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The Integration of Manure and Potassium Applications to Improve the Yield and Quality of Sweet Potato (*Ipomoea batatas* L)

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Abstract: The combination of organic and inorganic fertilizers for increasing the yield of sweet potato is better than providing a singular fertilizer. Therefore, this study aimed to determine the composition of KCl fertilizer dosage in various types of manure to increase the yield and quality of sweet potatoes. Meanwhile, a factorial randomized block design was used, and the first treatment was the KCl fertilizer dosage consisting of 50, 100, and 150 kg ha^{-1}. Furthermore, the second factor was the various types of manure, including goat, buffalo, cow, chicken, and control. All the treatment combinations were replicated three times, and each consisted of five samples. Meanwhile, the result evaluation was conducted on the fresh tuber weight, number, and harvest index. Also, an evaluation of the quality was conducted on carbohydrate content and total dissolved solids. The results showed that manure had more effect on all the outcome variables than KCl fertilization. Moreover, the interaction between KCl fertilizer and manure only affected carbohydrate content, while total dissolved solids were not affected.

Keywords: carbohydrate, inorganic fertilizers, integration, manure, total solid soluble.

肥料和钾肥的整合提高甘薯的产量和品质（番薯）

摘要：有机和无机肥料的组合比单用肥料要好，以提高甘薯的产量。因此，本研究旨在确定各种肥料中的氯化钾肥料剂量组成，以提高甘薯的产量和品质。同时，使用析因随机区组设计，第一个处理是由50、100和150 kg ha-1组成的氯化钾施肥量。此外，第二个因素是各种肥料，包括山羊，水牛，牛，鸡和对照。将所有处理组合重复三遍，每组由五个样品组成。同时，对新鲜块茎的重量，数量和收获指数进行了结果评估。另外，对碳水化合物含量和总溶解固体进行了质量评估。结果表明，施肥对所有结果变量的影响均大于氯化钾施肥。此外，氯化钾肥料和肥料之间的相互作用仅影响碳水化合物的含量，而总溶解固体则不受影响。

关键词：碳水化合物，无机肥料，肥料，肥料，总固溶性。

1. Introduction

The purpose of the introduction is to explain to sweet potato is one of the important tubers in tropical and sub-tropical countries such as China, India, Japan, Indonesia, Philippines, Thailand, etc. Among the tubers, sweet potato is ranked second place after cassava [1, 2]. This tuber uses a large number of nutrients. Therefore the addition of organic fertilizer is recommended to maintain soil productivity. Therefore, manure's application significantly impacts growth and yield [3]. Cows or green manures are commonly used as organic fertilizers for sweet potatoes [4]. Meanwhile, tubers grown in soils with low organic content need to be supported with the fertilizer of 5 to 10 tons ha^{-1} to increase their yield [5]. In Indonesia, there are diverse types of manures used as fertilizers in the cultivation of sweet potatoes.

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The concept of 'integrated nutrition management' utilizing all available organic and inorganic resources has become the dominant paradigm for increasing yield in small-scale farming systems [6]. Jian-wei et al. [7] showed that fertilization of potassium sulfate (K_2SO_4) or its chloride (KCl) improved the yield and quality of sweet potato. Therefore, K helps to facilitate translocation from the source (leaf) to the storage organ (sink) [8]. Meanwhile, manure plays a role in improving soil health [5]. The results showed that combining organic and inorganic fertilizers to increase sweet potato yield was better than giving a singular type [9, 10, 11]. Several studies on integrating KCl fertilizer and manure have been conducted. However, there is no integration between those compositions. Finally, this study's results are expected to determine the best type of manure to reduce the need for KCl fertilizer. Therefore, this study aimed to determine the composition of KCl dosage in various types of manure.

2. Materials and Methods

The field trial was conducted at the Farm of Indonesian Legumes and Tuber Crops Research Institute, Malang, from April–September 2019. The experimental conditions include 750 m above sea level, an average temperature of 28ºC, rainfall of 1928 mm year^{-1}, and soil type ranging from Entisol to Oxisol, maintained at about 15-22ºC [12].

The planting material was the shoot cuttings of Sukuh potato. They were planted in a tub with a size of 1 x 5 m and a distance of 100 x 25 cm. Meanwhile, the manure, KCl, and basic fertilizer Super Phosphate-36 (SP-36) were given at the same time as making tubs, while Urea fertilizers were given one week and one month after planting. Also, the SP-36 and Urea fertilizer doses were 105 kg ha^{-1}, while the KCl was adjusted to the treatment. Lastly, the potatoes were harvested when they became mature at about 170 days; each potato's average weight was 200 to 250 g. All of the samples were collected as fresh as possible and processed at the Agrotechnology laboratory, Agriculture Faculty for analysis. Samples were gently washed with tap water immediately after collection to remove sand and other extraneous material before being washed with distilled water, and then air washed.

The samples were then cut into small pieces, placed in a self-sealing bag and kept in a desiccator to prevent moisture gain or loss. They were then ready to determine their carbohydrate and their total soluble solids.

The result evaluation was conducted on the fresh weight of marketable and unmarketable tuber [13], total weight, the number of the marketable and unmarketable tuber, the total number, and harvest index. Meanwhile, the quality evaluation was conducted on the carbohydrate content (using a spectrophotometer) and total dissolved solids using a hand-refractometer [14].

Harvest index was measured using the formula:

$$\text{Harvest index}(\%) = \frac{\text{fresh weight of tuber per plot}}{\text{total fresh weight of the plant per plot}} \times 100\%$$

The data analysis used was the Factorial Random Block Design. The first factor was the type of manure consisting of goats, buffaloes, cows, and chickens, each of 20 tons ha^{-1} and control (not given manure). Meanwhile, the second factor was the dose of KCl, consisting of 50, 100, and 150 kg ha^{-1}. All the treatment combinations were replicated three times, and each consisted of 5 samples.

The statistical analysis was performed using SPSS v17. The data were expressed as means ± standard error and were statistically compared by Duncan's multiple range test (DMRT) at the $p < 5$ % level.

3. Results

3.1. Yield Performance

Sweet potato yield due to the addition of manure and KCl is more influenced by the manure. Therefore, it can be concluded that various doses of KCl do not have a real effect (Table 1). Furthermore, the yield consists of fresh weight marketable and unmarketable tuber, the total weight of marketable (Fig. 1), the number of a marketable and unmarketable, and the total number of tubers (Fig. 2). The best harvest index (Fig. 3) was achieved by applying goat manure. Meanwhile, the sweet potato without manure has a lower yield compared to the other.

Table 1 Performance of sweet potato results due to KCl fertilizer application

Treatment (KCl)	FWMT	FWUmT	TTFW	NMT	NumT	HI
50 kg ha^{-1}	971.11	79.10	1050.21	3.47	2.11	57.63
100 kg ha^{-1}	880.00	77.44	957.44	2.87	2.12	54.38
150 kg ha^{-1}	977.78	79.00	1056.78	3.61	2.36	55.47
	NS	NS	NS	NS	NS	NS

Remarks: FWMT: Fresh Weight of Marketable Tuber, FWUmT: Fresh Weight of Unmarketable Tuber, TTFW: Total Tuber Fresh Weight, NMT: Number of Marketable Tuber, NUmT: Number of Unmarketable Tuber, HI: Harvest Index, NS: Not Significant.

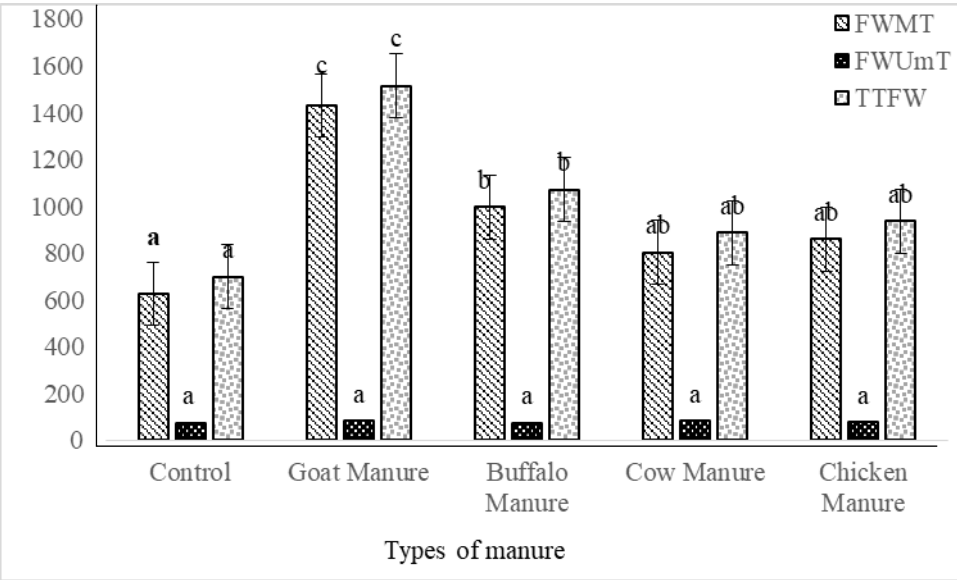

Fig. 1 Fresh weight of tuber due to integrated manure and potassium fertilizer

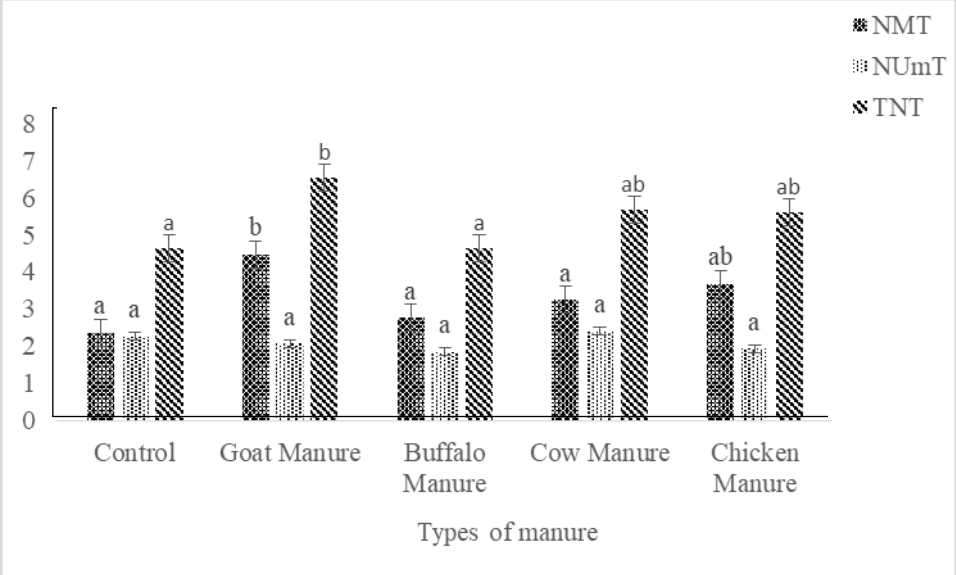

Fig. 2 Number of tubers due to the integration of manure and potassium fertilizer

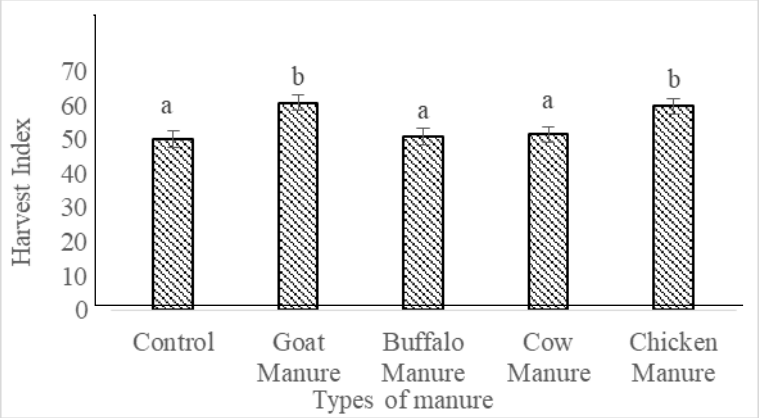

Fig. 3 Harvest index due to integrated manure and potassium fertilizer

The total fresh weight is a combination of marketable and unmarketable tubers. The unmarketable type weighed ≤ 100 g. However, goat manure showed a significant effect on the fresh weight of marketable types and their total weight. Meanwhile, the fresh weight of unmarketable tubers is not affected by the type of manure (Fig. 1). The marketable and the total weight of sweet potato tuber given goat manure were 1429.63 g and 1514.11 g.

A marketable amount of sweet potato with goat manure has a similar result to the tuber with chicken manure, 4.48 and 3.69. However, goat, cow, and

chicken manure have the same effect on the total tuber, which are 6.55, 5.67, and 5.52, respectively. Meanwhile, the number of unmarketable tubers is not affected by the type of manure (Fig. 2).

The harvest index illustrates plants' capacity to allocate biomass (assimilation) to the formed reproductive part [15]. Also, commercial yields of sweet potatoes are in the form of tubers. Therefore the index is the ratio of tubers to total plant biomass (shoots plus tubers). Furthermore, those given goat and chicken manure have a higher harvest index compared to other treatments. Lastly, the harvest index indicates the photosynthetic distribution between the tubers and the soil's remaining biomass above the plant (Fig. 3).

3.2. Quality Performance

The quality of observed sweet potato consisted of carbohydrates and the total dissolved solids. The analysis results showed that the integration of manure and KCl affect carbohydrate content (Table 2). Table 2 showed that manure is needed to increase the carbohydrate content of the sweet potato. This is seen in the treatment without manure (control). Meanwhile, integrating KCl fertilization with manure showed increased yield depending on their composition.

Table 2 Carbohydrates content due to interaction between types of manure and potassium fertilizer

Treatment KCl	Control		Goat manure		Buffalo manure		Cow manure		Chicken manure	
50 kg.Ha^{-1}	2.430	a	3.772	ab	1.316	a	1.448	a	3.808	ab
100 kg.Ha^{-1}	2.430	a	4.822	b	3.739	ab	2.759	ab	3.437	ab
150 kg.Ha^{-1}	1.989	a	3.451	ab	2.004	a	4.678	b	2.875	ab

Remarks: Means sharing the same letter in the columns/rows are not significantly different at the 5% P level according to the LSD test.

4. Discussion

The application of manure plays a direct role in improving the physical [16, 17], chemical [18], and biological properties of soil [19, 20]. The analysis of different manure results in Indonesia [21, 22] showed that goat manure has higher elemental potassium compared to other types. Therefore, it is very suitable for stimulating the development of fruit, flowers, and tubers [22]. In addition to the higher potassium content, goat manure also contains phosphorus in moderate amounts. In line with this research, sweet potato with goat manure has a higher weight and the total number of tubers and the harvest index. Meanwhile, applying single goat manure without integration with potassium fertilizer is less optimal for increasing carbohydrate content.

Potassium is a macro plant nutrient, such as N and P. Its fertilization produces greater yield and improves plant quality [23]. This nutrient is involved in enzyme function, photosynthesis, fruit formation [24], and resistance to drought stress [23]. Meanwhile, K's positive effects on the growth, yield, and quality of sweet potatoes have been widely reported [25, 26, 27] on cassava tuber.

Furthermore, it functions to form and stimulate the synthesis of proteins, carbohydrates, root growth, and development and increase the pressure of root turgor and nutrient absorption. The research results showed that K fertilizer increases carbohydrate content and starch of sweet potato tubers and yields per unit area [7]. Also, potassium plays a role in stimulating water absorption due to the presence of K + ions. Therefore, it easily spurs increased turgor cell pressure, which results in photosynthesis [28]. Furthermore, it spurs the process of plant assimilation and has an impact on the amount.

Dry sweet potato production depends on three factors, which are photosynthesis, respiration, and distribution of produced dry matter. Potassium is needed to transform solar energy into chemical form, increasing carbohydrate content [29]. It also has an important role in assimilating translocation into tubers by facilitating electrons in the plant transport chain [30].

Furthermore, this element plays a role in producing tubers, facilitating flowers' formation and the ripening of fruits and bulbs [31]. Both the P and K in the soil are interdependent. The P element increases exchangeable Potassium, while K increases the P's existence [32]. Therefore, their availability is very important to increase production yield. Moreover, P plays a role in producing roots that will become tubers and is used as a storage site for photosynthate. Also, K plays a role in the translocation of assimilates from leaves to all parts of the plant.

5. Conclusion

Integrating KCl fertilizer is needed for sweet potato cultivation, and each dose requires a different manure addition. Meanwhile, chicken manure can be used as an alternative in areas of less goat variety. Lastly, the use of singular KCl fertilizer can not improve the yield or quality of sweet potatoes. This study provides benefits for sweet potato farmers to utilize available manure to reduce the use of very high K fertilizer to increase sweet potato production.

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