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Cultivation Practices on the Productivity of Aloe vera (*Aloe vera* L.) Leaves in Pontianak City

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ABSTRACT

This study was undertaken to determine the effect of the implementation of various cultivation factors; fertilization (X_1), plant spacing (X_2), weeding (X_3), seed selection (X_4), hilling (X_5), leaf harvesting (X_6) and pest control (X_7) on the productivity of aloe vera leaves in Pontianak city, West Kalimantan. The research took place from June to December 2023. The results indicated that plant population, ash application, manure, pruning frequency, and harvesting frequency had very significant effects on aloe vera productivity, while urea and KCl fertilization had only significant effects. However, bed height, plant spacing per bed, seedling leaf count, seedling age, lime application, SP-36 fertilizer and pest control had no significant effects. The application rates were 932.25 kg/ha for ash, 133.00 kg/ha for urea, 209.38 kg/ha for KCl and 1.134 t/ha for manure. The greatest direct effect of cultivation practices on aloe vera productivity was from the harvesting frequency, with a contribution of 38.76%, followed by leaf pruning frequency (13.26%), ash application (13.19%), manure (5.69%), urea (2.05%) and KCl (2.02%). The indirect effects of urea, KCl and manure on productivity, mediated through ash, were found to be greater than their direct effects.

Key words: *Aloe vera*, Pontianak, practices, productivity

INTRODUCTION

The aloe vera (*Aloe vera* L.) plant, a succulent known globally as an important medicinal and ornamental plant, has long been recognized in Indonesia for its use as a remedy for various ailments (Kumar *et al*., 2019). Recently, this plant has gained increasing popularity due to its expanding benefits, such as being a source for raw materials used in the food, pharmaceutical and cosmetic industries (Maan *et al*., 2018). Today, various aloe vera products can be found in shops, stores, pharmacies, restaurants, supermarkets and online, indicating economic opportunities and potential benefits for national economic improvement (Martínez-Sánchez *et al*., 2020). Aloe vera has proven to adapt much better in West Kalimantan than in other regions. This has been acknowledged by international aloe vera experts, who lament that Indonesia has not fully utilized the comparative advantages of this plant (Ramadhia and Ichsan, 2018). The global, or at least regional, market interest in Indonesian aloe vera needs to be addressed through various programs supporting its cultivation, processing into agro-industrial products and marketing both domestically and internationally (Cristiano *et al*., 2016).

The components in aloe vera have numerous benefits for health, beauty and nutrition, such as for hair care, wound healing, skin care and health food and beverages. Aloe vera is also effective in lowering blood sugar levels for diabetic patients, controlling blood pressure, stimulating the immune system against cancer and strengthening body functions (Kaur, 2017; Saha *et al*., 2021).

Aloe vera gel contains various substances beneficial to human health, including minerals such as potassium, calcium, zinc, cobalt and chromium, vitamins A, B6, B12, C, E, niacin, choline, essential and non-essential amino acids, polysaccharides, saponins, lignins and anthraquinones (Nazir and Ahsan, 2017; Kaparakou *et al*., 2020). These substances are useful for tissue regeneration, formation, and replacement, metabolic regulation and nerve function. Additionally, Aloe vera contains glucose, mannose, aldonentose, L-rhamnose, and several enzymes such as amylase, catalase, lipase, lysine, threonine, valine, methionine, leucine, isoleucine, and phenylalanine (Rahman *et al*.,

2017; Liang *et al*., 2020). Aloe vera's benefits include acting as a hair tonic that strengthens and stimulates hair growth, smoothing the skin, treating burns, cleaning teeth, acting as an anthelmintic to expel worms and as an expectorant to clear mucus and ease coughs (Hekmatpou *et al*., 2019).

Aloe vera production in 2023 was 2,324,114 kg, in 2022 was 2,525,493 kg and in 2021 was 14,224,207 kg (BPS, 2024). There has been a decrease in aloe vera production from 2021 to 2023. Generally, a plant's yield is determined by environmental factors, plant genetics and maintenance. Environmental factors include soil and climate, while genetic factors relate to the characteristics of the plant material used. Maintenance factors cover fertilization, pest and disease control and related activities. Among the various cultivation practices carried out by farmers, some have influenced the increase in aloe vera leaf production (Billah *et al*., 2023). Therefore, research was needed to determine which agronomic practices should be reviewed for their impact on improving aloe vera leaf productivity.

MATERIALS AND METHODS

This research was conducted on aloe vera farms in north Pontianak district, Pontianak city, west Kalimantan Province, from June to December 2023. The primary data were gathered directly by the researcher through interviews with aloe vera farmers as respondents using a questionnaire. All aloe vera farmers in north Pontianak, totalling 40 farmers or heads of households (KK), were included.

The data analysis needed to determine the effect of cultivation techniques on aloe vera productivity in Pontianak city involved multiple regression analysis with dummy variables.

Cross-sectional coefficient analysis was used to examine the causal relationship between cause and effect variables. In this analysis, correlation coefficients were partitioned into the direct effects of the cause variables and the indirect effects transmitted through other lower-level variables.

RESULTS AND DISCUSSION

The multiple regression analysis on the effect of cultivation practices on aloe vera productivity showed that the combined effect of cultivation practices including bed height, plant spacing per bed, seedling leaf count, seedling age, plant population, lime application, ash, urea fertilizer, SP-36, KCl, manure, leaf pruning frequency and harvesting frequency had a very significant effect ($P < 0.01$) with a 96.1% and coefficient of determination (R^2). This indicated that the multiple regression model was very effective in explaining the contribution of independent variables (X = cultivation practices) to the variability in productivity (Y). The coefficient of determination showed that the model explained 96.1% of the variability in productivity due to cultivation practices, with 3.9% remaining unexplained by the model (Table 1).

Table 1. Results of partial regression analysis of cultivation practices on aloe vera productivity

Predictor	Coefficient regression	Standard error	t	P
Constant	-10.568	4.577	-2.31	0.030^{NS}
Bed height (X_1)	-0.02943	0.04512	-0.65	0.520^{NS}
Rows/plot (X_2)	-0.2498	0.4072	-0.61	0.545^{NS}
No. of seedling lesaves (X_3)	-0.0718	0.6153	-0.12	0.908^{NS}
Seedling age (X_4)	-0.2366	0.3484	-0.68	0.503^{NS}
Population (X_5)	0.00040721	0.000086	4.76	0.000**
Lime (X_6)	0.1867	0.5795	0.32	0.750^{NS}
Aloe vera leaf ash (X_7)	0.0022370	0.0005956	3.76	0.001**
Urea (X_8)	0.008127	0.003586	2.27	0.032*
SP-36 (X_9)	0.011697	0.006244	1.87	0.073^{NS}
KCl (X_{10})	0.003620	0.001692	2.14	0.042*
Manure (X_{11})	0.0008788	0.0002818	3.12	0.005**
Leaf pruning frequency (X_{12})	1.6625	0.4231	3.93	0.001**
Pest control (X_{13})	0.2540	0.5034	0.50	0.618^{NS}
Harvest frequency (X_{14})	6.280	1.243	5.05	0.000**

NS–Not significant. *,**Significant at P=0.05 and P=0.01, respectively.

The partial regression analysis indicated that plant population, ash application, manure, pruning frequency and harvesting frequency each had a very significant effect ($P < 0.01$) on aloe vera productivity, while urea and KCl fertilizers had only a significant effect ($P < 0.05$). In contrast, bed height, plant spacing per bed, seedling leaf count, seedling age, lime application, SP-36 fertilizer and pest control did not have a significant effect.

The results of the partial regression analysis showed that ash and manure each had a very significant effect ($P < 0.01$), while urea and KCl fertilizers each had a significant effect ($P < 0.05$) on aloe vera productivity. In contrast, lime application did not have a significant effect ($P > 0.05$). The average amounts of urea, SP-36, KCl, ash and manure applied can be seen in Table 2.

Table 2. Amounts of urea, SP-36, KCl and manure applied to aloe vera plants

Fertilizer type	Range (kg/ha)	Amounts (kg/ha)
Urea	0-300	133.00
SP-36	0-125	17.63
KCl	0-800	209.38
Ash	30-3.500	932.25
Manure	0-5.000	1.134.00

The application of urea fertilizer increased the productivity of the plants (Fig. 1). According to the regression equation, each additional unit of urea (1 kg of urea) increased aloe vera leaf productivity by 0.035 t/ha. The average application rate of urea fertilizer was 133.00 kg/ha. 95% farmers used urea as fertilizer. Contrarily, the application of SP-36 fertilizer did not show a significant effect on aloe vera productivity. Only 25% of farmers used SP-36 fertilizer. The average application rate of SP-36 fertilizer was 17.63 kg/ha.

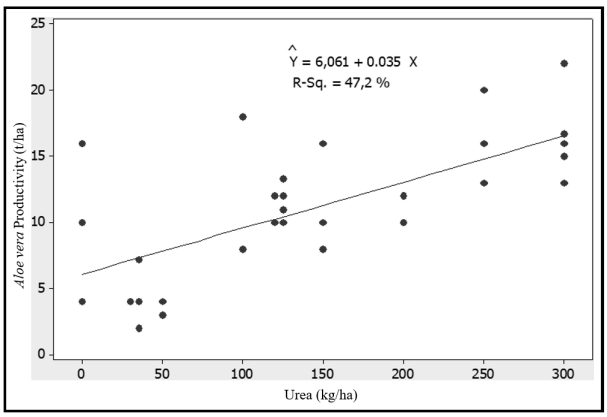

Fig. 1. Relationship between urea fertilization and aloe vera plant productivity.

In contrast, the application of KCl fertilizer showed a significant positive effect on aloe vera productivity, with application rates ranging from 0 to 800 kg/ha and an average of 209.38 kg/ha. The regression analysis indicated a very significant positive linear relationship between KCl fertilizer and productivity (Fig. 2). This indicated that higher KCl fertilizer application results in increased productivity, making KCl fertilizer highly necessary. It was also noted that a larger proportion of farmers used KCl fertilizer, reflecting its perceived importance. According to the regression equation, each additional unit of KCl fertilizer (1 kg) was estimated to increase aloe vera leaf productivity by 0.018 t/ha. Hence, 95% farmers used KCl fertilizer.

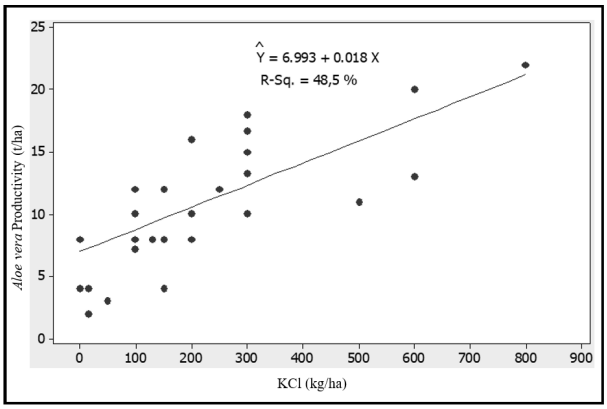

Fig. 2. Relationship between KCl fertilization and aloe vera plant productivity.

The application of manure showed highly significant effect on aloe vera productivity, with application rates ranging from 0 to 5 t/ha and an average application of 1.134 t/ha (Fig. 3). Regression analysis indicated highly significant positive linear relationship between manure application and productivity. According to the regression equation, each additional unit of manure applied (1 kg of manure) increased aloe vera leaf productivity by 0.003 t/ha. Among the farmers, 80% used manure.

The application of aloe vera leaf ash showed a significant positive effect on aloe vera productivity, with application rates ranging from 0 to 800 kg/ha and an average of 932.25 kg/ha. Regression analysis indicated a very significant positive linear relationship between aloe vera leaf ash and productivity (Fig. 4). According to the regression equation,

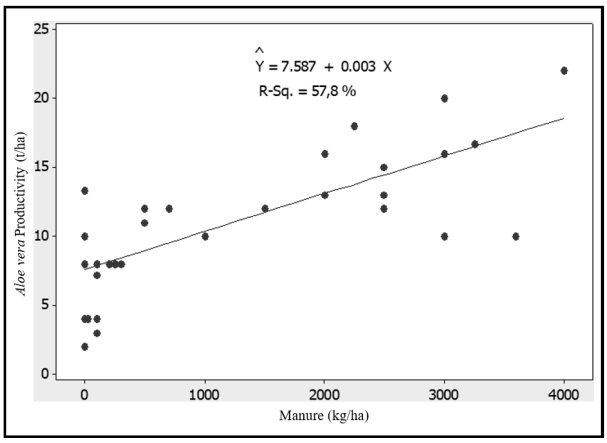

Fig. 3. Relationship between manure fertilization and aloe vera plant productivity.

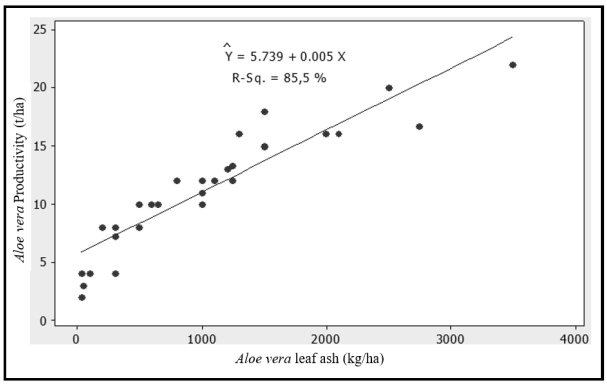

Fig. 4. Relationship between aloe vera leaf ash fertilization and aloe vera plant productivity.

each additional unit of aloe vera leaf ash applied (1 kg of ash) increased aloe vera leaf productivity by 0.005 t/ha.

The lime application had a significant effect ($P > 0.05$) on aloe vera productivity. Most aloe vera farmers did not apply lime (95%). The type of lime used was Dolomite lime. Pest control activities included managing pests, diseases and weed removal. Aloe vera diseases were generally not severe, but if there were wounds on the leaves or petioles, there was a high likelihood of infection by rot fungi or root rot caused by excessively moist soil. The partial regression analysis results indicated that pest control activities had non-significant effect ($P > 0.05$) on aloe vera productivity. Among aloe vera farmers, 72.5% practised pest control.

In intensively cared for aloe vera plants, disease symptoms were rarely observed. Infected plants were usually destroyed immediately to prevent spread of disease. Subsequent maintenance included weed removal and managing off shoots. Weeding was performed before supplementary fertilization, but it was typically done as soon as weeds were observed around the aloe vera plants. Weeding was done manually, and it was accompanied by cleaning the furrows between beds and raising soil that had settled from the beds.

This diligent approach ensured that the plants remained healthy and productive. Studies had shown that effective weed management was crucial for maximizing crop yield, as weeds competed with crops for essential nutrients, light and water. The manual weeding process not only helped in controlling unwanted vegetation but also contributed to maintaining soil structure and fertility, which are vital for plant growth.

With the availability of nutrients in sufficient quantities, the physiological processes within the plant will improve. The nutrients N, P and K are essential for plant growth, particularly during the vegetative phase, which includes the formation of stems, leaves and roots. Macronutrients such as N, P and K are crucial for the synthesis of proteins, fats, and various organic compounds that stimulate growth (Oldroyd and Leyser, 2020; Saloner and Bernstein, 2020). Partial regression analysis showed that the application of urea as a source of nitrogen (N) and KCl as a source of potassium (K) had a significantly positive effect on the productivity of aloe vera plants, except for SP-36 fertilizer as a source of phosphorus. This indicated that nitrogen and potassium were essential for the vegetative growth of plants.

Correlation analysis among cultivation variables ash, urea, KCl, manure and leaf weight exhibited a very significant positive linear relationship with productivity. In contrast, seedling leaf count, pruning frequency and harvesting frequency each showed a positive linear relationship with productivity. Bed height, plant spacing per bed, plant population, lime, SP-36 fertilizer and pest control had a non-significant correlation. The correlations between ash, urea, KCl and manure showed a significant relationship with leaf weight per leaf. While correlation analysis demonstrated the strength of relationships between variables, it did not fully capture causation. Therefore, cross-sectional coefficient analysis was used to break down correlation coefficients into two components: direct effects of cause variables and indirect

effects mediated through other lower-level variables.

The most significant direct influence of cultivation practices on aloe vera productivity was the frequency of harvest (38.76%), followed by the frequency of leaf pruning (13.26%), the application of ash (13.19%), manure (5.69%), urea (2.05%) and KCl (2.02%). The indirect influence of ash on productivity transmitted through urea was 0.645 × 0.143 = 0.092, through KCl was 0.707 × 0.142 = 0.100 and through manure was 0.768 × 0.239 = 0.184. Thus, the direct effect of applying ash on productivity remained greater compared to its indirect effects through urea, KCl and manure (Table 3 and Fig. 5).

The indirect effect of urea transmitted through ash was 0.645 × 0.363 = 0.234, through KCl was 0.589 × 0.142 = 0.084 and through manure was 0.618 × 0.239 = 0.148. The coefficient analysis showed that the indirect effect of urea became more significant when transmitted through ash and manure. The indirect effect of KCl transmitted through ash was 0.707 × 0.363 = 0.257, through urea was 0.589 × 0.143 = 0.084 and through manure was 0.515 × 0.239 = 0.123. It can be concluded that the indirect effect of KCl on productivity was more pronounced when transmitted through ash. The indirect effect of manure transmitted through ash was 0.768 × 0.363 = 0.279, through urea was 0.618 × 0.143 = 0.088 and through KCl was 0.515 × 0.142 = 0.073. The indirect effect of manure on productivity was more significant when transmitted through ash.

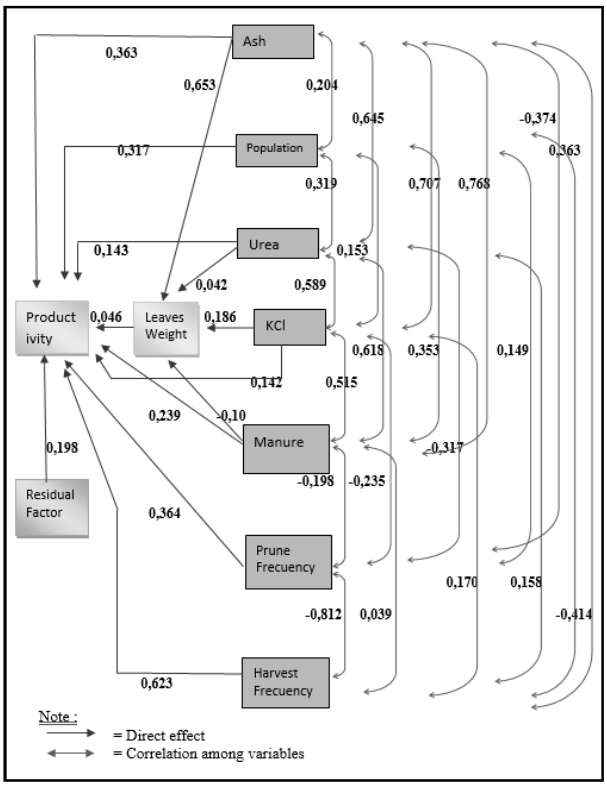

Fig. 5. Cross-sectional coefficient analysis of cultivation variables on aloe vera productivity.

Correlation analysis indicated a very significant relationship between ash, urea, KCl and manure with leaf weight per leaf.

Table 3. Cross-sectional coefficient analysis of direct effects of cultivation variables on aloe vera productivity

Variables	Coefficient (bi)	Standard deviation (Si)	Cross-sectional coefficient (pi)	Coefficient of determination (R^2)
		Productivity		
Bed height	-0.02428	4.641	-0.024	0.06
Spacing per bed	-0.2908	0.641	-0.040	0.16
Seedling leaves	-0.0524	0.3848	-0.004	0.00
Seedling age	-0.1534	0.744	-0.024	0.06
Plant population	0.00042384	3487	0.317	10.04
Lime	0.2031	0.4743	0.021	0.04
Aloe vera leaf ash	0.0020936	809	0.363	13.19
Urea	0.007283	91.8	0.143	2.05
SP-36 fertilizer	0.010669	35.79	0.082	0.67
KCl	0.003620	183.2	0.142	2.02
Manure	0.0008623	1290	0.239	5.69
Pruning frequency	1.568	1.083	0.364	13.26
Pest control	0.1271	0.4522	0.012	0.02
Harvesting frequency	6.122	0.4743	0.623	38.76
Leaf weight	0.882	0.2428	0.046	0.21
		Leaf weight		
Aloe vera leaf ash	0.00019605	809	0.653	42.67
Urea	0.0001099	91.8	0.042	0.17
KCl	0.0002221	183.2	0.168	2.81
Manure	-0.00001883	1290	-0.100	1.00

Coefficient analysis showed that the direct contribution of ash was higher (42.67%) compared to urea (0.17%), KCl (2.81%) and manure (1.00%).

Application of ash, urea, KCl and manure each showed a positive linear relationship with aloe vera productivity, whereas bed height, row spacing per bed, plant population, lime, SP-36 fertilizer and pest and disease control had non-significant correlations. This indicated that cultivation practices had a strong relationship with aloe vera productivity. According to cross-coefficient analysis, the most significant direct influence on productivity was the frequency of harvest with a contribution of 38.76%, followed by the frequency of leaf pruning (13.26%), ash application (13.19%), manure (5.69%), urea (2.05%) and KCl (2.02%). The frequency of harvest had the greatest effect on productivity. Increasing the number of harvests will also increase plant productivity. However, for continuous growth, the supporting elements need careful attention in providing essential nutrients for the plants.

Application of ash, urea, KCl and manure each had a direct effect on productivity. Among these, ash had the largest direct effect. The indirect effects of urea, KCl and manure on productivity, when transmitted through ash, were more significant than their direct effects. Thus, the role of urea, KCl and manure was more evident when combined with ash. Observations showed that farmers applied ash, urea and KCl together before planting. The combination of ash with urea, KCl and manure was expected to have a greater impact on productivity. Ash derived from dried aloe vera leaf skins and some weeds, mixed with lime during burning, results in elements that may substitute potassium (K), calcium (Ca), silica, and carbon. This indicates that ash has the potential to be used as an ameliorant in peat soil for aloe vera cultivation (Chowdhury *et al*., 2021).

The comprehensive study of aloe vera cultivation practices revealed several crucial insights into productivity optimization. Historical data demonstrated that farmers who implemented strategic fertilization schedules achieved higher yields.

The sequential application of fertilizers played a vital role. When farmers applied ash as a base treatment, followed by systematic additions of urea, KCl and manure, the plants exhibited enhanced growth characteristics. This synergistic effect was particularly pronounced in areas where soil conditions had previously been suboptimal. The research also indicated that the timing of these applications was crucial: farms that coordinated fertilizer applications with growth stages showed markedly improved outcomes.

Further analysis revealed that the soil amelioration properties of ash extended beyond its direct nutritional benefits. The ash treatment modified soil pH levels, which subsequently enhanced nutrient availability and uptake. The improved soil structure that resulted from ash application created more favourable conditions for root development and nutrient absorption.

The study also demonstrated that sustainable harvesting practices were intrinsically linked to long-term productivity. Proper harvest management significantly impacted both yield and gel quality. Farms that implemented controlled harvesting schedules, while maintaining proper nutrient management, sustained higher productivity levels over extended periods. This balanced approach proved essential for maintaining plant health and ensuring consistent yield patterns.

These findings contributed significantly to understanding the complex interplay between various cultivation practices and their cumulative effect on aloe vera productivity. The research emphasized that while individual factors showed positive correlations, it was the integrated approach to cultivation management that yielded the most substantial improvements in productivity.

The direct effect of leaf weight per leaf on productivity was minimal. This was due to the relatively uniform weight of harvested leaves, ranging from 0.7 to 1.6 kg, with an average weight of 1.15 kg per leaf. This suggested that productivity was more influenced by factors such as the number of leaves harvested, harvesting frequency and local climate.

CONCLUSION

- The plant population, the application of aloe vera ash, manure, pruning frequency and harvesting frequency each had a very significant effect ($P < 0.01$), and the application of urea and KCl each had only significant effect ($P < 0.05$), except for the bed height, plant

rows per bed, number of seed leaves, seedling age, lime application, SP-36 fertilizer and pest control.

- The greatest direct effect of cultivation practices on the productivity of aloe vera plants was from harvesting frequency, contributing 38.76%, followed by pruning frequency (13.26%), ash application (13.19%), manure (5.69%), urea (2.05%) and KCl (2.02%).
- The indirect effects of urea, KCl and manure on productivity, when channelled through ash, were greater compared to their direct effects.

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