Original Research Article

Application of Mitscherlich-Bray Equation to Establish Fertilizer Recommendation for Strawberry under Adtuyon Clay Loam

ABSTRACT

The nutrient requirement of strawberry is high, making it very responsive to fertilization. This study utilized the Mitscherlich-Bray equation to determine the theoretical maximum yield as the basis of comparison to the actual yield. The economics of fertilizer application in determining the fertilizer recommendation was considered. The theoretical maximum yield of the study is 12.29 t/ha^{-1}. Strawberry is found responsive to nitrogen and potassium fertilization. Applying 225-225-360 kg ha-1 of N, P_2O_5, and K_2O could achieve 95% of the theoretical maximum yield. However, it had a much higher amount spent on fertilization per kg of fruit yield than the current Hafza's recommendation. The fertilizer recommendation of 150-150-240 kg ha^{-1} of N, P_2O_5, and K_2O, respectively still the best option under Adtuyon clay loam for both economic and horticultural benefits.

Keywords: fertilizer recommendation, Mitscherlich-Bray equation, theoretical maximum yield, actual yield

1. INTRODUCTION

Strawberry (*Fragaria ananassa* Duch) is a crop with high economic value and documented nutritional benefits, popular in consumer diet, and suitable for sensory evaluation (Reganold et al., 2019). It grows best in cool areas and is tolerant to most soil types.

In the Philippines, the demand for strawberry fruits is high, especially during holidays when strawberry is utilized for dessert and wines (Osip et al., 2008). La Trinidad, Benguet, is the strawberry capital of the Philippines. They devoted 1.54% of the total agricultural land area to strawberry production. There are 18,820 farmers engaged in such production (Ticbaen, 2017). The average productivity of strawberry is 12 t/ha, with prices ranging from PhP 250 to 300/kg, which gave the province PhP 3.0 to 3.6 M gross income per hectare. The most significant impact of strawberry had brought the municipality into the world of agritourism which registered about 259,000 tourists in 2016 (Ticbaen, 2017).
In some areas in Mindanao, around 30 farmers in Dumangas, T'boli, South Cotabato were the beneficiary of the government anti-poverty program to start strawberry production in their 1.4 ha of lands (PCCT, 2017). In Davao, the Benwa Farm in Marilog District, Buda, Davao City, makes its name known through strawberry picking (Primer, 2017), and in Vincent Heights, Brgy. Obrero, Mintal (SunStar, 2017). Moreover, the Taglucop Strawberry Farm in Kitaotao, Bukidnon,

proves successful in strawberry production, which somehow has the same features as that of Lanao del Sur.

Epol strawberry farm production and processing in Bukidnon exemplified a successful venture in strawberry production (Almorado, 2019), potentially uplifting the farmers' economic status. Bukidnon and Lanao del Sur are endowed with a cool climate, an essential requirement for strawberry production. The cool climate in both areas is due to the high altitude and even rainfall distribution throughout the year (Almorado, 2019). Both areas also had low inherent soil fertility, which required fertilization.

Fertilizer is supplied to plants to meet the nutrient demand for growth and development. It assists the plants in growing vegetative mass and maintains the plant's current activity for fruit development. For strawberry, fertilizer requirement is high despite their small size (Morgan, 2006). At the high level of nitrogen, usually at 500 kg/ha, production of runners or strawberry transplants is viable under Claveria, Misamis Oriental conditions (Osip, 2008), while fruit production requires a high amount of potassium (Bibi et al., 2020).

Fertilizer recommendation needs to be reevaluated because the current rates are already obsolete. Since strawberry is viable to be grown in the Lanao del Sur Province, a fertilizer program should be developed to increase the size and weight of the fruit, attractive to the market, which is considered one of the challenges in strawberry production. Using the Mitscherlich-Bray equation helped understand sweet potato response to fertilizer application (Asio & de la Cruz, 2020). Hence, this study utilized the Mitscherlich-Bray equation on judicious fertilizer use for strawberry production.

This study aims to determine the theoretical maximum yield as the basis of comparison to the actual yield. It also looks into the economics of fertilizer application under Adtuyon clay loam.

2. MATERIAL AND METHODS

This study was conducted at the College of Agriculture Experimental Area, Mindanao State University-Marawi Campus, Lanao del Sur (7.9939° N, 124.2581° E) under Adtuyon clay loam. Adtuyon clay loam falls under *Typic Kandiudult*. It is soil that has undergone extensive leaching and accumulated clays in the subsoil with sufficient moisture throughout the year. It has a low cation exchange capacity. A typical representative of *Kandiudults* with andesite and basaltic rocks as the parent material. Hence, fertilization and liming are highly required.

Variety *Florida* was used in this study because of its aroma and sweetness, even though it is medium-sized. Due to expensive planting materials, mother strawberry plants were allowed to reproduce for six months inside the Plant Science Nursery. Fertilizer recommendations were 150- 150- 240 kg/ha N, P_2O_5, and K_2O, respectively (Hafza, 2008).

Treatments were established using this recommendation with no application, 50, 100, 150, 200, and 250% levels. It was laid out using Randomized Complete Block Design with four replications. Fertilizer was applied in four split applications from transplanting until fruit set development at two-week intervals. The soil contained 0.11% Total N, 1.06 ppm available P, and 104.72 ppm exchangeable K (Ouano, 2018).

Damaged, old and diseased leaves were removed from the plants with the use of pair of scissors. Removal of the runner was done after 60 days to promote flowering. Cypermethrin was used to control insect pests following the manufacturer's recommendation.

The yield data collected were subjected to the Mitscherlich-Bray equation as given below (Afzal et al. 2014).

$$\log (A-y) = \log A - c1b - cx$$

The theoretical yield was obtained by plotting log y (actual yield) to 1/x (amount of fertilizer applied).

Constants c1 and c were calculated separately following the equations:

$$c_1 = \frac{\log A - \log(A - yo)}{b}$$

$$c = \frac{(\log A - c1b) - \log(A - yx)}{x}$$

Where A=% theoretical maximum yield, y=actual yield obtained in q ha^{-1}, b=native soil test value in kg ha^{-1}, x=fertilizer nutrient applied in kg ha^{-1}, c_1 and c=constants i.e., the efficiency of soil and fertilizer nutrients respectively; yx is the yield obtained from the fertilized plots., yo is the yield obtained from control plots.

3. RESULTS AND DISCUSSION

The theoretical yield of strawberry was determined using the actual yield in terms of the Mitscherlich-Bray equation by plotting the log y and 1/x (Fig. 1). Strawberry plants can yield as much as 12.29 t ha-1. This theoretical maximum yield was comparable to the Municipality of Benguet, with an average yield of 12 t/ha (Ticbaen, 2017). The c1 and c values were 0.0061 and 0.00464 for N, 0.03179, and 0.00471 for P_2O_5 and 0.000377 and 0.002903 for K_2O, respectively. The ratio of c1/c indicates that a higher ratio means a lower response of strawberry plants. A lower ratio means a more significant response to fertilizer application (Asio & dela Cruz,

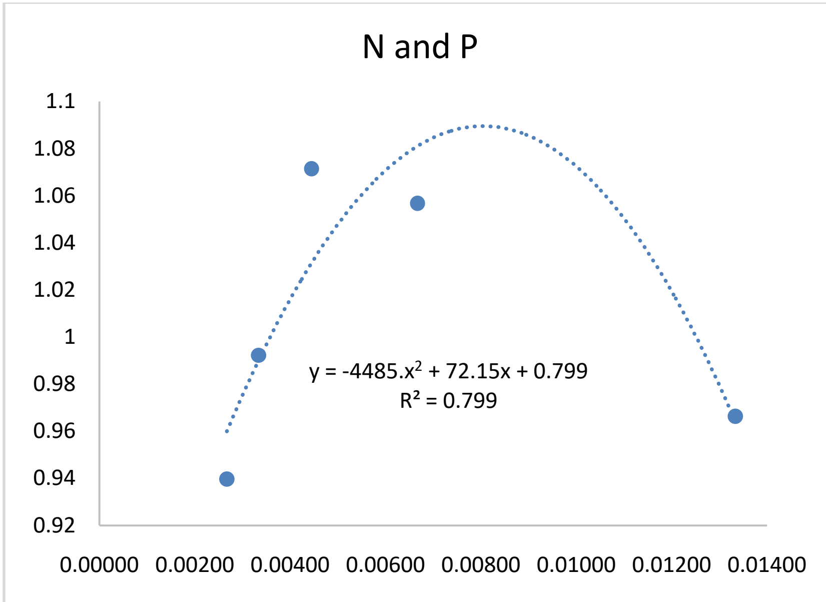
Table 1. Strawberry yield and the efficiency coefficient of soil and fertilizer NPK.

Treatments N applied kg ha^{-1}	Actual yield (t ha^{-1})	Calculated log y	1/x	c1	c	c1/c
				0.0016		

0	2.04					
75	9.25	0.9663	0.01333		0.007046	
150	11.40	1.0568	0.00667		0.007067	
225	11.79	1.0715	0.00444		0.00583	0.344454
300	9.82	0.9923	0.00333		0.002062	
375	8.70	0.9397	0.00267		0.001216	
Mean					(0.00464)	
Theoretical yield	12.29					

Treatments P_2O_5 applied kg ha^{-1}	**Actual yield (t ha^{-1})**	**Calculated log y**	**1/x**	**c1**	**c**	**c1/c**
				0.03179		
0	2.04					
75	9.25	0.9663	0.01333		0.0071985	
150	11.40	1.0568	0.00667		0.0071436	
225	11.79	1.0715	0.00444		0.0058812	6.743697
300	9.82	0.9923	0.00333		0.0021001	
375	8.70	0.9397	0.00267		0.0012465	
Mean					(0.00471)	
Theoretical yield	12.29					

Treatments K_2O applied kg ha^{-1}	**Actual yield (t ha^{-1})**	**Calculated log y**	**1/x**	**c1**	**c**	**c1/c**
				0.000377		
0	2.04					
120	9.25	0.9663	0.9663		0.004404	
240	11.40	1.0568	1.0568		0.004417	
360	11.79	1.0715	1.0715		0.003644	0.129947
480	9.82	0.9923	0.9923		0.001289	
600	8.70	0.9397	0.9397		0.00076	
Mean					(0.002903)	
Theoretical yield	12.29					



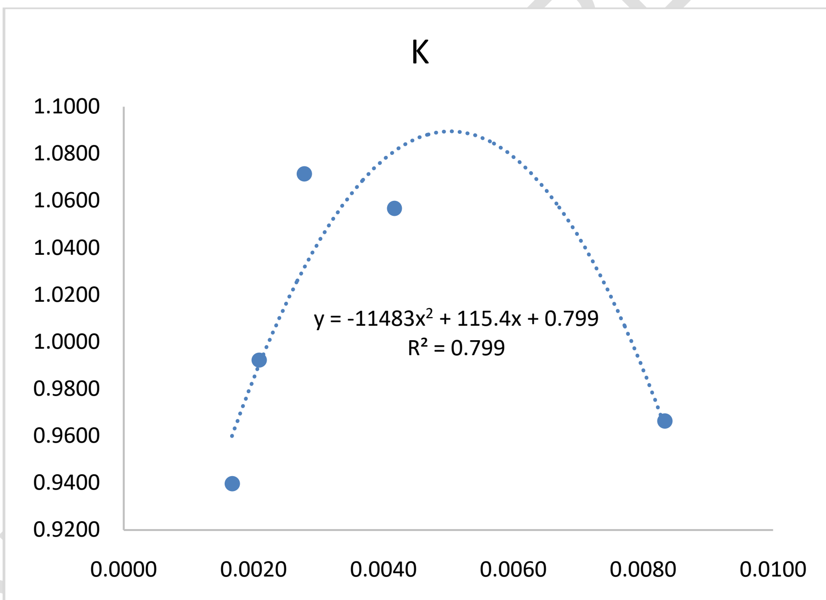


Fig. 1. Theoretical maximum yield (A) of strawberry from the plot of log y vs 1/x as affected by levels of NPK.

2020). A lower ratio was obtained from the fertilization of N and K_2O primarily because the interactive effects of these mineral nutrients are necessary as the former improved yield. At the same time, the latter improved fruit quality (Preciado-Rangel et al., 2020). The application of N and P alone yields a lower yield than a complete NPK application (Medeiros, 2015). The importance of K is vital since it participates in many metabolic activities such as fruit quality improvement and stress tolerance. Since this experiment was conducted in the field, plants received more stress from environmental factors such as too much sunlight, air and soil temperature, and rainfall. (Agüero et.al., 2015). Nitrogen is necessary during vegetative growth towards flower development. Also, the amount of fertilizer among treatments used was wide. Thus, responses were highly defined. The phosphorus response in this experiment is low, maybe because of the strongly acidic soil pH (pH 5.5). Phosphorus availability is between 6.0-7.5 (USDA, undated). Hence liming is necessary for this soil.

Fertilizer recommendation of 225-225-360 kg ha^{-1} of N, P_2O_5, K_2O, respectively, could achieve 95% of the theoretical maximum yield based on the actual yield. The current fertilizer recommendation of Hafza (2008) 150-150-240 kg ha^{-1} of N, P_2O_5, K_2O, respectively, could achieve 93% of the theoretical maximum yield. Half of Hafsa's fertilizer recommendation could achieve 75%, while twice the amount could attain 80%. This means 225-225-360 kg ha^{-1} of N, P_2O_5, and K_2O, respectively, already reached the peak of fruit production following fertilizer application. A further increase in the fertilizer application could lead to a decline in yield. The % calculated yield can achieve up to 98% of the strawberry yield among N, P_2O_5, K_2O fertilizer applications.

Strawberry is highly responsive to fertilizer application (Medeiros, 2015). Nutrient management is crucial to ensure higher yields and fruit quality of strawberry plants (Trejo-Trelles & Gomez-Merino, 2014). Fertilization should be a critical consideration in the production management of strawberry. This may lead to undersupply, resulting in low and unprofitable yield, or oversupply, increasing production costs and contributing to environmental problems (Asio & dela Cruz, 2020).

The result of the experiment can also be interpreted using Baule unit. Baule unit is defined as the amount of nutrient added which moves one way half closer to maximum yield (Ranganathan, 2019). At very low nitrogen content, one baule unit is equal to 47.45 kg ha-1, while one baule unit for K2O at a very low rating is 87.69 kg ha-1 for a 50% target yield. The standard range test was defined by PCAARD (2007). There was no recommendation drawn from P2O5 because of the wide range of treatments used. The standard range for phosphorus is between 10 kg/ha for very low to 50 kg/ha for high (PCARRD, 2007). The experiment ranges from 75-325 kg/ha, which has already surpassed the high P_2O_5 rating.

Table 2 shows the amount of fertilizer computed based on the Mitscherlich-Bray Equation depending on the target yield set. The N recommendation for 50, 60, 70, 80, and 90% target yield of the highest actual yield obtained from the experiment were 47.45, 66.52, 90.50, 122.84, and 172.62 kg/ha-1, respectively, for very low and 19.82, 38.94, 62.92, 95.25 to 145.03 kg/ha-1, respectively for low. No fertilizer recommendation is needed for soil with medium soil nitrogen content if the target yield is between 50-60% and high N content between 50-80%. Medium N soil requires 21.54, 53.87, and 103.65 kg/ha-1 of N application for a yield target between 70, 80, and 90% target yield, respectively.

For K, the target yield for 50, 60, 70, 80 and 90% of the highest actual yield requires 87.69, 118.21, 156.58, 208.31 and 287.96 kg/ha^{-1}, respectively for very low; 67.41,

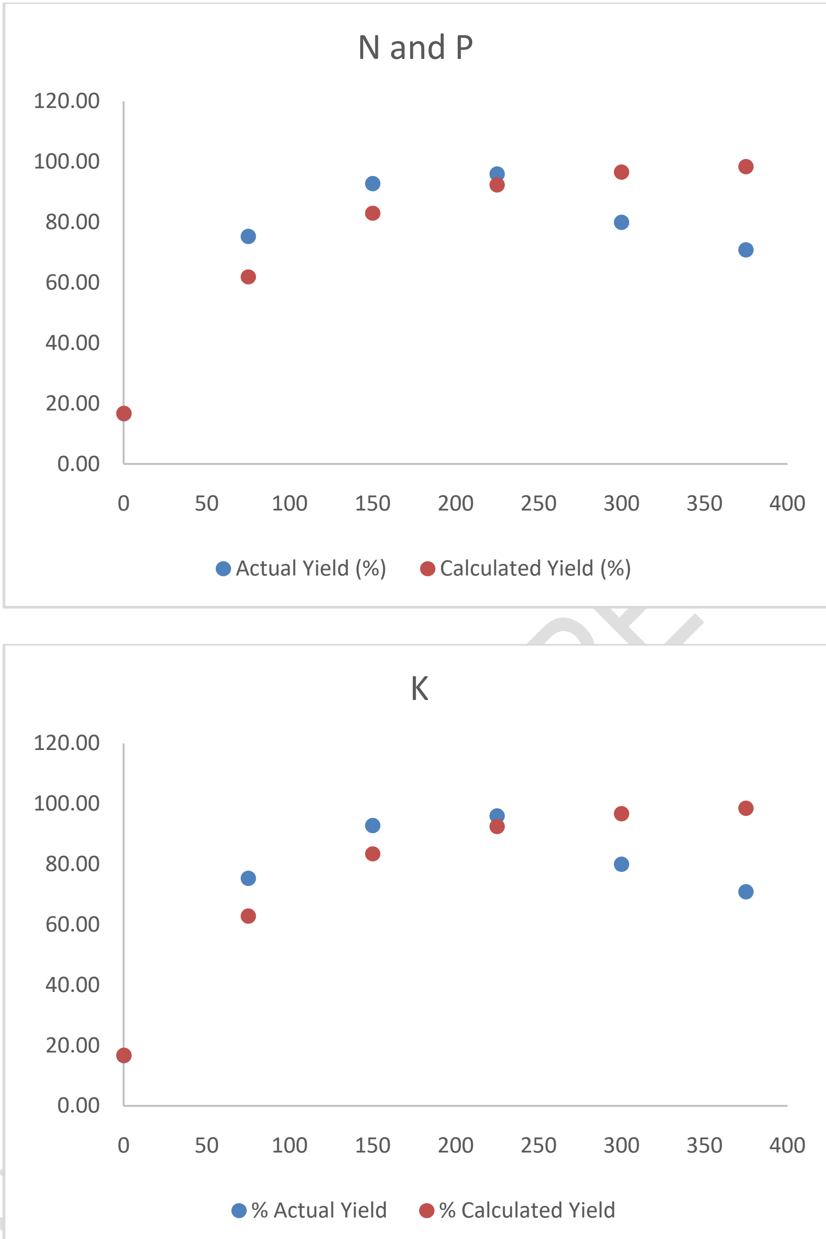


Fig. 2. Percent actual yield and calculated yield to that of the theoretical yield.

97.93, 136.30, 188.03 and 267.68 kg/ha^{-1}, respectively for low; 36.99, 67.51, 105.88, 157.61 and 237.26, respectively for medium K_2O soil. There is no recommendation for 50% target yield if the soil had high K_2O content. At 60% the soil K_2O requirement is 6.67 kg/ha, 70% is 45.04 kg/ha, 80% is 96.76 kg/ha and 90% is 176.42 kg/ha.

The economics of judicious fertilizer application is essential because fertilizer materials command a very high price in the market. In this study, diammonium phosphate (18-46-0), potassium chloride (0-0-60), and ammonium sulfate (21-0-0)

Table 2. Fertilizer Recommendation for very low, low, medium and high soil content for N and K_2O.

% From the Highest Actual Yield for N	Kg ha^{-1}			
	Very Low	Low	Medium	High
50	47.45	19.82		
60	66.52	38.94		
70	90.50	62.92	21.54	
80	122.84	95.25	53.87	
90	172.62	145.03	103.65	48.48

% From the Highest Actual Yield for K_2O	Kg ha^{-1}			
	Very Low	Low	Medium	High
50	87.69	67.41	36.99	
60	118.21	97.93	67.51	6.67
70	156.58	136.30	105.88	45.04
80	208.31	188.03	157.61	96.76
90	287.96	267.68	237.26	176.42

were used. Although the application of 225-225-360 kg ha-1 of N, P_2O_5, and K_2O, respectively, showed a higher percentage of the maximum attainable yield, the amount spent for every kg of strawberry yield was higher compared to the recommendation set by Hafza (2008), which was PhP 3.95 per kg of fruit yield. Half of Hafza's recommendations had a higher amount spent while increasing it further to 200, and 250% of the recommendation added production cost without economic benefits at all. Application of half of the fertilizer recommendation to strawberry plants had the lowest total spent on fertilizer materials. However, the amount spent per kg yield is higher because of the lower yield. The data suggest that the yield should not be the basis for the recommendation in determining the fertilizer rates. Considering the economic benefits derived from fertilizer application and the environmental impact is necessary for sound fertility management practices.

Table 3. Amount spent on fertilizer (Peso) / yield production) of strawberry.

Treatments	Total amount of fertilizer materials spent*	Yield (t ha^{-1})	Amount spent on fertilizer (Peso) / yield production)
0.5	18,304.78	9.25	8.97
1.0	36,609.55	11.40	3.95
1.5	54,914.33	11.79	4.81
2.0	73,219.10	9.82	6.21
2.5	91,523.88	8.70	9.31

*Prevailing market prices of the fertilizer materials as of December 2021: Diammonium phosphate- PhP 2,149.59; potassium chloride- PhP 1,621.49 and ammonium sulfate PhP 1,111.12 (PSA, 2022).

4. CONCLUSION

The Mitscherlich-Bray Equation can be a basis for determining the amount of fertilizer to be applied along with the economic benefits of the recommendation.

Strawberry is highly responsive to fertilizer application, particularly in N and K_2O nutrients. Two fertilizer options were very responsive as they reached 95 and 93% based on theoretical maximum yield. Considering economic benefits, applying 150-150-240 kg ha-1 of N, P_2O_5, and K_2O is still the best option. The equation is helpful in understanding fertilizer response to crops, and thus it should be used in soil fertility trials.

RECOMMENDATION

This study recommends separately conducting the study for N, P_2O_5, and K_2O set-up. Also, the range of P should be lowered, and the ranges should be narrower. Since this study is a preliminary test of fertilizer recommendation, a verification trial must be conducted.

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