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APPLICATION OF MITSCHERLICH-BRAY EQUATION ON MUNGBEAN CROP FOR ECONOMIC FERTILIZER USE

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Abstract

Mungbean (Vigna radiata L) is a substantial pulse crop because of its advantageous nutritional profile, soil refining capacity and adaptability to diverse climatic conditions. In Pakistan, it is cultivated on a larger scale, nevertheless, it faces a crucial loss due to unwise fertilizer management. Huge market constrictions and monetary gap is observed owing to mismanagement practices in fertilizer uses like time of application, right doses, methods of application and soil nutritional resources. In this regard, there is a dire need to evaluate the accurate amount of fertilizers required for obtaining maximum yield potential along with farmer-friendly financial management. For such analysis, the Mitscherlich-Bray equation is among the best possible estimators for theoretical and actual fertilizer demand in any crop. The equation was applied on our current experiment comprising ten treatments which were made by combination of three basic nutrients i.e. Nitrogen (N), Phosphorus (P) and Potassium (K) and applied at various rates. The theoretical yield was calculated by plotting log y (grain yield) versus 1/x (amount of nutrients applied). The results showed that P and K's maximum theoretical mungbean yield was 1350 kg/ha and 1138 kg /ha, respectively. The C1 values for P and K were 0.0271 and 0.0023, respectively. These values of C1 showed that K had a smaller value than P, indicating that soil K contributes less than Soil P to the growth of Plants. The results and understanding of this study can open new ways for the estimation, application and dosing of crops especially those that are fertilizer-sensitive. It will subject to a decrease in the losses which occur due to under and over-dosing of fertilizers as well as nutrient selection. Lastly, our study clearly depicts a model which, before application of nutrients into the soil can affirm economic gain in terms of inputs and crop yield.

Keywords: *Arid region, Economic analysis, Fertilizer use, Mitscherlich-bray equation, Vigna radiata L*

INTRODUCTION

Mungbean (*Vigna radiata* (L) Wilczek) is among the major legume crops grown in Pakistan and is widely consumed for its edible seeds (1). Its seeds are utilized in roasted, cooked, milled and sprouted form and used in making noodles, curries and soups as mungbeans are easy to digest and are a rich source of protein. It contains protein in a range of 20-24 per cent (2, 3). Mungbean stubbles are also a source of green manuring (4) and a good fodder source (5) which further improves the soil fertility. It can also be used as a catch crop due to short maturity (6).

In Pakistan, mungbean crop is cultivated in larger areas and Punjab accounts for 80% of this land and most of the varieties have a yield potential of 12-22 mound/acre (7). Most of its production is full filled in the Southern Punjab region as compared to other regions of the country (8).

Among many factors, one most imperative one is the lack of knowledge about nutrition applications as well as advanced production technology. Similarly, lack of useful attention on fertilizer application is also a main factor causing lesser mungbean yield (9).

In the current scenario of economic hype, inorganic fertilizers are becoming non-affordable for farmers (10) this situation requires a specific recommendation which includes site-specific input requirements in the cropping zones. Recent findings have shown that site-specific application of required nutrients shows better results as compared to general recommendations and it also reduces the input cost (11, 12).

The Mitscherlich-Bray equation is a mathematical model used in agriculture to estimate fertilizer requirements for crops, including mungbeans. This equation is named after the German agricultural chemist Eilhard Mitscherlich and the American soil scientist Alfred Bray. The Mitscherlich-Bray equation is particularly useful in determining the relationship between crop yield and the availability of a specific nutrient in the soil. The Mitscherlich-Bray equation is found very effective in estimating the actual requirement of fertilizer (11, 13, 14) because it is related to nutrient level in soil, yield as well as impact of soil fertility level on the yield of specific crops taken under consideration. The mitscherlich-Bray equation is now widely used to determine the fertilizer P requirement of various crops as well as resulting in saving of this precious input (15). The Mitscherlich-Bray equation provides insights into how much a nutrient deficiency or excess affects crop yield and helps farmers and agronomists make informed decisions about fertilizer application. It is important to note that the equation assumes a unimodal response, where yield increases with nutrient availability up to a certain point, beyond which further increases may have diminishing returns or negative effects.

This study aimed to estimate the crop fertilizer inputs according to the crop requirement with special emphasis on quantitative use which is not used, in most cases according to the site or soil condition. Use of overall recommended fertilizer in specific sites may cause harm to the farmer as well as the crop by implication of higher fertilizer costs and disturbing the soil microenvironment by over or under doses for the plant growth and development.

This study is specifically designed to formulate recommendations for fertilizer for Mungbean by using the Mitscherlich-Bray equation. Another objective was the comparison between soil tests based on general recommendations and the recommended use Mitscherlich-Bray equation concerning crop response as well as the economic use of fertilizer.

MATERIALS AND METHODS

Field trials were operated in 2022 at the research area of the Regional Agricultural Research Institute (RARI), Bahawalpur (27.2046°N; 77.4977°E), and Punjab Province, Pakistan. This region has the climate characteristics of desert. During the year, there is virtually no rainfall in Bahawalpur. According to Köppen and Geiger, this climate is classified as BWh. The average annual temperature is 26.1 °C (79.0 °F) in Bahawalpur. The rainfall here is around 223 mm (8.8 inches) per year. Around 3852.73 hours of sunshine are counted in Bahawalpur throughout the year.

The Bahawalpur Mung-17 variety was used as a planting material having high yield, good quality and drought tolerant. It is widely planted locally and was bred by the Regional Agricultural Research Institute, Bahawalpur. The fertilizer sources used for N fertilizer (urea containing 46% N), P fertilizer (Di Ammonium Phosphate containing 46% P2O5), and K fertilizer (potassium sulfate containing 50% K2O) were applied according to the treatment plan.

The experiment was comprised of ten treatments along with control; only P and K application @ 34 and 25 kg ha^{-1}; N, P and K application @ 12, 34 and 25 kg ha^{-1}; N, P and K application @ 23, 34 and 25 kg ha^{-1}; N, P and K application @36, 34 and 25 kg ha^{-1}; only N and K application @ 23 and 25 kg ha^{-1}; N, P and K application @ 23, 23 and 25 kg ha^{-1}; N, P and K application @ 23, 46 and 25 kg ha^{-1}; only N and P application @ 23 and 34 kg ha^{-1}; N, P and K application @ 23, 34 and 12 kg ha^{-1}; N, P and K application @ 23, 34 and 36 kg ha^{-1}, respectively. All treatments were arranged in a randomized complete block with three replications for a total of 69 trial plots. Before sowing, soil samples (pre-sowing) from the experimental area were collected, processed and analyzed. Physical and chemical soil analysis showed the soil is loamy and aerated having a pH 8.3. The topsoil (0-15-cm) layer contains 0.49% organic matter, 4.6 ppm available P, and 123 ppm available K. After soil analysis, the land with recommended methods. The seeds were soiled with hand drills at a seed rate of 23 kg ha^{-1}.

Each plot had an area of 22.5 m2 (9 m long, 2.4 m wide), with rows spacing ~ 60 cm apart. The plants were thinned at the two-leaf stage to a uniform density of 150,000 plants ha^{-1}. The fertilizers were applied to soil as a basal fertilizer to a depth of 15 cm when the seeds were sown. All cultural practices were carried out accordingly.

Rainfall data from the experimental site was recorded (Table I) harvesting was completed at the end of October. The grain yield was calculated after sun-dried thrusting. Yield was subjected under the Mitscherlich-Bray Equation as given blew (11).

Log (A¬¬¬-Y) = log A-c1b-cx

Where A= theoretical maxi yield %: y= actual yield in kg ha^{-1} local soil test value in kg ha^{-1} x= applied fertilizer nutrient in kg ha^{-1}:c1 and c= constants, i.e. efficiency of soil & fertilizer nutrients, respectively.

Table I. Location, rainfall and physiochemical properties of experimental site

Parameter	Unit	Location
Elevation	m	118
Latitude	N	27.2046°N
Longitude	E	77.4977 °E
Cropping season (June to October) rainfall during (i) 2021 (ii) 2022	mm	481
Sand	%	48
Silt		32
Clay	%	21
Texture	-	Loamy
pH	-	8.3
ECe	mS m^{-1}	59
Total Organic Carbon	%	0.49
Total N	%	
Phosphorus ($NaHCO_3$ extractable)	ppm	4.6
Potassium (NH_4OAc extractable)	ppm	123

Following parameters were calculated from Eq. (1)

i) Theoretical maximum yield by plotting log y against 1/x.

ii) Constants c1 and c for P and K separately.

$$C1 = \log A - \log (A-yo)/b \quad (2)$$

Where Yo = yield obtained from control plot

$$C = (\log A - c_1 b) - \log (A-yx)/x \quad (3)$$

Where yx= yield obtained at fertilizer dose x.

iii) Fertilizer P and K recommendations for mungbean at different soil fertility levels by following formula.

$$X = \log (A-c_1 b) - \log (A - yx)/c \quad (4)$$

RESULTS

The values of C1/C proportion from the mungbeans yield trial conducted at the Regional Agriculture Research Farm, Bahawalpur, found lower for Potassium assessments as contrast to Phosphorus assessments, showing more contribution of P fertilizer than K fertilizer in context of plant growth from the Mungbean grain yield acquired from field experiment conducted at RARI, Bahawalpur. From the Mungbean yield acquired from field experiment conducted at RARI, Bahawalpur, values of, c1/c, 1/x, c, c1, and y ratios were deliberate for different K and P (Table. II). Maximum output for k and P was 1138 and 1350 kg ha−1 respectively (Fig. 1 a and b) This result was like the past results of Nemeth (16) in wheat and corn crops and Afzal et al. (13) in groundnut, Sonar and Babhulkar (13) tested different levels of nutrient in wheat crops and found 80% of the theoretical maximum yield was superior to the comprehensively recommended dose. It detailed lesser C1:C qualities for K as compared to P showing high and maximum reaction to applied Potassium. Using mean C1 and C values, fertilizer recommendation of K and P for various scale of soil testing values ranges from 2.5 to 25 (kg/ ha) for Phosphorus and 200 to 400 (kg /ha) for Potassium were contributed to boost the mung crop (Table III) and maximum theoretical mung beans yield for P and K 1350 and 1138 kg /ha, respectively. The C1 values for P and K were 0.0271 and 0.0023, respectively. These values of C1 showed that k had smaller value than P which indicate that soil K contribute less than Soil P in the growth of Plants.

Table II. Mungbean grain yield and efficiency coefficients of soil and fertilizer

Treatments	Grain Yield (kg ha^{-1})	Log Y	1/x	C1	C	C1/C
P_2O_5 applied						
0	696			0.0271		
23	864	2.94	0.0435		0.0056	
34	1103	3.04	0.0294		0.0124	
46	1046	3.02	0.0217		0.0072	
Mean	927				0.0084	3.23
Theoretical maximum yield	1350					
K_2O applied						
0	851			0.0023		
12	1002	3.00	0.0833		0.0270	
25	1103	3.04	0.0400		0.0366	
36	1070	3.03	0.0278		0.0174	
Mean	1007				0.0270	0.085
Theoretical maximum yield	1138					

Table III. Fertilizer recommendations for Mungbean based on Mitscherlich- Bray concept

	Soil available nutrient (kg ha^{-1})	Percent theoretical maximum Grain yield				
		50	75	80	85	90
Phosphorus	2.5	28	64	75	90	111
	5	20	56	67	82	103
	7.5	12	47	59	74	95
	10	4	39	51	66	87
	12.5	0	31	43	58	79
	15	0	23	35	50	71
	17.5	0	15	27	42	63
	20	0	7	19	34	55
	22.5	0	0	11	25	46
	25	0	0	3	17	38
Potassium	200	0	5	9	13	20
	250	0	1	5	9	16
	300	0	0	0	5	11
	350	0	0	0	0	7
	400	0	0	0	0	3

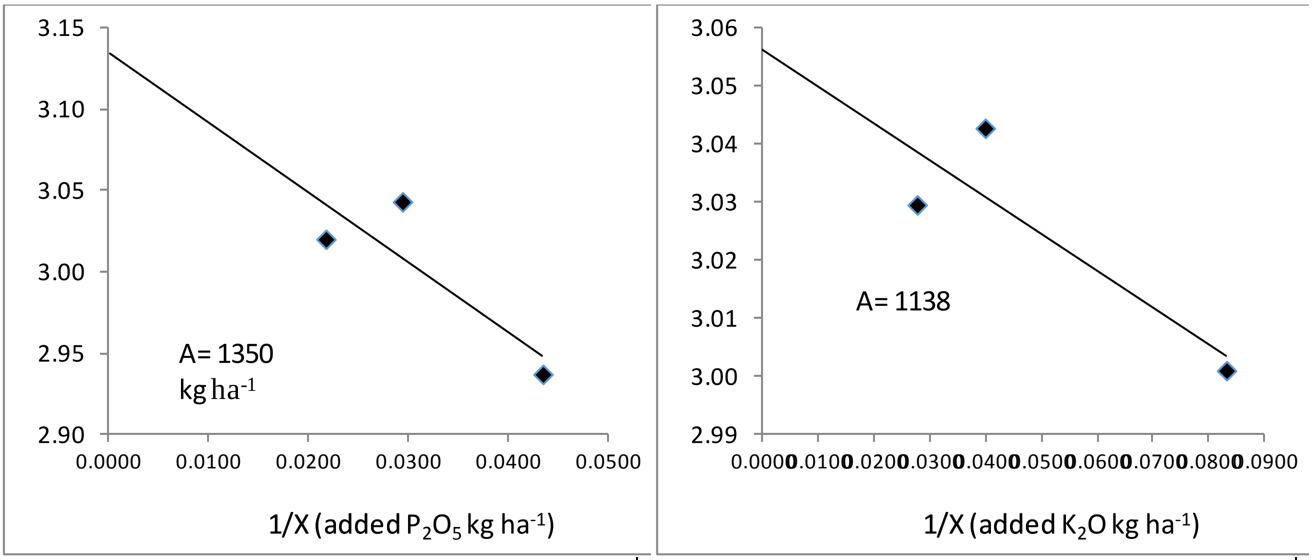

Fig. 1 (a). Maximum output for P2O5 after plotting Log Y and 1/X **(b).** Maximum output for K2O after plotting Log Y and 1/X

DISCUSSION

The trial data also revealed that following Mits–Bray equations level of fertilizer to fulfil 90% higher grain yield was low as compared to the general recommendation of 90 kg phosphorus oxide/ha and 60 kg potassium oxide/ha as maximum yield was exhibited by initial observations (Table III). Opposite to these results from an experiment carried out in Bretain-Colombia in sixty's, it also imagined the fertilizer recommendation by following the Mits–Bray equation amplified F need (16). However, Harrel's experiment (17) perceived the same results that to accomplish ninety per cent outcomes of corn, inceptive phosphorus about 15 kg/ha needed usage of about 81 kg phosphorus oxide/ha which is very low as compared to the requirement of Louisiana type soil, (17). That variance in outlook may be because of variance in extractants utilized for Phosphorus determination, it reveals that in calcareous soil, the Bray II test over states accessible phosphorus also when soil phosphorus has a value of 700 mg/kg it demonstrates the application of phosphorus at even (18). Trial data show that a higher output of about 1350 kg/ha was obtained by using an approved dose of phosphorus about 90 kg of phosphorus oxide per ha & potassium 60 kg of potassium oxide per ha . Apart from that their VCR value was low, this value was increased when treatment got 75% and 90% hypothetical output dose of fertilizer according to the Mitsc-Bray equation. Different parameters included RII, net return, and incremental return higher for 90% of the maximum output treated . According to Rashid et al. (18), under the same climate & soil conditions, lesser application of nutrients was economical as compared to higher. The efficiency of fertilizer use is lesser in rain-fed areas with outcomes of Sonar et al. (11) who observed that fertilizer use based on theoretically higher outcomes is best-endorsed phosphorus values in soil set after harvesting showed a similar pattern. As compared to controlling 75% theoretical output, the adjusted dose of treatment with fertilizer dose of 90% theoretical outputs gave a higher phosphorus value. These results are synchronized with the past report of chickpeas utilized as test crops under controlled soil and environment where utilization of 40 and 80 kg P2O5 ha $^{-1}$ resulted in a significant increase in soil-available P values. The application of different treatments on soil K values was not significant. The soils of these areas contain K-bearing minerals like biotite, muscovite, and K-feldspar acquired from parent material are replenished upon depletion of K from soil solution during the weathering process of these minerals by K release.

The trial data presented in the study underscore the importance of tailoring fertilizer recommendations to the specific needs of crops, as highlighted by the Mitscherlich-Bray (Mits-Bray) equations. The findings suggest that the Mits-Bray equations, which consider the relationship between nutrient availability and crop yield, provide a more accurate guide for fertilizer application compared to the general recommendations based solely on fixed nutrient quantities. This aligns with the notion that optimal nutrient levels vary across different soils, climates, and crops, emphasizing the need for precision agriculture.

A noteworthy observation is the discrepancy between the fertilizer levels recommended by the Mits-Bray equations and the conventional guidelines. The study indicates that following the Mits-Bray equations for phosphorus and potassium resulted in lower recommended levels for achieving a 90% higher grain yield compared to the standard recommendations. Such variations highlight the nuanced nature of nutrient requirements and the inadequacy of one-size-fits-all approaches. The role of soil characteristics, extractants used for nutrient determination, and regional factors cannot be overlooked in fertilizer management strategies.

Comparisons with other studies, such as those conducted in Bretain-Colombia and Harrel's experiment; underscore the context-dependent nature of fertilizer recommendations. Discrepancies in suggested fertilizer levels may arise from differences in soil types, methodologies, and regional conditions. The study emphasizes the need for a nuanced understanding of soil nutrient dynamics, particularly in calcareous soils where certain tests may overstate nutrient availability. This calls for a reevaluation of traditional soil testing methods to ensure accurate fertilizer recommendations aligned with the unique conditions of the study area.

Moreover, the economic implications of fertilizer use are explored in the context of net return and incremental return. The study suggests that, under specific climate and soil conditions, a lesser application of nutrients can be more economically viable than higher doses. This echoes the principle of efficient fertilizer use, especially in rain-fed areas. The results align with earlier findings that recommend phosphorus values based on theoretically higher outcomes but caution against excessive nutrient application. The discussion underscores the importance of not only maximizing crop yield but also optimizing the economic returns associated with fertilizer use, advocating for a balanced and sustainable approach to nutrient management in agriculture.

CONCLUSION

The results from this study showed that we require a site-specific nutrient management system that must be implemented other than the general recommendations, for the sake of more accurate, balanced and justified use of fertilizers that becomes economical also. It will not only boost the efficiency of fertilizer use but also economically less and wise use of inputs. The overuse of fertilizers for many years renders non-profitable results because of the high economic burden on the country, moreover, the farmers are also reluctant to buy costly fertilizers as they do not get the expected profit in terms of economic returns.

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