JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

Research Paper

Root Distribution Pattern of Three Chili Varieties on Vertisol Soil, Central Lombok

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DOI: 10.29303/jossed.v4i2.5238

Article Info
Received: August 30, 2023
Revised: October 19, 2023
Accepted: October 25, 2023
Published: October 31, 2023

Abstract: Plant roots have an important role in plant growth. Roots function as absorbers of water and other nutrients in the soil which are distributed to other body organs. Distribution patterns, root growth and root range influence plant growth and development. Vertisols are one of the dominant soil orders in southern Lombok, but their physical characteristics are rich in monmorillonite type clay which expands when wet and shrinks when dry. This study aims to analyze the pattern of root distribution through the root growth rate of the three chili varieties and to analyze the tolerance level of the three chili varieties. The field experiment was organized according to a Randomized Completely Block Design with three replications. The varieties of chili plants planted are Kara chilies, Dewata chilies and local chilies. Root growth rate was measured on serial plant samples observed every 20-day interval until day 60, during the growth period. The results obtained showed that the distribution patterns of the three varieties experienced an increasing trend in the rate of root growth, for the kara varieties it reached a figure of 4.65 cm, for local varieties is 5.54 cm; and in the dewata variety it is 2.67 cm. The tolerance level of chili plants to congested conditions was seen from the results of their root growth rates, the three varieties showed that they were Semi Tolerant (ST) to waterlogged environmental conditions on vertisol soils.

Keywords: Agriculture; Chili; Rainfall; Vertisol

Citation: Iemaaniah, Z. M., Mahrup, M., & Susilowati, L. E. (2023). Root Distribution Pattern of Three Chili Varieties on Vertisol Soil, Central Lombok. *Journal of Science and Science Education*, *4*(2), 145–152. https://doi.org/10.29303/jossed.v4i2.5238

INTRODUCTION

Chili plants are shrubs that usually live in tropical areas (Flowrenzhy et al., 2017). Chilies are a much needed commodity (Wangiyana et al., 2021) and have high economic value based on market demand (David et al., 2018) and needed in various circles ranging from household needs to industry (Hutauruk et al., 2020). Chili is needed in various types of cuisine, from home cooking to large restaurants. This plant contains a lot of vitamin C and contains capsaicin which causes a spicy taste in the fruit (Polii et al., 2019; Undang et al., 2015). Chili plants can grow on a planting medium with a crumbly soil texture and good permeability so that chili cultivation is closely related to weather and climate conditions (Saraswati & Purwanto, 2020). A good planting medium can help the growth of chili plant roots and have an impact on the development of chili plants.

The facts in the field show that chili plants can grow well in various areas in West Nusa Tenggara. This has encouraged various previous studies to determine chili's response to soil, water and climate conditions (Muliati & Ete, 2017). Some of the results of previous studies indicate that there are signs (indications) that lead to the mechanism of plant adaptation to environmental conditions. Kusumaningrum et al., (2021) reported that plant root architecture varies. Chili planting generally cannot be done during the rainy season, so to increase chili production, it is necessary to extend agricultural land for chili cultivation (Sofiarani & Ambarwati, 2020).

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The Mandalika Special Economic Zone is a new economic development area that is integrated with tourism development. This region has very large agricultural land (Iemaaniah et al., 2023) and as an area that is being prepared to become a farming center that is not only oriented towards meeting the food needs of the family (subsistence), but also as a supplier of fresh tropical vegetables and fruits. in the super priority tourist destination area. The physical characteristics of the soil in the area are dominated by the Vertisol order which is rich in monmorillonite clay (Wang et al., 2022) has a fairly good level of fertility, has a neutral soil pH (Matheus & Kantur, 2022). On the other hand, vertisol soils can be a major obstacle, especially because of their clay texture and can store a lot of water and it is difficult to get out of the soil's ground water (Garg et al., 2022) which causes a waterlogging effect during the rainy season (Utomo, 2016). Constraints as described above are used as the focus of study in this study, so that nutrient-rich Vertisol soil can bring prosperity to farmers. As indicator plants in the field experiment were superior chili varieties of Kara and Dewata, accompanied by local varieties. Chili varieties that are genetically superior can adapt to various environmental conditions that affect them (Yuliartini et al., 2021). So that these three varieties can show a pattern of growth rate and distribution of roots (root architecture) that reflects the mechanism of adaptation to waterlogging.

METHOD

The research was carried out using an experimental method through field trials arranged according to a Randomized Completely Block Design. As the treatment in this study were three varieties of chili plants, namely Kara, Dewata and local varieties. Var. Kara and Dewata as representatives of superior chili plants in terms of yield, while var. Local represents dry land typology horticultural crops. Field trials were carried out on paddy fields with the order Vertisol soils during the rainy season. Each treatment was repeated three times as a block.

Time and Place of the Trial

This research was conducted in one of the buffer zones of the Mandalika SEZ, namely Sukadana Village, Pujut District, Central Lombok Regency. The time for conducting the research was 3 months, from January to March 2023. The materials used in this research were kara chili seeds, Dewata chilies, and local chilies. Ground covers use plastic mulch to prevent surface flooding. Fertilizers, herbicides, insecticides used according to technical recommendations for local locations. The tools used are shovels, hoes, calipers, wooden planks, tracing paper, millimeter block paper, ruler, ballpoint pen.

Land Preparation

The experimental plot was made in the form of beds with a length of 10 m, a width of 1 m, a height of 40 cm. The distance between beds 50 cm. The total number of beds 9 pieces. Block positions are determined based on the direction of water inflow, respectively as block-1, block-2 and block-3. Each bed is permanently covered with plastic mulch with holes prepared according to the planting distance, namely 50 cm (in the row) and 70 cm across the row, so that there are two rows of plants in one bed.

Nursery Preparation and Planting

The chili seeds prepared were of three varieties namely var. Kara, var. Gods and local chili. The three varieties were sown (grown) in plastic bags with a diameter of 7 cm, a height of 10 cm, which were first filled with cage soil and compost in a 1:1 ratio. Nurseries last for 30 days, then transferred to the land that has been prepared.

Plant Maintenance and Fertilization

Plant maintenance includes watering if there is no rain for a long period (10 consecutive days) without rain. The amount of water given is measured each time water is added. Fertilization, and control of pests and diseases is carried out when there are signs or early symptoms of pest and or disease attack. The insecticides used are Profenopos® and Acrobat 50 WP® fungicide which are sprayed according to recommended doses.

NPK fertilization uses Ponska 15:15:15, which is given at a dose of 5-7 grams per plant. Time or frequency of fertilizer application, namely 3 times each at 10 days after planting (DAP), 28 HST and 42 HST.

Parameter Measurement and Data Analysis
Root Measurement

1. Documentation was carried out on sample series plants, which were observed from the time the plants were 20 HST (sampling-I), then at the end of the growth phase of the vegetative phase, which was marked by the emergence of flower premordia (sampling II), in the generative phase (fertilization), that is during the first harvest-I (sampling-III). At each time of root observation (plant sampling series), the age of the plant was recorded from the date of planting (DAP). The number of series plants observed in each observation was 3 chili plants for each variety. The serial plant sample is determined by systematic random sampling of all plants in the row, in such a way that each plant has the same chance of being observed as a serial sample.

2. Vector Measurement of Roots

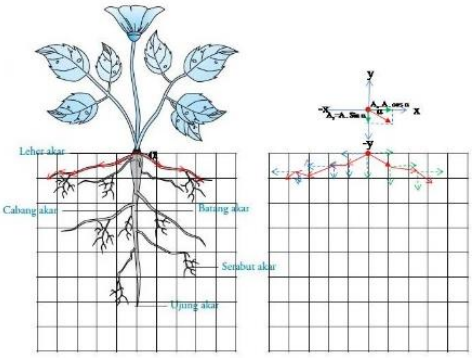

Figure 1. Root and Vector Architecture

Figure 1 illustrates plant root architecture in two dimensions (left) and an example of depicting roots in vector form (right). If the root length is denoted as vector A divided into several segments according to the boundaries: A1, A2 A3 ... An, then the components of the vector in the lateral direction (x-axis) and in the vertical direction (y-axis) can be expressed by the following formula:
The root length component laterally: A1x= A1. sin a1; A2x= A2. sin a2; A3x = A3. sin a3; Vector components in the vertical direction: A1y= A1.cos a1; A2y = A2. cos a2; A3y = A3. cos a3.

Then the resultant root length: RA = $\sqrt{(\sum Ax)^2 + (\sum Ay)^2}$, where cos 90o=0. The rate of root growth of chili plants can be determined by conducting periodic experiments on three varieties of chili plants. Root growth rate was carried out by measuring root length and number of roots (Rusdiana et al., 2000) every 20 days. Meanwhile, the generative parameters that will be observed are: plant height, plant dry weight and fresh fruit weight at harvest. Data for each of these parameters will be analyzed with Anova at the 5% level of significance.

3. Assessment of Tolerance of Chili Plants to Waterlogging
Assessment of the tolerance of chili varieties to water-logged conditions will be carried out by grouping one of the agronomic characters that are the same in all varieties based on standard deviation values, so that three criteria are obtained (Susilawati et al., 2012) that is:
Tolerant (T) = (xi > x + σ); Semi-tolerant (ST) = (x – std ≤ xi ≤ x + σ); Intolerant (TT) = (xi< x – σ). Where xi = the average value of one agronomic character for one variety, x = the average value of one agronomic character for all varieties, σ = standard deviation of one character for all varieties. A variety is said to be tolerant if it has dominant tolerant criteria and is said to be intolerant if the intolerant criteria are dominant among all varieties.

RESULT AND DISCUSSION

The morphology of chili plants in general can be influenced by the availability of nutrients in the soil. Chili plants can grow well by absorbing plant nutrients through plant roots. Chili plants have various varieties, including kara, dewata and local varieties. The plant roots of the three chili varieties have different distribution patterns. Planting chili plants should ideally be done in the summer (Sumarno et al., 2021) not during the rainy season and with vertisol soil planting media providing environmental conditions that can inhibit the growth and development of chili plant roots.

High rainfall causes vertisol soil to become clogged with water (Regassa & Elias, 2022) (waterlogging). Soil that is experiencing flooding will facilitate the occurrence of decay in plant roots and can inhibit plant growth (Fajriansyah et al., 2012). With such environmental conditions and with the same treatment on the three varieties it was found that the roots of the three varieties could develop well with the root growth pattern as follows:

Roots Distribution Pattern

The distribution pattern of chili roots was observed at intervals of every 20 days with three repetitions. Chili roots were observed on the 20th, 40th and 60th days after planting chilies in the experimental field with the resultant root length formula as follows $R_A = \sqrt{(\sum Ax)^2 + (\sum Ay)^2}$. The following is table 1 of the results of vector analysis of root growth patterns of three varieties of chili plants on days 20, 40 and 60.

Table 1. Rooting Rate of Three Chili Varieties

Varieties	HST Chili			Cumulative Growth Rate
	20	40	60	
Kara	5.15	8.57	9.8	4.65
Lokal	4.41	4.95	9.85	5.54
Dewata	6.7	8.86	9.37	2.67

Data Analysis, 2023

Based on the results of table 1 above, it can be seen that the distribution pattern of the chili roots of the three varieties always shows an increasing trend in the resultant length of the chili roots. The kara chili variety experienced a growth of 4.65 starting from the observation on the 20th day to the 60th day. At the 20-day observation interval, consecutive numbers were 5.15; 8.57 and 9.8. In local varieties, the rooting growth pattern experienced an increasing trend with a significant pattern increasing on days 40 to 60. On the 20th to 40th HST, the rooting pattern of local varieties did not experience a significant increase. Only experienced an increase of 0.54. Meanwhile, after the 40th day, the Rooting pattern experienced a significant increase, reaching 4.9 cm and overall an increase of 5.44 cm. The growth pattern on days 40-60 is the most significant increase compared to the other 2 chili varieties.

The third chili variety is Dewata chili, based on table 1 it is known that the growth pattern of Dewata variety is the same as the other 2 varieties which have also experienced an increase. The growth pattern of Dewata roots is not much different from kara chili. On the 20th day of observation, Dewata chili rooting obtained the resultant root length which was the greatest compared to the other 2 varieties, namely at 6.7 cm. In the 40th and 60th observations, the resultant growth was 8.87 cm and 9.37 cm respectively. The following is a diagram of the root growth pattern of the kara chili, local chili and dewata chili varieties.

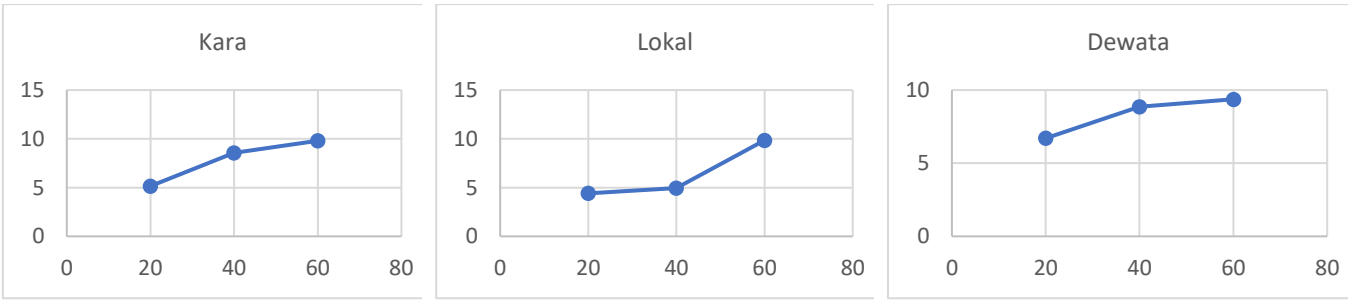

Figure 2. Rooting patterns of Kara Chilies, Lokal Chilies and Dewata Chilies

Rooting patterns of the three chili varieties on the 20th day of observation, Dewata chilies had the longest resultant roots, followed by Kara and local chilies. Likewise, observations on the 40th day showed that the resultant length of the roots of the Dewata chili plants was superior compared to the Kara and local varieties, meanwhile the resultant length of the roots of the local chilies showed a very large difference compared to the Kara and Dewata chilies. Rooting observations on day 60 showed quite significant results in increasing the length of local chilies. From the three varieties, the final resultant length on day 60 was almost the same, namely 9.8 cm; 9.85cm; and 9.37 cm. On the 60th day of observation, the local variety of chilies experienced the highest increase in resultant length compared to the other two varieties, so that when observing the roots on the 60th day the comparison was not much different. Based on the growth of root length from observations from days 20 to 60 and calculating the resultant root length, the numbers for kara, local, and dewata were respectively 4.65; 5.54; and 2.67, you can see a comparison of the growth rates in the following diagram.

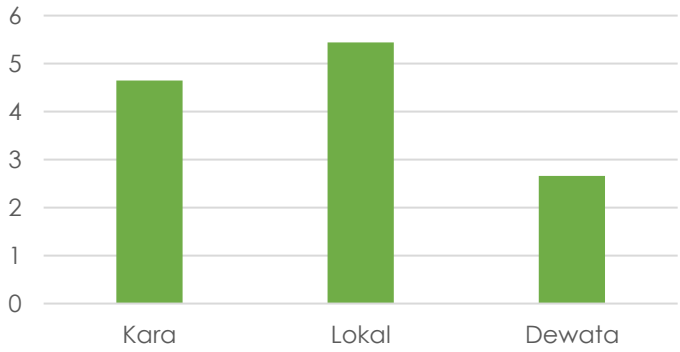

Figure 3. Roots Growth Rate of Three Chili Varieties

Based on the diagram above, the lokal chili is the longest root growth rate of all. The second is kara chili and the last is dewata chili. Root growth rate can be affected by growing media conditions. The planting of this chili variety was carried out on vertisol soil and during the rainy season, thereby affecting the moisture content of the soil which is more towards the saturation point of the soil. The planting media in the form of polybags and planting media that are directly in the rice fields results in differences in the growth rate of the roots. The rooting rate of plants planted in polybag planting media results in limited root growth (Daryanti et al., 2022). Meanwhile, this research was carried out on large agricultural land but also limited by mulch so that more flooding does not occur so that root growth is directed downward. Figures 3, 4 and 5 below are the results of observations of the root growth rate of 3 chili varieties.

Figure 4. Rooting of Kara Varieties 20 DAP (Left), 40 DAP (Middle), 60 DAP (Right)

Figure 5. Rooting of Local Varieties 20 DAP (Left), 40 DAP (Middle), 60 DAP (Right)

Figure 6. Rooting of Dewata Varieties 20 DAP (Left), 40 DAP (Middle), 60 DAP (Right)

Tolerance of Three Chili Varieties in Clogged Conditions (Water Logging)

The tolerance of chili plants was observed based on the root growth rate presented in table 1. The three chili varieties that were observed were then measured for the tolerance level of these plants by comparing the results of the average growth rate of each chili variety xi) with the results of the standard deviation of all varieties (σ) plus with the average growth rate of all observed chili varieties (x). The results of chili plant tolerance based on the resultant root growth obtained results as shown in table 2 below.

Table 2. Tolerance Levels of Chili Varieties

Varieties	xi	σ	x	σ +x	x- σ	Tolerance
Kara	7,84	2,1	7,52	9,62	5,42	ST (5,42 ≤ 7,84 ≤ 9,62)
Lokal	6,4	2,1	7,52	9,62	5,42	ST (5,42 ≤ 6,4≤ 9,62)
Dewata	8,31	2,1	7,52	9,62	5,42	ST (5,42 ≤ 8,31≤ 9,62)

Source: Data Analysis, 2023

Based on the results of research by observing root growth rates, it was found that the three varieties planted were not tolerant of waterlogging conditions. Of the three varieties planted, it is known that all varieties are in the semi-tolerant category to water-logged conditions in vertisol soil, and of the three chili varieties, the numbers that are close to tolerance indicate that the dewata variety is the variety that is most tolerant to water-logged conditions. The next variety is the kara variety and the one with the lowest tolerance to water-logged conditions of the three is the local chili variety. The tolerance levels for Dewata chili, Kara chili, and local chili are 8.31; 7.84; and 6,4.

Water-congested conditions occur because the planting of chili plants is carried out on agricultural land with vertisol soil types and during the rainy season. Chili plants that can grow well have soil conditions where water is available, namely conditions with appropriate soil moisture levels (Lelang et al., 2020). Intense rain conditions result in flooding of agricultural land so that it requires appropriate care and planting techniques. As a step to avoid rotting of the roots of the three varieties of chili plants, a fairly high bed was made and mulch was installed. According to the research results of Mariana et al., (2021) the condition of the chili plants that are flooded makes it easier for the chili plants to get anthracnose. This research applies planting techniques using high beds and the use of mulch, this is a step to avoid waterlogged roots.

Growth of The Chili Plant

Based on the root growth of the three varieties, lokal chili is the most improving growth compare to others. This condition is relate to growth of chili plant such as the plant weight, plant height, and yields. The comparison of the results of the three varieties was carried out using the ANOVA test with a significance level of 5%. The ANOVA test that was carried out on the three chili varieties yielded a very significant difference of 0.0001 in plant height, plant dry weight and yield of chili plants. And this table and figure below shows that local chili is the variety that can best adapt to waterlogging conditions on vertisol soils.

Table 3. Local Chili is the Variety

Varieties	Mean of Height	Mean of Dry Weight	Mean of Yield	N Non-Significant Ranges
Lokal	90	7,57	1,7	3[a]
Kara	57	6,3	1,3	3 [b]
Dewata	38	5,9	0,8	3 [c]

Source: Data Analysis, 2023

Figure 7. Chili Plants Lokal (left), Dewata (center), Kara (right)

CONCLUSION

It can be concluded from this research that the root distribution pattern of the three varieties of chili plants always experiences an upward trend. The three chili varieties have different increasing trends. The rooting distribution that is best known based on the growth rate. The most dominant rooting growth is the local chili variety, which reaches a growth rate of 5.54 cm, followed by the kara chili with 4.65 cm, and the Dewata variety, which is 2.65 cm. The tolerance levels of chili plants planted in waterlogging conditions of the three varieties were all included in the category of semi-tolerance to these conditions. The highest average growth rate was Dewata chili, namely 8.31; kara chili namely 7.84; local chili is 6.4. These three numbers are still between the number 5.42 to the tolerance number which reaches above 9.62. So that of the three varieties that were in the same level, and seen from the plant results (height, weight, and yields) that local chili is the variety that can best adapt to waterlogging conditions on vertisol soils.

ACKNOWLEDGEMENTS

The authors would like to thank the research team and the writing team for taking the time to travel the research location from planting to observation. The author also does not forget to say to the students who have assisted in the research observations and to thank the owner of the trial land, Mr. Asmul Jayadi. In addition, the authors would like to thank LPPM University of Mataram which has assisted in funding this research.

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