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Prediction of NPK doses based on targeted fruit sugar content in *Cucumis melo* L. 'Cantaloupe' using a simple regression method

Abstract. The fruit sweetness is the main target in melon plant production. The highest criterion of sweetness is excellent, with 16% of total sugar content. Modification of essential plant nutrients is the alternative to reach that category. So, this study aims to obtain optimum NPK doses using a simple regression method. The experiment was conducted in a greenhouse with a soilless culture hydroponic system from August until November 2023 using a completely randomized design (CRD) with five treatments and four replications. The parameters included leaf area, plant dry matter, leaf nutrient uptake, fruit weight, and fruit sugar content. Pearson correlation analysis showed that the total sugar content in fruit has a significantly positive correlation with potassium in NPK fertilizer treatments such as K_2O dose and K_2O uptake at 7 WAP, i.e., 0.932 and 0.973, respectively. According to the regression model y = -50.7 + 1.079 N + 0.251 P_2O_5 + 0.528 K_2O, the NPK formula fertilizer containing 31.56 g N, 23.99 g P_2O_5, and 50.42 g K_2O can be used by grower to produce excellent fruit sugar content.

Keywords: Melon · NPK · Potassium · Regression · Sugar

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Introduction

Melon (*Cucumis melo* L.) included a horticulture plant with fruit as an organ target. In Indonesia, the productivity of melon from 2018 until 2022 was 119 tons, 122 tons, 138 tons, 129 tons, and 119 tons, respectively (Statistic Indonesia, 2023). Food and Agriculture Organization (FAO) reported worldwide productivity of melons reached more than 28 million tons in 2020 (Xu et al., 2022). The data indicated an increasing number of people choosing melons to supply the demand for fruit. Manchali et al. (2021) stated that shape, size, taste, aroma, skin, and flesh color are criteria for consumers' acceptance of melon fruit. Indonesians prefer melon, which has characteristics such as large fruit size (2-3 kg), strong fruit aroma, crunchy flesh texture, high fruit sweetness (^{0}Brix 12-13), and relatively long shelf life of ±10 days (Khairi et al., 2017). In other countries, such as Taiwan, consumers prefer small size (1-2 kg), distinctive aroma, high fruit sweetness (^{0}Brix 13-14), and crunchy texture (Yam et al., 2020). Some reports said that the priority criterion is sweetness.

Adams (2023) stated that the sweetness quality criteria of 'Cantaloupe' melons by the refractive index of crop juices, including poor (8%), average (12%), good (14%), and excellent (16%). Hydroponic system melon has sweeter fruit than open-field melons. Genotype, light, temperature, humidity, water supply, nutrient composition, and pH of the nutrient solution affected melon production in the hydroponic systems (da Silva et al., 2019). Yam et al. (2020) reported that nutrient composition directly enhances the quality of melon fruit sweetness in a hydroponic system. Specifically, potassium positively correlates with melon fruit's increasing sugar content, as Rangel et al. (2018) reported. In hydroponic systems, Johnson & Mirza (2020) stated that plants are required to supply essential nutrients, such as nitrogen (N), phosphate (P), and potassium (K), to complete the plant life cycle optimally.

The determination of NPK formulation was reported using a mathematical regression model. Suminar (2017) recommends NPK doses of about 160.4 Kg/ha N, 43.7 Kg/ha P_2O_5, and 124.9 Kg/ha K_2O for sorghum production using multi-nutrient response regression with 15 treatments of NPK in three set experiments. Then, Li et al. (2023) found the ratio of NPK 1.53:1.00:3.36 to obtain the total sugar content of melon fruit about 13.34% using 23 treatments by regression surface response method. This study focuses on conducted NPK doses to produce excellent levels of sugar content (≥16%) and uses a simple regression method to simplify the methodology.

Materials and Methods

This research was conducted from August until November 2023 at a greenhouse in Cikampek, Karawang, West Java. The tools used include TDS and pH meters, SPAD-502 Konika Minolta chlorophyll meters, GBC Savanta AA spectrophotometer, and other laboratory tools. Meanwhile, materials used in this experiment are 'Cantaloupe' SweetNet8 seeds, cocopeat, rice husk biochar, raw water (TDS<100 ppm), ropes, polybags, sample plastic, Luff Schoorl reagent, and other laboratory materials.

This study's NPK fertilizer used PT Pupuk Kujang's formulas. NPK formulas should have highly different compositions for regression modeling purposes. Thus, NPK formulas are determined by the nutrition dominance principle to obtain different plant responses. Its were NPK 13-13-13 (generic), NPK 16-9-9 (N dominant), NPK 9-9-25 (K dominant), NPK 12-6-20 (NK dominant), and NPK 9-13-23 (PK dominant).

The experiment was a Completely Randomized Design (CRD) with five treatments and four replications. Each treatment used 40 plants on soilless culture integrated with a fertigation system. Nutrition solution was applied six times daily, about 2.000 mg/L in various volumes, followed by plant stages. Pollination is carried out manually using a paintbrush. Finally, fruit is harvested at 40 days after pollination.

The observation parameters were plant dry matter and leaf NPK uptake (BPSITP, 2023), leaf area (Toebo et al., 2019), fruit weight, and fruit sugar content (Lubis et al., 2022). Data were analyzed using Pearson correlation and a simple regression method using Minitab 21.4 software.

Results and Discussion

Observation was conducted on growth parameters, such as leaf area, leaf nutrient uptake (Table 1) and plant dry matter (Table 2) at 3 WAP and 7 WAP. Evaluation at 3 WAP to observe plant condition in the maximum vegetative phase and 7 WAP for the maximum generative phase (Zhang et al., 2016).

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Table 1. Leaf area and leaf nutrients uptake of melon in response to various NPK treatments.

Treatments	Leaf Area (cm^2)		Leaf Nutrients Uptake (%)					
	3 WAP	7 WAP	3 WAP			7 WAP		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
NPK 13-13-13	296.92	404.98	5.12	0.73	1.88	3.86	1.05	1.88
NPK 16-9-9	246.33	352.58	5.29	0.89	1.57	4.41	1.01	1.98
NPK 9-9-25	268.50	393.89	4.53	0.63	1.88	3.31	0.44	3.43
NPK 12-6-20	264.58	409.69	4.76	0.85	2.03	3.94	0.71	4.20
NPK 9-13-23	320.33	403.21	4.55	0.87	2.07	3.69	0.71	3.87

Note: WAP = week after planting. N = nitrogen. P_2O_5 = phosphate. K_2O = potassium.

Table 2. Dry weight, fruit weight, and fruit sugar content in response to various NPK treatments.

Treatments	Dry Weight (g)		Fruit Weight	Fruit Sugar Content (%)		
	3 WAP	7 WAP	Average (Kg)	Reducing	Sucrose	Total
NPK 13-13-13	31.00	167.13	1.26a	3.34	7.05	10.39
NPK 16-9-9	31.98	170.83	1.21a	3.36	7.10	10.46
NPK 9-9-25	35.73	166.63	1.30a	3.38	9.22	12.60
NPK 12-6-20	30.68	184.50	1.30a	3.41	9.28	12.69
NPK 9-13-23	29.93	218.90	1.26a	3.44	9.36	12.79

Note: WAP = week after planting.

Table 3. Pearson correlation coefficient between total sugar content and other parameters.

Parameter	Total Sugar (%)	
	Pearson Correlation (95%)	P-Value
Reducing Sugar (%)	0.863	0.060
Sucrose Sugar (%)	1.000	0.000*
N dose (g/plant)	-0.829	0.083
P_2O_5 dose (g/plant)	-0.285	0.642
K_2O dose (g/plant)	0.932	0.021*
N uptake 3 WAP (%)	-0.943	0.016*
P_2O_5 uptake 3 WAP (%)	-0.081	0.897
K_2O uptake 3 WAP (%)	0.755	0.140
N uptake 7 WAP (%)	-0.640	0.245
P_2O_5 uptake 7 WAP (%)	-0.877	0.051
K_2O uptake 7 WAP (%)	0.973	0.005*
Leaf area 3 WAP (cm^2)	0.265	0.667
Leaf area 7 WAP (cm^2)	0.545	0.342
Dry weight 3 WAP (g)	0.103	0.870
Dry weight 7 WAP (g)	0.569	0.317
Fruit weight average (Kg)	0.757	0.139

Note: *significant difference at the 0.05 probability level. Correlation 0.00-0.19 (very low); 0.20-0.39 (low); 0.40-0.59 (moderate); 0.60-0.79 (high); 0.80-1.00 (very high). Antagonism correlation (-); simultaneous correlation (+). WAP = week after planting. N = nitrogen. P_2O_5 = phosphate. K_2O = potassium.

Data were analyzed using Pearson correlation analysis to determine parameters that correlated with total sugar content as the main target of this study. Following Table 3, the total sugar content was only positive and significantly correlated with sucrose sugar, K_2O dose, and K_2O uptake at 7 WAP. However, total sugar negatively correlates with N uptake at 3 WAP.

The negative correlation (-0.943) means that the N uptake at 3 WAP has no linear response with total sugar content on melon fruit. Nitrogen has a dominant role in the vegetative phase of plants. Kumar et al. (2021) said that nitrogen on melon plants can increase melon fruit's dry matter and flesh color. A nitrogen deficiency in melon plants affects the fruit's decreasing weight and size (Grasso et al., 2022). So, if the N uptake at 3 WAP increases, the total sugar content will decrease.

Table 4. NPK fertilizers doses by multiple response prediction.

Categories*	Total Sugar Target (%)	Doses (g/plant)		
		N	P_2O_5	K_2O
Poor	8	31.56	23.99	35.26
Average	12	31.56	23.99	42.84
Good	14	31.56	23.99	46.63
Excellent	16	31.56	23.99	50.42

Note: *Total sugar categories following to Adams (2023).

The results of the correlation analysis in Table 3. showed a very high significance (0.000 p-value) and positive correlation (1.000) between sucrose sugar content and total sugar content. According to Stein & Granot (2018), sucrose is the final sugar product of the photosynthesis process, and it is distributed by the phloem vessels to all parts of the plant. Chaudhry and Varacallo (2023) stated that plants will store carbohydrates in simpler forms, such as sucrose, as food reserves so that when needed, the sucrose will be hydrolyzed into glucose through the glycolysis process.

Table 3. also describes essential information about the correlation between the total sugar content and potassium parameters, such as K_2O dose and K_2O uptake at 7 WAP were 0.932 and 0.973, respectively. It indicated a very high correlation. Potassium has a vital role in several plant physiological functions, such as carbohydrate metabolism, enzyme activity, osmotic regulation, water use efficiency, nitrogen element absorption, protein synthesis, and assimilate translocation (Dreyer et al., 2017; Rangel et al., 2018; Ho et al., 2020; Mostofa et al., 2022; Wang et al., 2023). Furthermore, Wang et al. (2024) explained that potassium is also crucial in the sugar synthesis process in leaves because it can influence the expression of genes that regulate sugar metabolism and assimilate transport. Potassium deficiency causes reduced sugar translocation from source to sink tissue (Koch et al., 2019; Ho et al., 2020). Moreira et al. (2022) stated that potassium deficiency can reduce sugar levels in melon fruit.

According to the results in Table 3, potassium has a high positive significant correlation to total sugar content in melon fruit. That result is similar to Table 4, which determines NPK doses by multiple response prediction. In Table 4., the recommendation of N and P_2O_5 to produce total sugar content in each category were similar to 31.56 g/plant and 23.99 g/plant, respectively, except for the doses of K_2O. This situation means that the K2O dose influences the total sugar content.

Conclusion

The total sugar content is the main target in the melon fruit production. It has a strong and significantly positive correlation with potassium in NPK fertilizer treatments, such as parameters of K_2O dose and K_2O uptake at 7 WAP were 0.932 and 0.973, respectively. NPK formula fertilizer containing 31.56 g N, 23.99 g P_2O_5, and 50.42 g K_2O can be used by the grower to produce melon fruit with excellent fruit sugar content according to regression model $y = -50.7 + 1.079\ N + 0.251\ P_2O_5 + 0.528\ K_2O$. In the following research topic, the recommendation of NPK doses should be tested to ensure the actual effect on the melon plant.

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