters:

- Number of leaves per plant
- Edible green weight (g) — leaves and petioles
- Root weight (g) — fresh root biomass
- Total biological weight (g) — sum of edible green weight and root weight
- Estimated yield (tons/ha) — projected fresh biomass per hectare

Statistical Considerations

The data was analyzed analytically. Median values, variances, and trends were presented. Considering the qualitative single-site approach, no statistical inferences were used. The findings give initial guidance to guide further multiple-location experiments.

Result and Discussion

Results

Morphological Traits

As show in **Fig 1**. Pak Choi plants grow uniformly over the winter. The maximum plant height was 33.97 cm, while the shortest height was 29.1 cm. Plant girth ranged from 27.5 to 31.5 cm. Root lengths ranged from 12.55 and 16.2 cm. The leaf proportions were significant, with a maximum length of 21.1 cm and a maximum width of 12.3 cm. These findings suggest that vegetative growth is strong, allowing for effective absorption of light and photosynthesis.

Yield and Biomass

Yield and biomass Attributes show in **Fig 2**. The overall biological weight per plant was between 291 and 322.3 g. Edible green biomass made up the largest portion, weighing between 155 to 169.7 g per plant. Root weight remained quite small. Leaf count per plant remained constant, between 22 to 25. The expected output per acre fluctuated from 26.3 to 30.7 tons, indicating significant production in Peshawar winter conditions.

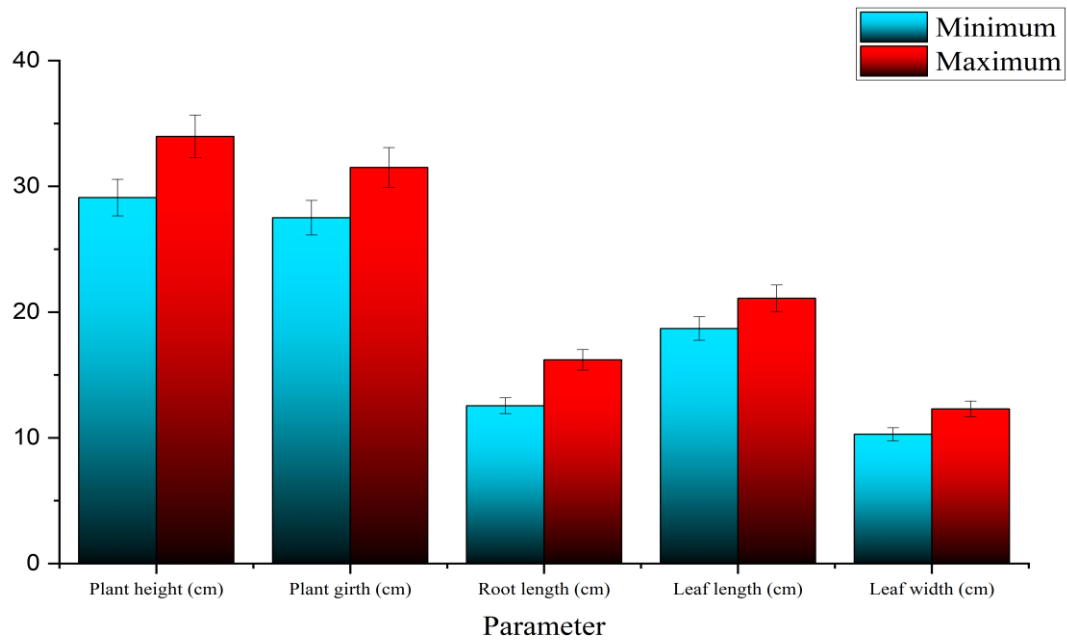


Fig 1. Morphological Parameters of Pak Choi. Plant height, Plant girth, Root length, Leaf length, Leaf weight

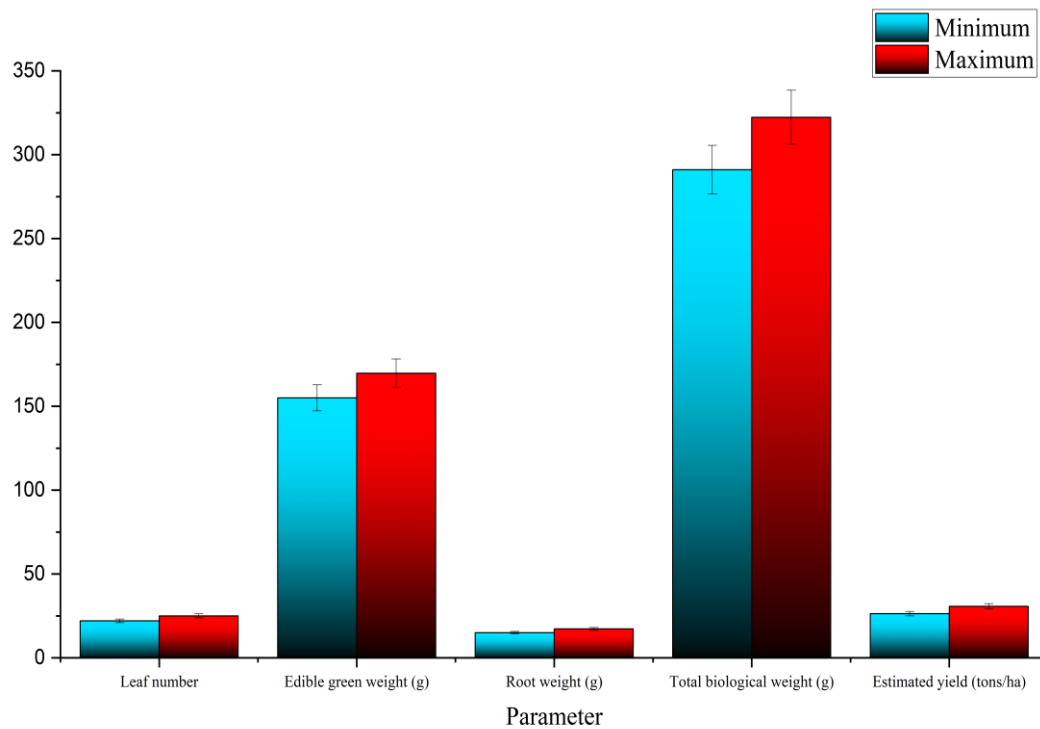


Fig 2. Yield and Biomass Attributes of Pak Choi. Leaf Number, Edible Green Weight, Root weight, Total biological weight, yield (ton/ha)

Correlation and Principal Component (PCA) Analysis for Growth, Yield, and Quality Attributes of Pak Choi

Pearson correlation matrix among the different growth, physiological, and yield attributes of Pak Choi, significant correlations were recorded between several traits **Fig. 3**. Positive correlations were observed between Ph vs Bwg (0.16), RL vs Ll (0.31), RL vs Bwg (0.29), Ll vs NL (0.35), and Lw vs NL (0.23).

In contrast, negative correlations were found in Ph vs Pg (-0.33), Ph vs Lw (-0.33), Ph vs Rw (-0.30), Pg vs Ll (-0.32), Lw vs Egw (-0.50), NL vs Y (-0.30), and Rw vs Y (-0.25). Similarly, weaker but noticeable positive correlations were recorded in Pg vs RL (0.14), Pg vs Lw (0.27), RL vs Egw (0.26), and Ll vs Bwg (0.14). No very strong negative correlations were observed among the measured traits; though moderate negative associations were present in several pairs as noted above.

The principal component analysis was calculated using the mean values of growth, yield, and quality traits of Pak Choi **Fig 4**. According to the scree plot **Fig 5**, the highest contribution to variance was observed in PC1 (22.98%) and PC2 (18.67%), which together accounted for approximately 41.65% of the total variance. In the loading plot (Fig 5), traits such as Lw, Pg, BL, NL, and RW showed positive loadings along PC2, while Bwt, EQW, and Ph exhibited stronger associations with PC1. These results indicate that the first two principal components effectively capture a significant portion of the variability among the measured traits, with distinct groupings of traits contributing to each component.

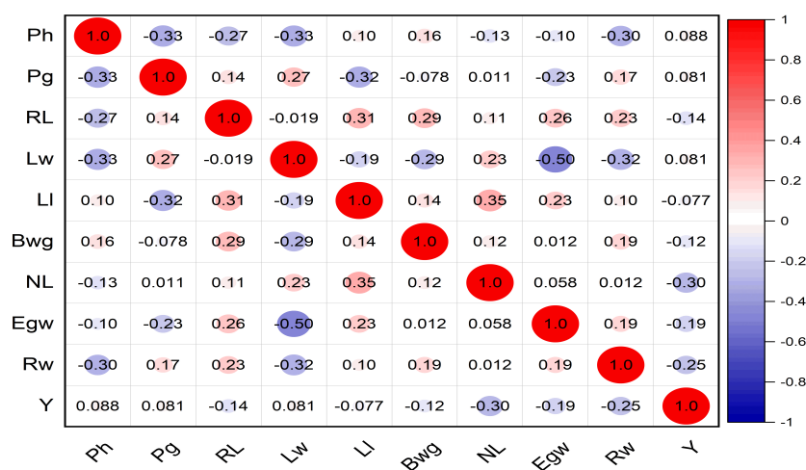


Fig.3 correlation of different attributes of pak Choi Ph Plant height, Pg Plant girth, RL Root length, Ll Leaf length, Lw Leaf weight, NL Leaf Number, Egw Edible Green Weight, Rw Root weight, Bwg Total biological weight, Y yield (ton/ha)

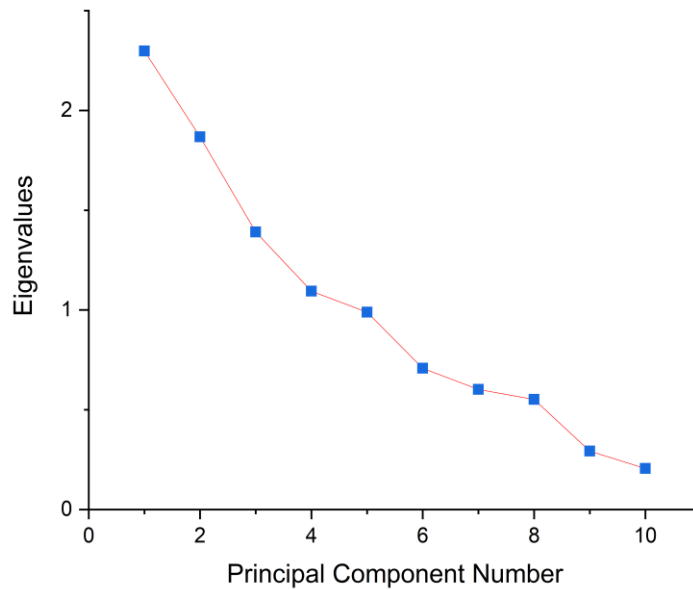


Fig.4 Eigen values for the different attributes of Pak Choi

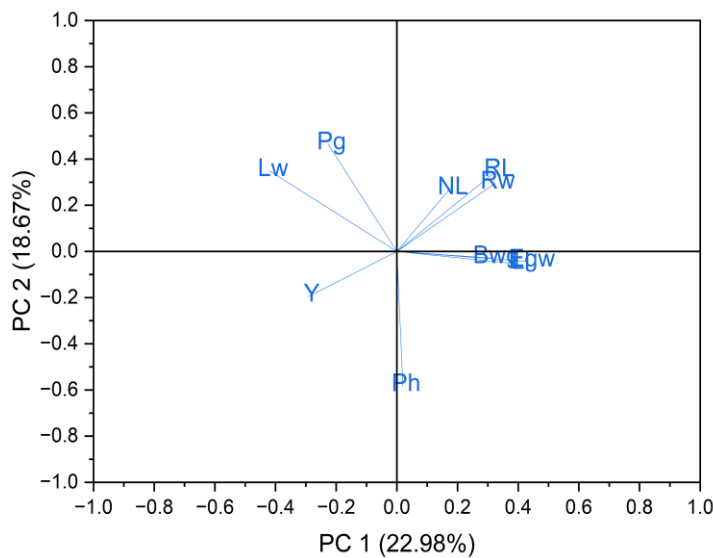


Fig 5: Principal component analysis of different attributes of Pak Choi Ph Plant height, Pg Plant girth, RL Root length, Ll Leaf length, Lw Leaf weight, NL Leaf Number, Egw Edible Green Weight, Rw Root weight, Bgw Total biological weight, Y yield (ton/ha).

Discussion

Pak Choi shown a good adaption to Peshawar's winter environment. The small basal development and high leaf number helped to improve light absorption and photosynthesis, resulting in increased vegetative biomass and production. The number of leaves on a plant may affect its basic growth pattern, since photosynthesis, leaf longevity, and nutrient movement all play a role in root

development (Abbas et al., 2025). Leaf quantity and size were strongly associated to edible green weight, indicating the crucial role of vegetative development in yield production.

Excessive amounts of chlorophyll, as seen by dark-colored leaf, is thought to be associated with improved photosynthetic activity and the availability of important nutrients that include A, C, and K vitamins, along with minerals like iron and calcium. These traits most likely led to the study's vigorous growth and high consumable biomass levels (Khan et al., 2024).

Farmers may improve photosynthesis and productivity by maintaining optimal spacing (25 × 45 cm), applying compost or basic amendments for availability of nutrients, and watering at the right time to enhance fleshy leaf growth. Water and nutrient schedule control techniques as well as density of vegetation control, need significant planning, because they directly affect the health of the plant, efficiency of photosynthesis, and overall productivity (Khan et al., 2025; Raheemullah et al., 2023).

The results presented match with worldwide research showing that cooler temperature and soil with adequate drainage boost Pak Choi growth (Gao et al., 2019; Rerkasem and Jamjod., 2013; Bari et al., 2024). Leaf growth takes priority over root biomass in leafy plants like Brassicas, indicating that materials are mostly given to edible sections. The constancy of leaf number suggests a predictable development pattern, which is ideal for picking and marketing.

The solid source-sink connection found, with high leaf biomass maintaining medium growth of roots, indicates that leaf photosynthesis ability is an important predictor of production. Proper environmental management, such as fertilizer and water delivery, is critical for maximizing productivity.

Conclusions and Recommendations

- Pak Choi (*Brassica rapa* L. var. *chinensis*) grows in Peshawar's winter conditions and produces a significant quantity of edible biomass.
- The crop may be included into winter cropping systems, offering nutritional and financial advantages.
- To achieve optimal development, farmers should maintain appropriate spacing and apply basic nutrient.
- Trials throughout many seasons and locations are advised to assess variety performance and adaptation to environmental conditions.

Limitations

The study was investigative in context, taking place at a single location and using just one cultivar. Advanced statistical analysis and physiological examinations were not conducted. The findings must be viewed basic and used to inform future study.

Data Transparency Statement

All data were obtained directly from field experiments. The original data set is accessible from the author by request.

References

- Abbas, M., Ahmad. M., Ali. H., Jabin. S., Khan. Z., Rahamdad, Iqbal. A., Ilyas. S.M., Ali. F., & Sufyan. A. (2025). Effect of pinching and salicylic acid application on flower and seed production in larkspur (*Delphinium ajacis* L.). *Plant Bulletin*. 4(1):117-124. <https://doi.org/10.55627/pbulletin.004.01.1161>
- Bari, M.U.H., M.M.S. Alam, M.S. Khan, F. Sundas, and S. Razaullah, 2024. Effect of Moringa leaf extract on growth and yield of tomato. *Int. J. Sustain. Res.*, 2:37-58. <https://doi.org/10.59890/ijsr.v2i1.1056>

- Gao, Y., J. Bao, J. Zhang, Y. Wang, Y. Guo and M. Xu. 2019. Effects of Different Nitrogen Application Rates on Yield and Quality of Pak Choi (*Brassica rapa* var. *chinensis*) in a Greenhouse. *Frontiers in Plant Science*, 10: 1317
- Khan, A., Ahmad. M., Arif. M., Ali. H., Jabin. S., Awan. M.T., Khattak. M.R., Khalil. I., Razaullah. S., Sufyan. A, Khan. Z and Abbas. M. 2024. Influence of Sucrose and Silver Nitrate to Ameliorate Post Harvest Performance of Gladiolus Spikes. *Indus Journal of Bioscience Research*, 2(02):1321-1328. DOI: <https://doi.org/10.70749/ijbr.v2i02.342>
- Khan, Z., Ahmad. M, Abbas. M, Rahamdad, Awan. T.M, Razaullah. S, Sufyan. A, and Iqbal. M. (2025) “Effect of Willow Bark Extracts and Pinching On Performance of Flax (*Linum Grandiflorum*)”, *Social Science Review Archives*, 3(4): 3984–3992. DOI: <https://doi.org/10.70670/sra.v4i1.1514>
- Khan, Z., Ahmad. M, Arif. M, Rahamdad, Ali Z, Ahsan. J, Abbas. M, Sufyan. A, Razaullah. S, A. Iqbal, and I. Ullah. (2025). Offseason Production of Cucumber Genotypes in Response to Salicylic Acid in Anti-Insect Walk-In Tunnel. *Review Journal of Social Psychology & Social Works*, 3(4):749–761. <https://doi.org/10.71145/rjsp.v3i4.502>
- Lu, L. And J. Yan. 2018. Nutritional composition and health benefits of chinese leafy vegetables: A Mini-Review. *J of Zhejiang univ-SCI B*, 19(10): 769–787.
- Raheemullah, F.U., K. Mehmood, M.Z. Sana, R. Ahmad, A. Mehmood, M. Haris, U.U. Rahman, F. Khan, F. Fida, M.S. Khan, and N.U. Haq, 2023. Effectiveness of aloe vera coating gel on shelf life of grapes. *J. Xi’an Shiyou Univ. Natural Science Edition.*, 19(2):1484-1496.
- Rerkasem, B. And S. Jamjod. 2013. Pak Choi (*Brassica rapa* L. subsp. *chinensis*) Production. In M. K. Upadhyaya (Ed.), *Asian Veg Res and Development Center (AVRDC) - The World VegCenter* (pp. 109-117). Springer.
- Self-Nutrition Data. 2014. Bok Choy, Raw. Self-Nutrition Data. <https://nutritiondata.self.com/facts/vegetables-and-vegetable-products/2383/2>
- Teixeira da Silva, J. A. 2019. *Brassica rapa* L.: Agricultural and Nutraceutical Properties. Springer.
- Tuquero, J., R.G. Chargualaf, and M. Marutani, 2018. Growing Bok Choy (*Brassica rapa* *Chinensis* Group) Varieties for Guam. *Food Plant Production*.