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PROFITABILITY AND IMPACT OF INORGANIC FERTILIZERS ON THE MAIZE PRODUCTION IN EKONA, CAMEROON

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SUMMARY

Declining soil fertility and low fertilizer use are the major abiotic factors limiting the maize production in Cameroon. Therefore, the design and introduction of appropriate fertilizer schemes, which would improve maize yields and provide incentives for smallholder farmers, are considered imperative. In 2018, a field experiment was conducted on the farm of the Institute of Agricultural Research for Development (IRAD) in Ekona, the south-west region of Cameroon, to investigate the profitability and impact of inorganic fertilizers on maize production. The experiment was laid out in a randomized complete block design with four replications and four treatments, using different fertilizer rates per hectare in each treatment (namely unfertilized control (T1), 50 kg urea + 50 kg N-P-K (T2), 100 kg urea + 100 kg N-P-K (T3) and 150 kg urea + 150 kg N-P-K (T4)). The results obtained indicate that all the maize growth parameters (plant height, number of leaves per plant, stem girth and leaf area) and yield components considered (cob length, cob diameter and test weight of 100 grains) were significantly ($P < 0.05$) higher in T4 than T1. The grain yields recorded ranged from 4.09–5.88 t ha⁻¹ and were also statistically ($P < 0.05$) higher in T4 than T1. The incremental income based on the fertilizer use was the highest in T4, followed by T3 and T2. The value cost ratio (VCR) was greater than 2 in all the treatments and was found to be highest in T2 (3.15), followed by T4 (2.52) and T3 (2.49). As T2, T3 and T4 did not differ statistically ($P > 0.05$), all the fertilizer rates considered were economically viable, but T4 provide the most cost-effective due to its higher grain yields and incremental income.

Key words: fertilizer, maize, incremental income, value cost ratio, soil fertility

INTRODUCTION

Although sub-Saharan African (SSA) countries have the fastest growing population and the highest soil depletion rates in the world, the use of inorganic fertilizers in these countries is the smallest in the world (less than 10 kg ha⁻¹) (Bationo et al., 2012; Jjagwe et al., 2020). As a result of low input and continuous cultivation, declining soil fertility has been cited as one of the major challenges to the crop production in SSA (Ngome et al. 2011; Tittone & Giller, 2013; Ngosong et al., 2019). In the case of the humid tropics, the decline in soil fertility is intense, mostly associated with low buffering capacity, low activity clay content and small nutrient reserves of most of the soils (which renders them vulnerable to erosion and compaction) (Koutika et al., 2005; Nanganoa et al., 2019a).

The combined average depletion rate of N, P and K of all the SSA countries is $54 \text{ kg ha}^{-1} \text{ yr}^{-1}$. Therefore, it is not surprising that nutrient limitation is the major obstacle for increasing crop yields in Africa (Sommer et al., 2013). Manure and composted organic waste have excellent potential to improve the nutrient content of deteriorated lands and to raise the nutrient level of plants (Temegne et al., 2020; Rurinda et al., 2020). However, farmers need to address a number of problems when using organic fertilizers such as increased labor requirements, limited sources of manure, and transportation (Wheeler, 2008; Odhiambo & Magandini, 2008; Ngome et al., 2013).

Over the past years, the promotion of inorganic fertilizers has become a resounding theme across SSA, especially following the First African Fertilizer Summit in Abuja, Nigeria, in mid-2006 (Sheahan, 2011). However, without the knowledge of fertilizer use profitability, programs encouraging fertilizer use to stimulate agricultural productivity could fail to achieve their purpose. Nevertheless, there have been upward trends in the fertilizer use in SSA to improve the yields of staple food crops like cereals. One of the most important cereals in SSA is maize (*Zea mays* L.). It is a staple food for over 600 million people in the region (Jjagwe et al., 2020). In Cameroon, maize is predominantly produced by smallholder resource farmers, who constitute about 70% of the farming population (INS, 2010). The present level of inorganic fertilizer use in Cameroon stands at 7 to 10 kg ha^{-1} , which is still considered very low compared to other countries in Asia and Europe where such use exceeds 150 kg ha^{-1} (Morris et al., 2007; Kotschi, 2015; Tayoh et al., 2016). According to Bumb (1995), one-third of the growth in cereal production globally can be attributed to fertilizer use. A number of recent studies have argued the positive yield response to the inorganic fertilizer use in maize production (Abebe & Feyisa, 2017; Abera et al., 2017; Ngosong et al., 2019; Temegne et al., 2020). However, the introduction and use of technologies that require additional labor for the establishment and management of crops will depend on the farmer's perception of their overall financial benefit. Farmers are likely to adopt technologies that would improve soil fertility if the returns on such investments are assured (Kimani et al., 2004; Mucheru-Muna et al., 2014).

Very few studies have addressed the issue of inorganic fertilizer use profitability in maize production (Liverpool-Tasie et al., 2017). Therefore, this study evaluates the profitability and impact of inorganic fertilizers on maize production. We hypothesized that inorganic fertilizer use would substantially increase grain yields and profitability of maize production.

MATERIAL AND METHODS

Site location

A field experiment was conducted on the farm of the Institute of Agricultural Research for Development (IRAD) in Ekona ($4^{\circ}14' 0'' \text{ N}$, $9^{\circ}20' 4'' \text{ E}$), Cameroon. Ekona is situated on the northeastern slopes of Mount Cameroon at 450 meters above sea level (Price, 1994) with humid tropical climatic conditions. It has two distinct seasons: a long rainy season from mid-March to mid-November and a short four-month dry season expanding from mid-November to mid-March. The mean temperature ranges between 23.70°C in the rainy season and 24.40°C in the dry season, with a high annual humidity of 76–90% (Etchu et al., 2012) and an average annual rainfall of 2,284 mm. These rich volcanic soils belong to the Ekona series, which was formed on older mudflows and have a well-developed argillic horizon (FAO-UNDP/ONAREST, 1980; Nanganoa et al., 2019b).

Experimental set-up

The experiment was laid out in a randomized complete block design (RCBD) with 4 treatments (Tab. 1) and 4 replications, thus creating a total of 16 experimental plots measuring $5 \times 5 \text{ m}$ each. The experimental plots and blocks were separated by 1 m and 1.5 m alleys respectively, whereas 2 m buffer strips surrounded the entire experimental field. The yellow maize variety CMS 8704 (with a maturity period of 80–120 days), obtained from the Institute of Agricultural Research for Development, was manually planted at a soil depth of about 3–5 cm and an inter- and intra-row spacing of $75 \times 30 \text{ cm}$, respectively. This maize was used because of its adaptability to different climatic zones, resistance to diseases and regional consumer preferences. Three seeds were sowed per stand and subsequently thinned to two plants per stand after germination. All the fertilizer treatments were applied as 2 split doses with 50% applied (urea and NPK-20-10-10) 2 weeks after sowing (WAS) and the remaining 50% 6 WAS. Fertilizer application was done during the later hours of the day, burying fertilizer in the ground about 5 cm from the plants to avoid burns and minimize nutrient loss through leaching and volatilization. Weeds were manually removed 2 WAS, 5 WAS, and 10 WAS. The systemic and contact insecticide Paraster 40EC (Active ingredient: 20gr/l imidachlopride + 20gr/l lambdacyhalothrine) was applied at a rate of 40 ml in a 16L knapsack sprayer 4 WAS and 8 WAS to reduce the level of insect infestation and damage (namely aphids and stem borer). The soil moisture during the entire experimental period depended on the local rainfall regime.

Table 1. Experimental fertilizer treatments performed

N°	Treatment per hectare	Treatment code	Quantity of fertilizer nutrient (kg ha ⁻¹)		
			N	P ₂ O ₅	K ₂ O
1	Unfertilized Control	T1	0	0	0
2	50 kg urea + 50 kg N-P-K (20-10-10)	T2	33	5	5
3	100 kg urea + 100 kg N-P-K (20-10-10)	T3	66	10	10
4	150 kg urea + 150 kg N-P-K (20-10-10)	T4	99	15	15

Data collection

Soil physicochemical properties

After clearing the experimental site in April 2018, pre-planting soil samples were randomly collected in a zigzag pattern at a depth of 0–20 cm with an auger and thoroughly mixed to form a composite sample. Prior to analysis, the soil was air-dried and sieved through a 2-mm screen to remove stones and plant debris. The pH of the soil was determined in the ratio of 1:2.5 (soil/water and soil/KCl) suspensions, using a digital pH meter. Available phosphorus was determined by the Bray II method (Van Reeuwijk, 1992), organic carbon by the Walkley and Black wet digestion method (Kalra & Maynard, 1991), and total nitrogen by the Kjeldahl digestion method (Bremner & Mulvaney, 1982). Soil exchangeable bases were determined after extraction with a 1 N ammonium acetate (NH₄OAc) solution at pH 7. Calcium and magnesium were analyzed with an atomic absorption spectrometer (AAS), whereas sodium and potassium were determined using a flame photometer (Rowell, 1994). Exchangeable acidity was determined by the 1 N KCl extraction method and titrated with 0.01 N NaOH, using phenolphthalein indicators (Van Reeuwijk, 1992). The Effective Cation Exchange Capacity (ECEC) was determined by the sum of exchangeable bases and acidity, whereas particle size distribution was determined by the pipette method. The textural class was assigned according to the USDA textural triangle (Van Reeuwijk, 1992). The physicochemical properties of the pre-planting soil of the experimental site are presented in Table 2.

Table 2. Physicochemical properties of soil before the experiment

Soil chemical properties	Value	Particle size distribution	Value
OC. %	2.71	Clay (%)	30.55
TN%	0.17	Silt (%)	57.53
C/N	16	Sand (%)	11.91
Av. P (mg/kg)	83	Soil texture	Silty clay loam
pH (H ₂ O) 1:2.5	5.99		
pH (KCl) 1:2.5	4.83		
Na ⁺ (cmol _c /kg)	0.29		
K ⁺ (cmol _c /kg)	0.79		
Mg ²⁺ (cmol _c /kg)	4.02		
Ca ²⁺ (cmol _c /kg)	16.92		
Al +H (cmol _c /kg)	0.08		
ECEC (cmol _c /kg)	22.10		

Legend: *OC: organic carbon; TN: Total nitrogen

Maize growth and yield

Maize growth and yield data were collected from six randomly selected and tagged plants on each plot, excluding 2 border rows from each side. Growth and yield parameters were then recorded at different stages of crop growth and development. The leaf area was determined by the non-destructive length x width method 9 WAS (leaf area = 0.75 (length x width), where 0.75 is a constant) (Saxena & Singh, 1965; Ngosong et al., 2019). Leaves were measured with a tailor's tape for each tagged plant and the leaf area determined in square centimeters. At 12 WAS, plant height was measured with a carpenter tape and expressed in centimeters, the number of leaves was visually counted on six randomly selected plants and recorded for each plant. Stem girth was measured with a thread at 10 cm above ground, and the actual measurements were determined with a carpenter's tape in centimeters for each plant. Six maize ears from each replicate were manually harvested on 9th August at physiological maturity, and the cob lengths and diameters were measured in centimeters with a tailor's tape and subsequently recorded. The cobs were sundried and then threshed. The dried maize grains were weighed using a balance to obtain the maize total yield (t ha⁻¹), whereas the randomly selected 100-maize grain weight (g) was recorded per treatment.

Economic analysis

To estimate the profitability of fertilizer use in maize production, the cost incurred on NPK -20-10-10 and urea fertilizers and maize grain income were considered. The value cost ratio (VCR) was employed to assess the viability of fertilizer use (Sommer et al., 2013): $VCR = \text{Value of yield increase obtained} / \text{Total cost of fertilizer}$ (Afzal et al., 2014). By convention, VCR should be greater than 2 in a developing economy to provide incentives for fertilizer use overcoming risks and costs of capital (CIMMYT, 1988). Fertilizer use efficiency (FUE) was calculated using the following formula: $FUE (\text{kg grains kg}^{-1} \text{ nutrient}) = (\text{Yield with fertilizer} - \text{Yield in control}) (\text{kg}) / \text{Nutrient (kg)}$ (Akram et al., 2007). The price of maize grains was set at 170 FCFA (0.34 USD) per kg, whereas the prices of urea and NPK-20-10-10 were 17500 (35 USD) and 20000 FCFA (40 USD) per 50 kg bag, respectively.

Statistical analysis

All the data sets obtained were analyzed using the statistical software package IBM-SPSS statistics 23. A one-way analysis of variance (ANOVA) was used to compare the different fertilizer treatments according to plant parameters, grain yields and economic analysis. Significant data means were compared by the post hoc Tukey's HSD test ($P < 0.05$).

RESULTS AND DISCUSSION

Soil characteristics

The textural class of the pre-planting soil at the experimental site was silty clay loam (Tab. 2). According to Landon (1991), the soil pH was in the preferred range (5.5-7.5) for most crops including maize. The soil organic carbon (2.71 %) and total nitrogen (0.17 %) were low, whereas exchangeable K (0.79 cmol/kg), Ca (16.92 cmol/kg) and Mg (4.02 cmol/kg) were high. The available phosphorus determined (83 mg/kg) was very high (Tab. 2). Based on the soil nutrients analysis, nitrogen was found to be the limiting macro-nutrient.

Growth parameters

The mean plant height, number of leaves per plant, stem girth and leaf area were highest in T4 (150 kg urea + 150 kg N-P-K), followed by T3 (100 kg urea + 100 kg N-P-K) and T2 (50kg urea + 50kg N-P-K). The lowest measurements were recorded in T1, i.e. the unfertilized control (Tab. 3). With the exception of T1, the mean plant heights were not significantly different ($P > 0.05$) in T4, T3 and T2. With the same fertilizer rates, Temegne et al. (2020) recorded significantly higher mean plant (the *RVD*T maize variety) height in T3 (100 kg urea + 100 kg N-P-K) than T2 (50 kg urea + 50 kg N-P-K) and T4 (150 kg urea + 150 kg N-P-K) at 9 WAS. Ngosong et al. (2019) recorded a similar increase in maize (CMS 8704) plant height with an increase in Urea-N rate. Amin (2011) attributed the increase in plant height to the fact that nitrogen promotes plant growth and increases the number and length of the internodes, which results in a progressive increase in plant height. The number of leaves was significantly greater ($P < 0.05$) in T4 than that in T1 and T2, whereas the stem girth and leaf area were significantly higher in T4 than T1 (Tab. 3). Koul (1997) also argued that nitrogen application resulted in higher values of plant height, leaf area, number of leaves and stem diameter of fodder maize. Onasanya et al. (2009) attributed the increase in number of leaves and leaf area to increased nitrogen rates.

Table 3: Impact of fertilizer rates on maize growth parameters (Mean $\pm$ SD)

Treatment code	Plant height (cm)	No of leaves per plant	Stem girth (cm)	Leaf area (cm ²)
T1	248.70 $\pm$ 58.11b	11.29 $\pm$ 1.37b	6.63 $\pm$ 0.99b	768.78 $\pm$ 133.22b
T2	283.01 $\pm$ 26.31a	11.71 $\pm$ 1.12b	7.20 $\pm$ 0.73ab	848.13 $\pm$ 108.29ab
T3	283.11 $\pm$ 45.74a	12.71 $\pm$ 1.37a	7.29 $\pm$ 0.88a	855.28 $\pm$ 123.09ab
T4	287.66 $\pm$ 37.85a	13.21 $\pm$ 1.41a	7.63 $\pm$ 0.82a	907.03 $\pm$ 163.28a

Legend: T1 - unfertilized control; T2 - 50kg urea + 50kg N-P-K (20-10-10); T3 - 100kg urea + 100kg N-P-K (20-10-10); T4 - 150kg urea + 150kg N-P-K (20-10-10); Values within columns with different letters are significantly different ($P < 0.05$)

Grain yield and yield components

Significant differences were found in the mean cob length, cob diameter, 100 grain test weight, and grain yields of maize in the treatments considered (Tab. 4). The greatest mean cob length, cob diameter, and test weight of 100 grains were determined in T4 and the smallest in T1. The mean grain yield ranged from 4.09 – 5.88 t ha⁻¹ with the highest in T4, followed by T3 and T2 (Fig. 1). With the exception of the control (T1), T2, T3 and T4 were not significantly ($P > 0.05$) different (Fig. 1). Consistent with the results of Achiri et al., (2017), our findings indicate a progressive increase in the mean grain yield of maize with increased doses of NPK and urea fertilizers. Ngosong et

al. (2019) and Temegne et al. (2020) also report higher maize grain yields with increasing nitrogen fertilizer rates. However, under similar volcanic soil and climatic conditions, Ngosong et al. (2019) highlighted the potential long-term detrimental effects of higher nitrogen fertilization ($> 100 \text{ kg N ha}^{-1}$), which can compromise the sustainability of such arable systems. They suggested N application rates between 50 and 100 kg N ha^{-1} as optimum for the sustainable maize production in the volcanic soils of Buea, the south-west region of Cameroon. The greatest fertilizer use efficiency (FUE) was recorded in T2, followed by T4 and T3 (Fig. 2). Accordingly, these fertilizer rates were found to have similar effects on the increase in maize grain yields.

Table 4: Effect of different rates of fertilizers on the grain yield and yield components of maize

Treatment code	Cob length (cm)	Cob diameter (cm)	Test weight of 100 grains (g)
T1	$16.15 \pm 3.28\text{b}$	$14.86 \pm 1.27\text{b}$	$26.69 \pm 4.23\text{c}$
T2	$16.68 \pm 2.68\text{ab}$	$15.74 \pm 1.31\text{ab}$	$30.47 \pm 3.64\text{bc}$
T3	$17.34 \pm 1.87\text{ab}$	$15.65 \pm 1.19\text{ab}$	$32.44 \pm 0.74\text{b}$
T4	$18.06 \pm 2.18\text{a}$	$15.98 \pm 1.03\text{a}$	$33.21 \pm 2.63\text{a}$

Legend: T1 - unfertilized control, T2 - 50kg urea + 50kg N-P-K (20-10-10); T3 - 100kg urea + 100kg N-P-K (20-10-10); T4 - 150kg urea + 150kg N-P-K (20-10-10); Values within columns with different letters are significantly different ($P < 0.05$)

Figure 1. Impact of fertilizer rates on maize grain yields (Mean $\pm$ SD)

(Values across fertilizer rates with different letters are significantly different ($P < 0.05$). T1: unfertilized control, T2: 50kg urea + 50kg N-P-K (20-10-10), T3: 100kg urea + 100kg N-P-K (20-10-10), T4: 150kg urea + 150kg N-P-K (20-10-10); SD – Standard deviation)

Figure 2. Efficiency of the use of fertilizer with different nutrients (T2: 50kg urea + 50kg N-P-K (20-10-10), T3: 100kg urea + 100kg N-P-K (20-10-10), T4: 150kg urea + 150kg N-P-K (20-10-10); SD – Standard deviation)

Profitability of fertilizer use

The fertilizer treatments considered increased the overall financial returns, compared to the profit gained with no fertilizer use (Tab. 5). The highest incremental income was recorded in T4 (341.09 USD) and the lowest in T2 (161.62 USD) (Tab. 5). The highest value cost ratio (VCR) was recorded in T2 (3.15) and the lowest in T3 (2.49) (Fig. 3). Statistically, the incremental income and VCR were not significantly different ($P > 0.05$). The VCR values obtained for all the fertilizer rates were greater than 2 (Fig. 3), thus confirming their profitability in maize production under rain-fed conditions. A median VCR of 2.8 for maize in Eastern and Southern Africa has been reported (Sommer et al., 2013).

Table 5. Profitability of different fertilizer treatments in maize production

Treatment	Fertilizer applied (kg/ha ⁻¹)		Grain yield (kg/ha ⁻¹)	Extra yield over control (kg/ha)	Value of increased yield (USD/ha)	Cost of fertilizer (USD)	Incremental income (USD/ha)
	N-P-K	Urea					
T1	0	0	4091.11	/	/	/	/
T2	50	50	4840.61	749.50a	236.62a	75.00	161.62a
T3	100	100	5275.59	1184.48a	373.94a	150.00	223.94a
T4	150	150	5884.24	1793.13a	566.09a	225.00	341.09a

Legend: Values across fertilizer rates with the same letters are not significantly different ($P > 0.05$); T1 - Unfertilized Control; T2 - 50kg urea + 50kg N-P-K (20-10-10); T3 - 100kg urea + 100kg N-P-K (20-10-10); T4 - 150kg urea + 150kg N-P-K (20-10-10)

Figure 3. VCR for different level of fertilizer application to maize (T2: 50kg urea + 50kg N-P-K (20-10-10), T3: 100kg urea + 100kg N-P-K (20-10-10), T4: 150kg urea + 150kg N-P-K (20-10-10); SD – Standard deviation)

CONCLUSION

The results obtained indicate that increasing doses of urea and N-P-K – 20-10-10 fertilizers exert significant effects on the growth performance and yield of maize in Ekona, the south-west region of Cameroon. The VCR values obtained for all the fertilizer rates were greater than 2, thus confirming their profitability in maize production under rain-fed conditions. However, T4 (150kg urea + 150kg N-P-K) proved the most cost-effective of all the fertilizer treatments considered due to its higher grain yields and incremental income. Therefore, the design and introduction of proper fertilizer schemes could significantly improve maize yields and provide incentives for smallholder farmers in Ekona.

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REFERENCES

- Abebe Z. & Feyisa H. (2017): Effects of Nitrogen Rates and Time of Application on Yield of Maize: Rainfall Variability Influenced Time of N Application. *International Journal of Agronomy*, Article ID 1545280, 10 pages, <https://doi.org/10.1155/2017/1545280>.
- Abera T., Debele T., Wegary D. (2017): Effects of Varieties and Nitrogen Fertilizer on Yield and Yield Components of Maize on Farmers Field in Mid Altitude Areas of Western Ethiopia. *International Journal of Agronomy*, Article ID 4253917, 13 pages. <https://doi.org/10.1155/2017/4253917>.
- Achiri D.T., Mbaatoh H.M., Njualet D. (2017): Agronomic and Yield Parameters of CHC202 Maize (*Zea mays* L.) Variety Influenced by Different Doses of Chemical Fertilizer (NPK) in Bali Nyonga, North West Region Cameroon. *Asian Journal of Soil Science and Plant Nutrition*, 2(4): 1-9.
- Afzal S., Islam M., Ur-Rehman O. (2014): Application of Mitscherlich–Bray Equation for Fertilizer Use on Groundnut. *Communications in Soil Science and Plant Analysis*, 45(12): 1636-1645, DOI: 10.1080/00103624.2014.907911.
- Akram A., Fatima M., Ali S., Jilani G., Asghar R. (2007): Growth, yield and nutrients uptake of sorghum in response to integrated phosphorus and potassium management. *Pakistan Journal of Botany*, 39: 1083–1087.
- Amin M.E.M.H. (2011): Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). *Journal of the Saudi Society of Agricultural Science*, 10(1): 17–23.
- Bationo A., Hartemink A., Lungu O., Naimi M., Okoth P., Smaling E., Thiombiano L., (2012): Waswa B. Knowing the African soils to improve fertilizer recommendations. In: Improving Soil Fertility Recommendations in Africa Using the Decision Support System for Agrotechnology Transfer (DSSAT); Al, K.E., Ed.; Springer: Dordrecht, The Netherlands, 19–42.

- Bremner J.M. & Mulvaney C.S. (1982): Nitrogen-total. In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, A. L., Miller, R. H. and Keeney, D. R. (Eds.), American Society of Agronomy, Madison, Wisconsin: Soil Science Society of America. pp: 595 –624.
- Bumb B. (1995): Global Fertilizer Perspective, 1980–2000: The Challenges in Structural Transformation. Muscle Shoals, AL: IFDC.
- CIMMYT (International Maize and Wheat Improvement Center) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Mexico City: CIMMYT.
- Etchu K., Ndzi V., Ndamukong K., Oben B. (2012): Comparative performance of grasscutters (*Thryonomys swinderianus*) fed maize and rodent pellets as concentrate supplement under intensive management system in Cameroon. *African Journal of Agricultural Research*, 7(6): 883-891. <https://doi.org/10.5897/ajar10.677>.
- FAO-UNDP/ONAREST (1980): Soils and soil fertility management of lands of the Ekona Banana Estate,” Technical Report no. 11, Ekona, Cameroon: Cameroon Development Corporation.
- INS (2010): The population of Cameroon: Reports of presentation of the final results of the 3rd General Census of Population and Habitats (RGPH): Central Bureau of Census and Population Studies (BUCREP), National Institute of Statistics of Cameroon (INS), Ministry of Economy and Finance, Yaounde, Cameroon (In French).
- Jjagwe J., Chelimo K., Karungi J., Komakech A.J., Lederer J. (2020): Comparative Performance of Organic Fertilizers in Maize (*Zea mays* L.) Growth, Yield, and Economic Results. *Agronomy*, 10: 69. doi:10.3390/agronomy10010069.
- Kalra Y.P. & Maynard D.G. (1991): Methods manual for forest soil and plant analysis. Information Report NOR-X-319, Forestry Canada, Edmonton, Alberta: Northwest Region, Northern Forestry Centre, pp: 116.
- Kimani S.K., Macharia J.M., Gachengo C., Palm C.A., Delve R.J. (2004): Maize production in the central highlands of Kenya using cattle manures combined with modest amounts of mineral fertilizer. *Uganda Journal of Agricultural Sciences*, 9: 480–490.
- Kotschi J. (2015): Adverse impacts of mineral fertilizers in tropical agriculture. A soiled reputation. A study commission by Heinrich Böll Foundation, WWF Germany.
- Koul G.G. (2007): Effect of sowing methods, nitrogen levels and seed rates on yield and quality of fodder maize (*Zea mays* L.). M.Sc. Thesis, Faculty of Agriculture, University of Khartoum, Sudan.
- Koutika L.-S., Hauser S., Kanga J.M., Yerima B. (2005): Comparative study of soil properties under *Chromolaena odorata*, *Pueraria phaseoloides* and *Calliandra calothyrsus*. *Plant and Soil*, 266(1-2): 315-323. <https://doi.org/10.1007/s11104-005-2279-3>.
- Landon J.R. (1991): *Booker tropical soil manual*. UK: Longman Scientific and Technical Essex.
- Liverpool-Tasie L.S.O., Omonona B.T., Sanou A., Ogunleye W.O. (2017): Is increasing inorganic fertilizer use for maize production in SSA a profitable proposition? Evidence from Nigeria. *Food Policy*, 67: 41–51.
- Morris M.A., Kelly V.A., Kopicki R.J., Byerlee D. (2007): Fertilizer use in African agriculture: Lessons Learned and Good Practice Guidelines. Direction in development. Agriculture and rural development. The International Bank for Reconstruction and Development / The World Bank.
- Mucheru-Muna M., Daniel Mugendi D., Pypers P., Mugwe J., Kung'u J., Vanlauwe B., Merckx R. (2014): Enhancing maize productivity and profitability using organic inputs and mineral fertilizer in Central Kenya Small-Hold Farms. *Experimental Agriculture*, 50(2): 250-269. doi:10.1017/S0014479713000525.
- Nanganoa L.T., Njukeng J.N., Ngosong C., Atache S.K.E., Yinda G.S., Ebonlo J.N., Ngong J.N., Ngome F.A. (2019a): Short-Term benefits of Grain Legume Fallow Systems on Soil Fertility and Farmers' Livelihood in the Humid Forest Zone of Cameroon. *International Journal of Sustainable Agricultural Research*, 6(4): 213-22.
- Nanganoa L.T., Okolle J.N., Missi V., Tueche J.R., Levai L.D., Njukeng J.N. (2019b): Impact of different land-use systems on soil physicochemical properties and macrofauna abundance in the humid tropics of Cameroon. *Applied and Environmental Soil Science*, 2019(2): 1-9. <https://doi.org/10.1155/2019/5701278>.
- Ngome A.F., Becker M., Mtei M.K., Mussegnug F. (2011): Fertility management for maize cultivation in some soils of Western Kenya. *Soil & Tillage Research*, 117: 69-75.
- Ngome A.F., Becker M., Mtei M.K., Mussegnug F. (2013): Maize productivity and nutrient use efficiency in Western Kenya as affected by soil type and crop management. *International Journal of Plant Production*, 7(3): 517-536.
- Ngosong C., Bongkisheru V., Tanyi C.B., Nanganoa L.T., Tening A.S. (2019): Optimizing Nitrogen Fertilization Regimes for Sustainable Maize (*Zea mays* L.) Production on the Volcanic Soils of Buea Cameroon. *Advances in Agriculture*, Article ID 4681825: 8 pages, <https://doi.org/10.1155/2019/4681825>.
- Odhambo J.O., & Magandini V.N. (2008): An assessment of the use of mineral and organic fertilizers by smallholder farmers in Vhembe District, Limpopo province, South Africa. *African Journal of Agricultural Research*, 3(5): 357-362.
- Onasanya R.O., Aiyelari O.P., Onasanya A., Oikeh S., Nwilene F.E., Oyelakin O.O. (2009): Growth and Yield Response of Maize (*Zea mays* L.) to Different Rates of Nitrogen and Phosphorus Fertilizers in Southern Nigeria. *World Journal of Agricultural Sciences*, 5(4): 400-407.
- Price N. (1994): Alternate cropping in the management of *radopholus similis* and *cosmopolites sordidus* two important pests of banana and plantain. *International Journal of Pest Management*, 40(3): 237-244. <https://doi.org/10.1080/09670879409371890>.
- Rowell D.L. (1994): *Soil science: Methods and applications*. England, UK: Addison Wesley Longman Singapore Publishers (Pte) Ltd. pp: 350.

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- Rurinda J., Zingore S., Jibrin J.M., Balemi T., Masuki K., Andersson J.A., Pampolinog M.F., Mohammed I., Mutegia J., Kamarah A.Y., Vanlauwei B., Craufurdj P.Q. (2020): Science based decision support for formulating crop fertilizer recommendations in sub Saharan Africa. *Agricultural Systems*, 180: 102790. <https://doi.org/10.1016/j.agsy.2020.102790>.
- Saxena M.C. & Singh Y. (1965): A note on leaf area estimation of intact maize leaves. *Indian Journal of Agronomy*, 10: 437-439.
- Sheahan M.B. (2011): Analysis of Fertilizer Profitability and Use in Kenya. PhD Thesis, Michigan State University, United State of America.
- Sommer R., Bossio D., Desta L., Dimes J., Kihara J., Koala S., Mango N., Rodriguez D., Thierfelder C., Winowiecki L. (2013): Profitable and Sustainable Nutrient Management Systems for East and Southern African Smallholder Farming Systems – Challenges and Opportunities, Working Paper, pp. 92. doi: 10.13140/RG.2.1.2498.2642.
- Tayoh L.N., Kiyo L.M.R., Nkemnyi M.F. (2016): Chemical fertilizer application and farmers perception on food safety in Buea, Cameroon. *Agricultural Science Research Journal*, 6(12): 287 – 295.
- Temegne N.C., Ngome F.A., Suh C., Youri A., Basga S.D. (2020): Determining Appropriate Fertilizer Scheme for Maize and Sorghum Cultivation in the Sahel Agroecological Zone of Cameroon. *Journal of Experimental Agriculture International*, 42(8): 50-58.
- Tittonell P. & Giller K. (2013): When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, 143(1): 76–90.
- Van Reeuwijk, L.P. (1992): Procedures for soil analysis. 3rd Edn., Wageningen: International Soil Reference and Information Centre (ISRIC).
- Wheeler S.A. (2008): What influences agricultural professionals' views towards organic agriculture? *Ecological Economics*, 65(1): 145 – 154.

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