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Suitability of Microclimate for Maize and Edamame

Fatiha Zacky Nurikadevi[1], Mahindra Dewi Nur Aisyah[1], Iqbal Erdiansyah[1], Ilham Muhklisin[1], Tirto Wahyu Widodo[1]

[1] *Department of Agriculture Production, State Polytechnic of Jember, Indonesia*

Correspondence should be addressed to:
Fatiha Zacky Nurikadevi
a42210410@student.polije.ac.id

Abstract:
Climate change impacts on maize cause a decrease in yields, changes in phenology, heat stress, water scarcity, and vulnerability to pests and diseases. Enhancing agricultural resilience to climate change highly recommended using intercropping between maize and edamame. This research aims to determine the suitability of climatic factors for maize and edamame in different patterns (monoculture of maize; intercropping of maize and edamame; intercropping with basil; and intercropping with lemongrass). This research was conducted from June to September 2024 in the Kebonsari field, Jember. The results show that climate factors affect maize and edamame soybean plants, particularly soil temperature and humidity, which have an influence of more than 50%.

Keywords:
border, climate change, intercropping

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INTRODUCTION

Climate change by human activities such as deforestation, burning, and industrial residues. Climate change affects temperature increases, rising sea levels, severe natural disasters, changes in ocean currents, and changes in precipitation patterns (Rawat et al., 2023). These changes impact various aspects of life, including health, water availability, agriculture, and biodiversity. Climate change poses significant challenges in the agricultural sector through extreme weather events such as droughts, floods, and storms. Such events lead to crop failures, soil erosion, water scarcity, and worsening agricultural systems (Rawat et al., 2023). The increase in temperature and weather changes can reduce and diminish yields and food security in several regions. Specifically, the impact of climate change on maize includes decreased yields, changes in phenology, heat stress, water scarcity, and increased vulnerability to pests and diseases (Rawat et al., 2023). Hertel et al. (2010) explain that improving agricultural resilience to climate change can be achieved by adjusting planting systems, such as crop rotation and intercropping.

Intercropping is a planting method that involves growing multiple crops in a single planting season (Pambudi et al., 2024). The intercropping pattern uses the spaces between main crops to plant other crops. This gap maximizes the use of microclimates such as sunlight, temperature, humidity, and so on (Pambudi et al., 2024). Maize can be intercropped with soybeans (Kholid et al., 2023). Integrating soybeans into maize cultivation offers advantages such as greater land efficiency, increased soil fertility, higher soil nitrogen levels, reduced pest damage, and enhanced crop yield

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diversification (Aisyah & Herlina, 2018). According to Neo and Ceunfin (2017) said the impact of intercropping maize with legume increases maize yields.

Companion plants can be supplemented with barriers. Barriers are chosen based on their ability to repel pest insects from approaching cultivated plants. Some barriers, such as basil and lemongrass, can help address pest issues. Barriers also influence the microclimate of the cultivation environment (temperature, humidity, and sunlight). The research results by Aisyah et al. (2022) indicated that land with barriers has soil that is more humid than land without barriers. Research on intercropping patterns with maize and barrier has been widely conducted, but primarily to determine the intensity of pest attacks. Therefore, this research was conducted to examine the suitability of the microclimate for maize and edamame. The results of this research are expected to provide additional information in the field of agriculture.

METHOD

This research was conducted in the agricultural land on Jalan Singosari, Kebonsari, Sumbersari District, Jember, from June 2024 to September 2024. The tools and materials used include hoes, hand trowels, dibbers, kenco, scales, measuring tapes, writing instruments, camera, knapsacks, buckets, watering cans, sickles, edamame seeds, Kumala F1 variety waxy maize seeds (500 grams), Biomax 1 variety edamame seeds (1500 grams), 180 lemongrass seedlings, 360 basil seedlings, 1 ton/ha of manure, 300 kg/ha of urea fertilizer, 350 kg/ha of NPK Phonska fertilizer, 5 grams/16 L of chemical pesticide, and liquid smoke.

This research design is an experiment using four planting patterns as follows:

1. P1: Monoculture (maize)
2. P2: Intercropping (maize + edamame)
3. P3: Intercropping (maize + edamame + basil barrier)
4. P4: Intercropping (maize + edamame + lemongrass barrier)

Correlation and regression analyses were performed to determine the relationship between the microclimate and production results. The stages of this research include land preparation, planting, maintenance, harvesting, observation, and data analysis. Observation parameters consist of:

a. Sunlight Intensity
   The measurement of light intensity using the Lux Light Meter application was conducted daily at three times: morning (7:00 – 8:30), afternoon (11:30 – 13:30), and evening (16:00 – 17:00) (Wentasari & Sesanti, 2016).
b. Air Temperature and Humidity
   The measurement using a hygrometer thermometer was conducted daily at three times: morning (7:00 – 8:30), afternoon (11:30 – 13:30), and evening (16:00 – 17:00) (Wentasari & Sesanti, 2016).
c. Soil Temperature and Humidity
   The measurement using a 3-in-1 Soil Tester was conducted daily at three times: morning (7:00 – 8:30), afternoon (11:30 – 13:30), and evening (16:00 – 17:00) (Wentasari & Sesanti, 2016).
d. Soil pH
   The measurement using a 3-in-1 Soil Tester was conducted daily at three times: morning (7:00 – 8:30), afternoon (11:30 – 13:30), and evening (16:00 – 17:00).

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e. Rainfall
Rainfall data for the research period, June to September 2024, were obtained from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) in Jember.

RESULT

Microclimate Conditions for Each Planting Pattern

The research was conducted during the dry season in the dryland. The environmental conditions are shown in Table 1.

Table 1. Micro Climate Conditions for Each Planting Pattern for Maize – Edamame

Climate Factor	Necessary		Crop Patterns			
	Maize	Edamame	Monoculture	Intercropping	Intercropping + Basil	Intercropping + Lemongrass
Rainfall (mm)	85 – 200	100 – 400	1.88	2.04 – 5.06	1.88 – 5.06	5.06 – 9.9
Air Temperature (°C)	23 – 27	23 – 27	30	30	29.9 – 30	29.4 – 30
Air Humidity (%)	80 – 90	75 – 90	67	67 – 68	67 – 68	68
Soil pH	5.8 – 6.2	6.6 – 7.0	7.7	7.4 – 7.6	7.5 – 8.1	7.7 – 8.1
Soil Temperature (°C)	23 – 27	23 – 27	30.7	29.6 – 29.5	30.1 – 30.3	29.9 – 30
Soil Humidity (%)	80 – 90	75 – 90	63	67 – 68	66	66

The daily light intensity above the maize averages 49859–55416 lux. According to Pambudi et al. (2024), light intensity affects air and soil temperatures and humidity, which, in turn, influence plant photosynthesis. The research land conditions were generally less suitable for the optimal growth needs of maize. The land conditions during the research for edamame were also less suitable, similar to those of maize plants. The daily light intensity above the edamame averages 49,922 – 50,524 lux. Edamame belongs to the C3 group, grows well under shade, and fixes nitrogen to support its growth, allowing it to be intercropped with maize, which belongs to the C4 group and requires direct sunlight (Kholid et al. 2023).

The Relationship Between Microclimate and Yield

The production yields of maize and edamame due to climate conditions that do not meet the optimal requirements of the plants are shown in Table 2.

Table 2. Production Results of Maize and Edamame

Plating Patterns	Yield(ton/ha)	
	Maize	Edamame
Monoculture	0.14	10.35
Intercropping	0.25	0.54
Intercropping + Basil	0.19	0.25
Intercropping + Lemongrass	0.15	0.14

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Correlations are used to determine the strength of the relationship between variables; the correlation becomes stronger as the correlation coefficient approaches 1. A positive correlation (1) indicates a direct relationship, while a negative correlation (-1) indicates an inverse relationship between the variables. The results of the microclimate correlation with maize and edamame yields are shown in Table 3.

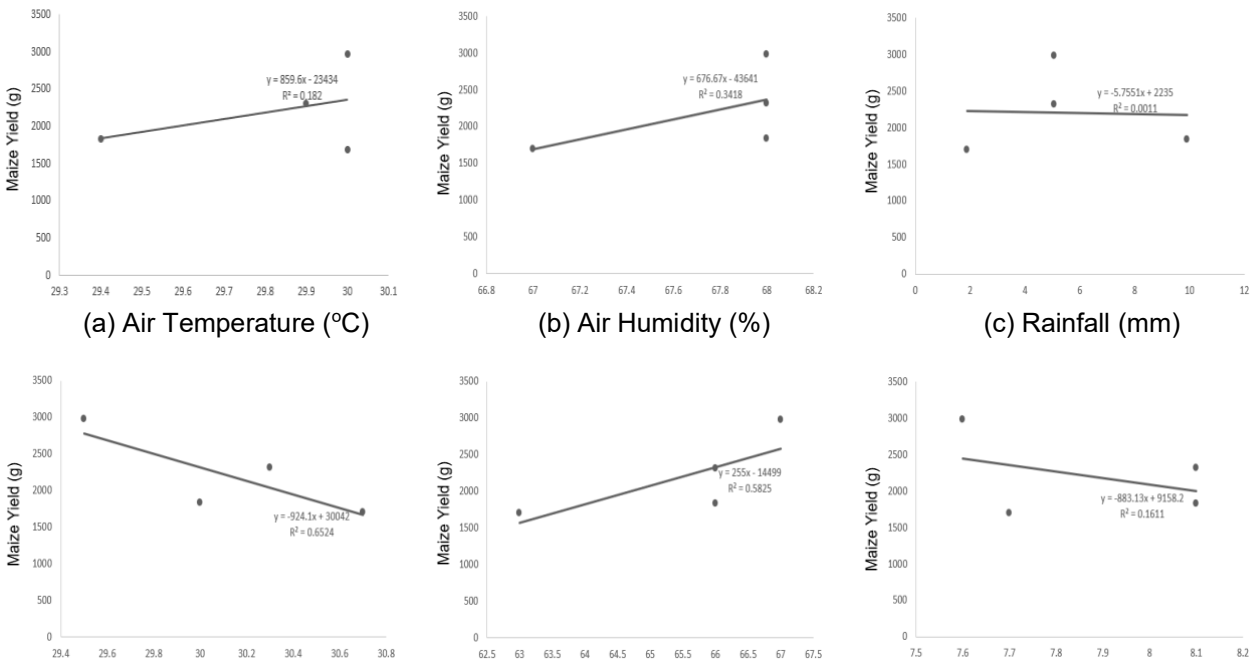
Table 3. The Relationship of Microclimate to Maize and Edamame

Climate Factor	Correlation Coefficient			
	Maize	Correlation	Edamame	Correlation
Rainfall (mm)	-0.03	Negative Very Low	-0.69	Negative Strong
Air Temperature (°C)	0.43	Positive Low	< 0	Not Related
Air Humidity (%)	0.59	Positive Medium	-0.72	Negative Strong
Soil pH	-0.40	Negative Low	-0.91	Negative Very Strong
Soil Temperature (°C)	-0.81	Negative Strong	-0.77	Negative Strong
Soil Humidity (%)	0.76	Positive Strong	0.96	Positif Very Strong

The results of the correlation analysis between the microclimate and maize indicate that soil temperature and humidity are positively correlated with maize yield. The correlation coefficient values are -0.81 and 0.76 at a 5% significance level (r-table 0.8). For edamame, the results show that pH and soil humidity correlate with edamame yield. The correlation coefficient values are -0.91 and 0.96 at a 5% significance level (r-table 0.87).

The Impact of Microclimate on Maize

Regression analysis shows that soil temperature ($R^2 = 0.65$) and soil humidity ($R^2 = 0.58$) have the greatest impact on maize yields, underscoring the importance of humidity in maintaining plant physiological balance under drought stress.



(a) Air Temperature (°C) (b) Air Humidity (%) (c) Rainfall (mm)

(d) Soil Temperature (°C) (e) Soil Humidity (%) (f) Soil pH

Figure 1. The Impact of Microclimate on Maize Yield

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The Impact of Microclimate on Edamame

The regression relationship between edamame yield and climate factors shows that soil pH (R^2 = 0.82) and soil humidity (R^2 = 0.92) significantly affect productivity. The high R^2 values indicate that the effectiveness of the cultivation system heavily relies on the balance of the soil microclimate.

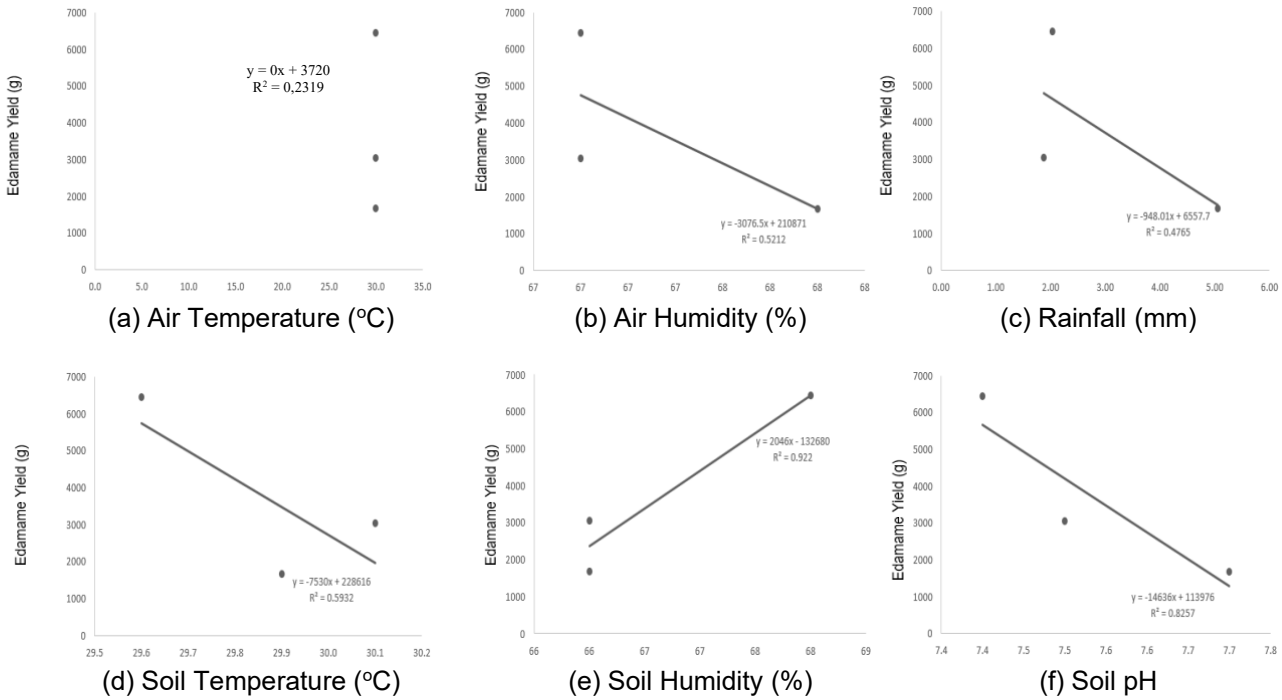

Figure 2. The Impact of Micro Climate and Edamame Yield

DISCUSSION

High light intensity affects the exposed soil by increasing soil temperature and decreasing soil humidity. Air and soil humidity in the research area are both below 70%. The low soil humidity is influenced by the low groundwater level and dry-season conditions, leading to soil drying in the cultivation area (Vien et al. 2023). According to Nurhayati and Aminuddin (2016), air humidity below 80% results in plants lacking water and minerals due to increased transpiration. The soil pH across all planting patterns is alkaline, as it is above neutral (6.5–7.0). Himarwanti (2021) states that a pH above 7.0 can reduce maize yield quality. According to Grandel (2020), alkaline soil results from cultivation land being too dry and having low rainfall. A high soil pH affects the availability of nutrients for maize growth (Yulianingsih, 2020). Alkaline soil can reduce the availability of nutrients such as zinc, phosphorus, iron, and manganese. Nutrient deficiencies can disrupt plant metabolism (Abadi et al., 2016).

The correlation results between the microclimate and maize yield indicate strong relationships between soil temperature and humidity. The significance values for the correlation between soil temperature and humidity and maize yield are -0.81 and 0.76, indicating that soil temperature has a negative correlation with maize yield; as soil temperature increases, maize yield decreases. On the other hand, soil humidity has a positive correlation with maize yield; as soil humidity increases, maize yield also increases. Furthermore, the relationship between the microclimate and maize yield was analyzed using regression equations to determine the microclimate's impact on yield. The regression

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results show that the impact of climatic factors on maize yield, specifically soil humidity, has an R2 value of 0.5825, indicating that soil humidity accounts for 58.25% of the variation in maize yield. Meanwhile, soil temperature has an R2 value of 0.6524, indicating that soil temperature accounts for 65.24% of the variation in maize yield.

Rainfall, temperature, and humidity account for 60-70% of edamame growth (Sugiantoro, 2023). Based on the observations, the land conditions are less suitable for optimal edamame growth. High temperatures lead to low environmental humidity, reducing water availability. Observations indicate that the pH during the study increased because low rainfall reduced water availability. The water content in cultivated land affects pH (Pambudi et al. 2024). pH affects the availability of both micro- and macronutrients, thereby influencing plant growth and yield (Wahyudi, 2017).

The correlation results between the microclimate and edamame yield indicate strong relationships with soil pH and moisture. The significance values for the correlations between soil pH and moisture and edamame yield are -0.91 and 0.96, respectively, indicating that soil pH negatively correlates with edamame yield; as soil pH increases, edamame yield decreases. On the other hand, soil moisture positively correlates with edamame production; as soil moisture increases, edamame production also increases. Next, the relationship between the microclimate and edamame production was analyzed using regression equations to determine the microclimate's impact on edamame yield. The regression results showed that the impact of climatic factors on edamame yield at soil pH had an R2 value of 0.8257, indicating that soil pH explains 82.57% of the variation in edamame yield. Meanwhile, soil moisture had an R2 value of 0.922, indicating that it accounts for 92.2% of the variation in edamame yield. Humidity indicates the availability of groundwater, while pH indicates the availability of soil nutrients.

CONCLUSION

The climatic conditions in the cultivation environment of each planting pattern do not meet the optimal needs of maize and edamame. Climatic factors significantly affect the yield of maize and edamame. The highest yield was found in the intercropping pattern of maize and edamame, with maize yielding 0.25 tons/ha and edamame yielding 0.54 tons/ha. The regression and correlation results between climatic factors and the yields of maize and edamame indicate that soil-climatic factors influence yield. The soil climatic factors that significantly affected maize and edamame were temperature, pH, and soil moisture at 65%, 58%, 83%, and 92%, respectively. The high R^2 value indicates that the efficiency of the cultivation system highly depends on the balance of the soil microclimate.

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