

# Economic Evaluation of Nitrogen Efficient Maize Genotypes in Western Ethiopia

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**Abstract** – Low soil fertility is one of the major constraints to maize production in western Ethiopia. The soils are deficient, particularly in Nitrogen (N). Experiments were conducted to identify N efficient maize genotypes and determine economically profitable N level for N efficient open-pollinated and hybrid maize. The experiments were conducted on-farmers fields at five locations, namely, Bako, Shoboka, Tibe, Ijaji and Gudar in western Ethiopia. Two set of experiments comprising of five open-pollinated and five hybrid maize genotypes were combined with six N application levels in complete factorial arrangement. The N levels ranged from 0 to 230 kg N ha<sup>-1</sup> with 46 kg N ha<sup>-1</sup> intervals. The experiments were laid out in a randomized complete block design with three replications. Results revealed that out of the open-pollinated and hybrid maize genotypes evaluated, only Ecaval-1 and CML373/ CML202/ CML384, respectively, were regarded as N use efficient genotypes as they were able to perform outstandingly well at both the 0 and 230 kg N ha<sup>-1</sup> level. These two genotypes yielded on average 5.9% at the lowest N level and 17.5% at the highest N level better than the two local checks, viz. Kulani and BH 540. Therefore, these two N use efficient genotypes qualify for recommendation to resource-poor farmers and subjected to economic analysis using the partial budget procedure to determine rate of N that would give acceptable returns at low risk to farmers. Economic analysis indicated that application of 46 and 92 kg N ha<sup>-1</sup> for open-pollinated genotype Ecaval-1 and hybrid CML373/ CML202/ CML384, respectively, were agronomically optimum and economically viable within 20% variability in cost of production inputs such as N fertilizer and value of maize yields.

**Keywords** – Economic Evaluation, Maize, Nitrogen Efficient, Partial Budget, Price Variability.

## I. INTRODUCTION

Nitrogen (N) is the most limiting factor in the production of maize in Ethiopia. In the western part of the country maize is mostly grown by resource-poor farmers on Nitisols low in N [28]. This leads to low and unstable maize production, and consequently reduces income and food security of small-scale farmers. Fertilizer N besides being important in profitable maize production, it is an expensive input which can also cause harm to the environment. Any use of N fertilizer therefore requires specific management practices to optimize its efficiency and profitability.

A central issue with fertilizer N should be to minimize losses during crop establishment when demand for N is low and to maximize availability during vegetative and reproductive growth of crops when demand for N is high. Several factors related to the management of fertilizer N

can influence its efficient use by maize [12]. They are inter alia type of fertilizer [1] [16] [17], rate of application [12], time of application [8] [12] [13] [15] [17] [22], method of placement [5], soil water content [18] [19], early planting to capture the flush of mineralized N often experienced in soils [4].

The two most important factors controlling the N content of maize grain are the uptake of N from the soil and the translocation of N from the vegetative parts to the grain. Several studies showed genotypic differences in maize with regard to the translocation and partitioning of N during grain development [3] [9] [10] [11] [12]. Appreciable differences were found among maize genotypes in their apparent propensity to translocate N from the rest of the plant parts to the developing ear. About half of the N in the grain at maturity appeared to have been translocated from other above ground plant parts. These results have demonstrated that although maize can absorb substantial quantities of N following silking, mobilization of vegetative N accumulated before silking provides the major source of N in the grain.

Until now very little effort was made in developing maize genotypes that suit the needs of small-scale farming systems. Small-scale farmers seldom have the financial resources or available technology to exploit their environmental potential, or to rectify the production constraints such as N deficiencies. Perhaps the most attractive alternative is to select or breed maize genotypes that are efficient in utilizing N at both low and high N levels [25] [26].

Usually, potentially high yielding maize genotypes are selected under well-fertilized conditions where N supply is sufficient. These genotypes may not perform well under poor-fertilized conditions where N supply is insufficient [20], very common where small-scale farmers plant maize. Some researchers [2] [14] reported that there is sufficient genetic variability to select or breed maize genotypes that can perform well on soils with low N supplying capacities. The use of maize genotypes with such abilities will not only be cost effective but also of sustainable value as pointed out by [7]. It is a matter of fitting these genotypes to the environment instead of altering the environment by adding fertilizer N.

In its international maize trials, the International Maize and Wheat Improvement Center (CIMMYT) has developed genotypes that are considered to be able to yield well under both low and high N soil fertility conditions [2]. Small-scale farmers in western Ethiopia can benefit if some of these CIMMYT genotypes are introduced into their farming systems. Unfortunately, the economic benefits of these maize genotypes are largely missing.

Hence, this study was conducted to identify N efficient maize genotypes and determine economically profitable N rate for N efficient open-pollinated and hybrid maize in western Ethiopia.

## II. MATERIALS AND METHODS

### A. Experimental Sites

The experiments were conducted on-farmers fields at five locations viz. Bako, Shoboka, Tibe, Ijaji and Gudar in western Ethiopia. Bako is located at 09001'N and 37002'E, Shoboka at 09006' N and 37021'E, Tibe at 09029'N and 37032'E, Ijaji at 09043'N and 37047'E, and Gudar at 08009'N and 38008'E latitude and longitude, respectively. The altitude for Bako, Shoboka, Tibe, Ijaji and Gudar are 1650, 1695, 1730, 1820 and 2000 meter above sea level, respectively.

### B. Experimental Layout

Two set of experiments comprising of five open-pollinated and five hybrid maize genotypes were combined with six N application levels in complete factorial arrangement. The N levels ranged from 0 to 230 kg N ha<sup>-1</sup> with 46 kg N ha<sup>-1</sup> intervals. The experiments were laid out in a randomized complete block design with three replications. The open-pollinated and hybrid maize genotypes used are listed in Table 1. Each set consists of four CIMMYT genotypes and a local check. Selection of the CIMMYT genotypes was based on their yield response to low and high N conditions at Bako research center in a preliminary study.

Urea and triple super phosphate were used as N and P sources, respectively. Half of the urea was applied at planting and the remaining half at 35 days after sowing when maize was at knee-height. The triple super phosphate was applied at the recommended rate of 20 kg P ha<sup>-1</sup> in a band at planting.

Table 1. List of open-pollinated and hybrid maize genotypes used in the experiments at the five sites

Open-pollinated	Hybrids	Source
Ecaval-1	CML388/CML202/CML384	CIMMYT
Ecaval-2	CML373/CML202/CML384	CIMMYT
Ecaval-5	LPSC3H44/CML202/CML380	CIMMYT
Ecaval-14str	TUXPSEQ/CML202/CML384	CIMMYT
Kulani	BH-540	Local

### C. Economic Analysis

The economic evaluation was done on the grain yield data that was significantly affected by N fertilization treatments to consolidate the statistical analysis thereon. This evaluation comprised of a partial budget with dominance, marginal and sensitivity analysis as described by [6]. The minimum acceptable rate of return was set at 100% and grain yield were adjusted downwards by 10% to minimize bias.

To estimate economic parameters, maize was valued at an average open market price of 1.02 Ethiopian Birr (EB) per kg grain and fertilizer was valued at a fixed official

price of 5.80 EB per kg N. Some of the concepts used in the partial budget analysis are given below:

- Mean grain yield (kg/ha): Average yield of each treatment across sites.
- Gross field benefit (GFB) per ha: Product of real price of maize and the mean yield for each treatment.
- Total variable cost (TVC): Sum of costs of all variable inputs and management practices.
- Net benefit (NB) per ha: Difference between the GFB and the TVC.

The dominance analysis procedure was used to select potentially profitable treatments from the range that was tested. Treatments were ranked in order of ascending TVC from the lowest to the highest cost to eliminate those treatments costing more but producing a lower NB than the next lowest cost treatment. The selected and rejected treatments by using this technique are referred to as undominated and dominated treatments, respectively. For each pair of ranked undominated treatments, a percentage marginal rate of return (% MRR) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in crop management practices or inputs expressed as percentage. The % MRR is given by the following Equation:

$$\% MRR = \frac{\Delta NB}{\Delta TVC} * 100$$

Thus, a MRR of 100% implies a return of one Birr on every Birr of expenditure in the given variable inputs.

## III. RESULTS AND DISCUSSION

### A. Maize Grain Yield

The combined analysis over locations showed significant ( $P < 0.05$ ) grain yield difference among genotypes, N rates and interaction between genotype by N rate (Table 2). Grain yield of all genotypes increased progressively with higher N application rates and the highest yields were recorded at the 230 kg N ha<sup>-1</sup> level. This effect was most prominent with the first increment of N application and then declined gradually with subsequent increments of N application. Researchers [20] [21] stated that N use efficient genotypes are those genotypes that yield well at both low and high N soil fertility conditions, whereas N use inefficient genotypes are those that yield well only at high N soil fertility conditions.

Therefore, the genotypes were ranked based on the grain yield realized at the lowest and highest N levels, viz. 0 and 230 kg N ha<sup>-1</sup> (Table 2). At these two N levels the ranking of seven genotypes were inconsistent. Only the two open-pollinated genotypes Ecaval-5 and Kulani and one hybrid genotype TUXPSEQ/ CML202/ CML384 ranked similar at the two N levels, viz. either 4 or 5. These low rankings disqualify them for recommendation to resource-poor farmers.

Inspection of Table 2 shows that at the 0 kg N ha<sup>-1</sup> level three open-pollinated genotypes such as Ecaval-1, Ecaval 2 and Ecaval-14str and three hybrid genotypes viz. CML388/ CML202/ CML384, CML373/ CML202/ CML384 and LPSC3H/ CML202/ CML380 yielded the best with no significant differences between them. Out of

these genotypes Ecaval-1 and CML373/ CML202/ CML384 yielded significantly the best at the 230 kg N ha<sup>-1</sup> level. Consequently, only Ecaval-1 and CML373/ CML202/ CML384 can be regarded as N use efficient genotypes as they were able to perform outstandingly well at both the 0 and 230 kg N ha<sup>-1</sup> level. These two

genotypes yielded on average 5.9% at the lowest N level and 17.5% at the highest N level better than the two local checks Kulani and BH-540. Therefore, these two N use efficient genotypes qualify for recommendation to resource-poor farmers and subjected to economic analysis.

Table 2. Effect of N fertilization on the grain yield of open-pollinated and hybrid maize genotypes.

Genotypes	N levels (kg ha <sup>-1</sup> )						Rank	
	0	46	92	138	184	230	Lowest N	Highest N
<b>Open-pollinated</b>								
Ecaval-1	3145ab	4348b	5158a	5645a	5913a	6051a	3	1
Ecaval-2	3363a	4649a	5212a	5520ab	5653ab	5728b	1	2
Ecaval-5	2601c	3760c	4309b	4588c	4774c	4873c	5	5
Ecaval-14str	3247ab	4343b	4941a	5285b	5484b	5542b	2	3
Kulani	2999b	4082b	4576b	4852c	5030c	5107c	4	4
<b>Hybrids</b>								
CML388/CML202/CML384	3506a	4803a	5667a	6239b	6580b	6667b	1	2
CML373/CML202/CML384	3194ab	4674ab	5770a	6636a	7123a	7403a	3	1
LPSC3H/CML202/ CML380	3344a	4455bc	5277b	5678c	5901c	6018c	2	4
TUXPSEQ/CML202/CML384	2428c	3507d	4322c	4888d	5195d	5335d	5	5
BH540	2989b	4142c	5010b	5686c	6110c	6352b	4	3

Means within a column for each group followed by the same or no letter(s) are not significantly different from each other at 5 % probability level.

### B. Economic Evaluation of N Levels for Maize Genotypes

Two maize genotypes such as open-pollinated genotype Ecaval-1 and hybrid CML373/ CML202/ CML384 were identified as N use efficient. The partial budget showed that among the N levels with which these genotypes were tested, the highest NB was obtained at an application of 138 kg N ha<sup>-1</sup> with Ecaval-1 and 184 kg N ha<sup>-1</sup> with CML373/ CML202/ CML384 (Table 3). However, an application of 46 kg N ha<sup>-1</sup> gave the highest MRR for both genotypes. The dominance analysis lead to the selection of the 46, 92 and 138 kg N ha<sup>-1</sup> levels for Ecaval-1 and the 46, 92, 138 and 184 kg N ha<sup>-1</sup> levels for CML373/ CML202/ CML384 ranked in increasing order of TVC. A MRR of below 100% is considered low and unacceptable to farmers [6]. Such a return would not offset the cost of capital and other related transaction costs while still giving an attractive profit margin to serve as an incentive. Based on this guideline the 138 kg N ha<sup>-1</sup> level for Ecaval-1 and the 184 kg N ha<sup>-1</sup> level for CML373/ CML202/ CML384 are eliminated.

The sensitivity analysis indicated that even the 92 kg N ha<sup>-1</sup> level for Ecaval-1 and the 138 kg N ha<sup>-1</sup> level for CML373/ CML202/ CML384 are not conducive to stable production (Table 4). However, the 46 kg N ha<sup>-1</sup> level for Ecaval-1 and the 92 kg N ha<sup>-1</sup> level for CML373/ CML202/ CML384 are well above the minimum acceptable threshold. These results agree with the findings of [27] in western Ethiopia that an application of 92 kg N ha<sup>-1</sup> to maize gave acceptable economic returns. References [23] [24] also reported application of N fertilizer to maize consistently gave acceptable economic returns to small-scale farmers in Kenya.

### IV. CONCLUSIONS

The combined analysis showed highly significant difference among maize genotypes, N rates and interaction between genotype by N rate on grain yield indicating sufficient genetic variability to select maize genotypes that can perform well on soils with low and high N supplying capacities. Progressive increase in maize grain yield with incremental levels of N was observed in all genotypes tested. However, only two maize genotypes viz. the open-pollinated Ecaval-1 and the hybrid CML373/ CML202/ CML384 were qualify as N use efficient. These two CIMMYT genotypes on average out yielded their respective local genotypes with 5.9% at a low N application and with 17.5% at high N application. The partial budget analysis revealed that the application of 46 kg N ha<sup>-1</sup> for the open-pollinated Ecaval-1 and 92 kg N ha<sup>-1</sup> for the hybrid CML373/ CML202/ CML384 were economically robust and remained profitable within a price variability of 20%.

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Table 3. Partial budget with dominance and marginal analysis to establish the profitability of maize production for the two N use efficient genotypes

Genotype	N level (kg ha <sup>-1</sup> )	TVC (EB ha <sup>-1</sup> )	NB	MRR (%)
Ecaval-1	0	0	2887.1	--
	46	266.8	3724.7	313.9
	92	533.6	4201.4	178.7
	138	800.4	4381.7	65.6
	184	1067.2	4360.9	D
	230	1334.0	4220.8	D
CML373/CML202/ CML384	0	0	2932.1	--
	46	266.8	4023.9	409.2
	92	533.6	4763.3	277.1
	138	800.4	5291.4	198.0
	184	1067.2	5471.7	67.6
	230	1334.0	5462.0	D

TVC = total variable costs, NB = net benefit, MRR = marginal rate of return, D = dominated treatment

Table 4. Sensitivity analysis to establish the stability of maize production for the two N use efficient genotypes

Genotype	N level (kg ha <sup>-1</sup> )	TVC (EB ha <sup>-1</sup> )	NB	MRR (%)*
Ecaval-1	0	0	2309.7	--
	46	320.2	2873.0	176.0
	92	640.3	3147.7	85.8
CML373/ CML202/ CML384	0	0	2345.7	--
	46	320.2	3112.4	239.5
	92	640.3	3597.2	151.4
	138	960.5	3913.0	98.6

\*Denotes 20% increase in fertilizer cost and 20% decrease in grain price. TVC = total variable cost, NB = net benefit and MRR = marginal rate of return

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