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Impact of Hypoxic Root Zone Conditions on Growth and Survival of Black behi Pechay (*Brassica rapa* L.) Under Bacnotan, La Union, Philippines

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***Abstract*— *Waterlogging, often caused by excessive rainfall, threatens crop productivity by depriving roots of oxygen. Pechay is a vital crop for food security, capable of producing significantly more food per unit area than cereal crops. This study assessed the growth response of Black Behi under different waterlogging durations (0, 24, 48, and 72 hours). Two weeks after sowing, seedlings were transplanted into polyethylene pots and grown for another two weeks before submersion. The study found that pechay plants, particularly the Black Behi variety, reacted differently depending on how long they were submerged in water. Those exposed to waterlogging for 72 hours (T_3) had the lowest survival and recovery rates, along with the poorest growth in terms of plant height and number of leaves. In contrast, plants submerged for only 24 hours showed growth nearly equal to those that were not submerged at all (T_0), suggesting that pechay can tolerate brief flooding. Overall, the results indicate that Black Behi pechay can withstand waterlogging for up to 48 hours (T_2) without major damage. These insights are valuable for farmers aiming to grow flood-tolerant pechay, especially in areas frequently affected by heavy rains or short-term flooding. The study suggests that pechay can tolerate waterlogging for up to 48 hours, but prolonged submersion negatively impacts plant development and survival. These findings are useful for guiding flood-resilient pechay cultivation.*

***Keywords*— Black behi, Hypoxic, Pechay, Subnersion, Waterlogging**

I. INTRODUCTION

In the Philippines, agriculture remains a backbone of the economy, providing food, employment, and income—especially in rural communities. Among the many vegetables grown locally, *pechay* (*Brassica rapa* L.) stands out as a popular leafy green due to its short growing cycle, nutritional value, and adaptability. It plays a key role in household food security and contributes significantly to the income of smallholder farmers.

Pechay which belongs to the Brassiceae family, is one of the most famous vegetables in the Philippines. It is also thought to be one of Asia's first green vegetables. As a result, it has a considerable impact on the Philippine economy and the nutrition of the Filipino people. Pechay is used mainly for its soft, young, yet thoroughly developed leaves. The succulent petioles are frequently chosen. Soups and stir-fried dishes contain it as a primary ingredient. Its green petioles and leaves are sometimes used as a garnish in cuisine (Rubia, 2024).

Black Behi is other variety of pechay which is adapted to both lowland and highland. This selection has proven adaptability in a wide range of Philippine climatic conditions. It is selected for weight and uniformity. The plants are vigorous and large, forming thick petioles originating from its broad, thick, and compact base (East-West Seed, 2024).

Waterlogging creates hypoxic conditions in the root zone, meaning oxygen becomes limited in the soil. Without adequate oxygen, root respiration and nutrient absorption are impaired, leading to stunted growth, poor yield, or even crop failure. This condition forces the plant to switch to anaerobic respiration, which is inefficient and damaging over time.

As climate change increases the frequency of extreme rainfall and flooding, these hypoxic conditions are expected to become more common. Understanding how different pechay varieties respond to waterlogged and oxygen-deficient soils is therefore crucial. This study aims to assess the performance of pechay variety Black behi under hypoxic root zone conditions to help determine the maximum number of hours can pechay survive to waterlogging stress and support more climate-adaptive vegetable farming in the Philippines.

II. METHODOLOGY

2.1 **Research Design**

The study was laid out following simple Randomized Complete Block Design with three blocks and 6 sample plants per treatment per block. The treatments are as follows:

T_0 – Control (Non-submersion)

T_1 – 24 Hours

T_2 – 48 Hours

T_3 – 72 Hours

2.2 Procedures

2.2.1 Seed sowing and seedling preparation

Two to three (2–3) seeds of pechay seeds were sown per hole in seedling trays filled with fine, ordinary garden soil. The trays were placed under nursery conditions. After two (2) weeks, healthy and uniform seedlings were selected and transplanted into individual plastic pots measuring 4 x 6 inches. The seedlings were maintained under the nursery for another two (2) weeks to ensure proper establishment before treatment application.

2.2.2 Waterlogging Treatments

Waterlogging conditions was simulated using *lona*-lined submersion ponds. Each potted seedlings were carefully submerged in water, ensuring that the entire shoot is covered with water without submerging the leaves entirely. Water levels were regularly checked and adjusted to ensure they consistently reached the plant shoot level across all treatments.

The experiment followed a staggered submersion schedule to ensure that all treatments concluded simultaneously. Plants in T_3, assigned to the 72-hour submersion treatment, were submerged first. After 24 hours, plants in T_2, designated for 48-hour submersion, were submerged. On the third day, plants in T_1 underwent the 24-hour submersion treatment. Meanwhile, the control treatment (T_0) was not submerged but were placed adjacent to the submersion ponds to ensure they were exposed to similar environmental conditions as the submerged treatments.

After completing their designated submersion durations, plants from each subplot were removed from the *lona* ponds and returned to the observation area beside the pond. The plants were arranged following their original positions during the submersion process to maintain uniform exposure and arrangement throughout the observation period.

For the post submersion observation, all potted plants were observed daily for a 3-day period. Parameters such as plant wilting, recovery, new leaf formation, and signs of stress or mortality were recorded. This observation period was assessed the short-term impact of waterlogging on plant recovery and survival.

III. RESULTS AND DISCUSSIONS

Percentage Survival at Post Submersion

It can be gleaned from the table that a significant difference exists in the percentage survival of pechay subjected to varying submersion durations. A perfect survival rate (100%) was observed among plants under the control treatment, which were not submerged in water. This result is statistically comparable to the plants that were submerged for only 24 hours, suggesting that short-term submersion does not significantly affect the survival of pechay. Plants submerged for 48 hours exhibited a slightly lower survival rate of 87.01%, which was still statistically comparable to those submerged for 24 hours (92.58%). This suggests that pechay may possess a level of tolerance to brief periods of waterlogging, likely due to its ability to maintain oxygen transport and root function under mildly hypoxic conditions.

However, a marked decline in survival rate was noted at the 72-hour submersion level, with only 72.18% of plants surviving. This result supports the hypothesis that prolonged submersion has detrimental effects on pechay, potentially due to anoxic stress, impaired root respiration, and reduced nutrient uptake. According to Herzog et al. (2016), in their study on wheat (*Triticum aestivum)* prolonged flooding leads to oxygen deficiency in the root zone, which adversely affects plant metabolism and can lead to cellular damage or death. The decrease in survival after 72 hours of submersion indicates that this duration surpasses the tolerance threshold for pechay under the experimental conditions.

Table 1. Percentage Survival of Black behi Pechay as Affected by Submersion Period

Treatments	Percentage Survival at Post Submersion Period (%)*
T_0 – Control (Not Submerged)	100.00^{a}
T_1 – 24 Hours	92.58^{ab}
T_2– 48 Hours	87.01^{b}
T_3 – 72 Hours	72.18^{c}

*=significant at $p < 0.05$. Means with the same letter are not significantly different; means with the same letters are significantly different.

This trend aligns with the findings of Pang et al. (2017), who reported that Brassica crops, including pechay and Chinese cabbage, experience significant reductions in survival and biomass accumulation under waterlogged conditions exceeding 48 hours. Similarly, Yamauchi et al. (2018) noted that oxygen deprivation in root tissues under extended flooding causes the accumulation of toxic metabolites and limits aerobic respiration, which are critical for cell maintenance and survival.

Conversely, some studies suggest that certain cultivars or varieties of leafy vegetables exhibit greater tolerance to waterlogging. For example, research by Ahmed et al. (2013) on mustard greens (a close relative of pechay) demonstrated high survival rates even after 72 hours of flooding, particularly when the plants were in earlier developmental stages. These discrepancies could be attributed to genetic variation, differences in root architecture, and physiological adaptations such as adventitious rooting.

The observed results in this study highlight the sensitivity of pechay to prolonged submersion, emphasizing the need for water management strategies during periods of heavy rainfall or poor drainage. The findings also suggest the importance of screening and selecting pechay varieties with greater flood tolerance for areas prone to waterlogging.

Initial Plant Height

Table 2 shows the plant height of Black behi pechay (*Brassica rapa* L.) before 72-hour submersion period. The initial plant height, recorded two weeks after sowing, showed no statistically significant differences among the varieties. This indicates that all pechay varieties exhibited relatively uniform growth under normal conditions prior to the application of the submersion treatment.

The absence of significant differences in initial plant height suggests that pechay used in the study have comparable early growth vigor and morphological development when grown under the same environmental and agronomic conditions. This uniformity is crucial in ensuring that subsequent differences observed post-treatment can be attributed to the imposed submersion stress rather than inherent differences in initial plant growth. According to Gomez and Gomez (1984), ensuring homogeneity in initial measurements is essential in treatment-response studies to validate the reliability of the experimental results. Furthermore, early plant height is often influenced by genetic factors, seedling vigor, and uniform cultural practices such as nutrient availability, irrigation, and light exposure (Taiz et al., 2015).

Final Plant Height

Analysis of Variance showed a significant difference in plant height at 72 hours post-submersion. A particularly noteworthy result was that plants under the control treatment (non- submerged) reached the tallest height of 114.50 cm and the only treatment that showed an increase in height after 72 hours. In contrast, all submerged plants either decreased in height or showed a little growth. The decline in height was most pronounced in plants submerged for 72 hours.

Interestingly, the plants submerged for only 24 hours experience a very little decrease in height (0.3cm), indicating that their physiological functions were already affected, albeit not to a destructive extent. This stagnation suggests that even short-term submersion can disturb normal plant metabolic activities such as cell elongation and nutrient transport.

Waterlogging or submersion affects plant growth by limiting oxygen availability in the root zone, which is crucial for aerobic respiration. Oxygen deprivation leads to a decline in root metabolic activity, causing reduced nutrient uptake and inhibition of hormone-regulated growth processes such as gibberellin-induced stem elongation (Setter & Waters, 1996). According to Jackson and Colmer (2005), hypoxic conditions resulting from waterlogging suppress cell division and elongation, thereby halting vertical growth. Similarly, Dat et al. (2004) noted that prolonged submersion triggers ethylene accumulation and reactive oxygen species (ROS) formation, which in turn leads to oxidative stress and leaf senescence.

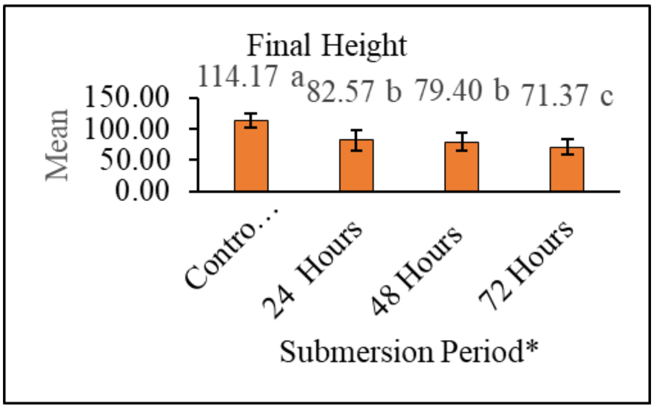

Fig. 1. Final Plant Height

In a study on *Brassica* crops, Malik et al. (2002) observed that plant height and biomass accumulation were significantly reduced after 48 to 72 hours of waterlogging. These findings are consistent with the present results, where extended submersion caused visible signs of stress and growth retardation.

In summary, the observed reduction or stagnation in plant height under submerged conditions confirms that waterlogging severely impairs physiological processes essential for plant development. The lack of oxygen disrupted hormonal signaling, and stress responses collectively contribute to growth inhibition and in some cases, deterioration of plant structure (Herzog et al., 2016).

Leaf Number

As to the final number of leaves gathered at the post-submersion period after 72 hours, analysis of variance revealed a significant difference among treatments as can be gleaned from Figure 2. This indicates that the duration of submersion had a measurable impact on the leaf number of pechay. It can be observed that plants under the control treatment (no submersion) continued to produce new leaves, demonstrating normal vegetative growth under non-stress conditions. In contrast, all plants subjected to submersion—whether for 24, 48, or 72 hours—exhibited a decrease in the final number of leaves compared to their initial counts. This decline in leaf number among submerged plants can be attributed to several physiological responses to flooding stress. Submersion limits oxygen availability to plant tissues, leading to hypoxic or anoxic conditions that impair aerobic respiration, damage cellular structures, and hinder growth processes (Bailey-Serres & Voesenek, 2008). As a result, energy production becomes inefficient, and leaf senescence or abscission may be triggered as a survival mechanism (Jackson & Colmer, 2005).

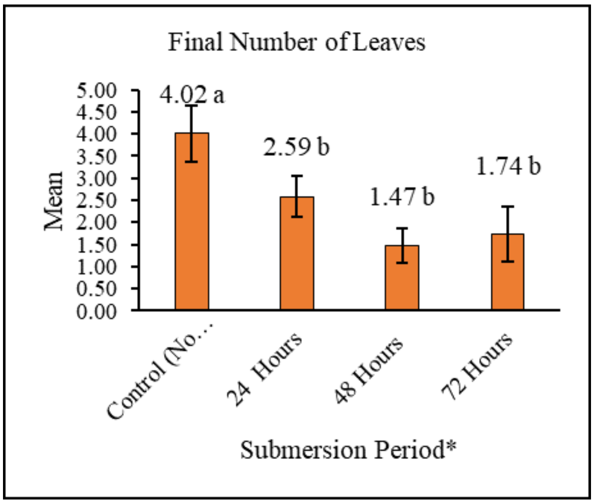

Fig. 2. Leaf Number

*=significant at $p< 0.05$. Means with the same letter are not significantly different; error bars represent standard deviation.

Percentage Survival Recovery

The results of the analysis of variance showed very highly significant differences among the treatment groups. Unsurprisingly, plants in the control group—those not submerged at all—had a 100% survival rate. These were statistically similar to the plants submerged for just 24 hours, which still managed a high recovery rate of 98.15%. However, survival dropped sharply in plants submerged for 72 hours, suggesting that longer submersion severely hampers the plants' ability to recover.

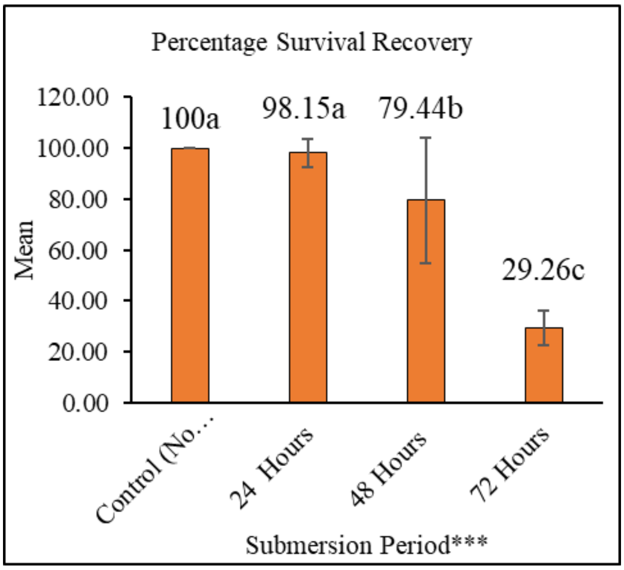

Fig. 3. Percentage Survival Recovery

***=very highly significant at $p< 0.05$. Means with the same letter are not significantly different; error bars represent standard deviation.

This pattern points to a strong inverse relationship between the length of submersion and the chances of plant survival. The longer the pechay plants stayed underwater, the less likely they were to survive. This finding is consistent with the work of Jackson and Ram (2003), who noted that prolonged flooding limits the oxygen plants need to breathe and produce energy, making it harder for them to survive. Colmer and Voesenek (2009) also highlighted how waterlogged conditions affect root function and cause stress due to lack of oxygen—something particularly challenging for crops like pechay that are not naturally adapted to wet environments.

It is worth noting that plants can cope with short-term flooding, like 24 hours, by temporarily slowing down their metabolism, closing their stomata, and using up stored energy. But when the flooding lasts too long, these coping mechanisms are no longer enough. That is when we start to see signs of serious stress like leaf yellowing and tissue damage, which explain the low survival rate in the 72-hour treatment (Yamauchi et al., 2018). Malik et al. (2014) made similar observations in their research, showing that different crops have varying limits when it comes to surviving under water, depending on how well they can maintain internal balance and oxygen flow.

IV. CONCLUSION

Pechay plants submerged for 72 hours exhibited significantly lower percentage survival, reduced recovery survival percentage, shorter plant height, and fewer leaves during the post-submersion period. This indicates that prolonged waterlogging severely affects the physiological and morphological performance of pechay, limiting its ability to recover and resume normal growth after stress. Pechay variety Black behi can tolerate waterlogged conditions for up to 24 hours. Submersion beyond this period can significantly inhibit growth and development, leading to detrimental effects on the crop.

REFERENCES

[1] Ahmed, S., Iqbal, N., Khan, M. A., & Ashraf, M. (2013). Waterlogging tolerance of mustard (Brassica juncea): Physiological and biochemical basis. Plant Growth Regulation, 69(3), 247–258. https://doi.org/10.1007/s10725-012-9763-z

[2] Bailey-Serres, J., & Voesenek, L. A. C. J. (2008). Flooding stress: Acclimations and genetic diversity. Annual Review of Plant Biology, 59, 313–339. https://doi.org/10.1146/annurev.arplant.59.032607.092752

[3] Dat, J. F., Vandenabeele, S., Vranová, E., Van Montagu, M., Inzé, D., & Van Breusegem, F. (2004). Dual action of the active oxygen species during plant stress responses. Cellular and Molecular Life Sciences, 61(23), 2917–2926. https://doi.org/10.1007/s00018-004-4229-6

[4] East-West Seed. (2024). Pechay Variety Guide: Pavo and Other Hybrid Selections. https://www.eastwestseed.com.ph

[5] Gomez, K. A., & Gomez, A. A. (1984). Statistical Procedures for Agricultural Research (2nd ed.).

[6] Herzog, M., Striker, G. G., Colmer, T. D., & Pedersen, O. (2016). Mechanisms of waterlogging tolerance in wheat: A review. New Phytologist, 209(1), 245–259. https://doi.org/10.1111/nph.13659

[7] Jackson, M. B., & Colmer, T. D. (2005). Response and adaptation by plants to flooding stress. Annals of Botany, 96(4), 501–505. https://doi.org/10.1093/aob/mci205

[8] Jackson, M. B., & Ram, P. C. (2003). Physiological and molecular basis of susceptibility and tolerance of rice plants to complete submergence. Annals of Botany, 91(2), 227–241. https://doi.org/10.1093/aob/mcf242

[9] Malik, A. I., Colmer, T. D., Lambers, H., Setter, T. L., & Schortemeyer, M. (2014). Short-term waterlogging has long-term effects on the growth and physiology of wheat. New Phytologist, 176(3), 590–598. https://doi.org/10.1111/j.1469-

[10] Malik, C. P., Singh, M. B., & Sinha, A. K. (2002). Early vegetative growth uniformity in Brassica cultivars under controlled nursery conditions. Journal of Plant Growth Regulation, 21(1), 45–52. https://doi.org/10.1007/s00344-002-0020-3

[11] Pang, J., Zhou, M., Mendham, N., Shabala, S., & Shabala, L. (2017). Stay-green trait associated with waterlogging tolerance in Brassica species. Functional Plant Biology, 44(1), 48–57. https://doi.org/10.1071/FP16161

[12] Rubia, A. C. (2024). Pechay as a cultural and economic crop in the Philippines. Asian Journal of Agricultural Studies, 12(1), 45–53.

[13] Setter, T. L., & Laureles, E. V. (1996). The beneficial effect of reduced elongation growth on submergence tolerance of rice. Journal of Experimental Botany, 47(9), 1551–1559. https://doi.org/10.1093/jxb/47.9.1551

[14] Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2015). Plant physiology and development (6th ed.). Sinauer Associates.

[15] Yamauchi, T., Colmer, T. D., Pedersen, O., & Nakazono, M. (2018). Regulation of root traits for internal aeration and tolerance to soil waterlogging–flooding stress. Plant Physiology, 176(2), 1118–1130. https://doi.org/10.1104/pp.17.01157