CORRELATION OF ROOT CHARACTERS TO SEED CHARACTERS OF 27 SOYBEAN GENOTYPES (GLYCINE MAX (L.) MERILL) IN THE RAINY SEASON WITHOUT APPLICATION OF N FERTILIZER

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ABSTRACT Fulfillment of N element requirement in soybean cultivation is supported not only by environmental condition, but also by N-fixing microbial activity. One group of bacteria that is able to provide nutrients for plants is Rhizobium japonicum bacteria which causes the formation of root nodules. The purpose of this study was to analyze the relationship of root characters, and to find out which characters have the greatest influence on the seed weight of 27 soybean genotypes (Glycine max (L.) merill) in the rainy season without N fertilizer. The relationship between the observed characters was analyzed using correlation test, while to determine the direct and indirect effects of each character on the results were analyzed using path analysis. The relationship between the characters of the number of effective taproot nodules and the number of effective fibrous root nodules on seed weight per plant had a positive but not significant correlation. The greatest direct influence on seed weight per plant was shown in the character of the number of effective taproot nodules.
Keywords: Path Analysis, soybean, N Fertilizer, Rainy season

1. **Introduction**

The increase in national soybean seed needs is inversely proportional to soybean production. In the period 2012-2022, national soybean production continues to experience a significant decline, and shows a downward *trend* of 7% [1] [2] [3]. This factor is of particular concern, especially for the government in efforts to develop national soybeans. One of the efforts to develop national soybeans can be improved through the launch of New Superior Varieties (VUB). Superior varieties resulting from breeding generally have one or more special advantages, such as high yield potential, tolerance to pests and diseases, high quality, and resistance to environmental stress [4].

Soybean cultivation in Indonesia is generally carried out in the second planting season (MT), namely after the upland rice harvest from February to March [5]. In the second MT, there are fluctuations in the number of rainy days and the amount of rainfall so that soybeans are susceptible to water stress. Ruminta *et al.* [6] stated that changes in rainfall have a significant effect on the vegetative and generative organs of soybean plants. Until now, there has been no specific soybean cultivar available that is able to adapt to high soil water content conditions, so it is necessary to select cultivars that have been released to see their adaptability in the rainy season [7] .

The negative impacts caused by planting soybeans during the rainy season are soil conditions that contain too much water, nutrient balance, and increased development of plant diseases. Koryati *et al.* [8] stated that 80% of the air that surrounds the earth is nitrogen, but most of it is in the form of N2 which cannot be utilized by plants. The advantage is that in the rainy season the nitrogen contained in the air can be dissolved in the form of nitrate and transferred by rainwater into the soil so that it can be utilized by plants.

The increased N content in the rainy season allows soybean cultivation activities to be carried out without adding N nutrients to the soil. The results of the study by Muis *et al.* [9] stated that water-saturated cultivation creates better environmental conditions for the growth of soybean plant roots because of the sufficient water supply, thus triggering plants to form more roots and root nodules. The increase in the number of effective root nodules will increase the N fixation process carried out by Rhizobium bacteria . The results of the study by Korobko et al. [10] reported that increasing the number of effective root nodules will increase the amount of nitrogen fixed.

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Fulfillment of N element needs in soybean cultivation is supported not only by environmental conditions, but also by the activity of N-fixing microbes. One group of bacteria that can provide nutrients for plants is *Rhizobium japonicum bacteria* which causes the formation of root nodules[11]. The relationship between bacteria and soybean plants is generally mutualistic, and under favorable conditions this symbiosis can meet the N needs of its host plants by 74 - 90% of the total plant needs [12] . Based on this, soybean plants can meet the N needs of plants through the activity of *Rhizobium japonicum bacteria* .

The increasing content of N nutrients carried by rainwater through runoff will disrupt the life cycle of soybean plants. Nitrogen is a nutrient needed by soybeans for vegetative plant growth. Excessive N availability will cause plant vegetative growth to take longer, as well as disrupt root development and the N fixation process by bacteria. Salvagiotti et al. [13] stated that there is a negative relationship between N availability and the N fixation process carried out by bacteria. Salvagiotti et al. [14] reported that the higher the availability of N in the soybean root zone, the less nitrogen absorption from the fixation process by bacteria will be. Li et al. [15] stated that the process of nitrogen fixation carried out by bacteria is greatly influenced by the presence of a host carrying bacteria, inoculation, and environmental conditions.

Based on the description above, it shows that there is a relationship between the availability of N in the rainy season and the activity of Rhizobium japonicum bacteria in the process of fulfilling the nitrogen needs of soybean plants. Therefore, the relationship between the two will be studied in 25 genotypes from crosses. The purpose of this study was to analyze the relationship between root characters , and to analyze the characters that have the most significant effect on the seed weight of 27 soybean genotypes (*Glycine max* (L.) merill) in the rainy season without N fertilizer.

2. Materials and Methods

2.1 Materials and tools

The materials used were seeds of 25 soybean genotypes from crosses (Table 1) and 2 check cultivars consisting of Deja 2 and Detam 4, polybags measuring 45×45 cm, soil, single P (SP-36) and K (KCl) fertilizers, pesticides, water, labels, markers, stakes, and raffia ropes. The tools used in the experiment included all the tools commonly used by farmers in soybean cultivation, scissors, *staples* , *cutters* , analytical scales, stationery, and cameras.

Table 1. Experimental Genotypes

Genotype	Pedigree	Genotype	Pedigree
UM001	Yellow Gepak x Pearl 3 (2)	UM014	Pearl 3 x Detam 2 (1)
UM002	Yellow Gepak x Detam 4 (1)	UM015	Pearl 3 x Detam 2 (2)
UM003	Yellow Gepak x Detam 4 (2)	UM016	3 x Biosoy Pearl (1)
UM004	Yellow Gepak x Detam 4 (3)	UM017	Pearl 3 x Biosoy (2)
UM005	Deja 2 x Pearl 3 (1)	UM018	Pearl 3 x Biosoy (3)
UM006	Deja 2 x Pearl 3 (2)	UM019	Detam 4 x Deja 2 (1)
UM007	Deja 2 x Pearl 3 (3)	UM020	Detam 4 x Deja 2 (2)
UM008	Deja 2 x Detam 2 (1)	UM021	Detam 4 x Det 2 (1)
UM009	Deja 2 x Detam 2 (2)	UM022	Detam 4 x Det 2 (2)
UM010	Deja 2 x Detam 2 (3)	UM023	Detam 4 x Det 2 (3)
UM011	Deja 2 x Detam 1 (1)	UM024	Detam 4 x Bio (1)
UM012	Deja 2 x Detam 1 (2)	UM025	Detam 4 x Bio (2)
UM013	Pearl 3 x Detam 4 (1)		

2.2 Time and Place of Research

This research was conducted in December 2023 – March 2024 at the Techno Park land of the Faculty of Agriculture, University of Majalengka, located at Jl. Pancurendang, Babakan Jawa Village, Majalengka District/Regency, with an altitude of 146 meters above sea level.

2.3 Data analysis

This study was conducted using the Randomized Block Design method. The relationship between observed characters was analyzed using a correlation test, while to determine the direct and indirect effects of each character on the results were analyzed using path *analysis* .

The observed characters are the number of effective nodules of taproot (grains), the number of effective nodules of fibrous roots (grains), dry weight of roots (g) and seed weight per plant (grams). The observed environmental parameters include altitude, temperature, humidity, and rainfall.

3. Results and Discussion

Environmental conditions during the experiment

The results of soil analysis conducted at the Fertility and Plant Nutrition Laboratory of Padjajaran University showed that the soil used in the experiment had a soil pH of 6.50 with neutral criteria. The pH value of the experimental soil, in addition to being obtained from the results of laboratory analysis, was also obtained from the results of soil measurements in the field using a *soil tester* and obtained an average pH value of 6.43 and an average soil moisture of 22%. The pH value desired by soybean plants ranges from 6.0 - 6.8 [16]. Thus, the pH of the experimental soil is classified as appropriate. The high and low pH is influenced by the soil moisture factor [17]. Increasing soil moisture is a form of positive correlation with the rainfall factor [18]. High soil moisture causes the pH value to continue to decrease, creating a sour atmosphere [19].

The average minimum temperature during the experiment ranged from 23.6 - 24.3 ^{o} C and the average maximum temperature ranged from 30.4 - 33.1 ^{o} C. The optimal temperature for soybean plants is around 25 - 27 ^{o} C [20]. The growth rate of soybean plants will decrease if the temperature is in the range of <18 and >35^{o}C, and every 1^{o}C increase in temperature can reduce yields by around 17% [21]. Based on this theory, the temperature in the experimental field is included in the appropriate conditions for soybean plants.

The average humidity during the experiment ranged from 70.7 - 83.7%. The optimal humidity for soybean plants is 50% RH [20]. Thus, the humidity in the experimental location is less suitable because it tends to be higher. Air humidity affects the seed cooking process and seed quality. Air humidity in high rainfall conditions can reduce seed quality and seed quality, because soybean seeds have hygroscopic properties, namely they easily absorb water vapor in the surrounding area [22]. This is reinforced by the results of research by Chairudin et al. [23] which states that high air humidity inhibits the plant's metabolic process, one of which is indicated by a decrease in the number of filled pods. In addition, high air humidity can encourage the growth and development of pests and diseases so that it will indirectly affect the growth and development of soybean plants.

Daily rainfall during the experiment ranged from 234.3 - 624.9 mm/month, with an average number of rainy days of around 26 - 31 days/month. Meanwhile, the optimum rainfall for soybean plants is between 100 - 200 mm/month [20]. Based on this, it shows that the rainfall at the experimental location is relatively high. High rainfall conditions will cause several disadvantages such as creating a poor drainage system, inhibiting the growth of soybean plants, and can affect soybean yields [7].

Relationship between root characters and soybean genotype yields in the rainy season

The results of the correlation analysis showed that the root characters showed a significant positive relationship. The results of the correlation analysis can be seen in (Table 2).

Table 2. Correlation Between Root Character Relationships and Seed Weight of 27 Soybean Genotypes (Glycine max (L.) Merill) in the Rainy Season Without Application of N Fertilizer.

Variable	X1	X2	X3	Y
X1	1			
X2	0.463*	1		
X3	0.286*	0.516*	1	
Y	0.037	0.139	0.153	1

Note: * = significant at the 5% level; x1 = number of effective root nodules on taproot; x2 = number of effective root nodules on fibrous roots; x3 = root dry weight; Y = seed weight per plant

Table 2 shows a positive correlation occurs in all tested characters. This shows that increasing root characters will cause an increase in seed weight per plant. Characters that show a significant relationship are the number of effective root nodules on the taproot (x1) with the number of effective root nodules on the fibrous root (x2), the number of effective root nodules on the taproot (x1) with the dry weight of the root (x3), and the number of effective root nodules on the fibrous root (x2) with the dry weight of the root (x3). The relationship between root characters and seed weight per plant shows an insignificant relationship.

The greater the number of root nodules formed in the soybean root system, the higher the root dry weight. This is due to the large amount of biomass formed in the roots. The results of the study by

Maslard et al. [24] reported that the condition of soybean plant roots can be used as an indicator of genetic variability and can show the process of nutrient absorption, water, and adaptability to environmental changes. Kunert et al. [25] reported that the selection carried out on root characters can directly see the plant metabolism process, gene and protein identification against drought stress.

The results of the cross-finding analysis showed that the largest direct influence on seed weight per plant was shown in the character of the number of effective root nodules of fibrous roots (0.156) and root dry weight (0.111). The complete analysis results can be seen in Figure 1.

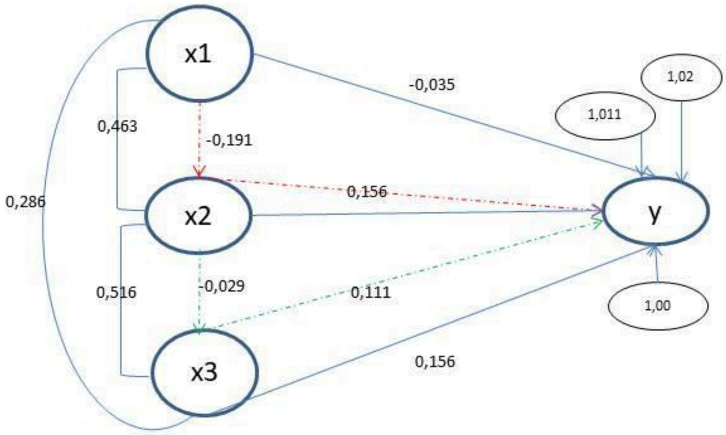

Figure 1. *Path* analysis diagram of the relationship between root characters and seed weight of 27 genotypes.

Each root character showed a very low direct effect on yield compared to its indirect effect. The results of the analysis showed that the number of effective root nodules on fibrous roots showed a higher direct effect compared to the number of effective root nodules on taproots. This indicates that the presence of root nodules on fibrous roots plays a higher role in increasing seed weight per plant compared to effective root nodules on taproots. The direct effect of the number of effective root nodules on fibrous roots on root dry weight showed the highest (0.516). Nakano et al. [26] reported that increasing the number of effective root nodules will increase the nitrogen fixation process carried out by bacteria so that the development of roots and plant crowns will increase so that the absorption of water and nutrients in the soil increases.

Table 3. Direct Effect and Indirect Effect

Variable	Direct Effect				Indirect effect	
	X1	X2	X3	Y	X2	X3
X1		0.463	0.286	-0.035	-0.191	-0.156
X2			0.516	0.156		-0.029
X3				0.156		

Where: x1 = number of effective root nodules on taproot; x2 = number of effective root nodules on fibrous roots; x3 = root dry weight; Y = seed weight per plant

Nitrogen enters the plant from the soil or from legume root nodules in the form of nitrate (NO $^{3-)}$ or ammonium (NH $^{4+}$). Root nodules can only fix free N into available N, which can only support vegetative plant growth . This is reinforced by Agustina [27] who stated that physiologically the N element plays a role in plant growth, and as a component of hormones and enzymes, it plays an important role in plant metabolism such as plant respiration and genetics.

Rhizobium bacteria activity begins since the formation of roots, namely by infecting plant roots so that root nodules are formed. These root nodules will be able to bind nitrogen from the air at the age of 10-12 days after planting. The amount of nitrogen fixed by rhizobium bacteria will continue to increase during the flowering period, and reach a maximum at the end of flowering and will experience a drastic decrease during the pod filling period. Therefore, the weight of plant seeds cannot be determined by the character of the plant root nodules.

High rainfall during the study affected the physical characteristics of the soil. The research land with clay soil character had a less good effect, because clay soil has a very fine texture which causes a strong water and nutrient binding capacity, but the high level of compaction results in poor drainage, especially in high rainfall conditions [28]. Soil conditions that experience compaction affect the formation of root nodules so that their development and activity will be hampered [29]. In addition, in high rainfall conditions, the intensity of sunlight every day will decrease so that plants experience competition in capturing sunlight. This is in line with Gardner *et al.* [30] who stated that low seed weight is caused by the large competition between seeds in obtaining photosynthate that can be stored.

Figure 1 shows that the root character that has the greatest direct influence on seed weight per plant is the character of the number of effective root nodules of the taproot. The effective root nodules of the taproot are larger in size compared to the effective root nodules of fibrous roots, allowing the rhizobium bacteria in the effective root nodules of the taproot to work more actively. The large size of the effective root nodules of the taproot is caused by the amino acid tryptophan in the taproot which tends to be higher. The roots release several substances, especially tryptophan compounds, which cause the development of bacteria and microbes around the plant roots. This is in line with Setiawan and Wahyudi [31], who stated that the amino acid tryptophan is a precursor to auxin, causing auxin levels to increase. The results of a study by Krisdianto, et al [32] stated that the highest auxin levels were found at growing points such as the tip of the coleoptile, shoots, leaf growing points and roots. Based on this, high levels of auxin in the taproot cause the size of the root nodules to be larger and the rhizobium bacteria to work more actively.

4. Conclusion

Planting soybeans in the rainy season has a significant impact on the growth and yield of soybean plants. Nutrient balance is the main problem faced in rainy season conditions. The relationship between characters is important information for selecting soybeans that are resistant to rainy season conditions. Based on the results of the study, the relationship between root characters and seed weight per plant showed a positive but insignificant relationship, as well as its direct effect. A significant direct relationship was shown between root characters, namely the number of effective root nodules on tap roots, the number of effective root nodules on fibrous roots and root dry weight. The highest direct effect was shown in the character of the number of effective root nodules on fibrous roots and root dry weight on seed weight per plant compared to the direct effect of the number of effective root nodules on tap roots on seed weight per plant.

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