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OPTIMIZING FERTILIZER USE FOR GRAPES CULTIVATION IN PAKISTAN USING THE MITSCHERLICH–BRAY EQUATION

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Abstract

Grapes *Vitis vinifera*, being the important fruit crop is produced in temperate region and consumed all over Pakistan owing to its taste and superior nutritional values. However, the infrequent fertilizer inputs and exhausted natural resources have given rise to number of hurdles in quality grapes production. Among the yield depriving imperative factors, fertilizer management plays a substantial role. In this regard, an experiment was designed to assess different doses of nitrogen (N), phosphorus (P) and potassium (K) in grapevines sown at three different sites located in district attock. The main objective of the study was to estimate NPK requirement in grapes crops under soil conditions of attock so that judicious fertilizer use can be achieved. Nitrogen and potassium were kept constant in each treatment whereas P₂O₅ was applied at 5 different concentrations i.e. P₂O₅ @0 kg/ha, P₂O₅ @230 kg/ha, P₂O₅ @300 kg/ha, P₂O₅ @365 kg/ha and P₂O₅ @430 kg/ha. Grapes yield was measured at individual site and treatments. The yield and fertilizer data were also subjected to Mitscherlich–Bray Equation. The comparison between actual yield and theoretical grape yield was made and the results exhibited that pursuant to Mitscherlich–Bray equation, amount of fertilizer desirable to achieve 90% of theoretical maximum yield was less as compared to general recommendation of P₂O₅ kg/ha⁻¹. Soil which has initial level of 10 kg P ha⁻¹ would entail about 428 kg P₂O₅ ha⁻¹ fertilizer application to attain 90% of theoretical yield. This study is significant for farmers as well as for scientists because the soils of Pakistan are facing a fertility diminution so over or under application of soil amendments can results in economic losses. Mitscherlich–Bray Equation modeled the actual requirement of the fertilizers, hence there will be no chances of non-judicious fertilization in attock soils that harbor grapes crop.

Keywords: Economic uplift, Profitability, Theoretical yield, *Vitis vinifera*

INTRODUCTION

Pakistan being an agricultural country has a variety of natural fruits and vegetables that contain ample nutritional qualities. Pakistan has a diverse climate and it allows the cultivation of nearly all types of fruits like temperate (apple, cherry, pear, apricot, grape, strawberry, currants, peaches, plum etc.), tropical (mango, guava, banana, tamarind, papaya etc.) and subtropical fruits (pomegranates, date, fig, oranges etc.) (1). The Southern part of the country produces tropical fruits whereas the temperate fruits thrive best in the northern areas of the Pakistan (2-4).

Grape (*Vitis vinifera* L.) belongs to the family Vitaceae and is among the most cultivated fruits across the world (5). It has great nutritional properties but it contains significant quantities of minerals, vitamins, organic acids, sugars (5), phenolics, antioxidants that are required by human body for daily activities, moreover the antioxidants prevent cardiovascular diseases as well as have anti cancerous properties (6). Being a non-climacteric fruit, grapes have critical harvest time. Proper maturity time enhance fruit quality, flavor and its shelf life (7).



Grapes in Pakistan are mostly consumed as raw fruit (8) however its seed extract and seed oil are also used for health. Grape seed extract also contained potential anti cancerous properties (9, 10). Moreover, commercial juice products from concord grapes are used in medical research studies and results showed that it has potential benefit against the onset stage of cancer (11). The northern areas of the Punjab province, Baluchistan and KPK have a wide variety of grapes but quality harvest is restricted due to biotic and abiotic factors (12-14).

Grapes vines are successful in a wide range of soil conditions however, it is heavy clay soils, poorly drained, shallow or sodic soils are not good for plant healthy growth. grapevines require ample amount of moisture which it receives directly in the form of rain and during dry season irrigation is also applied.

Grapes cultivation is time intensive and requires proper care and management and considerable expertise for obtaining maximum yield. An estimated yield loss is 70% if the crop is mismanaged and crop loss can reach up to 90% if the adequate inputs are not provided on right time and in optimum quantities (15). Aujla et al (16) identified factors like poor irrigation, inadequate fertilizer utilization, poor pruning and training techniques, poor pest management and lack of resources as the basic barriers in low yield.

Among these factors, fertilizers are significant as yield and quality of grape crops are closely related nitrogen, phosphorus and potassium absorption during the crop duration (17, 18). At different crop growth stages, the fertilizer needs are different, however the soils already deficient in nutrients exaggerate the conditions for fruit failure (19). Hence accurate and regular Grapes have varying demands for N, K and P among different growth stages. Moreover, the availabilities of the N, K and P nutrient elements in soils are limited, and this makes it difficult to meet the growth requirements of grapes. Therefore, ensuring the rapid and accurate monitoring of the nutrient statuses of N, K and P in grape crops at different growth stages is critical for formulating a fertilization management system based on scientific and reasonable considerations to ensure the yield and quality of grapes.

Traditional crop nutrition diagnoses mainly rely on destructive field sampling and slow laboratory analyses, and the nutrient concentrations determined at individual points can be quite different from the actual nutrients present in croplands (20). By keeping in view, the importance of fertilizers and their judicious usage under the changing climatic, soil as well as socio economic concern, this experiment is design to evaluate Mitscherlich–Bray Equation on the fertilizer use as well as its actual demand by the soils for successful grapes cultivation. The model study will estimate the theoretical fertilizer demand for obtaining yield under our soils and environmental conditions, which will further help researchers and farmers to schedule their fertilizer inputs according to the site requirement.

MATERIALS AND METHODS

EXPERIMENTAL SITE DESCRIPTION

The experiment was carried out at three farmer fields located in the District Attock. The city experiences long, muggy and sunny summers while winters are short, cold and clear. The average temperature of the city is 39°F to 104°F. The district receives rainfall throughout the year at different intensities. More than half of the rain is received during the 31 days around August 01 with some heavy spells as well. The pre sowing soil analysis report is given in Table I.

Table I. Pre-sowing soil analysis report of the experimental area

Texture	Depth	EC	PH	Organic Matter	Available P	Available K
LOAM	0-15	0.6	7.73	0.75	5.6	100
	15-30	0.7	7.32	0.1	4.1	100
	30-60	0.69	7.21	0	3.5	120
	60-90	0.62	7.22	0	2.4	120

EXPERIMENTAL SETUP

The vineyard in Attock research station is well maintained from many previous years. For this experiment, healthy grape vines (age of 5 to 6 years) were selected and grown at the three selected farmers'

fields. The vines were maintained at 2.4 m distance and had row to row distance of 3.0 m. The grape variety was and vines were spur pruned at 2 buds in winter during the 2nd fortnight of January. The experiment comprised of 5 fertilizer treatments i.e. Nitrogen and potassium were kept constant in each treatment whereas p₂o₅ was applied at 5 different concentrations i.e. P₂O₅ @0 kg/ha, P₂O₅ @230 kg/ha, P₂O₅ @300 kg/ha, P₂O₅ @365 kg/ha and P₂O₅ @430 kg/ha. In addition to rainfall, normal irrigation was applied in furrows (when required) to avoid water stress. Harvest timing was decided based on physiological maturity and local commercial acceptability of table grape cultivars when most of the berries reach 16–18°brix.

MODEL EXPLANATION OF MITSCHERLICH-BRAY EQUATION

The yield data collected were subjected to the Mitscherlich-Bray equation as given below (21).

$$\log (A-y) = \log A - c_1b - cx$$

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:

$$C_1 = \text{Log } A - \log(A - y_0) / b$$

$$C = (\log A - c_1b) - \log (A - yx) / x$$

Where A=%theoretical maximum yield, y=actual yield obtained in qha⁻¹, b= native soil test value in kgha⁻¹, x=fertilizer nutrient applied in kgha⁻¹, c₁ and c=constants i.e., the efficiency of soil and fertilizer nutrients respectively; yx is the yield obtained from the fertilized plots, y₀ is the yield obtained from control plots.

RESULTS AND DISCUSSION

From the grapes yield acquired from 3 sites of farmer's field experiment, values of y, 1/x, c₁, c, and c₁/c ratios were calculated for different P and K fertilizer levels (Table II). Theoretical maximum yield for 3 sites P was 43,652, 35481 and 44668 kg ha⁻¹ respectively. (Figs. 1, 2 and 3). The C₁ values for P for site I to III were 0.010014, 0.0139994 and 0.018671, individually (Table II). The c₁ values for P were smaller at site I than Site III, showing less contribution of soil P₂O₅ at site I and at Site III more role of soil P in plant growth.

Table II. Grapes yield and efficiency coefficients of soil and fertilizer phosphorus

Site-I Farmer's Name : Ali Hussain						
Treatments	Yield (kg ha ⁻¹)	Log Y	1/x	c ₁	C	c ₁ /c
P ₂ O ₅ applied (kg ha ⁻¹)						
0	10,245	4.01	0.000	0.010014		
230	24,896	4.40	0.006		0.0014747	
300	30,774	4.49	0.005		0.0018818	
365	31,755	4.50	0.004		0.0016607	
430	31,946	4.50	0.003		0.0014232	
Mean	25,923				0.0016101	6.22
Theoretical maximum yield	43,652					
Site-II Farmer's Name : Shah Nawaz						
Treatments	Yield (kg ha ⁻¹)	Log Y	1/x	c ₁	C	c ₁ /c
P ₂ O ₅ applied (kg ha ⁻¹)						
0	12,593	4.10	0.000	0.0139994		
230	26,915	4.43	0.006		0.002511	
300	27,877	4.45	0.005		0.002175	
365	30,057	4.48	0.004		0.002316	
430	30,294	4.48	0.003		0.002015	6.21
Mean	25,547				0.002254	
Theoretical maximum yield	35,481					

Site-III Farmer's Name : Muhammad Sheraz						
Treatments	Yield (kg ha ⁻¹)	Log Y	1/x	c ₁	C	c ₁ /c
P ₂ O ₅ applied (kg ha ⁻¹)						
0	18,228	4.26	0.000	0.018671		
230	33,607	4.53	0.006		0.002226	
300	36,697	4.56	0.005		0.002367	
365	37,669	4.58	0.004		0.002138	
430	37,872	4.58	0.003		0.001844	
Mean	32,815				0.002144	8.71
Theoretical maximum yield	44,668					

The c₁/c proportion was found to be low for Site II P series tests as compared to Site I and Site III series tests, showing higher response of P fertilizer application at Site II. These outcomes are in concomitance with past finding of Ali *et al.*, (22), who conducted trial on two sites in South Punjab, Pakistan utilizing Raya (*Brassica juncea L.*) as a test crop, Sonar and Babhulkar (23), who conducted trial at various areas in India utilizing wheat (*Tritium aestivum*) as a test crop and Sher Afzal *et al* (21), who conducted tests at different sites in Northern Rainfed areas Punjab Pakistan, utilizing groundnut (*Arachis hypogaea*) as a trial crop. They detailed lower c₁/c qualities at Site II than Sites I and III for P showing higher reaction to applied P at Site II. Using the mean c₁ and c values, fertilizer recommendation of P for common range of soil test values from 2.5 to 25 kg ha⁻¹ for P for all Sites and were determined for grapes crop (Table III).

Table III. Phosphorus Recommendations for grapes based on Mitscherlich- Bray concept

Soil available phosphorus (kg ha ⁻¹)	Percent theoretical maximum pod yield				
	50	75	80	85	90
2.5	133	283	331	393	482
5	115	265	313	376	463
7.5	97	247	296	358	446
10	79	229	278	340	428
12.5	61	212	260	323	411
15	44	194	242	305	393
17.5	26	176	225	287	375
20	8	159	207	269	357
22.5	0	141	189	251	339
25	0	123	171	234	322

These fertilizer recommendations give a choice for level of fertilizer application keeping in view the target yield and initial soil fertility level. Soil having initial level of 10 kg P ha⁻¹ would require about 428 kg P₂O₅ ha⁻¹ fertilizer application to attain 90% of theoretical maximum yield as demonstrated by initial trial. It was also observed that on the basis of Mitscherlich–Bray equations amount of fertilizer needed to achieve 90% of theoretical maximum yield was less as compared to general recommendation of 200 kg P₂O₅ ha⁻¹ (Table III). Opposite to our findings, from research experiment conducted in British Columbia in mid-sixties, it was presumed that generally the fertilizer recommendation based on Mitscherlich–Bray equation overestimate fertilizer requirement (24). However, like our findings, Harrell (25) saw that a soil having initial P (Olsen) level of 15 kg ha⁻¹ required utilization of 81 kg P₂O₅ ha⁻¹ for accomplishing 90% of hypothetical greatest yield of corn (*Zea mays*), which is much lower than fertilizer recommendations for Louisiana soils. This difference in opinion might be due to difference in extractants utilized for soil P analysis, as it has been reported that that Bray II soil P test overestimate available P in calcareous soils, and resultantly there is need to apply P fertilizer even, when soil has P value of 700 mg kg⁻¹ (25).

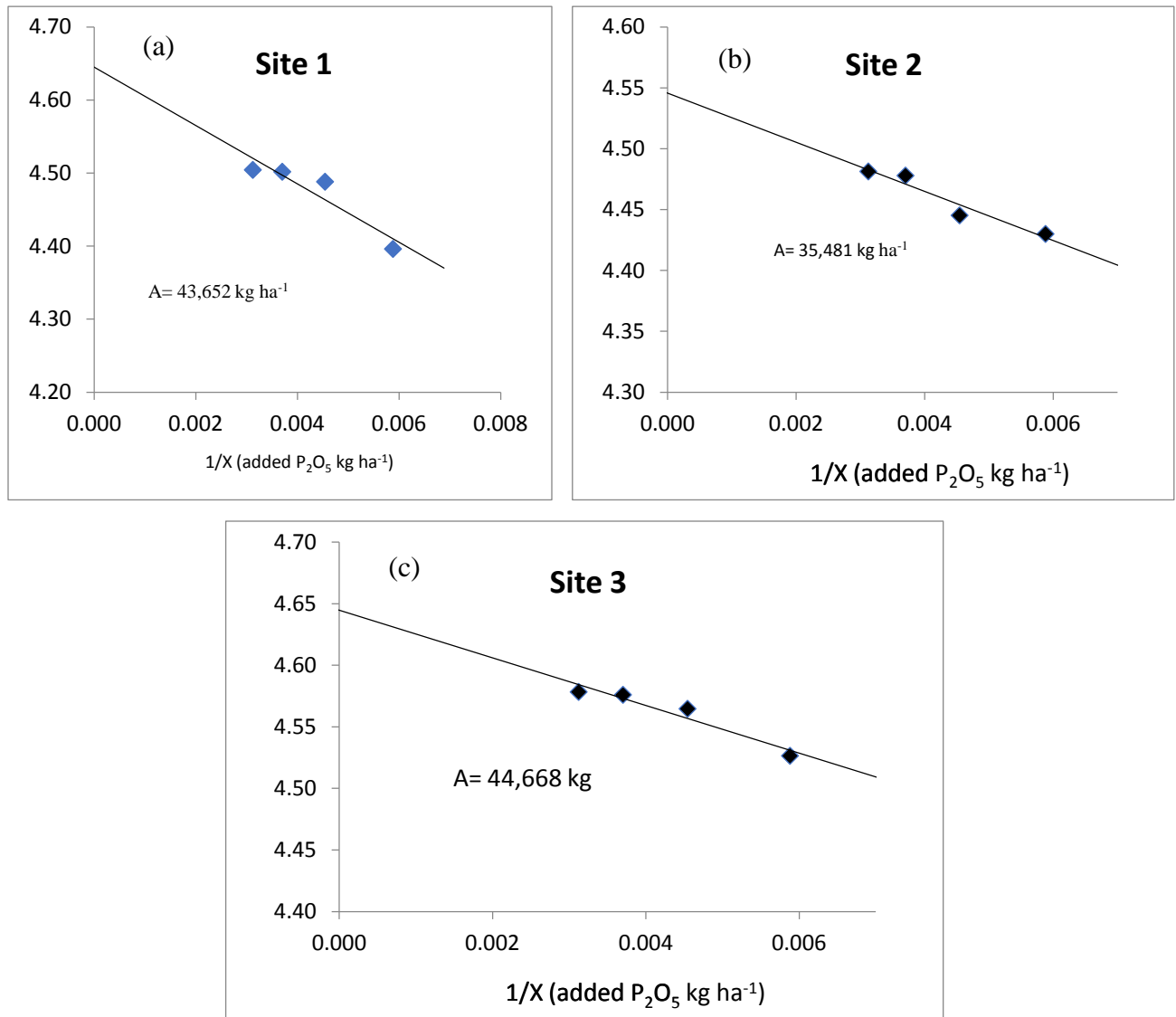


Fig. 1. (a) Theoretical maximum yield at site 1 (b) Theoretical maximum yield at site 2 (c) Theoretical maximum yield at site 3

Table IV (a). Profitability of fertilizer use on grapes under various treatments at site 1

T	Fertilizer			BY	YI	VIY	COF	VCR	AE
	N	P ₂ O ₅	K ₂ O						
Control	0	0	0	10,245	0	0	0	0	0
Recommended dose	322	300	160	24,896	143	1144000	78260	14.61	2.09
75% of maximum yield	322	229	160	30,774	200	1600000	59739	26.7	1.14
90 % of maximum yield	322	428	160	31,755	210	1680000	116347	14.43	2.03

Where: T=treatments; Fertilizer= Fertilizer applied (kg ha⁻¹); BY= Bunch yield (kg ha⁻¹); YI=% increase over control VIY= Value of increased yield; COF= Cost of Fertilizer; AE= Agronomic Efficiency

Table IV (b). Profitability of fertilizer use on grapes under various treatments at site 2

T	Fertilizer			BY	YI	VIY	COF	VCR	AE
	N	P ₂ O ₅	K ₂ O						
Control	0	0	0	12,593	0	0	0	0	0
Recommended dose	322	300	160	26,915	113.7	909600	78260	11.62	2.6
75% of maximum yield	322	229	160	27,877	121.3	970400	59739	16.24	1.88
90 % of maximum yield	322	428	160	30,057	138.6	1108800	116347	9.5	3.08

Where: T=treatments; Fertilizer= Fertilizer applied (kg ha⁻¹); BY= Bunch yield (kg ha⁻¹); YI=% increase over control VIY= Value of increased yield; COF= Cost of Fertilizer; AE= Agronomic Efficiency



Table IV (c). Profitability of fertilizer use on grapes under various treatments at site 3

T	Fertilizer			BY	YI	VIY	COF	VCR	AE
	N	P ₂ O ₅	K ₂ O						
Control	0	0	0	18,228	0	0	0	0	0
Recommended dose	322	300	160	33,607	84.3	672000	78260	8.58	3.5
75% of maximum yield	322	229	160	36,697	101.3	810400	59739	13.56	2.26
90 % of maximum yield	322	428	160	37,669	106.6	852800	116347	7.3	4.01

Where T=treatments; Fertilizer= Fertilizer applied (kg ha⁻¹); BY= Bunch yield (kg ha⁻¹); YI=% increase over control VIY= Value of increased yield; COF= Cost of Fertilizer; AE= Agronomic Efficiency

The data of the field trials showed that maximum yield of 1003 kg ha⁻¹ was gotten with utilization of recommended dose of fertilizer P (90 kg P₂O₅ ha⁻¹) and K (60 kg K₂O ha⁻¹).

Maximum yield was obtained with recommended dose of fertilizer, but VCR values were low. VCR was higher for treatment getting 75% and 90% hypothetical yield fertilizer dose based on Mitscherlich–Bray equation. All the parameters relevant to economics fertilizer such as net income, incremental return, net return and RII were higher for 90% of maximum yield treatment (Table IV a,b,c). Under similar soil and climate conditions, Rashid (26) saw that in limited moisture supply situation, lower levels of nutrient application (50 kg N and 25 kg P₂O₅ ha⁻¹) were better and economical than higher fertilizer doses; fertilizer use efficiency is normally lower under rain fed conditions as compared irrigated ones (27, 28). These outcomes additionally are in concurrence with the findings of Sonar and Babhulkar (23) that saw that fertilizer use on the basis of 80% theoretical maximum yield was better than general recommendation of fertilizer for wheat in India. Soil P values determined from post- harvest sample showed similar pattern. Treatment receiving recommended dose and the treatment with fertilizer dose adjust at 90% of theoretical maximum yield showed higher P values as compared to control and 75% theoretical greatest yield. These outcomes are in concurrence with the findings of a past report led under comparable soil and environment utilizing chickpea as test crop where utilization of 40 and 80 kg P₂O₅ ha⁻¹ resulted in significant increase in soil-available P values.

CONCLUSION

Nutrient deprived soils in Pakistan are among the top barriers in producing ample and quality yields of crop. In addition the low exposure of the farmers towards the scientific facts related to nutrients uptake and assimilation is making situation worse as they add fertilizers without scientific prescribed protocols. In this regard, it is the duty of scientists and extension workers to help them by suggesting the right amount of fertilizers according to the crop and soil need. Mitscherlich-Bray-Equation is a mathematical model which helps in devising the exact fertilizer needs on the basis of previous fertility status of soils. Conclusively the use of Mitscherlich bray equation prior to sowing of crops on larger areas, the actual nutrient requirement can be estimated, which will result in economic uplift for the farmer as well as over or under use of fertilizers are avoided.

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