PRECISION MAIZE NUTRITION: EVIDENCES FROM ON-FARM EXPERIMENTATION OF QUEFTS ESTIMATED NUTRIENT REQUIREMENT FOR VARIABLE DENSITIES IN SMALLHOLDER FARMERS IN ETHIOPIA #9424

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ABSTRACT

Models are important for optimizing crop nutrient requirement. In this study QUantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model was used to estimate nutrient requirement of maize for two pant densities (farmers' practices and re-designed) on fields of three farmers wealth classes (poor, medium and wealth). The on-farm study was conducted in 2017 and 2018 with 3 x 2 x 3 fertilizer, plant density and wealth class in factorial combination. The result revealed that interaction effect among the factors is not significant. In 2017, fertilizer use, plant density and wealth class had a significant efficient on maize yield in CRV and in both seasons in Jimma. QUEFTS estimated nutrients resulted in higher yield, but the yield was not significantly higher compared to the farmers' fertilizer uses (FFU) in both regions. Redesigning plant density from farmers' practices to 53,333 plants/ha in CRV and to 62,000 plants/ha in Jimma resulted in significant yield improvement. The yield from fields of medium farm was significantly lower than rich fields of rich farms in Jimma. QE fertilizer use reduced maize yield variability only in Jimma. FFU and QE fertilizer uses were profitable in both regions. In addition, redesigned plant densities were also profitable in growing maize in both regions. This investigation gives insights the importance of using models to optimize nutrient requirement of crops for a better yield and profitability.

Keywords: Ethiopia, Maize, Model, Nutrient requirement, On-farm experiment, Profitability

INTRODUCTION

Food insecurity is a concern in sub-Saharan African countries including Ethiopia. A three-fold cereal production increase is projected to support the population in 2050 (Alexandratos and Bruinsma, 2012). Maize is a dominant and potential cereal crop for food security in Ethiopia (Abate *et al.*, 2015). Most smallholder farmers mainly grow the crop for subsistence. Improving the productivity of this crop is addressing the food security constraints of many people. Despite the large maize production potential (favorable climate, diverse genotypes for most of agro-ecologies and well-drained soil) of the country, the current maize yield is far below the potential yield. The current focus to increase production is improving cereal productivity with improved and farm context crop management technologies.

Low maize productivity in Ethiopia is mostly due to sub-optimal crop management such as nutrients (Getnet et al., 2022; Seyoum *et al.*, 2019; Seyoum *et al.*, 2018)). Agricultural models that follow target-oriented approach for example QUantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) are believed to optimize N, P and K nutrients in balanced proportion (Ponsioen *et al.*, 2006). However, previous research on maize management practices hardly addressed the use of models for optimizing nutrients. Planting density of the crop has been given less attention and land resources are not efficiently used in smallholder

farmers. Moreover, farms are heterogeneous in their socio-economic conditions. They need different intervention approaches based on their constraints and opportunities (Descheemaeker et al., 2016; Giller *et al.*, 2011)). The objectives of this paper were to (1) test and evaluate QUEFTS estimated nutrient requirement of maize in relation to farmers, practices under farmers' practices and redesigned plant density at fields of variable farm class and (2) to assess the interaction of fertilizer use, plant density and wealth class on maize yield.

MATERIALS AND METHODS

Treatments: farmers' practices and nutrient estimation using QUEFTS model

Farmers' practices (fertilizer use and plant density) were obtained from the farm survey in the regions (Tesfaye *et al.*, 2019). Factors and levels were shown on Table 1. Nutrients estimation by QUEFTS was based on 50% of Yw target yield (van Ittersum and Rabbinge, 1997). The 50% of Yw in CRV and Jimma are 3.1and 7.5 t/ha respectively. Nutrient (N, P and K) uptake was estimated to the given target yield. Soil supplied nutrients (N, P and K) were estimated and were subtracted from the total uptake. The remaining uptake was supplied only from the fertilizer and then corrected for their recovery fractions. Farms were classified into three wealth classes such as poor, medium, and rich based on their resource endowment. A total of 12 farms (4 poor, 4 medium and 4 rich) were selected and their fields were used for the experimentation.

Table 1. Amounts of N, P and K in fertilizer use treatments and plant densities in CRV and Jimma.

Region	***Levels***	***Factors***	***Nutrients (kg/ha)***		
CRV		**Nutrient mgt**	N	P	K
	1	0 NPK	0.0	0.0	0.0
	2	FFU	21.5	12.8	0.0
	3	QUEFTS, 50%Yw	40.8	0.0	12.2
		Plant density (ha^{-1})			
	A	Farmers' practices	32,443		
	B	Redesigned	53,333		
Jimma		**Nutrient mgt**	**N**	P	K
	1	0 NPK	0.0	0.0	0.0
	2	FFU	53.2	30.0	0.0
	3	QUEFTS, 50% Yw	149.8	9.0	130.6
		Plant density (ha^{-1})			
	A	Farmers' practices	27,724		
	B	redesigned	62,000		

Variability of maize yield was assessed based on CV (%). It is the ratio of standard deviation to mean expressed in percentage. Profitability was assessed from value cost ratio. A value cost ratio greater than 1 is profitable whereas a value cost ratio less than or equal to 1 is non-profitable.

RESULTS

Overall, interaction effect among the factors was not significant. Farmers' fertilizer uses (FFU) and QUEFTS estimated (QE) fertilizer use significantly improved maize yield compared

to the control in both seasons and regions but there was no significant difference between them. The effect of fertilizer was stronger (p=0.0002 in both seasons) in Jimma than CRV (p=0.002 in 2017 and p=0.007 in 2018) (Tesfaye et al., 2019). On average, FFU and QE fertilizer use improved maize yield by 53% and 57% respectively in CRV whereas in Jimma the yield advantage of these fertilizer uses compared to control were 42% and 69% respectively. QE fertilizer use resulted in 2.5% and 19% yield advantage compared to FFU. Similar to the ealier studies in the country (Seyoum *et al.*, 2019), plant density significantly improved yield (p=0.0003 in CRV in 2017; p=0.00002 and 0.001 in Jimma in 2017 and 2018). Though not consistent across regions, the effect of wealth class was significant (Fig.1). Fields of medium wealth class resulted in significantly lower yield in Jimma whereas in CRV, fields of rich farms resulted in significantly higher yield in 2017 season.

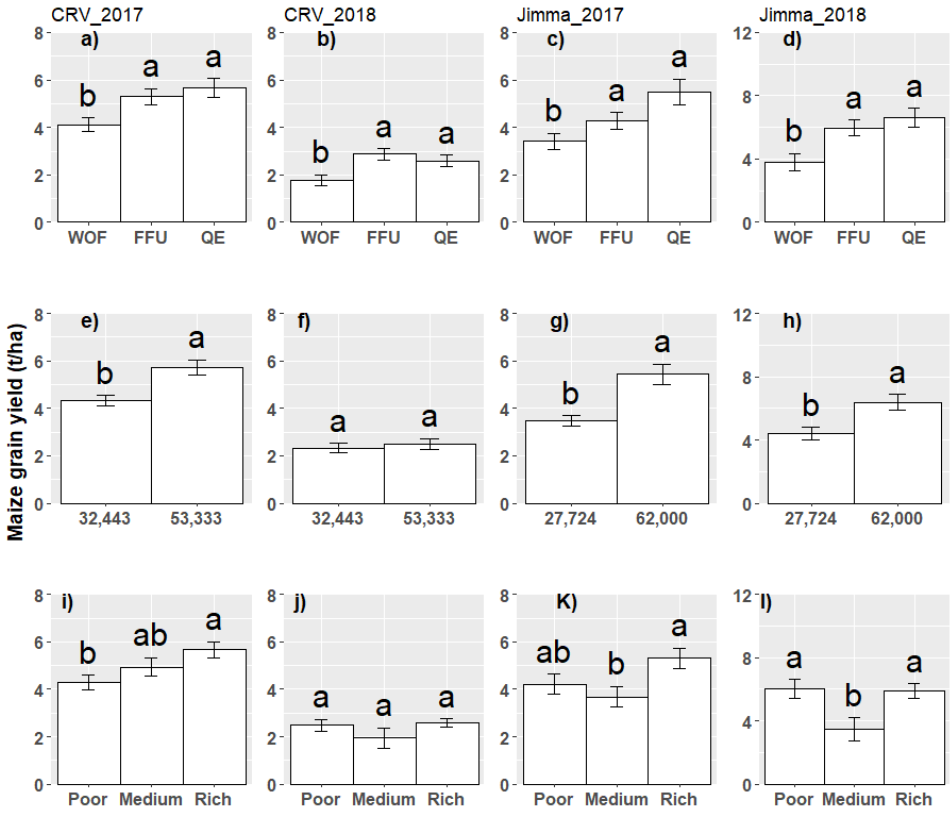

Fig. 1. Grain yield response of maize to fertilizer use (a, b, c, d), plant density (e, f, g, h) and wealth class (i, j, k, l) in 2017 and 2018 in CRV and Jimma regions in Ethiopia. WOF, FFU and QE stands for without fertilizer, farmers' fertilizer use, and QUEFTS estimated fertilizer use respectively.

Yield response variability

Growing maize without fertilizer was associated with high variability. In CRV, FFU resulted in low variability in both farmer's practice and redesigned plant densities whereas in Jimma, QE fertilizer requirement was resulted in low yield variability.

Table 2. Coefficient of variation of maize yield in CRV and Jimma areas under various fertilizer uses and plant densities.

Region	Fertilizer use	Farmer's practice density			Redesigned density		
		CV (%)			CV (%)		
		2017	2018	Average	2017	2018	Average
CRV	WOF	29.0	60.0	***44.5***	33.5	53.3	***43.4***
	FFU	24.0	29.3	***26.7***	25.4	44.9	***35.2***
	QE	25.0	43.8	***34.4***	33.7	40.8	***37.3***
Jimma	WOF	42.4	50.5	***46.5***	51.9	62.3	***57.1***
	FFU	32.7	46.9	***39.8***	34.2	29.8	***32.0***
	QE	37.4	30.1	***33.8***	32.4	27.2	***29.8***

Economic feasibility of fertilizer uses and plant densities

The value cost ratio of farmer's fertilizer use, and QE nutrient requirement of maize practices were greater than 1 in both regions under low density (farmers 'practices) and redesigned (intermediate) density (Fig. 2). This shows that fertilizer both FFU and QE fertilizer are profitable in maize production.

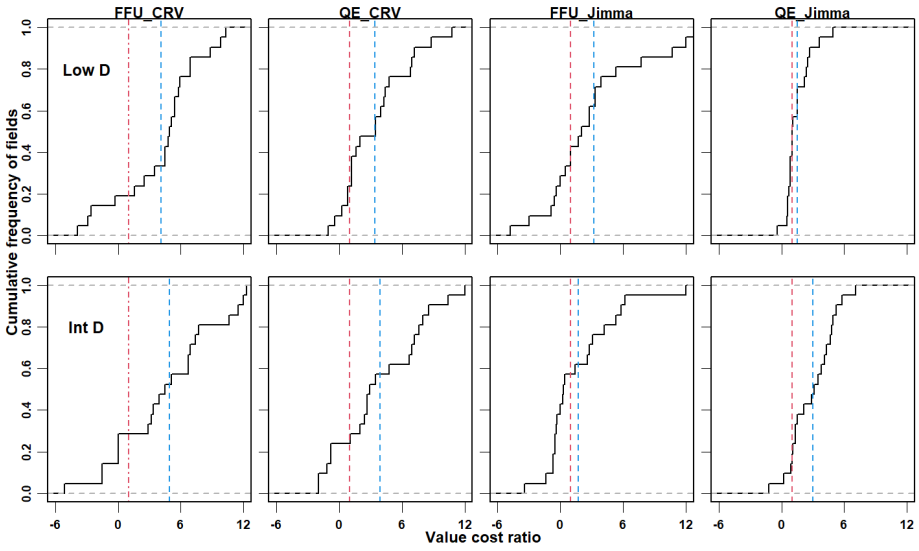

Fig. 2. Profitability of fertilizer uses of maize in CRV and Jimma under farmer practices and redesigned plant densities.

In CRV, redesigning plant density from 32,443 plants/ha to 53,333plants/ha was profitable under all fertilizers uses (without fertilizer, FFU and QE). However, in Jimma, redesigning plant density was profitable mostly under QE fertilizer use. In the same region, increasing plant density from farmers' practices (27,724 plant/ha) to redesigned (62,000 plant/ha) resulted in moderate profitability under control and FFU.

CONCLUSION

The study evaluated fertilizer use in maize using two plant densities on fields of variable wealth class farms in CRV and Jimma areas in Ethiopia. Farmers' fertilizer use (FFU) and QUEFTS estimated (QE) fertilizer requirement improved maize yield in both regions and were profitable based on market setup in the respective areas during the study period. Increasing

planting density from farmers' practices to intermediate (32,443 plants/ha to 53,333 plant/ha in CRV and 27,724 plants/ha to 62,000 plants/ha in Jimma) highly improved maize yield and were profitable in both regions. QE fertilizer use reduced yield variability only in Jimma area.

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