TROPICAL PLANTATION JOURNAL

Tropical Plantation Journal. Vol. 4 (2025), No.2
Journal home page: https://jurnal.akpy-stiper.id
ISSN : **2828-1551** e-ISSN : **2828-1543**
DOI : https://doi.org/10.56125/tpj.v4i2.66

Morphological Tolerance of Jack Bean Landraces (*Canavalia ensiformis* L.) to Drought Stress

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Article History: Received: 21 April 2025, Final Revision: 15 June 2025, Accepted: 10 July 2025, Online Publication: 30 July 2025

ABSTRACT

Canavalia ensiformis L., or jack bean, is a type of secondary crop native to Asia and Africa. In South and Southeast Asia, particularly in India, Sri Lanka, Myanmar, and Indo-China, jack bean can now grow successfully in tropical climates and on a variety of soil types, including those with low to high pH and little or no water. Drought is a significant abiotic factor leading to low soil water availability. These conditions stress plants. The first response in plants facing severe water deficit conditions is to close their stomata, closing or narrowing the stomata that supply water, especially to the roots. The research aims to understand the morphological responses, identify adaptation mechanisms, and improve understanding of the interactions between jack bean landraces to drought stress. The research was conducted at the hydroponic house of the Faculty of Agriculture, Universitas Asahan, from December 2023 to March 2024. The research method used a factorial experiment arranged with a Completely Randomized Block Design consisting of 3 levels of watering and 1 control. The first watering treatment was carried out once a day, the second treatment was carried out every two days, the third treatment was carried out every three days, and the control was carried out twice a day, namely morning and evening. Each watering was 30 ml per plant. The results of this study indicate that drought stress can inhibit the growth of jack bean, including plant height, leaflet number, and leaf area. Based on the Ward Method dendogram, the drought tolerance level of each jack bean landrace varies. Genotype 3 (Malang), genotype 4 (P1.2) (small patterned Banyumas), and genotype 1 (P1.1) (Banyumas) are categorized as sensitive. Genotype 2 (P2.1) (Indramayu) is categorized as moderate. And genotype 5 (P2.2) (small patterned Indramayu) is categorized as tolerant. The jack bean plant with the highest tolerance level only looks wilted on the leaves, it doesn't immediately turn yellow under drought stress treatment.

Keywords: *Canavalia ensiformis* L., drought stress, jack bean, landrace, morphology.

INTRODUCTION

Canavalia ensiformis L., or jack bean, is a type of secondary crop native to Asia and Africa. In South and Southeast Asia, particularly in India, Sri Lanka, Myanmar, and Indo-China, jack bean is widely cultivated. Jack bean can now grow successfully in tropical climates and on a variety of soil types, including those with low to high pH and little or no water. It has also spread throughout the

tropics and adapted elsewhere, including Indonesia (Akib et al., 2017).

Jack bean have health benefits. Jack bean are rich in fiber, protein, and carbohydrates. Red jack bean contain 32% protein, 60.55–74.62% carbohydrates, 4.20–5.50% fiber, and 0.99–1.21% healthy fats in black, red, and white bean. Low-fat foods like white jack beans contain 27.4% protein. Due to the low glycemic index (GI) of jack bean, which is between 40.71% and 44.05%, low-GI foods are an excellent choice for a diabetic diet (Kasno, 2016).

Drought is a significant abiotic factor leading to low groundwater availability. These conditions stress plants. The first response in plants to severe water deficits is to close their stomata, closing or narrowing the stomata that supply water, especially to the roots. Changes at the cellular and molecular levels are a response in plants experiencing drought stress, characterized by reduced growth rates, a decrease in root ratio, and a reduction in leaf area. Mild drought stress experienced by plants can result in decreased growth rates during the vegetative phase, which includes leaf, stem, and root growth. It is during this growth phase that plants require large food reserves for energy (Song A, 2011).

Drought can impact plant metabolism, including difficulty absorbing nutrients, inhibited cell division and enlargement, decreased enzyme activity, and stunted plant growth and development due to stomata closure. The effects of water shortages can also be seen in their duration (Supriyanto, 2013).

Based on the above review, the research aims to understand the morphological response, identify adaptation mechanisms, and improve understanding of the tolerance of jack bean plants to drought stress.

RESEARCH METHODS

Research Location

The research was conducted in the campus of Asahan University, precisely in the experimental garden field of the Faculty of Agriculture, Asahan University, Asahan Regency, North Sumatra Province with an altitude of ± 25 meters above sea level. The implementation of this research began in December 2023 to March 2024.

Materials and Tools

The tools used include: bamboo for shade supports, hoes, machetes, measuring tape, machetes, rakes, stationery, paranet as an air circulation door, research plot boards, watering cans, hygrometers, and seedling trays. The materials used for the research were sword bean seeds (*Canavalia ensiformis* L.) with 5 landrace genotypes from several regions in Indonesia.

Methods

For selection, this study used a 50-hole seedling tray measuring 54 cm long and 28 cm wide with a top hole size of 4.8 x 4.8 cm, a hole depth of 4.5 cm, and a bottom hole size of 3.1 cm. The research method used a factorial experiment arranged with a Completely Randomized Block Design consisting of 3 levels of watering and 1 control. The first watering treatment was carried out once a day, the second treatment was carried out every two days, the third treatment was carried out every three days, and the control was carried out twice a day in the morning and evening with a water discharge of 30 ml per seedling tray hole.

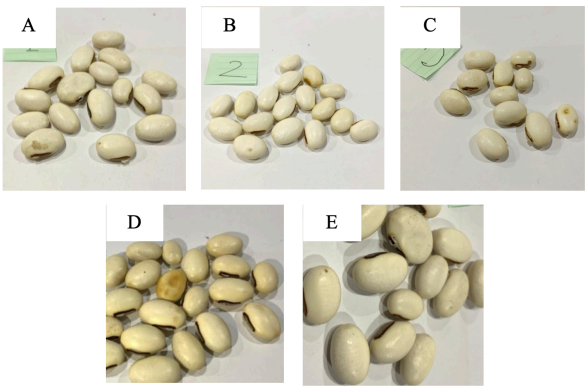

Figure 1. Jack bean seeds. A. (Banyumas). B. (Indramayu). C. (Malang). D. (small patterned Banyumas). E. (small patterned Indramayu).

A soil sample analysis was conducted before the

experiment. The type of sample taken was soil sent by the Faculty of Agriculture of Asahan University, located at Jl. Jend. Ahmad Yani, Kisaran 21224, with letter number 001/025/FP-UNA/2024 in 1 sample wrapped in plastic. After being analyzed by the Palm Oil Research Center, PPKS Laboratory, PT. RPN Medan on January 29–March 7, 2024, order number 21–24 was known to have results with certificate number 427/0.1/Sert/III/2024.

Table 1. Weight per 100 seeds of each genotype used in the study

Genotype	Weight per 100 seeds (g)
P1.1 (Banyummas)	145.20
P2.1 (Indramayu)	143.05
P3 (Malang)	138.00
P1.2 (small patterned Banyumas)	136.31
P2.2 (small patterned Indramayu)	138.20

Seedling trays are prepared as planting containers, and soil from the previously sifted research area is then added. Once the soil is smooth and free of clumps, the soil is then placed into the seedling trays. The prepared seeds are then placed 2 cm into the planting medium to ensure proper growth and strong rooting.

Temperature and humidity measurements are performed twice a week. Temperature measurements are taken at 6:00 a.m. and 1:00 p.m. Temperature and humidity measurements are made using a temperature-regulating device called a hygrometer.

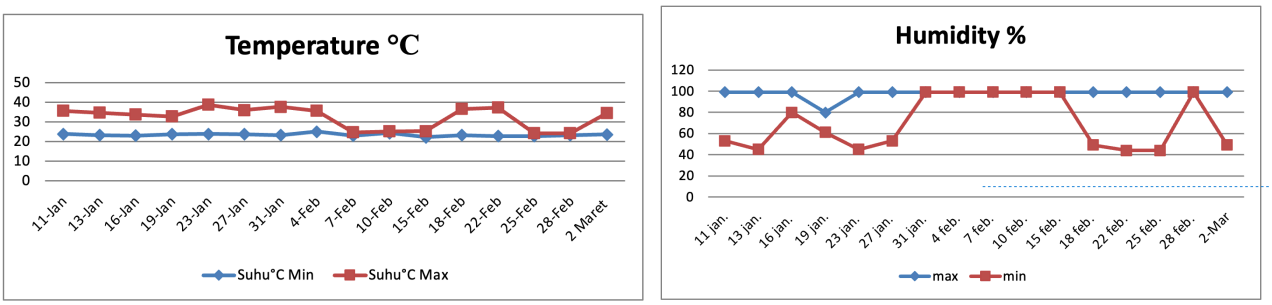

Figure 2. Minimum and maximum temperature (°C) and humidity (%) data (January-March 2024) in the research area.

It is known from the picture above, there is a significant difference between temperature and humidity. Serhat and Mut (2007) stated that the effect of germination temperature on germination power is important to study because the variation in optimal germination temperature requirements depends on the plant species.

Research Parameters

Plant Height (cm)

Plant height was measured using a measuring tape, starting from the stem at ground level to the tip of the tallest leaf. Plant height was measured when the leaves began to turn yellow at 50% after treatment.

Number of Leaves and Leaflets

The number of leaves counted are leaves that are fully open and is done by counting the total number of leaves of the jack bean plant in each plant sample. The number of leaflets counted are leaflets that are fully opened and is done by counting the total number of leaflets of the jack bean plant in each plant sample.

Leaf Area (cm^2)

The leaf area measured is the area of a fully opened leaf, which is then measured using a ruler or tape measure. Leaf area measurements utilize the ImageJ application. Calculations are performed after the plant has been harvested.

Weight of Fresh Plant (g)

Weight of fresh plant is measured after harvesting. Before weighing the fresh plant weight, the lower part of the plant (roots) must be separated.

Plant weighing is carried out while the plant is still fresh using a digital scale.

Drought Stress Tolerance Index and Data Analysis

First, by creating a compatible scale, there are 3 scales: 1.) Tolerant; 2.) Moderate; 3.) Sensitive, using the Fuzi Membership Function Value (MFV) method (Chen, et al. 2012). Before the MFV analysis, a drought stress tolerance index was created for watering once every three days. Diagrams were made using the Microsoft Excel application on the insert menu, namely pivotChart. The analysis was made using the hierarchical cluster method. All data analysis used the SPSS version 16.0 application (SPSS, Chicago, United States).

RESULTS AND DISCUSSION

Plant Height (cm)

Four weeks after planting, the jack bean plants that received drought stress experienced different levels of drought stress. The plants that received daily watering were taller due to leaflet emergence, which led to taller plants. Meanwhile, the plants that received watering every two to three days were shorter because the emerging leaflets were not fully opened or even did not appear at all.

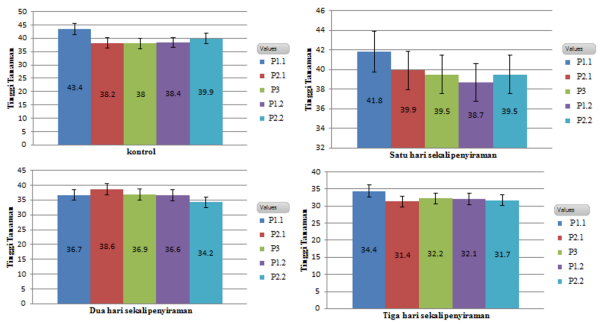

Figure 3. Diagram of plant height with control treatment, watering once a day, once every two days, and once every three days. P1.1 (Banyumas). P2.1 (Indramayu). P3 (Malang). P1.2 (small patterned Banyumas). P2.2 (small patterned Indramayu).

The control treatment was watered twice daily, in the morning and afternoon. The adequate water supply allowed the plants to continue growing leaflets and increase leaf volume. Several genotypes showed clear differences in growth, despite receiving the same treatment. The highest plant height in the control was P1.1 (Banyumas), reaching 43.4 cm.

In the treatment of watering every three days, the height of the sword bean plants has decreased significantly and is shorter than the treatment below. The treatment was carried out according to the scheduled date, watering was done in the afternoon with a water dose of 30ml per seedling tray hole. The plant height is clearly shorter due to the lack of water supply in the soil so that the process of photosynthesis is hampered and closes the stomata, so that the plants look more wilted. The superior plant height in the treatment every three days was P1.1 (Banyumas) with a height of 34.4 cm.

Growth inhibition causes plants to grow shorter, reducing the amount of water available for plant absorption and, consequently, the number of branches. For each plant species and growth stage, watering frequency significantly influences soil moisture. Water stress disrupts plant growth regulators, resulting in reduced plant growth and incomplete leaf development in newborn leaves. Plant growth and development into adulthood will be hampered if there is insufficient watering (Kuswandi, 2015). Water deficiency can result in stunted growth and abnormal plant development; persistent water shortages throughout the growth stage will cause the plant to suffer and ultimately die. Wilting leaves are the first clear indicator. This wilting is caused by the plant's rate of water evaporation being faster than its rate of water absorption (Bahri, 2017).

Number of Leaves and Leaflets

The results of the data on the variety of leaf numbers in jack bean plants aged 4 weeks after planting which received drought stress treatment were not much different because at the age of 4 weeks the jack bean plants had only produced 2 leaves.

Leaflet growth only occurs in plants that receive control treatment and once-a-day watering treatment, because the plants do not lack water in

the soil so that the photosynthesis process occurs and continues to produce high leaflets. Leaflet growth in plants that receive control treatment and once-a-day also varies, some have grown but the leaflets have not opened perfectly. In the control treatment, the genotype with the number of leaflets that grow and open perfectly is genotype P1.1 (Banyumas) with an average of 4 leaves. And in the once-a-day treatment, the superior genotype is genotype P3 (Malang) which is also on average 4 leaves. Meanwhile, in plants that receive treatment every two to three days, all five genotypes do not produce leaflets.

Leaf Area (cm^2)

The results of the data on the variety of leaf area or leaf area of the jack bean plant showed significant differences. Data were taken after the drought stress treatment. Leaf area measurements were carried out using the imageJ application. The leaf area of the jack bean plants that received the control treatment and the once-daily watering treatment was wider, while the once-every-two-day and once-three-day watering treatments were lower because the leaves of the plants that received the once-every-two-day and once-three-day treatments wilted and shrank.

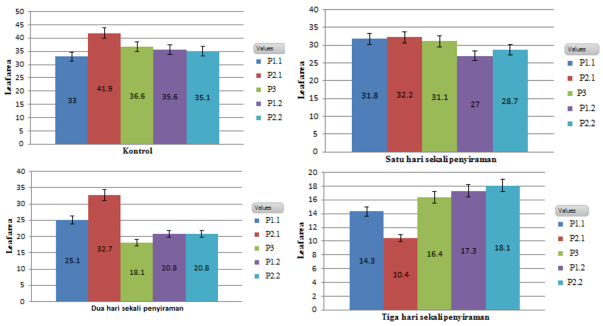

Figure 4. Leaf area diagram for control treatment, watering once a day, once every two days, and once every three days. P1.1 (Banyumas). P2.1 (Indramayu). P3 (Malang). P1.2 (small patterned Banyumas). P2.2 (small patterned Indramayu).

In the control treatment, genotype P2.1 (Indramayu) had the highest leaf area, at 41.9 cm^2. In the one-day watering treatment, the genotype with the widest leaf area was genotype P2.1 (Indramayu) with a leaf area of 32.2 cm^2. In the every-two-day watering treatment, P2.1 (Indramayu) had the highest leaf area, at 32.7 cm^2. In the every-three-day watering treatment, the highest leaf area was found in genotype P2.2 (small and patterned Indramayu) with an area of 18.1 cm^2.

Reduced leaf area and dry weight, decreased photosynthesis and transpiration rates, stunted root and aboveground plant growth, and damage to amino acids, enzymes, and other proteins are all effects of drought stress. Damage to amino acids, enzymes, and proteins involved in photosynthesis and transpiration, which are essential for root, stem, and leaf growth, is a result of this activity. Plants benefit from smaller plants during the dry season because they use less water and are less damaged by plant tissue (Song Ai, 2011).

Fresh Weight (g)

In the control treatment, the genotypes that had the highest weight were P1.1 (Banyumas) with a weight of 5.61 grams. And in the once-a-day treatment, the highest weight was in the Malang genotype with a weight of 5.71 grams. In the plants that received the treatment every two to three days, a drastic decline began to be seen, because the plants had wilted due to lack of water supply so that their weight also decreased. In the treatment of watering every two days, the highest weight was in the P2.2 genotype (small and patterned Indramayu) with a weight of 3.28 grams. And in the treatment of once every three days, the plant weight decreased further. The highest weight was in the P2.1 genotype (Indramayu) with a weight of 1.06 grams.

Percentage of Fresh Leaf

The results of the analysis of variance showed no significant difference in the number of fresh leaves in the 4-week-old jack bean plants that received drought stress treatment. The number of fresh leaves was only found in plants that received the control treatment and were watered once a day. In plants that were watered every two to three days, no fresh leaves were found because the plants lacked a water supply, which hampered photosynthesis, and the lack of water caused the leaves to wilt.

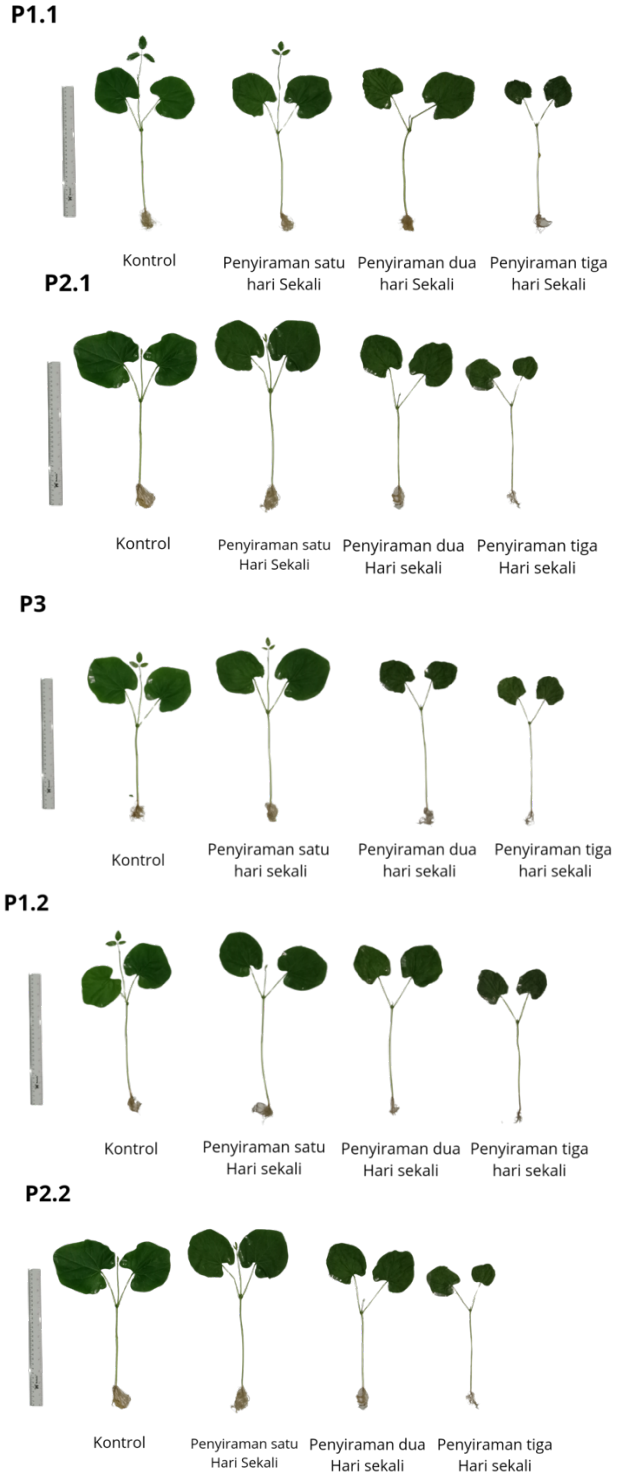

Figure 5. Visualization of five genotypes in the control treatment, watering once a day, watering once every two days, and watering once every three days. P1.1 (Banyumas). P2.1 (Indramayu). P3 (Malang). P1.2 (small patterned Banyumas). P2.2 (small patterned Indramayu).

Drought Stress Tolerance Indeks

The drought stress tolerance index was obtained by using the formula for the data on the highest stress level treatment (values for watering every three days) divided by the control value, then taking the average (Wu et al, 2019).

Table 2. Drought Stress Tolerance Index for Watering Every Three Days for Each Genotype

Genotype	Plant Height	Number of Leave	Number of Leaflet	Leaf Area	Fresh Weight	Average
P1.1	0.79	1.00	0.5	0.43	0.18	0.58
P2.1	0.82	1.00	1.00	0.24	0.23	0.65
P3	0.84	1.00	0.6	0.44	0.19	0.61
P1.2	0.83	1.00	0.6	0.48	0.25	0.63
P2.2	0.79	1.00	0.75	0.51	0.25	0.66

The ability of plants to maintain tissue potential by increasing water uptake or reducing water loss is known as tolerance to high tissue water potential (dehydration avoidance). By controlling stomata, producing waxy layers, growing thick hairs, and reducing surface evapotranspiration by narrowing leaves and shedding older ones, plants can expand their root systems and reduce epidermal conductance. Dehydration tolerance, or the capacity of plants to maintain cell turgor pressure by increasing cell elasticity or lowering water potential through the accumulation of solutes such as sugars and amino acids (Ezward et al., 2023).

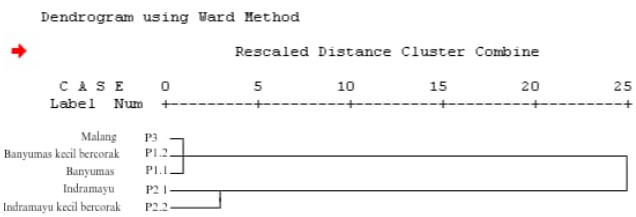

Figure 6. Dendogram of tolerance index to drought stress in the five genotypes of jack bean

The dendrogram uses three scales: sensitive, moderate, and tolerant. This dendrogram shows that genotype 3 (Malang), genotype 4 (P1.2) (small patterned Banyumas), and genotype 1 (P1.1) (Banyumas) are categorized as sensitive. Genotype 2 (P2.1) (Indramayu) is categorized as moderate. And genotype 5 (P2.2) (small patterned Indramayu) is categorized as tolerant.

CONCLUSION

Based on the research results, it can be concluded that drought stress treatment significantly affected several observed parameters, including plant height, leaflet number, leaf area, and leaf fresh weight. Jack bean (*Canafalia ensiformis* L.) has striking morphological characteristics: large seeds, broad leaves, and white seeds. The results of this study indicate that drought stress can inhibit the growth of jack bean plants, including plant height, leaflet number, and leaf area. Based on the Ward Method dendogram, the drought tolerance level of each jack bean landrace varies. Genotype 3 (Malang), genotype 4 (P1.2) (small patterned Banyumas), and genotype 1 (P1.1) (Banyumas) are categorized as sensitive. Genotype 2 (P2.1) (Indramayu) is categorized as moderate. And genotype 5 (P2.2) (small patterned Indramayu) is categorized as tolerant. The jack bean plant with the highest tolerance level only looks wilted on the leaves, it doesn't immediately turn yellow.

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