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Correlation of Soil Chemical, Biological, and Physical Characteristics on Productivity of Maize in Cibugel District, Sumedang Regency

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ABSTRACT
Maize as one of the national food commodities, experiences an increase in demand every year. Both internal and external factors influenced the growth of corn plants. Internal factors originated from the plant, such as inherited genetic traits, while external factors came from the environment, including soil properties and climate. External factors that affected plant growth included biological, physical, and chemical soil characteristics. This research aimed to understand the interrelation between soil acidity (pH), phosphorus availability (P), cation exchange capacity (CEC), nitrogen-fixing bacteria, earthworm population, carbon-nitrogen ratio (C/N), and soil texture on the productivity of maize in Cibugel District and how these factors were interconnected to support plant growth. The research employed a descriptive survey and comparative method, with soil samples taken from 18 soil samples from six villages in the Cibugel Subdistrict, Sumedang Regency. The correlation analysis results showed a significant positive relationship between cation exchange capacity and corn productivity and a significant negative relationship between available phosphorus and corn productivity. This implied that increasing cation exchange capacity could enhance productivity while increasing available phosphorus could decrease productivity. The research aided in identifying soil characteristics influencing high land productivity in the area.
Keywords: Available phosphorus; cation exchange capacity; maize; productivity.

ABSTRAK
Jagung, sebagai salah satu komoditas pangan nasional, mengalami peningkatan kebutuhan setiap tahunnya. Untuk memenuhi kebutuhan jagung, perhatian terhadap lahan menjadi kunci dalam menentukan kesuburan tanah. Pertumbuhan jagung dipengaruhi oleh faktor internal dan eksternal. Faktor internal berupa sifat genetik tanaman, sementara faktor eksternal melibatkan sifat karakteristik tanah. Penelitian ini bertujuan untuk memahami hubungan antara tingkat kemasaman tanah (pH), ketersediaan fosfor (P), kapasitas tukar kation (KTK), populasi bakteri penambat nitrogen (BPN), populasi cacing tanah, rasio karbon-nitrogen (C/N), dan tekstur tanah terhadap produktivitas jagung pipil. Metode deskriptif survei dan komparatif digunakan dengan pengambilan sampel tanah dari 18 sampel tanah di enam desa di Kecamatan Cibugel, Kabupaten Sumedang. Hasil analisis korelasi menunjukkan hubungan positif signifikan antara kapasitas tukar kation dan produktivitas jagung, serta hubungan negatif signifikan antara ketersediaan fosfor dan produktivitas jagung. Peningkatan kapasitas tukar kation dapat meningkatkan produktivitas, sementara peningkatan ketersediaan fosfor dapat menurunkannya. Penelitian ini membantu mengidentifikasi karakteristik tanah yang mempengaruhi produktivitas jagung di Kecamatan Cibugel.
Kata Kunci: Fosfor tersedia; jagung; kapasitas tukar kation; produktivitas.

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INTRODUCTION

The increasing national food demand by 1.47% annually (BPS, 2010) necessitates efforts in providing adequate agricultural land resources. If the ongoing land conversion is not balanced with the establishment of new agricultural land, a serious threat to food security may arise. Data from BPS (2021) indicates that the national productivity of corn reaches 57.09 tons per hectare, with West Java Province, particularly Sumedang Regency, contributing the highest productivity. In Indonesia, corn plays a crucial role as a staple food and is the second most important food commodity after rice. Corn (Zea mays L.) serves as a vital protein source for the Indonesian population and provides essential dietary fiber. Corn also contains minerals such as calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), phosphorus (P), and iron (Fe), as well as essential fatty acids, isoflavones, and other components (Suarni, 2009). The type of agricultural land used for growing corn significantly contributes to its productivity. To achieve optimal productivity in suboptimal land, it is essential to understand the factors influencing the growth of corn plants.

The growth of corn plants is influenced by two main factors: internal and external factors. Internal factors encompass the genetic traits inherited by the plants, while external factors involve environmental conditions, including soil and climatic characteristics. External factors in plant growth involve various aspects, such as biological, physical, chemical, and climatic factors. The plant's response to environmental conditions is a crucial element that can affect the growth and yield of crops (Soleymani, 2017).

All soil properties, involving physical, chemical, and biological play a crucial role in regulating the plant growth process, which, in turn, affects the quantity and quality of crops. Neglecting these aspects can result in suboptimal plant growth due to unmet basic needs. To identify the main growth factors with the greatest influence on corn plant growth, a land analysis considering the characteristics of soil biological, chemical, physical, and climatic properties is required. Conducting this analysis based on these characteristics will serve as a key determinant in understanding the factors driving corn plant growth in suboptimal land. Thus, an understanding of the primary factors influencing corn productivity and the necessary agricultural inputs in such lands in Sumedang Regency can be obtained.

MATERIALS AND METHODS

Time and Location of the Study

This research was conducted in six villages scattered across the Cibugel District, Sumedang Regency, at an elevation of approximately ±750 meters above sea level (masl) during the period from September 2022 to March 2023. Sample collection included the characteristics of land, the variety of corn plants used (NK Sumo 7238 dent corn), and soil processing techniques.

Material

In this study, various field equipment was employed, comprising tools such as the Munsell soil color chart, geological compass, bore, shovel, hoe, field knife, plastic zipper bags, labels, writing tools, camera, sample rings, and the Global Positioning System (GPS). Additionally, laboratory equipment utilized included beakers, measuring glasses, pH meter, analytical balance, Berkefeld filter, shaking machine, conductivity meter, clinometer, rack, as well as studio necessities like Microsoft Office Word and Excel. The ArcGIS application was also employed for spatial and statistical data analysis. The research materials encompassed administrative maps, working maps, slope maps, elevation maps, and climate maps.

Method

This study employed survey, descriptive, and comparative methodologies based on the distinctions in Soil Mapping Units (SPL). The establishment of SPLs involved overlaying maps such as slope charts, climate representations, and elevation diagrams. One observation point was selected as a representative for each unique land unit to facilitate field data collection. The research process was segmented into three phases: pre-survey, survey, and post-survey. In the pre-survey phase, activities encompassed gathering secondary data, crafting SPL maps, and determining observation points based on SPL variations and accessibility. In this context, 18 observation points were identified at the research site. Field data collection transpired during the survey stage, where land characteristics were scrutinized through physiographic and morphological land examinations. This stage also involved field data collection during the survey. Field assessments were conducted by scrutinizing land morphology, soil traits, and zig-zag soil sampling to scrutinize soil features, encompassing physical, chemical, and biological properties. The method applied was composite sampling to discern physical and chemical properties, along with rhizosphere soil sampling to ascertain biological features at specific points with equivalent volume and timing. Five distinct points on a piece of land were chosen for soil sampling. Each soil specimen was subsequently examined at the Soil Physics Laboratory, Soil Biology Laboratory, and Soil Fertility and Plant Nutrition Laboratory of the Department of Soil Science and Land Resources, Faculty of Agriculture, Universitas Padjadjaran. Corn plant production data in the field were quantified by generating a 1 x 1 m grid map on mature crops. Following this, the harvested weights in the plot were documented and converted into per-hectare units. In the post-survey phase, the soil samples obtained underwent analysis in the laboratory. Laboratory analyses encompassed texture scrutiny (pipette method), pH (H2O), cation exchange capacity (destilation method), Organic C (Walkley & Black) (Association of Official Agriculture Chemists, 2002), P2O5 (P-Bray1) (Bray and Kurtz, 1945), earthworm population, BPN population (total plate count), and total N (macro Kjeldahl distillation).

RESULTS AND DISCUSSION

Research Location

The study was conducted in Cibugel Sub-district, Sumedang Regency, comprising six villages with a total area of 54 hectares. According to BPS data (2020), the population growth is recorded at 1.29% per year. Cibugel is bordered by Sukaraja, Jayamandiri, Buanamekar, Cibugel, Cipasang, Jayamekar, and Tamansari villages. Soil samples were collected at three points in each village using the composite sampling method with uniform land criteria.

Climate Characteristics

The Cibugel Sub-district receives a monthly rainfall of approximately 314-379 mm and more than 200 mm annually. It is classified as the Oldeman (1975) climate type with a wet season lasting for 3-4 consecutive months. The results from kriging interpolation using the ArcGIS application indicate three temperature classes in Cibugel Sub-district: 22.4 °C, 23.2 °C, and 23.7 °C. The majority of the Cibugel Sub-district is situated at elevations ranging from 500-1000 meters above sea level (masl), with some points in Jayamekar Village and Buanamekar Village reaching 1000-1500 masl. According to BPS data (2020), most of this area is characterized by highlands, with Buanamekar Village having slope/peak characteristics.

Soil Characteristics

Based on the conducted research, the Cibugel Sub-district has three soil orders: Entisol, Andisol, and Inceptisol. Andisol soil exhibits characteristics of high organic matter (>3%), light texture, friability, low bulk density (<0.9 g/cm¬2), and high P retention (>85%). Andisol is typically found in regions with aquic, udic, and ustic moisture regimes. In contrast, Inceptisols have undergone horizon formation, indicating structural development, although they are still considered immature soils. Inceptisol soil profiles possess properties of parent material that are not fully mature. These soils have medium to high nutrient content, black or grayish color, with a soil depth reaching 1-2 meters. The soil structure is crumbly and friable. The distribution of Entisol soil groups in Cibugel Sub-district is suspected to be related to the presence of volcanic slopes on Mount Simpay in Sukaraja Village, influencing the region's mountainous relief topography.

Corn Productivity

According to the 2021 West Java Open Data (Table 1), the total corn productivity is 1,569.5 kw/ha, showing a 7.83% increase with an average annual corn productivity value of 1,398.86 kw/ha over the past 7 years. In 2021, Sumedang Regency had the highest corn productivity value, reaching 91.11 kw/ha.

Table 1. Corn Plant Productivity

Scale of the region	Productivity (Ku/ha)						Average
	2016	2017	2018	2019	2020	2021	
Nasional	52.2	52.3	53.3	55.2	54.74	57.09	54.14
Sumedang Regency	80.53	75.06	76.96	77.23	69.86	91.11	78.45
Cibugel District	75.75	67.45	75.28	72.19	73.39	69.01	72.18

Source: Field Data from the Technical Implementation Unit of Agriculture in Cibugel Sub-district, Department of Agriculture, Sumedang Regency (2022), Open Data West Java.

The national agricultural productivity has been consistently increasing over time, reflecting efforts towards improvement and efficiency in the sector. Sumedang Regency, in particular, has a higher productivity rate than the national average. In 2016, the productivity in Sumedang Regency reached 80.53 kg/ha, reaching its peak at 91.11 kg/ha in 2021, becoming the highest in West Java Province. Despite fluctuations in corn plant productivity in Sumedang Regency, overall, the productivity values have been increasing, indicating positive progress. Cibugel Sub-district, as the corn production center in the regency, experienced fluctuations in productivity during the period of 2016-2021. In 2016, corn productivity in Cibugel Sub-district reached 75.75 kg/ha, experiencing a decline in the following years. This data was obtained through the grid mapping method verified by the Technical Implementation Unit of Agriculture in Cibugel Sub-district (Tabel 2).

Table 2. Corn Plant Productivity in Cibugel Sub-district, 2023

No	**Village**	**Maize productivity (Ku/ha)**
1.	Cipasang 1	99,03
2.	Cipasang 2	76,05
3.	Cipasang 3	96,28
4.	Sukaraja 1	100,32
5.	Sukaraja 2	87,38
6.	Sukaraja 3	90,62
7.	Cibugel 1	92,23
8.	Cibugel 2	87,38
9.	Cibugel 3	96,28
10.	Jayamekar 1	61,49
11.	Jayamekar 2	63,11
12.	Jayamekar 3	65,53
13.	Buanamekar 1	69,58
14.	Buanamekar 2	63,11
15.	Buanamekar 3	72,01
16.	Jayamandiri 1	98,71
17.	Jayamandiri 2	101,94
18.	Jayamandiri 3	104,86

Source: Technical Implementation Unit of Agriculture in Cibugel Sub-district

Table 3. Pearson Correlation Among Parameters

	BPN	Cacing	PH	KTK	CN	P tersedia	Pasir	Debu	Liat	Produktivitas
BPN	1.00	0.33	0.34	-0.01	0.22	-0.29	-0.29	-0.11	0.40	0.14
Cacing	0.33	1.00	0.02	-0.06	0.16	-0.35	-0.14	-0.27	0.39	0.32
pH	0.34	0.02	1.00	0.22	-0.22	0.19	0.27	-0.25	-0.06	0.26
KTK	-0.01	-0.06	0.22	1.00	-0.24	0.54 *	0.30	-0.26	-0.08	0.24
CN	0.22	0.16	-0.22	-0.24	1.00	-0.44	-0.06	-0.34	0.37	0.07
P tersedia	-0.29	-0.35	0.19	0.54 *	-0.44	1.00	0.51 *	0.07	-0.60 *	-0.36
Pasir	-0.29	-0.14	0.27	0.30	-0.06	0.51 *	1.00	-0.48 *	-0.60 *	0.08
Debu	-0.11	-0.27	-0.25	-0.26	-0.34	0.07	-0.48 *	1.00	-0.41	-0.42
Liat	0.40	0.39	-0.06	-0.08	0.37	-0.60 *	-0.60 *	-0.41	1.00	0.29
Produktivitas	0.14	0.32	0.26	0.24	0.07	-0.36	0.08	-0.42	0.29	1.00

**Based on Pearson Correlation Analysis, the table above shows several significant correlations (r > 0.5)

Table 4. Land Characteristics

No Sampel	BPN (CFU/mL)	Cacing	pH	KTK (cmol/kg^{-1})	CN	P tersedia (ppm)	Pasir (%)	Debu (%)	Liat (%)	Produktivitas (Ku/ha)
1	1.38 x 10^8	24.00	5.21	10.72	4.62	7.93	13.36	34.55	52.09	9903
2	1.95 x 10^8	27.00	5.28	11.18	7.85	7.75	11.4	35.7	52.9	7605
3	1.895 x 10^8	29.00	5.58	15.51	6.18	12.75	21.29	32.41	46.3	9628
4	1.145 x 10^8	28.00	5.25	9.30	6.90	11.27	28.89	32.7	38.42	10032
5	1.75 x10^8	30.00	5.32	11.50	10.01	8.12	22.47	25.84	51.68	8738
6	1.56 x 10^8	27.00	5.32	10.08	8.27	9.42	14.07	40.34	45.58	9062
7	1.22 x 10^8	29.00	5.45	14.06	4.78	12.20	31.71	34.47	33.82	9223
8	1.32 x 10^8	30.00	5.10	16.30	7.73	12.57	15.44	35.36	49.2	8738
9	0.545 x 10^8	25.00	5.24	14.49	5.50	11.27	20.87	36.4	42.73	9628
10	0.965x 10^8	22.00	5.23	12.86	5.09	13.49	15.71	42.83	41.46	6149
11	0.895 x 10^8	29.00	5.26	13.08	4.56	17.39	22.98	36.28	40.74	6311
12	1.9 x 10^8	32.00	5.38	11.43	5.23	14.79	18.95	40.52	40.52	6553
13	1.09 x 10^8	35.00	5.17	10.23	8.52	9.04	23.07	31.64	45.3	6958
14	1.605 x 10^8	30.00	5.05	9.51	6.27	8.30	14.1	45.3	40.6	6311
15	1.32 x 10^8	31.00	5.40	9.01	5.23	8.67	14.52	33.28	52.2	7201
16	1.355 x 10^8	45.00	5.22	9.92	8.01	6.64	13.56	31.73	54.71	9871
17	1.68 x 10^8	40.00	5.33	10.50	5.50	6.26	7.69	43.91	48.41	10194
18	1.95 x 10^8	41.00	5.32	16.40	5.20	11.08	21.7	26.31	51.98	10486

Source: Laboratory Analysis Results in 2023

Table 5. Pearson Correlation between Land Characteristics and Corn Productivity

Variabel 1	Variabel 2	Korelasi R	Nilai-P
BPN	Produktivitas	0.14	0.572
Cacing	Produktivitas	0.32	0.201
PH	Produktivitas	0.26	0.307
KTK	Produktivitas	0.24	0.347
CN	Produktivitas	0.07	0.781
P tersedia	Produktivitas	-0.36	0.140
Pasir	Produktivitas	0.08	0.751
Debu	Produktivitas	-0.42	0.086
Liat	Produktivitas	0.29	0.235

Correlation Analysis Among Parameters

Tabel 3, There is a strong positive correlation between Cation Exchange Capacity and P availability, indicated by an r value of 0.54. The application of organic fertilizers in the research location can enhance soil nutrition, organic carbon, and Cation Exchange Capacity, while reducing P fixation in the soil. As a result, phosphorus becomes more available for plants. This finding aligns with previous research by Elesta and colleagues (2022), stating that organic fertilizer application can increase soil Cation Exchange Capacity due to the high humus content resulting from fertilizer application. It also enhances P availability because of the nutrient content, especially P_2O_5, present in organic fertilizers. Fertilizer application will release P that is fixed in acidic soils in the research location, as Al, Fe, and Ca ions in the soil solution can bind with organic anions derived from soil organic matter. Consequently, the concentration of Al, Fe, and Ca ions interacting with available P decreases, increasing P availability for plants.

Correlation Analysis between Land Characteristics and Corn Productivity

There is no significant correlation (Tabel 5), between variable 1 (as the independent variable Tabel 4) and variable 2 (as the dependent variable) at a confidence level of 0.05. The P-value is an indicator of the probability of a relationship between two variables in the sample; the table indicates that a high P-value suggests that the relationship between the variables does not reach an accepted level of significance (0.05) due to a lack of evidence to conclude that the relationship is statistically significant. A small sample size and high variability in the data may contribute to the low significance level of the data.

Correlation Analysis of Available P with Corn Productivity

Figure 1. Scatterplot of Available P with Corn Productivity

In soil environments, the availability of phosphorus (P) reaches its peak when the pH value is in the range of 5.5 to 7.0. If the pH exceeds or falls below this range, the P content may decrease. Acidic soils will have available P in the form of HPO42- ions, while in neutral soils, P will be present in the form of HPO42-. Although only about 0.1% to 1% of P in the soil can be absorbed by plants, the rest is bound and unavailable to plants. Phosphorus (P) availability in soil tends to be lower compared to other nutrients, especially in acidic soils where P can easily be adsorbed by other elements. The correlation between P availability and corn productivity shows an r value of -0.36, indicating a negative relationship. This means that the higher the P availability, the lower the corn productivity, as the available P is difficult for plants to absorb. Pearson correlation also reveals a positive relationship between P availability and cation exchange capacity, with an r value of 0.54. This indicates that as P availability increases, cation exchange capacity will also increase.

Correlation Analysis of Cation Exchange Capacity (CEC) with Corn Productivity

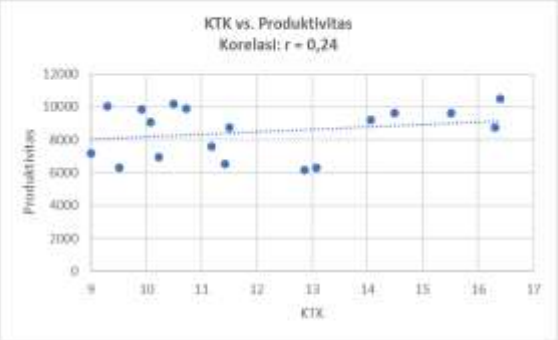

Figure 2. Scatterplot of Cation Exchange Capacity (CEC) with Corn Productivity

The correlation analysis between cation exchange capacity (CEC) and corn plant productivity shows an r value of 0.24, indicating a weak correlation between cation exchange capacity and corn productivity (see Figure 2). From the Pearson correlation results, the relationship between cation exchange capacity and rainfall has an r value of -0.16, indicating that the correlation between cation exchange capacity and rainfall is not statistically significant or is weak. This finding aligns with the research by Syahidar Khalid (2019), stating that high rainfall can impact nutrient availability in the soil, including cation exchange capacity, where high rainfall can lead to nutrient loss in the soil and reduce cation exchange capacity availability.

Stepwise Regression Analysis of Soil Characteristics

Table 6. Multiple Linear Regression Equation Using Stepwise Method

Regression Equation:
Y = 7597,5209 + 382,0469*KTK - 353,1106*P tersedia
R^2 = 0,391; r = 0,625; R^2 Terkoreksi = 0,310
F = 4.818; Sig = 0.02

The results of multiple regression analysis indicate that there are two independent variables that have a significant impact on corn plant productivity, namely phosphorus (P) availability and cation exchange capacity. The constant has a value of 7597.5209 with a P-value of 0.024 at a 95% confidence level. According to the regression analysis results, Cation Exchange Capacity and phosphorus availability are the main factors influencing corn productivity. The coefficient for Cation Exchange Capacity is 382.0469 (P-value = 0.023), while phosphorus availability has a coefficient of -353.1106 (P-value = 0.012). This means that an increase in Cation Exchange Capacity will increase corn productivity, while an increase in phosphorus availability will decrease corn productivity. The R2 value of 0.391 indicates that Cation Exchange Capacity and phosphorus availability contribute 39.1% to the variation in corn productivity.

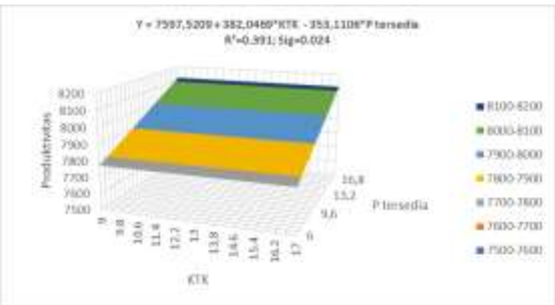

Figure 3. Multiple Linear Regression of Available P and Cation Exchange Capacity (CEC) on Corn Productivity.

CONCLUSION

Based on the research conducted in Cibugel Sub-district, it can be concluded that the availability of phosphorus (P) and cation exchange capacity significantly influence corn plant productivity. A positive relationship was identified between cation exchange capacity and corn productivity, while a negative relationship exists between phosphorus availability and corn productivity. Multiple linear regression analysis indicates that available P and cation exchange capacity have the most significant influence, contributing approximately 39.1% to the variation in corn productivity. These findings are crucial for designing land management strategies in Cibugel Sub-district, emphasizing the optimization of phosphorus availability and cation exchange capacity to enhance corn productivity.

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