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# Application Of Mitscherlich-Bray Equation For Fertilizer Use In Barley Production In The Wolaita Of Southern Ethiopia

Research Article

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## Abstract

The experiments were intended at three locations in order to formulate different levels of NPK fertilizers recommendations of barley based on Mitscherlich-Bray equation at Wolaita zone southern Ethiopia. The experiments were laid out in RCBD with factorial arrangements applying N PK with three replications. Treatments were levels of N (0.23 and 46, P, 0, 10, 20 and 30 and K, 0, 25 and 50 kg ha-1) in all possible combinations. Theoretical maximum yield of barley was calculated by plotting logy versus 1/x (amount of nutrients applied). Fertilizer recommendation for various soil fertility levels and yield target were developed, and their validities were tested by conducting three field verification trials on the same soils. The results showed that although general recommended fertilizer dose resulted in highest yield of barley at all the locations, but total value cost ratio and net revenue were lowest with this fertilizer treatment, and maximum yield treatment was superior in terms of economics of fertilizer. The model considers the interactions of N, P, and K, and soil properties adjusted potential yield of the region which predicts crop yields from chemical soil characteristics, as an indicator of soil fertility.

**Keywords:** Barley; Nitrogen; Phosphorus; Potassium; Total Value Cost Ratio.

## Introduction

Barley (Hordeumvulgare L.) is one of the most important, economically valuable and widely used cereal crops. The crop is used for preparing traditional food and beverage consumptions [13]. The 2013/2014 production year, 1,908,262 tons were produced from a total of 1,019,477 ha of land in Ethiopia [7]. However, in Ethiopia barely yields have been consistently well below the East African and world average yields [7]. In Ethiopia, soil acidity is present a major challenge to bring about increased and sustainable productivity in order to feed the ever-increasing population of the country [1]. Most of the Ethiopian soils including Nitisols are low in soil fertility due to erosion and absence of nutrient recycling. On the contrary, most of the areas used for production of grains especially teff, wheat and barley fall under the low fertility soils [15]. Acidity is a major constraint for barley production in Ethiopia. Hailu and Getachew (2006) [11] reported a triple yield increase by application of 3 t ha-1 of lime compared to no lime at Adadi, southwest Shewa. Shiferaw and Anteneh (2014) reported highest barley grain yield (2,792 and 3,279.3 kg ha$^{-1}$) was recorded from combined application of NPK at the rate of 46/40/50 kg ha$^{-1}$ and half the recommended lime rate (3.84 and 0.85 t ha$^{-1}$ at Chencha and Hagerselam, respectively). A pot experiment conducted on soils collected from different land use systems in West Oromia revealed that maximum mean barley yield for both 50 and 100 mesh lime particle sizes (LPS) were obtained at 6 t ha$^{-1}$ of lime rate on the forest land, followed by 8 and 10 t ha$^{-1}$ on grazing and cultivated lands, respectively [5]. Liming of acid soils at Dera (Shemekebele) and Jabitehenan (Manakebele) in northwestern Amhara region based on regional soil laboratory recommendation [4] increased food barley productivity by 50% by application of 2 t ha-1 of lime (3.65 t ha$^{-1}$ as compared to 2.43 t ha$^{-1}$ grain

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yield without liming). Kiros G and Haile M (2014) [14] reported 133% grain yield advantage by combined application of 1.65 t $ha^{-1}$ lime and 30 kg $ha^{-1}$ P as compared to control (no lime and fertilizer) in the central highlands of Ethiopia. The partial nutrient balances revealed that in teff and barley based farming for N and K were clearly negative for teff and barley based farming system in the central highlands of Ethiopia -25 kg N $ha^{-1}$ $year^{-1}$ -87 kg K $ha^{-1}$ $year^{-1}$ for barley [10]. According to Kiroset al. (2014) [14] the national level depletion rate for N, P and k was calculated at -122 kg N $ha^{-1}$ $year^{-1}$, -13 kg P $ha^{-1}$ $year^{-1}$ and -82 Kg K $ha^{-1}$ $year^{-1}$, respectively. According to Astatkeet al. (2004) [2] proved a sharp increase in barely grown on Vertisols with an application of 50 kg $ha^{-1}$ $K_2SO_4$ and KCl, respectively. Potassium uptake and availability for plant growth and development vary depending on environmental influences associated with a particular set of growing conditions. Soil acidity and deficiency of nutrients, particularly P and K are the key soil related constraints that account for low yield of barley in Wolaitazone of southern Ethiopia [15]. The soil pH at the testing sites of Wolaita area ranged from 5.3 to 5.6 crop land and the concentrations K was 0.32 to 0.45$Cmol_c kg^{-1}$ [15, 17]. Likewise [15] reported that K had no eject on crop when applied without N, but had a significant eject on the yield of crop when applied with P fertilizer. The yield response obtained may be linear, exponential or curvilinear. It was for the first time a mathematical equation was used to find the relationship between the yield and applied nutrients. The Mitscherlich-Bray equation can be used as a tool for estimating fertilizer requirements of a crop from soil test values because it relates crop yield, soil nutrient level, and applied fertilizer levels in such a way that impact of soil fertility level on crop yield is taken into account. The present study was designed with following the objectives [5, 6].

To express fertilizer recommendationfor barley on the basis of Mitscherlich-Bray equation.

To verify and compare the soil test-based fertilizer recommendationwith those of site-specific recommendation based on Mitscherlich-Bray equation interms of barley response and economics of fertilizer use.

## Materials and methods

### Description Of Experimental Sites

The study was conducted in Kokate, Doga Mashido and Gurimo Koyisha, Wolaita Zone, southern of Ethiopia (Figure 1). The experimental sites are located from 6°53'.03"N and 37° 48'50.60"E, 6°53'20.3"N and 37°37'40.8"E, 6°57'15.3"N and 37°44'49.9"E, Kokate, Doga Mashido, Gurimo Koyisha, respectively, with an altitude range of 1900-2132 meters above sea level. The long-term weather information at experimental sites shows average annual rainfall of 1149 mm with bimodal distribution pattern giving rise to two distinct seasons. The short rains (Belg season) is between March and May, whereas the heavy summer rains (Meher season) is between June and October, with a peak in August. The mean annual temperature is 20 °C (NMA, 2016) [17].

### Experimental Design and Treatments

The experiment was laid out in randomized complete block design (RCBD) with replicated three times of three nutrients three rates for N (0, 23, 46 kg $ha^{-1}$) and K (0, 25, 50 kg $ha^{-1}$) and four rates for P (0, 10, 20 and 30 $kgha^{-1}$). The total treatment combinations and the rates of P are basis of common practices of fertilizer application on barely production in the Wolaita. The size of each plot will be 3 m x 3 m (9 $m^2$) and the space between plots and blocks were 1m and 1.5 m, respectively. All doses of P (triple superphosphate) and K (potassium chloride) were applied as basal dressing at sowing, while the N (urea) was applied split form, one-half applied at sowing and the other half at early booting. In all plots, the barley variety HB1307 was sowing at a rate of 100 kg ha-1 on July 30 and harvested on November 17. The harvesting plants was air-dried and weighed to determine aboveground dry matter. Grain as separated from straw manually and weighing to determine grain yield [9, 16].

### Soil Laboratory Analysis

Soils at all experimental sites were sampled before sowing; soils were sampled from 0-20cm depth from 108 spots of the experimental field. All samples were then air-dried, ground to pass a 2-mm sieve and stored. Proceeding to analysis, soil samples of the same depth, from different replicates and collected soil samples were composited to one sample and air-dried, ground and sieved using 2 mm sieve [20, 22]. Then the composite soil sample was analyzed for the determination of soil particle size, Soil pH in water in ratio of 1:2.5, organic carbon content, total nitrogen,cation exchangeable capacity, available phosphorus, exchangeable Ca, Mg and K exchangeable acidity, available Fe, Mn, Zn and Cu were extracted by diethylenetriaminepentaacitic acid (DTPA) method.

### Plant Laboratory Analysis

Ten non-boarders barley plant rows per plots were randomly selected from each plot for grain and straw analysis. The grain and straw of N, P and K contents were determined by wet acid digestion procedure as suggested by FAO (2008). The nutrients uptake by straw and grain were calculated by multiplying nutrients contents by straw and grain yield (kg $ha^{-1}$). Total nutrients uptake, by whole biomass was calculated by summing up the nutrients uptake of grain and straw. Nutrients use efficiency were calculated using procedures described by [8].

Barley yields were recorded at harvested and the data subjected to

**Figure 1. Location map of study sites.**

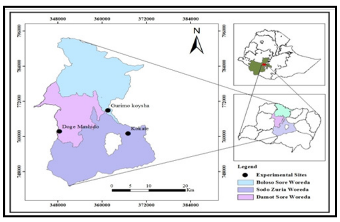


**Table 1. Soil physicochemical properties of experimental sites before planting.**

| Parameters | Unite | Locations | | | Reference |
|---|---|---|---|---|---|
| | | Gurimo Koyisha | Doge Mashido | Kokata | |
| pH (in $H_2O$) (1.2.5) | | 6.70 | 6.33 | 5.17 | Jackson (1973) |
| pH (in KCl) | | 5.20 | 6.40 | 4.67 | |
| Organic Carbon | % | 0.98 | 2.83 | 1.76 | SahlemdhinSertsu (1999). |
| Sand | % | 24 | 28 | 39 | Bouyoucos (1962) |
| Silt | % | 30 | 44 | 44 | |
| Clay | % | 46 | 28 | 17 | |
| Textural class | | Clay loam | Clay | Clay | |
| Total N | % | 0.12 | 0.12 | 0.14 | Bremner&Mulvaney(1982) |
| Available P | mg $kg^{-1}$ | 17.7 | 17.32 | 17.29 | Bray & Kurtz (1945) |
| Available K | mg $kg^{-1}$ | 192 | 136 | 180 | Morgan (1941) |
| CEC | $Cmolckg^{-1}$ | 17 | 24 | 16 | Black (1965) |
| Exchangeable Ca | $Cmolckg^{-1}$ | 10.8 | 11.8 | 9.8 | SahlemdhinSertsu (1999). |
| Exchangeable Mg | $Cmolckg^{-1}$ | 5.25 | 5.94 | 5.44 | SahlemdhinSertsu (1999). |
| Exchangeable K | $Cmolckg^{-1}$ | 0.5 | 0.45 | 0.41 | SahlemdhinSertsu (1999). |
| Exchangeable acidity | $Cmolckg^{-1}$ | 0.48 | 0.48 | 0.63 | Pansuet al. (2001) |
| Available Fe | mg $kg^{-1}$ | 112 | 105 | 202 | Lindsay &Norvell (1978) |
| Available Cu | mg $kg^{-1}$ | 10.6 | 11.4 | 10.4 | Lindsay &Norvell (1978) |
| Available Zn | mg $kg^{-1}$ | 10.6 | 8.4 | 14.3 | Lindsay &Norvell (1978) |
| Available Mn | mg $kg^{-1}$ | 114 | 110 | 138 | Lindsay &Norvell (1978) |

Mitscherlich-Bray equation. The following parameters were calculated [21].

Log (A-y) = log A -$c_1$b -cx -----------------------(1)

Where A = % theoretical maximum yield; y = actual yield in kg $ha^{-1}$; b = native soil test value in kg $ha^{-1}$; x = fertilizer nutrient applied in kg $ha^{-1}$; c1 and c = constants, i.e., efficiency of soil and fertilizer nutrient, respectively. Following parameters were calculated from Equation (1).

A. Theoretical maximum yield by plotting log y against 1/x
B. Constants c1 and c for N, P and K separately

$c_1$= log A-log(A-$y_o$)/b ------------------------- (2)

Where $y_o$= yield obtained from control plots

c=(logA-$c_1$b)=log(A-yx)/x ---------------------- (3)

Where yx= yield obtained at fertilizer dose x

C. Site specific recommendation of fertilizer N, P and K for barley at different levels by following formula.

x = log(A-$c_1$b)-log(A -yx)/c -------------------------(4)

**Economic Analysis**

The field verification trials on barley was also conducted at the three locations to know the utility and comparative financial advantage of Mitscherlich-Braybased fertilizer recommendation over generalized fertilizer recommendation based on soil test values. The economic analysis was performed to compare the relative costs and returns for each system. Net return and gross benefit was calculated according to the formula given by CIMMYT (1988) was used for economic appraisal.

## Results and Discussions

From the barley yields obtained at three locations"y, 1/x,$c_1$,c, and $c_1$/c" ratios were calculated Ranganathan et al. (1969) for various N, P and K fertilizer levels (Table 2). The yields increased with increase in the rates of N, P and K application but the increases were greater due to N application as compared to P and K application. Theoretical maximum yields of barley were 4215, 4753 and 3714 kg $ha^{-1}$ respectively for P, K and K sequence in three experiments sites (Doga Mashido, Kokate and Gurimo Koyisha) (Table 2). The $c_1$value was found to be 0.00706, 0.01141 and 0.010931 for N, 0.01598, 0.01604 and 0.010591 for P and 0.01043, 0.01704 and 0.01766 for K series, in the three sites respectively. The $c_1$ values for N were smaller than that of P and K at two sites (Doga Mashido and Kokate ) indicating less contribution from soil N while more contribution from soil P and K for the growth of barley. On other hand, soil N althoughless contribution than K at Gurimo Koyishasites. The ratio of $c_1$/c was found to be low for N series experiment (0.20) while it was more in the case of P (0.4973) and K series (0.511) at experiment sites (Gurimo Koyisha and Doga Mashido) indicating a higher response to fertilizer N than that of fertilizer P and K. These results are in line with those noted by other worker [19, 21]. Utilizing the mean $c_1$ and c values, fertilizer N, P and K requirements were computed for common range of soil testvalues from 0.12% to 0.14 N %, 17.29 -17.70 mg P $kg^{-1}$, 136 -190 mg kg K $ha^{-1}$ (Table 1). The fertilizer recommen-

**Table 2. Barley yield and efficiency coefficients of soil and N, P and K fertilizer.**

| Treatments | Yield (kg ha$^{-1}$) | logy | 1/x | $c_1$ | c | $C_1$/c |
|---|---|---|---|---|---|---|
| K applied (kg ha$^{-1}$) | Doga Mashido | | | | | |
| 0 | 986 | 2.9938 | 0.001001 | 0.01043 | - | |
| 25 | 1265 | 3.1021 | 0.000790 | - | 0.03442 | 0.3030 |
| 50 | 1490 | 3.1731 | 0.000579 | - | 0.03499 | 0.2980 |
| Mean | 1247 | - | - | - | - | 0.3005 |
| Theoretical maximum yield | 3713 | - | - | - | - | |
| TSP applied (kg ha$^{-1}$) | | | | | | |
| 0 | 986 | 2.9938 | 0.001001 | 0.01598 | | |
| 10 | 1252 | 3.0971 | 0.000367 | | 0.03249 | 0.4918 |
| 20 | 1357 | 3.1325 | 0.000156 | | 0.03424 | 0.4667 |
| 30 | 1524 | 3.1829 | 0.000656 | | 0.03482 | 0.4589 |
| Mean | 1279.75 | | | | | 0.4724 |
| Theoretical maximum yield | 4215 | | | | | |
| Nitrogen applied (kg ha$^{-1}$) | | | | | | |
| 0 | 986 | 2.9938 | 0.001001 | 0.00706 | | |
| 23 | 1346 | 3.1291 | 0.000743 | | 0.03415 | 0.2067 |
| 46 | 1498 | 3.1755 | 0.000667 | | 0.03497 | 0.2042 |
| Mean | 1276.7 | | | | | 0.2042 |
| Theoretical maximum yield | 3721 | | | | | |
| K applied (kg ha$^{-1}$) | Kokata | | | | | |
| 0 | 1203 | 3.0802 | 0.00083 | 0.01704 | | |
| 25 | 1791 | 3.2531 | 0.000558 | | 0.03761 | 0.4530 |
| 50 | 1856 | 3.2685 | 0.000538 | | 0.03588 | 0.4749 |
| Mean | 1617 | | | | | 0.4639 |
| Theoretical maximum yield | 4753 | | | | | |
| TSP applied (kg ha$^{-1}$) | | | | | | |
| 0 | 1203 | 3.0802 | 0.00083 | 0.01607 | | |
| 10 | 1428 | 3.1547 | 0.0007 | | 0.03976 | 0.4041 |
| 20 | 1640 | 3.2148 | 0.000609 | | 0.03510 | 0.2289 |
| 30 | 1645 | 3.2161 | 0.0006079 | | 0.03567 | 0.2252 |
| Mean | 1479 | | | | | 0.2860 |
| Theoretical maximum yield | 4521 | | | | | |
| Nitrogen applied (kg ha$^{-1}$) | | | | | | |
| 0 | 1203 | 3.0802 | 0.00083 | 0.01141 | | |
| 23 | 1752 | 3.2435 | 0.00057 | | 0.03509 | 0.3251 |
| 46 | 1900 | 3.2787 | 0.000526 | | 0.03585 | 0.3182 |
| Mean | 1618 | | | | | 0.3216 |
| Theoretical maximum yield | 4752 | | | | | |
| Treatments | Yield(kg ha$^{-1}$) | logy | 1/x | $c_1$ | c | $C_1$/c |
| K applied (kg ha$^{-1}$) | Gurimo Koyisha | | | | | |
| 0 | 815 | 2.911 | 0.001226 | 0.01766 | | |
| 25 | 1271 | 3.1041 | 0.0007867 | | 0.03423 | 0.5159 |
| 50 | 1396 | 3.1448 | 0.000716 | | 0.03479 | 0.5076 |
| Mean | 1161 | | | | | 0.5117 |
| Theoretical maximum yield | 3714 | | | | | |
| TSP applied (kg ha$^{-1}$) | | | | | | |
| 0 | 815 | 2.911 | 0.001226 | 0.016591 | | |
| 10 | 1100 | 3.0413 | 0.000909 | | 0.032077 | 0.5173 |
| 20 | 1324 | 3.1218 | 0.0007552 | | 0.033765 | 0.4914 |
| 30 | 1463 | 3.1652 | 0.0006835 | | 0.034322 | 0.4833 |
| Mean | 1175 | | | | | 0.4973 |
| Theoretical maximum yield | 3224 | | | | | |
| Nitrogen applied (kg ha$^{-1}$) | | | | | | |
| 0 | 815 | 2.911 | 0.0001226 | 0.010931 | | |
| 23 | 1477 | 3.1693 | 0.000677 | | 0.034949 | 0.3128 |
| 46 | 1613 | 3.2076 | 0.0006199 | | 0.034310 | 0.3185 |
| Mean | 1301 | | | | | 0.3156 |
| Theoretical maximum yield | 3284 | | | | | |

dations provide a choice for choosing a yieldtarget in accordance with the monetary aspects, thus providing a dual benefit tothe farming community.

**Table 3. Profitability of fertilizer use efficiencies on barley under various treatments on three locations.**

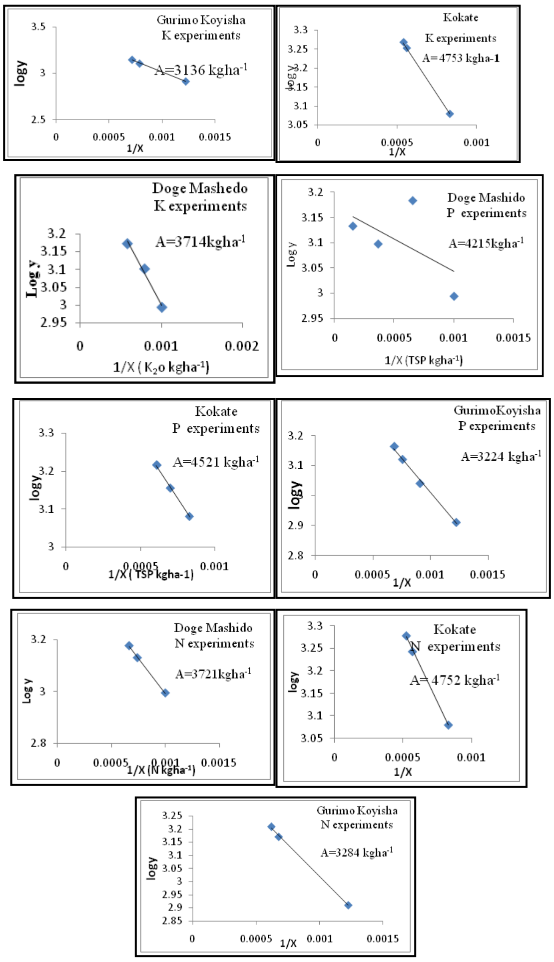
| Treatment | Actual yields (kg $ha^{-1}$) | Adjusted grain yield | Fertilizer cost (Birr) | Total variable cost (TVC) (Birr) | Total revenue | Net revenue | Gross net revenue | Nutrients use efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | AE | RE | PE |
| | | | | | | | | (kg $kg^{-1}$) | (%) | (kg $kg^{-1}$) |
| **Kokate** | | | | | | | | | | |
| K0 | 1203 | 1082.7 | 1082.7 | 0 | 0 | 6496.2 | 6496.2 | 0 | 0 | 0 |
| K25 | 1791 | 1612.17 | 900 | 1060 | 9673.02 | 8613.02 | 8.12 | 23.53 | 61.75 | 38.12 |
| K50 | 1856 | 1670.49 | 1800 | 1960 | 10022.94 | 8062.94 | 4.11 | 13.06 | 45.86 | 28.48 |
| P10 | 1428 | 1285.47 | 900 | 1060 | 7712.82 | 6652.82 | 6.27 | 22.53 | 57.24 | 39.38 |
| P20 | 1640 | 1476.27 | 1800 | 1960 | 8857.62 | 6897.62 | 3.51 | 21.86 | 56.08 | 38.98 |
| P30 | 1645 | 1480.5 | 2700 | 2860 | 8883 | 6023 | 2.11 | 14.73 | 40.54 | 36.34 |
| N23 | 1752 | 1576.8 | 630 | 790 | 9460.8 | 8670.8 | 10.97 | 23.86 | 57.73 | 41.33 |
| N46 | 1900 | 1710.27 | 1260 | 1420 | 10261.62 | 8841.62 | 6.22 | 10.81 | 52.25 | 20.68 |
| **Gruimo Koyisha** | | | | | | | | | | |
| K0 | 815 | 733.77 | 0 | 0 | 4402.62 | 4402.62 | 0 | 0 | 0 | 0 |
| K25 | 1271 | 1143.9 | 900 | 1170 | 6863.4 | 5693.4 | 4.86 | 18.22 | 69.09 | 26.37 |
| K50 | 1396 | 1256.85 | 1800 | 2070 | 7541.1 | 5471.1 | 2.64 | 11.62 | 49.56 | 23.44 |
| P10 | 1100 | 990.54 | 900 | 1170 | 5943.24 | 4773.24 | 4.07 | 28.53 | 53.45 | 53.37 |
| P20 | 1324 | 1191.6 | 1800 | 2070 | 7149.6 | 5079.6 | 2.45 | 25.43 | 50.06 | 50.79 |
| P30 | 1463 | 1317.15 | 2700 | 2970 | 7902.9 | 4932.9 | 1.66 | 21.6 | 43.30 | 49.88 |
| N23 | 1477 | 1329.3 | 630 | 900 | 7975.8 | 7075.8 | 7.86 | 28.76 | 65.59 | 43.84 |
| N46 | 1613 | 1451.7 | 1260 | 1530 | 8710.2 | 7180.2 | 4.69 | 17.34 | 57.04 | 30.39 |
| **Doge Mashido** | | | | | | | | | | |
| K0 | 986 | 2313 | 0 | 0 | 13878 | 13878 | 0 | 0 | 0 | 0 |
| K25 | 1265 | 2314.8 | 900 | 1170 | 13888.8 | 12718.8 | 10.87 | 11.17 | 38 | 29.4 |
| K50 | 1490 | 2314.8 | 1800 | 2070 | 13888.8 | 11818.8 | 5.7 | 10.08 | 37.39 | 26.95 |
| P10 | 1252 | 2339.1 | 900 | 1170 | 14034.6 | 12864.6 | 10.99 | 26.63 | 60.22 | 44.23 |
| P20 | 1357 | 2357.1 | 1800 | 2070 | 14142.6 | 12072.6 | 5.83 | 18.55 | 43.18 | 42.95 |
| P30 | 1524 | 2368.8 | 2700 | 2970 | 14212.8 | 11242.8 | 3.78 | 17.93 | 38.44 | 40.20 |
| N23 | 1477 | 2727 | 630 | 900 | 16362 | 15462 | 17.18 | 11.31 | 54.77 | 20.65 |
| N46 | 1613 | 3059.1 | 1260 | 1530 | 18354.6 | 16824.6 | 10.99 | 11.13 | 54.08 | 20.58 |

The site specific recommendations of fertilizer N, P and K based onMitscherlich-Bray equation were calculated for obtaining the predictable yield of barley (Table 2). The results revealed that as the number of rates increased; there was increase in fertilizer N, P and K requirements of barley. The theoretical maximum yield obtained from K (4753kg $ha^{-1}$), P (4215kg $ha^{-1}$)and N (3714 kg $ha^{-1}$) Kokate, Doga Mashido and Gurimo Koyisha , respectively . The results of two confirmation trials (Table 3) revealed that the highest barley grain yields of 1900 kg $ha^{-1}$ was obtained under N46 of theoretical maximum yield treatmentin Kokate. However, theoretical maximum yield treatment was significantly superior to all other treatments, which was on par at both the locations. This treatment also resulted increased with increase use efficiencies inbarleyyields at all the locations. Considering the barley yields obtained and the economics offertilizer use of theoretical maximum yield treatment based on Mitscherlich-Bray equation was superior to general recommended dose and asper soil test basis. Maximum yield was obtained with recommended fertilizerdose, but TVC value was very higher for treatments receiving N46 kg $ha^{-1}$..All the parameters relevant to economics of fertilizer such as net return, and total net return, were higher for N46 of maximum yield treatment at all locations (Table 3). This result line with Rashid (2010) [18] observed that in limited moisture supply situations, lower levels of nutrient application (50 kg N and 25 kg $P_2O_5$ $ha^{-1}$) were better and economical than higher fertilizer doses; fertilizer use efficiency is generallylower under rainfed conditions as compared with irrigated ones [12]. These results are also in agreement with the findings of Sonar and Babhulkar (2002) [21] who observed that fertilizer use on the basis of 80% theoretical maximum yield wasbetter than general recommendation of fertilizer for wheat in India.

## Conclusion

In this study, model has been established to estimate soil nutrient supply from soil chemical properties for barley in the Wolaita zone, southern Ethiopia, to estimate indigenous nutrient supplying capacity of soils, N, P, and K requirements for barely and their use efficiencies of nutrients as affected by fertilizer levels, it is strongly needed that a system of site-specificnutrient management should be adopted instead of general recommendations in

**Figure 2. Theoretical maximum yield of barley in field experiments at three locations.**




order tomake the use of fertilizer more rational and economical. It will result in increased fertilizer use efficiency and saving of this costly input. Application of higher rates of fertilizers as has been practice in past decade is not economically profitable because of high prices offertilizers. Consequently, the data are employed calibration exercise, so as to widen the application of Mitscherlich-Bray Equation. Finally, validations have done using input and yield date from fertilizer trials in other party of Wolaita zone and a sensitivity analysis than reveals to what extent changes in input parameterization of nutrient requirements of barley affect mode output.

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