NUTRIENT EXPERT MODEL: A CONNEXION BETWEEN FERTILIZER RECOMMENDATION AND IMPROVED MAIZE PRODUCTIVITY

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Abstract. *Maize as one of the staple crops in Nigeria requires an increase in yield per unit area due to the increase in the human population. This will go a long way in filling the gaps between the low farmers' yields and the attainable yields. An experiment was carried out in 2017 and 2018 growing seasons in the Institute for Agricultural Research, Samaru (11°11'N 07°38'E, altitude 686m) Northern Guinea Savanna of Nigeria, to evaluate the yields of two maize varieties (SAMMAZ 14 and 29) under different fertilizer recommendations using Farmers recommended rate (120:60:60) and Nutrient Expert model (NE) recommendations (160:90:74). The research was achieved in Randomized Complete Block Design with six treatments and three replications. The study revealed that NE V1 fertilizer recommendation and farmers recommended practice produced 300% higher yield in comparison to control ($p \leq 0.05$). There was no statistical difference in the yield and growth parameters between fertilizer recommendation from the model and farmers' recommended practice rate. This is due to the assumptions of the NE model that all nutrient sources come from mineral fertilizers. The study novelty is the introduction of a new technique of fertilizer recommendation that can supplement the existing farmers' blanket recommendation system. We conclude that different components of site-specific nutrient management can be incorporated into Nutrient Expert and can serve as an effective tool for the nutrient recommendation for Maize in Nigeria.*

Keywords: *Nutrient expert; Fertilizer recommendations; Nutrient managements; Maize*

INTRODUCTION

Maize (*Zea mays*) belongs to family Poaceae and subfamily Panicoideae. It is a major cereal crop cultivated in the Savannah and rainforest zones of Nigeria. Its production surpass that of rice and wheat in the country, with a production estimated at 5.5 millions tons per year in 2002 (Olaniyan & Lucas, 2004) and 9.2 millions tons per year in 2011 (Olaniyan, 2015). This is inadequate compared to the total demand of the product in the country coupled with competition between humans and animal feeds (Kaul et al., 2019). Increasing trend of human population requires sustainable food production which can be achieved with intensive cultivation on the same piece of land under good agricultural management practices. Increased in yield using mineral fertilizer complemented with organic fertilizers has been widely documented (Efthimiadou et al., 2010; Mahmood et al., 2017). Fertilizer recommendation has been developed for different crops which are normally based on blanket rates across agroecological zones. Some farmers adopt these rates while some apply fertilizers below the recommended rates usually due to costs and unavailability of mineral fertilizers. Because of spatial differences in soil nutrient status, the need for site-specific and system-specific fertilizer recommendation becomes crucial.

Site specific nutrient management (SSNM) is among the component of precision agriculture, that combines the ability of soil to supply deficit nutrient to plant at different growth stages. Nutrient Expert is a computer based support tool developed to help in estimation of fertilizer rates based on the SSNM principles of the fertilizer 4 'R' (right source, right dose, right method of application and right time of application) stewardship (Satyanarayana et al., 2013). Nutrient Expert model (**NE V1**) simply integrates biophysical and socio-economic factors and enables a strategic formulation of site-specific nutrient management guidelines for maize. It have used with success in major cereal crops such as rice, wheat and maize in some Asian countries (Dutta et al., 2014; Sapkota et al., 2014). The tool uses site-specific management principles to quickly and systematically formulate fertilizer recommendations for maize tailored to a specific field growing environment (IPNI, 2016). It determines fertilizer requirements for specific growing conditions based on multi-location on-farm nutrient omission trials and existing site agronomic and soil information. The tool generates site-specific fertilizer recommendation for maize as a test crop based on prevailing biophysical conditions. This work therefore evaluates different fertilizer recommendations based on the farmers' recommended practice and nutrient expert rates on the performance of maize in Samaru Northern guinea savanna zone of Nigeria.

MATERIALS AND METHODS

The experiment was carried out in the research field of Institute for Agricultural Research, Ahmadu Bello University, Nigeria (11 º 10'38.77'' N, 07º 36'42.36'' E. 686m altitude) (Figure 1). The experiment was conducted in the growing season of 2017 and 2018. The field was laid out in randomized complete block design (RCBD) with two maize varieties (SAMMAZ 14 and SAMMAZ 29) and six treatments (control (CTR), 0.5 farmers recommended rate (FP1), farmers recommended rate (FT2), 0.6 nutrient expert rate (NE1), 1.6 nutrient expert rate (NE2), and nutrient expert rate (NE3)) as summarized in

Table ***1***. These were replicated 3 times. Nutrient expert (**NE** V1) rate was generated to target 6000 kg maize grain yield per hectare with the assumptions of 15.5% moisture at harvest, field size as 1ha, inorganic NPK as the only input applied in two-splits, maize variety as open pollinated, plant density of 55,000 plants/ha, spacing of 75 x 25cm and 1 plant/hole. Other assumptions into the model were that no crop residues returned to the soil (which is the true representative of a typical savanna cropping system) and soils are poor in fertility. Having generated the fertilizer recommendation from the model, the rates were formulated as given in Table 1. The experiment was laid out in a 4.5 x 4m plots separated by 2m between adjacent plots and replicates. The surface soil (0 - 30cm) of the plots were sampled and analysed for physical and chemical properties using routine laboratory methods. These properties include particle size distribution, total organic carbon, pH, available phosphorus, and total nitrogen.

Agronomic practices include land preparation and layout of the experimental field. Planting was done when the rainy season sets, while fertilizer application and rates was based on farmer's recommended practices and based on the recommendation by the NE V1 model (Table 1). Fertilizers were applied for each major nutrient as straights/single sources in mineral forms i.e., Urea (45 % N), single super phosphate (SSP; 18% P_2O_5) and muriate of potash (MOP, 60% K_2O). All P and K sources and 50% N were supplied basally at 2 weeks after sowing (WAS) while the remaining 50% N was applied at 6 WAS. Other cultural practices such as thinning, and weeding were carried out as recommended. Data on growth and yield parameters such as plant height and leaf area were collected at 3, 6 and 9 WAS, and 100-grain weight and dry matter grain/stover yield were collected at harvest. All data collected in the experiment were subjected to statistical analysis of variances with Statistical Analysis Software (SAS, 2020). Differences among the treatment means was evaluated using Least Significant Difference (LSD).

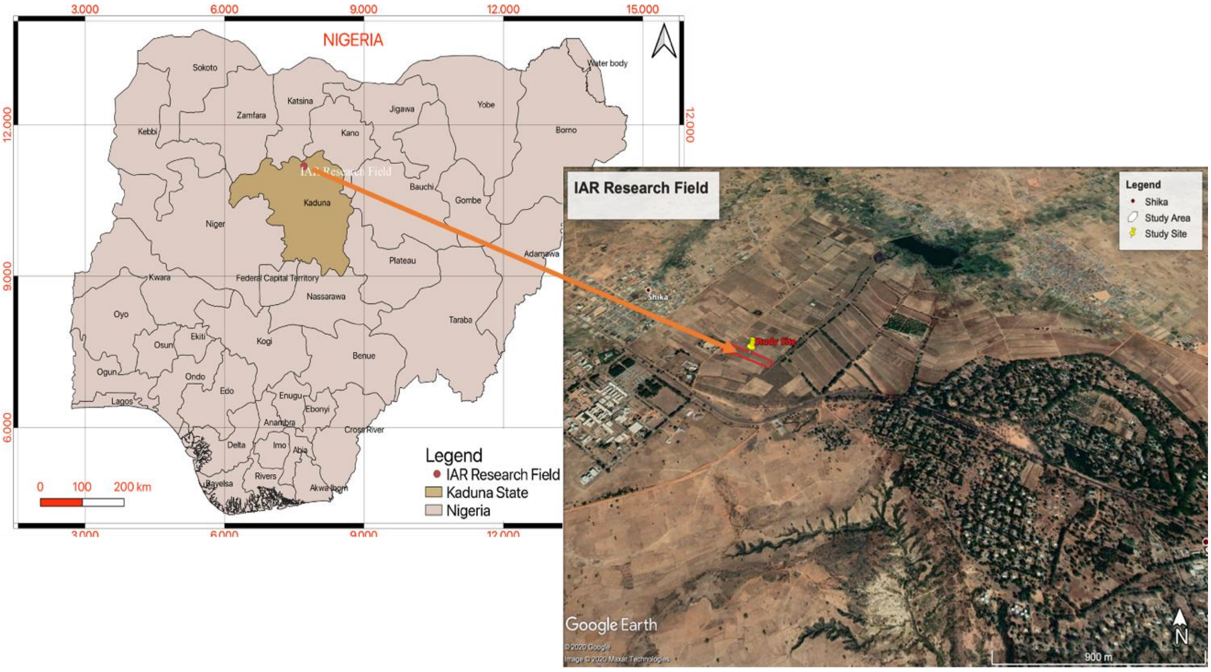

Fig. 1: Map of the study area (IAR research field) showing the experimental fields

Table 1

Application rate of nutrients applied at nutrient expert and farmer's recommendation practice.

Treatments (T)	Application rate kg ha^{-1}		
	N	**P**	**K**
CTR	0	0	0
FP1	60	30	30
FP2	120	60	60
NE1	96	54	44
NE2	192	108	89
NE3	160	90	74

N = Nitrogen, P = Phosphorous, K = Potassium, CTR = Control, FR1 = 0.5 Farmers Recommended Rate; FP2 = Farmers Recommended Rate, NE1 = 0.6 Nutrient Expert Rate, NE2 = 1.6 Nutrient Expert Rate, NE3 = Nutrient Expert Rate

RESULTS AND DISCUSSION

The result of the physical and chemical analysis of the soils shows that the soils were loam in texture with organic carbon content of 12.6 g kg^{-1} at 0-15 cm depth and 3.75 g kg^{-1} at 15-30 cm depth respectively. Soil pH_{CaCl2} was acidic with 5.0 and 5.1 for the respective soil depths, while available P, Total N and exchangeable bases content of the soil were all low, indicating poor soil fertility. This reflect the true nature of the savanna soil of Nigeria (Raji et al., 2015).

Plant height at 6 and 9 weeks after sowing (WAS), and leaf area at 9 WAS were significantly affected by fertilizer management treatments (Table 2). Higher plant height was observed in NE3 (119.04 cm) over CTR (63.63 cm). This shows that plant height increased with balanced fertilizer under NE V1. It was well documented that balanced fertilization produce the highest plant height (Elanchezhian et al., 2017; Gomaa et al., 2017), whereas no fertilized plot (control) produce the minimum height which is in accordance to our findings. Also, higher leaf area was observed in FP1 (566.91 cm^2) over CTR (333.32 cm^2). It was observed that treatments with higher nitrogen produce higher leaf area. This result is in agreement with the previous findings that higher nitrogen promote leaf area during vegetative growth (Belay & Adare, 2020). No significant differences were observed in the interaction and between the maize varieties in terms of plant height and leaf area at 9 WAS, this is because the two varieties have similar physiological traits. Maize varieties with similar physiological traits produce statistically the same yield (Ambroży-Deręgowska & Szulc, 2021).

Higher significant result was found between the fertilizer treatments in terms of 100-grains weight, grain yield, stover yield, number of cobs and stand counts per plot (Table 3). Farmers' recommended practice produces higher grain yield and stover yield over the unfertilized control. The highest grain yield (3842.6 kg/ha) and stover yield (3850 kg/ha) was recorded in FP1 which is statistically similar to all the other fertilized treatments and significantly higher than unfertilized control grain yield (766.7 kg/ha) and stover yield (1312.06 kg/ha) respectively. Belay and Adare (2020) and (Kirda et al., 2005) showed that maize grain yield significantly increases with balanced fertilizer treatments. Higher stover yield observed was also due to balanced fertilization as more assimilate results in the accumulation of higher plant biomass (Elanchezhian et al., 2017; Gomaa et al., 2017). Also, the highly significant differences observed in number of cobs and stand counts between the fertilized treatment and unfertilized control is attributed to balance fertilization, as many stands failed during vegetative growth in the unfertilized control. These result to the higher grain and stover yields in fertilized treatments compared to the unfertilized control.

Overall, the farmers' recommended rate and the NE V1 rates produces a very close grain yield with more than 93% accuracy (3.2 – 3.8 tons/ha). Pooniya et al. (2015) observed that the nutrient expert treatments exhibited greater agronomic efficiency of applied nitrogen and phosphorus over control. It was reported by Wang et al. (2020) that nutrient expert provide better agronomic and environmental benefits in fertilizer optimization for crop nutrient management and environmental quality. It was also reported that nutrient expert management reduces environmental footprint by 21.4 – 26.0 % and increasing yield by 3.9 – 6.9 % with less nitrogen rate compared to farmers practice (Huang et al., 2021). These findings suggest that nutrient expert could safely be used as recommendation tool for maize fertilization in Northern guinea savanna of Nigeria.

Table 2

Effect of fertilizer management on plant height and leaf area on two maize varieties in Samaru, Northern guinea Savannah of Nigeria.

Treatments (T)	**Plant height (cm) @ 3WAS**	**Plant height (cm) @ 6WAS**	**Plant height (cm) @ 9WAS**	**Leaf area (cm^2) @ 3WAS**	**Leaf area (cm^2) @ 6WAS**	**Leaf area (cm^2) @ 9WAS**
CTR	25.33	48.87b	63.63b	89.39	282.47b	333.32c
FP1	22.47	84.59a	116.74a	101.87	340.14ab	566.91a
FP2	23.91	75.08a	111.65a	92.28	358.62a	534.69ab
NE1	22.66	74.87a	104.73a	101.34	313.45ab	518.18ab
NE2	25.19	82.96a	107.48a	99.11	302.96ab	457.98b
NE3	24.38	76.42a	119.04a	112.33	338.09ab	524.92ab
LOS	NS	***	***	NS	NS	***
SE±	1.05	5.12	6.93	10.14	21.06	30.26
Varieties (V)						
SAMMAZ 29	21.79b	74.33	107.32	95.57	321.47	486.69
SAMMAZ 14	26.18a	73.27	100.43	103.21	323.78	491.98
LOS	***	NS	NS	NS	NS	NS
SE±	0.61	2.95	3.99	5.85	12.16	17.47
Interactions						
T*V	*	NS	NS	NS	NS	NS

CTR = Control, FR1 = 0.5 Farmers Recommended Rate; FP2 = Farmers Recommended Rate, NE1 = 0.6 Nutrient Expert Rate, NE2 = 1.6 Nutrient Expert Rate, NE3 = Nutrient Expert Rate, LOS = level of significant, SE = standard error, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, NS = not significant, WAS = week after sowing.

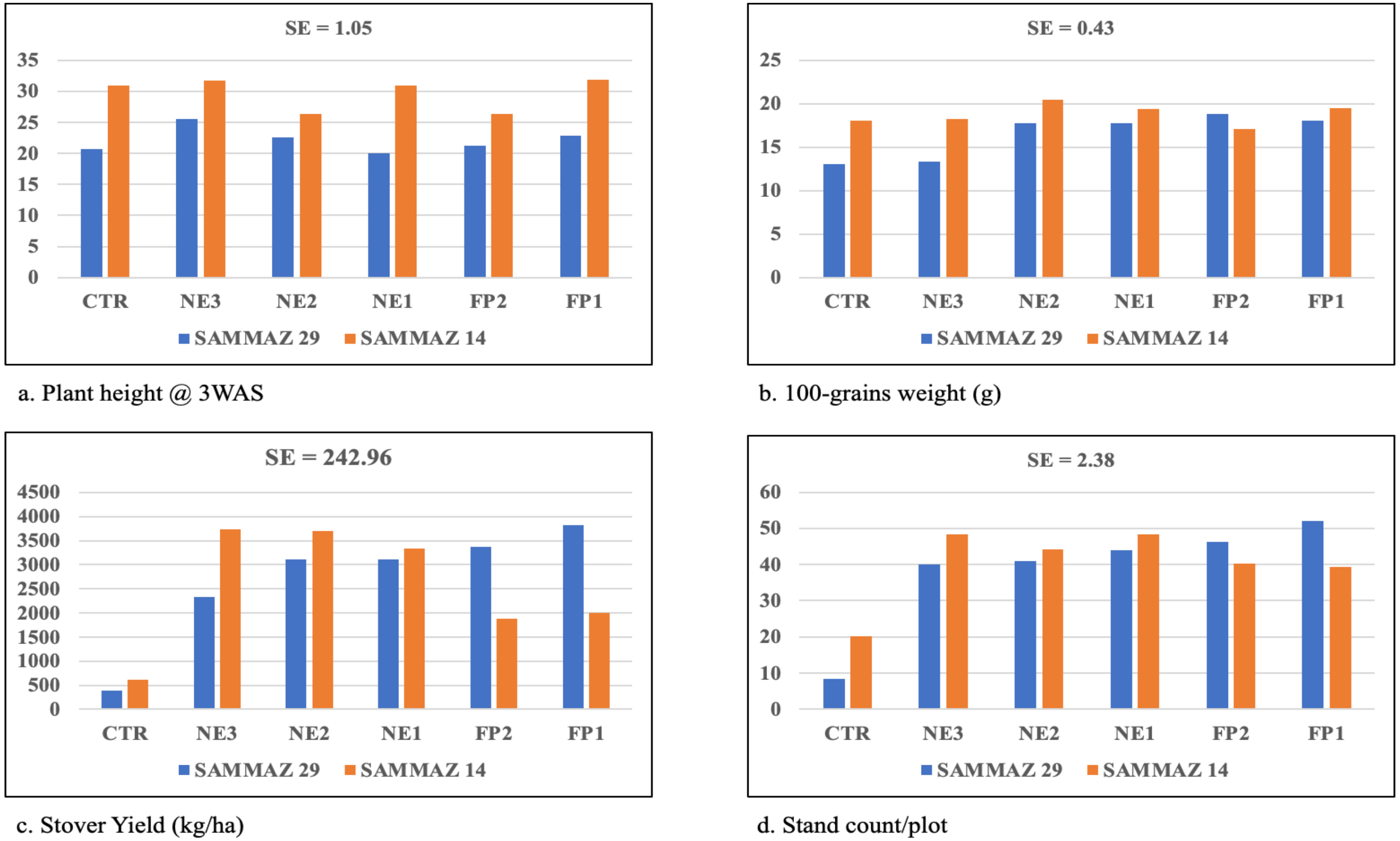

Fig. 2: Interaction of maize varieties and different fertilizer rates on some maize growth and yield parameters.

Table 3

Effect of fertilizer management on grain yield and yield components on two maize varieties in Samaru, Northern guinea Savannah of Nigeria.

Treatments (T)	**100-grains weight (g)**	**Grain Yield (kg/ha)**	**Stover Yield (kg/ha)**	**No. of cobs/plot**	**Stand count/plot**
CTR	16.91b	766.7b	1312.0b	26.25b	26.58b
FP1	18.92a	3842.6a	3850.0a	42.92a	44.00a
FP2	19.18a	3537.0a	3400.0a	42.83a	42.83a
NE1	18.71a	3222.2a	3255.6a	39.33a	40.92a
NE2	18.40a	3324.1a	3500.0a	42.25a	46.00a
NE3	17.83ab	3486.1a	3459.3a	42.58a	43.33a
SE±	**	***	***	***	***
LOS	0.43	242.96	238.49	2.38	2.68
Varieties (V)					
SAMMAZ 29	17.80b	3018.2	3069.4	41.14	40.94
SAMMAZ 14	18.84a	3041.4	3190.2	37.58	40.28
SE±	**	NS	NS	NS	NS
LOS	0.25	140.27	137.69	1.37	1.55
Interactions					
T*V	**	NS	*	NS	**

CTR = Control, FR1 = 0.5 Farmers Recommended Rate; FP2 = Farmers Recommended Rate, NE1 = 0.6 Nutrient Expert Rate, NE2 = 1.6 Nutrient Expert Rate, NE3 = Nutrient Expert Rate, LOS = level of significant, SE = standard error, * = p < 0.05, ** = p < 0.01, *** = p <0.001, NS = not significant, WAS = week after sowing.

CONCLUSIONS

In the present study, nutrient expert (NE V1) was used to estimate the yield of maize in different fertilizer management. Nutrient expert rate generated was to target 6 tons maize grain per hectare with assumption of 15.5 % moisture at harvest, 1 hectare field size, NPK as the only input fertilizer applied in two-splits, maize variety as open pollinated, plant density of 55,000 plants/ha, no crop residue returned to the farm, and soils are poor in fertility. The study was conducted in two growing seasons. The results of the field validation suggested that the NE V1 as a trial tool is effective in estimating the fertilizer recommendation, as NE-based fertilizer recommendations proved to produce statistically same yield and yield components like the farmers' recommendation practices. Thus, this validate the software as the input's sources were assumed to be based on the mineral fertilizer only. We recommend that further research could be undertaken to evaluate the software in recommending fertilizer rates by altering different management practices and incorporating different sources of nutrient such as manure into the model. This will provide a timely approach in achieving the site-specific nutrient management for precision crop production, and also the software is easy to operate and handle by field extension workers.

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