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Impact of Tillage and Phosphorus Application on Agronomic Efficiency of Maize (*Zea mays L.*) in the Eastern Part of DRC

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

There is limited information on the impact of tillage and Phosphorus application on Phosphorus Agronomic efficiency of maize and, the implication for crop yield on different soil types in the Eastern part of DRC. To bridge this gap in knowledge, a study was undertaken in the major rainy season of 2018 on an Orthi-Ferric Acrisol at Walungu and Rhodic Lixisol at Mulungu in the Easter montain of DRC. The experiment was laid out in a split-plot design with four replications for both locations. There were two variants for the tillage factor: conventional tillage (CT) and no-tillage (NT) systems and four phosphorus application rates: 0, 30, 60 and 90 kg P_2O_5 in the form of triple superphosphate (TSP) designated as P_0, P_{30}, P_{60} and P_{90}, with basal applications of nitrogen and potassium at the rates of 90 kg N ha^{-1} and 60 kg K_2O ha^{-1}. Phosphorus use efficiency indices such as partial factor productivity (PFP) and agronomic efficiency (PAE) were evaluated. The results

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showed tillage to generally influence P use efficiency of maize in both experimental sites at harvesting with good values for CT. Phosphorus was efficiently utilized by the maize crops at on both soils. Significant tillage x phosphorus interactions ($p<0.05$) were recorded among treatment combinations with regards to PFP and PAE at both Walungu and Kabare Though CTP_{60} Kabare recorded the highest grain yield comparable to that of CTP_{60} at Walungu. Although its limitation in most of tropical soil, Phosphorus can be used efficiently under valuable tillage systems for sustainable crop production in this area.

Keywords: Tillage; phosphorus; maize; PAE and economic analysis.

1. INTRODUCTION

Several factors constrain maize production in the Eastern part of Democratic Republic of Congo (DRC) as well as in most of sub-Sahara of Africa (SSA) agroecosystems. These include declining soil fertility with little or inadequate use of mineral fertilizers, poor weed and pest management, inappropriate tillage practices, and unfavourable climatic conditions [1]. Tillage practices are commonly used by farmers to incorporate nutrients into the soil to maximize the availability of nutrients to crop plants. Crop yield is a function of soil nutrient composition and availability and as such the application of fertilizers is important. However, poor soil management practices coupled with inefficient use of fertilizers has generally jeopardized soil quality and health, making food security a problem to contend with in SSA. Fertilizer nutrient application in DRC and Sub-Saharan Africa is approximately 8 kg ha^{-1} [2] and 9 kg ha^{-1} respectively which is far below the global mean of 101 kg ha^{-1} [3].

The nutrient status of soils must be taken into consideration and appropriate mechanisms developed in order to enhance efficient use of fertilizer nutrients by crops to increase yield. The dominant use of nitrogen-based fertilizers in developing countries has led to an imbalance of nutrients in soils [4]. To improve the efficiency of nitrogen fertilizer use and its associated adverse effect of over-application, nutrient balance should be improved by promoting the use of phosphate fertilizers [4].

The interest and awareness of the public of the need for increasing crop nutrient use efficiency is great but easily misunderstood and misrepresented [5]. According to the author, Phosphorus is one of the most important nutrients for crop growth and much emphasis should be placed on its efficient use for sustainable crop production for food security [6] because of the vital roles it plays in plants for energy storage, root development and early maturity [7]. According to Marschner [8], adequate information on nitrogen and phosphorus accumulation and redistribution patterns in maize under soil tillage systems are necessary to obtain higher yields and to improve their use efficiencies.

Several reports have been made about phosphorus being the second most limiting nutrient in crop production [9]. The effects of phosphorus application on crop production in DRC have also been investigated by several scientists [10,11]. It has been reported that phosphorus generally has a positive influence on crop yields and that soil P and soil properties such as pH, Al and Fe oxides affect the response of crops to applied phosphorus [12,13]. Despite the several research works conducted on phosphorus in DRC, there is paucity of information on the impact of tillage and P use efficiency on crop growth and the implications for crop yield. And also, sufficient information on P uptake and use efficiency of maize of growth under different tillage systems on different soil types will enhance efficient application and utilization of the nutrient under cropping systems. This will cut down cost of fertilizer inputs and mitigate adverse environmental impacts of over–application. It will also help farmers to know the appropriate tillage system and rate of P that will enhance optimum P use efficiency of crops on a particular soil type, thereby increasing productivity.

Working on the hypothesis that P application under no-tillage and conventional tillage systems significantly influence P uptake and use efficiency of maize, the objective of this study was to evaluate P use efficiency of maize under different rates of P application and two tillage systems using indices such as partial factor productivity and agronomic efficiency; and its effects on growth and yield performance in the Eastern part of DRC.

2. MATERIALS AND METHODS

2.1 Description of the Experiment Sites

The study was conducted during the major rainy season of 2018 at two locations: Agricultural farm of Catholic University of Bukavu (UCB) in Walungu and Crop Research Station (INERA) in Kabare with different soil types, Orthi-Ferric Acrisol and Rhodic Lixisol, respectevely. Both Walungu and Kabare sites are located in the South Kivu province of DRC. The experimental site at Ikoma (Walungu) lies within -02,34°, 28,44° and is about 56 km West of Bukavu whilst that at Mulungu (Kabare) is located at -02,18°, 28,47° about 20 km North of Bukavu. These areas are characterized by a bi-modal rainfall pattern, with the main cropping season running from September to January and the short cropping season from February to May. The region study is also considered of high potential for agriculture. The main farming systems comprise Cassava and cereal crops intercropped with food legumes.

The experiment design is shown in Fig. 1.

The experiment was laid out in a split-plot design with four replications at both locations. The factors considered in the experimental treatments were tillage systems (main plot factor) and levels of P application (sub-plot factor). The tillage treatments were two and the levels of P application treatments were four as shown in Table 1, given as a factor of 2 x 4 treatments. One of eight treatment combinations (Table 2) was allocated to each of the 24 subplots at the study locations. The experimental treatments are outlined in Table 1 and the treatment combinations outlined in Table 2.

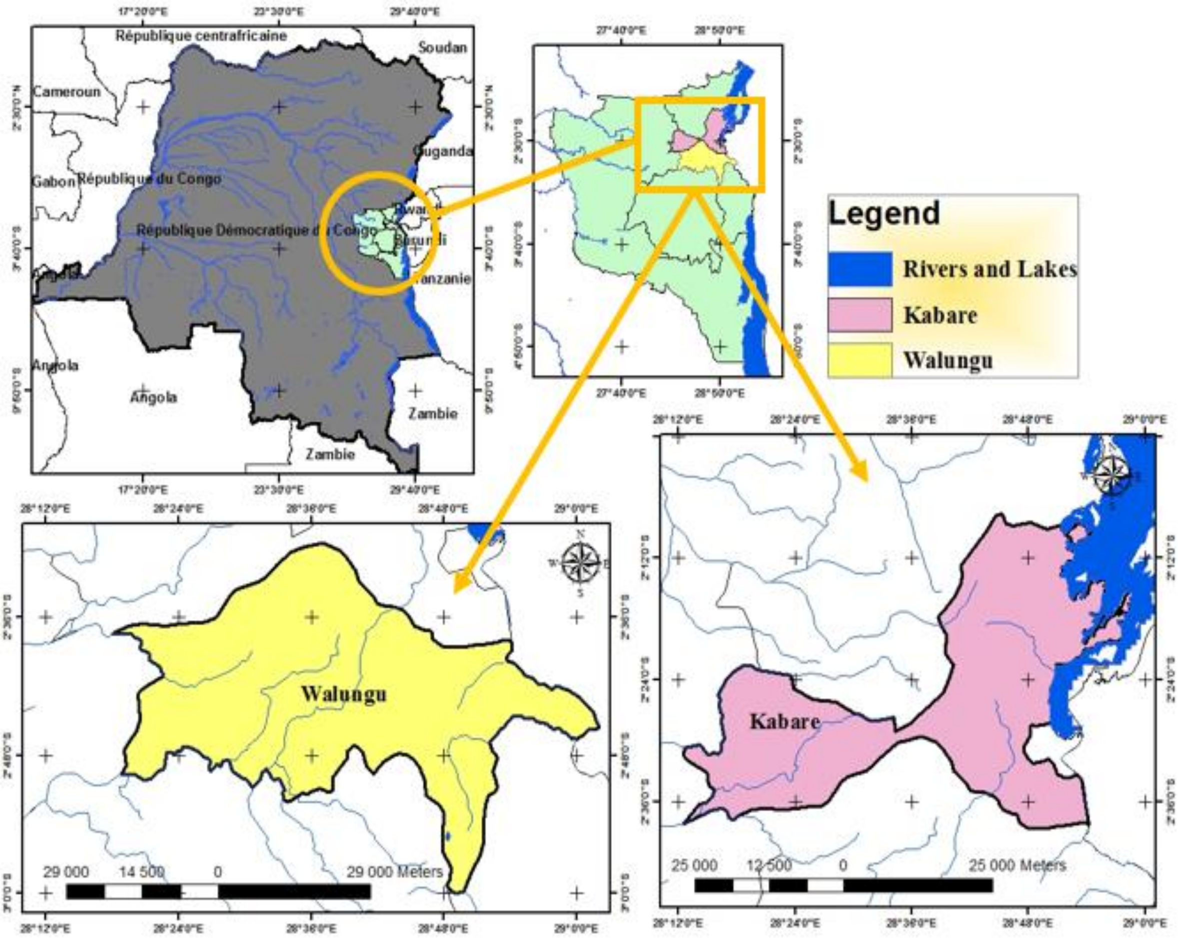

Fig. 1. Location of the study area showing (a) the study site in the Democratic Republic of the Congo, a country located in central Africa; (b) the study site of Sud-Kivu province in the Democratic Republic of the Congo; (c) the study sites in the Kabre Territory and (d) the study sites in the Walungu territory

Table 1. Description of treatments used for the experiment and their plot allocations

Treatments	Plot allocation	Description
Type of tillage	Main plot	NT: Non-tillage
		CT: Conventional tillage
Levels of P	Sub plot	P_0: 0 kg P_2O_5 ha^{-1}
		P_{30}: 30 kg P_2O_5 ha^{-1}
		P_{60}: 60 kg P_2O_5 ha^{-1}
		P_{90}: 90 kg P_2O_5 ha^{-1}

Table 2. Treatment combinations applied in the field experiments

Treatments	Treatments details
NTP_0	Non-tillage + 0 kg P_2O_5 ha^{-1}
NTP_{30}	Non-tillage + 30 kg P_2O_5 ha^{-1}
NTP_{60}	Non-tillage + 60 kg P_2O_5 ha^{-1}
NTP_{90}	Non-tillage + 90 kg P_2O_5 ha^{-1}
CTP_0	Conventional tillage + 0 kg P_2O_5 ha^{-1}
CTP_{30}	Conventional tillage + 30 kg P_2O_5 ha^{-1}
CTP_{60}	Conventional tillage + 60 kg P_2O_5 ha^{-1}
CTP_{90}	Conventional tillage + 90 kg P_2O_5 ha^{-1}

The experimental fields for the two locations were first slashed with cutlass to clear off the vegetation and tree stumps uprooted. A land area of 35.5 m x 15.0 m (532.5 m^2) was demarcated for each location with every main plot measuring of 17.5 m x 3.0 m (52.5 m^2) and sub - plots 4.0 m x 3.0 m (12.0 m^2). Alleys of 1 m were left between main plots or blocks and 0.50 m between sub-plots. For the conventional tillage treatment plots, the land was ploughed and harrowed to a fine tilth with a disc plough and disc harrow, respectively. With the no-tillage treatment plots, the land was prepared by spraying the plots with Glyphosate (Round-up) before sowing. Weeding was carried out manually with hoe at three and six weeks after emergence for CT plots and Insect pests were controlled by spraying crops with Lamda 2.5 EC.

Maize seeds were sown manually at a spacing of 80 cm x 40 cm at three seeds/hill and seedlings later thinned to two/hill two weeks after sowing (2 WAS) to give a planting density of 80 plants per sub-plot corresponding to 62,500 plants/ha on each experimental field. Straight fertilizers of urea, triple superphosphate (TSP) and muriate of potash (MOP) were applied to the treatment plots. The mode of application to the maize plants was by band placement. A basal application of urea (60 kg ha^{-1}) was carried out at a uniform rate to all the treatment plots, two weeks after sowing (2 WAS). At 6 WAS, treatment plots were "top dressed" with 30 kg ha^{-1} of urea amounting to application of 90 kg N ha^{-1}. Triple superphosphate was applied 2 WAS to the maize plants on the respective treatment plots at the following rates: 0, 30, 60 and 90 kg P_2O_5 ha^{-1}. Potassium Chloride (KCl) was applied 2 WAS at a rate of 60 kg K_2O ha^{-1}.

2.2 Soil Sampling, Preparation for Analysis and Laboratory/Analytical Methods

The analysis of the physico-chemical properties of the soils was carried out in the Chemistry Laboratory of Catholic University of Bukavu (UCB), Bukavu, DRC. The soil samples were analyzed for pH, organic C, total N, available P, exchangeable cations (Ca, Mg, K, Al + H, Fe) and particle size distribution. The analyzed samples were rated using the standard ratings of the Soil Laboratory of Catholic University of Bukavu (UCB). Particle size analysis was carried out using the hydrometer method which fundamentally depends on Stokes' Law [14]. The soil pH was determined in a 1:1 (soil: water) ratio using a HI 9017 Microprocessor pH meter [15]. Soil organic carbon was determined by the modified Walkley-Black method as described by Nelson and Sommers [16]. The total nitrogen content of the soil samples was determined by the Kjeldahl digestion and distillation procedure as described in Soils Laboratory Staff [17]. The available phosphorus in the soil samples was extracted with Bray's No.1 extracting solution (0.03 M NH4F and 0.025 M HCl) as described by Bray and Kurtz [18]. Exchangeable cations determination Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 M ammonium acetate (NH4OAc) extract [19] whereas the exchangeable acidity (hydrogen and aluminium) was determined in 1.0 M KCl extract [15]. For the determination of calcium and magnesium in the soil samples were determined using McLean [20] description. The amount of base used was equivalent to exchangeable acidity (Al^{3+} + H^+). The extractable iron contents of the soils were determined using Atomic Absorption Spectrometry (Olson, 1982).

2.3 Measurement of Data Collection Parameters of Maize

Five plants were randomly selected and tagged from the middle rows of each plot for the measurement of growth parameters of maize. Plant height was measured at two-week interval from 2 WAS to 9 WAS using a 5 m metallic meter-rule. The average height of five plants randomly selected from each treatment plot was then determined. For the measurement of dry matter, three plant stands were randomly selected from a 1 m^2 area within the middle rows of each plot for the determination of dry matter at 5 WAS, 7 WAS and 12 WAS respectively, at both experimental sites. The plants were cut at the ground level using a sharp knife and weighed to obtain the total fresh weight. The biomass was later dried in an oven at 80°C for 48 hours to a constant weight to obtain the dry matter. At harvesting, the grain yield was obtained by shelling the grains from the cobs. They were put in a brown envelope and oven-dried at a temperature of 80°C for 48 hours to a constant weight. The dry weight was then recorded to obtain the grain dry matter yield per plot and then extrapolated to kg. ha^{-1}. Leaf area index (LAI) was obtained by leaf area of plant and plant ground area. The measurement of LA was attained by measuring the length and breadth of the leaf was multiplied by the correction factor 0.75 following the formula used by Adeoye et al*.* [21]. Hundred seed weight After oven drying, hundred seeds were counted from each brown envelope representative of each treatment plot and weighed to obtain the hundred seed weight. Harvest index was calculated by using the formula suggested by Donald [22]. Calculations of P partial factor productivity and agronomic efficiency were carried out using formulae by Dobbermann [23].

For the economic analysis, the technical budget, described in Noronha [24] was used, and also in the analysis of the experiments carried out by Filho et al*.* (2010), Binotti et al*.* (2010) and Sabundjian, et al*.* (2014). The best alternative is the one offering net benefits or more profit margins (Filho et al*.,* 2010). The results were calculated from the price of inputs and outputs from the experiment and the costs of fertilizer.

Table 3. Physico-chemical properties of soil (0-15 cm) at experiment sites

Parameters	**Crop research (INERA/Mulungu)**	**Agricultural farm of Catholic University of Bukavu (UCB) Walungu (Ikoma)**
Chemical properties		
pH (1:1 H_2O)	6,04	5,30
C (%)	3,18	2,45
N (%)	0,26	0,16
C/N	13,17	15,31
MO (%)	5,49	4,22
P (mg/kg soil)	34,52	26,18
Exchangeable bases (cmol(c)/kg soil)		
K^+	0,79	0,35
Ca^{2+}	2,36	2,16
Mg^{2+}	0,77	0,67
ECEC (cmol(c)/kg soil)	18,13	4,83
Exchangeable acidity (Al^{3+} + H^+) (cmol(c)/kg soil)	0.32	0.38
Extractable Fe (mg/kg soil)	159,34	189,54
Extractable (mg/kg soil)	130,80	110,80
Physical properties		
Clay (%)	20,41	23,70
Silt (%)	26,81	38,90
Sand (%)	54,85	41,70
Texture	Sandy loam	

2.4 Statistical Analysis

Data on all parameters obtained from the study were subjected to Analysis of Variance (ANOVA) using General Statistical Software Package [25]. The Least Significant Difference (LSD) method was used for the separation of treatment means at 5 % probability. Regression analysis was carried out to establish the correlation between principal parameters.

3. RESULTS

3.1 Growth and Yield Parameters of Maize under Tillage Systems and Phosphorus Application

The results from Table 4 did not show any significant difference ($p > 0.05$) in plant height between the two tillage systems used at the two locations though the tallest plants were generally observed under the conventional tillage system. In comparing the different rates of phosphorus applied, it was observed that the fertilizer rates significantly enhanced plant height following 4 WAS until maturity. The highest values were mostly recorded for maize plants which received 90 kg P_2O_5 ha^{-1}. The values were however, not significantly different ($p > 0.05$) from those recorded under P60 treatments. Significant ($p < 0.05$) tillage x phosphorus interactions were observed on plant height of the maize variety at Kabare and Walungu throughout the growing cycle (Table 4).

Results of leaf area index at different sampling days are shown in Table 5. The results from Table 5 did not show any significant difference ($p > 0.05$) in leaf area index between the two tillage systems used at the study sites. The leaf area index did differ significantly among the different P fertilizer rates. Furthermore, the tillage by phosphorus rates interaction was significant ($P > 0.05$) in the two locations.

Table 4. Effects of tillage and P application on Plant height at 3, 5, 7 and 9 weeks after sowing in two sites (Kabare and Walungu)

Treatment	3WAS		5WAS		7WAS		9WAS	
	Walungu	Kabare	Walungu	Kabare	Walungu	Kabare	Walungu	Kabare
Tillage				**cm**				
NT	11.22	14.42	14.14	21.51	57.30	39.15	97.60	82.18
CT	11.53	15.00	15.15	23.05	58.30	38.45	108.20	86.82
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Rates of P application (kg P_2O_5 ha^{-1})								
P_0	9.43	12.07	11.20	19.20	36.60	34.73	80.80	71.97
P_{30}	11.53	15.60	13.33	22.60	48.50	38.30	92.70	79.83
P_{60}	12.20	17.93	17.00	24.80	69.40	43.03	121.50	88.53
P_{90}	12.33	13.23	18.10	22.63	80.60	39.13	126.70	77.67
LSD (0.05)	1.11	3.18	1.74	3.28	12.69	6.07	9.22	6.06
Interaction								
NTP_0	9.40	13.07	7.10	20.93	36.10	36.20	86.60	79.60
NTP_{30}	12.87	15.60	13.40	21.87	49.50	40.07	94.90	82.07
NTP_{60}	12.40	18.47	16.87	23.80	64.80	43.67	118.00	91.53
NTP_{90}	11.47	12.87	19.60	19.67	82.50	36.67	122.90	75.53
CTP_0	9.47	11.07	11.67	17.47	37.00	32.27	75.00	64.33
CTP_{30}	10.20	15.60	13.27	23.33	47.50	36.53	90.50	77.60
CTP_{60}	12.00	17.40	15.13	25.80	65.90	42.40	105.00	85.53
CTP_{90}	13.20	13.60	16.60	25.60	78.70	41.60	130.50	79.80
CV (%)	7,8	7.20	9.5	11.70	7.50	12.40	7.10	11.0
LSD (0.05)	3,19	3.99	2.97	9.63	15.92	19.85	16.75	27.77

Values are means of four replicates. CT=Conventional tillage, NT=No-tillage, P_0=0 kg P_2O_5 ha^{-1}, P_{30}=30 kg P_2O_5 ha^{-1}, P_{60}=60 kg P_2O_5 ha^{-1}, P_{90}=90 kg P_2O_5 ha^{-1}, LSD=Least significant differences of means, CV=Coefficient of variation, NS=Not significant at $p > 0.05$

Table 5. Effects of tillage and P application on Leaf area index at 3, 5, 7 and 9 weeks after sowing in two sites (Kabare and Walungu)

Treatment	3WAS		5WAS		7WAS		9WAS	
	Walungu	**Kabare**	**Walungu**	**Kabare**	**Walungu**	**Kabare**	**Walungu**	**Kabare**
Tillage								
NT	0.276	0.04	0.326	0.414	1.472	0.65	1.982	1.365
CT	0.323	0.05	0.290	0.525	1.260	0.56	1.969	1.213
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Rates of P application (kg P_2O_5 ha^{-1})								
P_0	0.065	0.05	0.095	0.423	0.602	0.49	0.938	0.95
P_{30}	0.172	0.05	0.235	0.445	1.277	0.62	1.458	1.33
P_{60}	0.347	0.05	0.363	0.456	1.565	0.75	2.012	2.18
P_{90}	0.615	0.04	0.538	0.467	2.222	0.58	3.293	1.57
LSD (0.05)	0.186	0.010	0.075	0.014	0.296	0.203	0.457	0.366
Interaction								
NTP_0	0.730	0.05	0.113	0.3	0.543	0.55	0.940	0.83
NTP_{30}	0.147	0.05	0.270	0.3	1.523	0.76	1.607	1.45
NTP_{60}	0.357	0.04	0.357	0.5	1.637	0.77	2.047	2.21
NTP_{90}	0.527	0.03	0.563	0.3	2.187	0.51	3.333	1.17
CTP_0	0.057	0.05	0.077	0.6	0.660	0.46	0.937	0.80
CTP_{30}	0.197	0.05	0.200	0.5	1.030	0.49	1.310	1.20
CTP_{60}	0.337	0.05	0.370	0.3	1.493	0.65	1.977	2.16
CTP_{90}	0.703	0.04	0.513	0.5	2.257	0.65	3.253	1.17
CV (%)	7.8	8.3	9.5	13.9	6.6	13.6	8.9	12.7
LSD (0.05)	3.19	0.013	0.175	0.33	0.711	0.203	0.575	0.607

Values are means of four replicates. CT=Conventional tillage, NT=No-tillage, P_0=0 kg P_2O_5 ha^{-1}, P_{30}=30 kg P_2O_5 ha^{-1}, P_{60}=60 kg P_2O_5 ha^{-1}, P_{90}=90 kg P_2O_5 ha^{-1}, LSD=Least significant differences of means, CV=Coefficient of variation, NS=Not significant at p > 0.05

Table 6. Effects of tillage and P application on dry matter at 5, 7 and 12 weeks after sowing in two sites (Kabare and Walungu)

Treatment	5WAS		7WAS		12WAS	
	Walungu	**Kabare**	**Walungu**	**Kabare**	**Walungu**	**Kabare**
Tillage						
NT	555.65	217.78	694.43	3350.02	3879.32	5994.44
CT	559.67	228.56	752.34	3416.67	4101.41	6632.22
LSD (0.05)	NS	NS	NS	NS	NS	NS
Rates of P application (kg P_2O_5 ha^{-1})						
P_0	482.45	1948.89	603.43	3024.45	1828.43	5522.22
P_{30}	531.33	2080.23	608.45	3330.22	2697.56	6488.89
P_{60}	563.45	2324.45	783.55	3382.22	6722.45	7331.11
P_{90}	652.43	2453.33	898.67	3824.44	4714.67	5911.11
LSD (0.05)	113.7	520.43	94,2	644.21	1585.42	1804.51
Interaction						
NTP_0	524.54	1871.11	641.56	2866.67	2132.43	4982.22
NTP_{30}	484.65	2066.67	665.76	3577.78	2812.45	5586.66
NTP_{60}	575.76	2475.56	781.45	2973.33	6425.47	7071.11
NTP_{90}	639.43	2573.33	922.55	3982.22	4648.59	6337.78
CTP_0	538.43	2026.67	565.67	3182.22	2523.13	5457.78
CTP_{30}	480.78	2066.67	551.54	3026.66	3083.16	6640.00

Treatment	5WAS		7WAS		12WAS	
Tillage	Walungu	Kabare	Walungu	Kabare	Walungu	Kabare
CTP_{60}	551.32	2475.56	786.78	3791.11	7019.45	7591.11
CTP_{90}	665.34	2573.33	875.48	3666.67	4780.39	6840.00
CV (%)	14.2	3.2	10.4	8.6	11.6	2.7
LSD (0.05)	150.5	407.07	179.0	1007.01	3566.9	1492.61

Values are means of four replicates. CT=Conventional tillage, NT=No-tillage, P_0=0 kg P_2O_5 ha^{-1}, P_{30}=30 kg P_2O_5 ha^{-1}, P_{60}=60 kg P_2O_5 ha^{-1}, P_{90}=90 kg P_2O_5 ha^{-1}, LSD=Least significant differences of means, CV=Coefficient of variation, NS=Not significant at p > 0.05

Table 7. Maize grain yield and hundred seed weight under tillage and P application

Treatment	Number of seeds per ear		100-Seed weight (g)		Grain yield (kg ha^{-1})		Harvest index	
Tillage	Walungu	Kabare	Walungu	Kabare	Walungu	Kabare	Walungu	Kabare
NT	350.92	353.23	24.68	25.50	3273.26	4047.05	0.42	0.39
CT	364.91	444.43	29.83	28.77	3494.35	4375.09	0.48	0.41
LSD (0.05)	NS	NS	4.09	2.82	206.75	212.77	0.05	0.13
Rates of P application (kg P_2O_5 ha^{-1})								
P_0	223.38	361.17	19.11	24.94	2185.97	2718.22	0.45	0.41
P_{30}	275.04	448.34	23.38	25.98	3232.39	4030.93	0.50	0.43
P_{60}	567.03	517.43	35.47	31.01	4962.47	5478.00	0.46	0.49
P_{90}	366.65	368.56	27.07	30,61	4194.55	4618.02	0.35	0.44
LSD (0.05)	22.22	163.29	1.73	5.35	305.17	786.86	0.10	0.79
Interaction								
NTP_0	220.02	293.66	20.27	27.45	2299.32	2497.24	0.45	0.35
NTP_{30}	270.74	347.45	25.12	24.46	3187.43	3985.6	0.51	0.41
NTP_{60}	356.73	425.78	28.59	33.49	3890.51	5566.75	0.48	0.48
NTP_{90}	556.35	347.54	36.72	32.50	3796.31	4140.54	0.31	0.47
CTP_0	226.73	375.65	17.94	22.42	2072.43	2939.2	0.46	0.41
CTP_{30}	279.38	470.68	21.63	27.40	3277.54	4076.27	0.49	0.40
CTP_{60}	376.06	443.94	25.54	33.53	4593.56	5389.24	0.44	0.44
CTP_{90}	577.74	487.85	34.22	28.72	4035.54	5095.64	0.41	0.45
CV (%)	4.9	12.6	5.2	15.1	7.10	14.90	8.10	17.60
LSD (0.05)	36.84	151.40	3.21	8.15	620.7	1109.56	0.14	6.10

Values are means of four replicates. CT=Conventional tillage, NT=No-tillage, P_0=0 kg P_2O_5 ha^{-1}, P_{30}=30 kg P_2O_5 ha^{-1}, P_{60}=60 kg P_2O_5 ha^{-1}, P_{90}=90 kg P_2O_5 ha^{-1}, LSD=Least significant differences of means, CV=Coefficient of variation, NS=Not significant at p > 0.05

With reference to data on dry matter of maize plants at 5WAS, 7WAS and 12WAS (Table 6), tillage did not significantly affect the dry matter accumulation throughout the growing cycle at both Walungu and Kabare. Maize plants under conventional tillage system produced a significantly greater dry weight as compared to those cultivated under no-tillage system. Like the tillage system, phosphorus application had a significant impact on the above-ground biomass dry matter of maize on both soils. The biomass dry matter increased in the order of P0 < P30 < P 90 < P60 at all sampling times. Significant tillage x phosphorus interactions were observed among treatment combinations at the three sampling periods at the two experimental sites. Generally, the highest biomass dry matter was recorded under CTP60 and the least under NTP0 at both sites.

The type of tillage system used significantly affected ($p < 0.05$) the grain yield of maize at both sites with conventional tillage producing higher grain yield than no-tillage (Table 7). Grain yield was significantly ($p < 0.05$) affected by the different rates of phosphorus applied. The highest grain yield at Walungu (4962.47 kg ha^{-1}) was produced by P60 followed by P90 (4194.55 kg ha^{-1}). The values recorded under application of 60 kg and 90 kg P_2O_5 ha^{-1} were statistically at par with each other ($p > 0.05$). At Kabare, the highest grain yield was also obtained on P_{60} treatment plots (5478.00 kg ha^{-1}) followed by P90 (4618.02 kg ha^{-1}) with the lowest yield on the control plot. Generally, it was observed that the grain yields recorded at Kabare were higher than those recorded at Walungu. The combination of different tillage systems and rates of P applied significantly affected ($p < 0.05$) the grain yields on the two soils with CTP_{60} producing a significantly higher grain yield than the other treatments. The effect of the different rates of P applied on hundred seed weight of maize was significant ($p < 0.05$) at both locations with 60 kg P_2O_5 ha^{-1} producing higher values than the other rates of P applied and the control. Significant tillage x phosphorus interactions were observed in the 100-seeds weight at Walungu and Kabare. The 100-seeds weight (20.27 g) was recorded under NTP_0 at Walungu and the highest (33.49 g) at Kabare. All components of the yield followed the same trend at both locations.

3.2 Phosphorus Agronomic Efficiency (Pae) and Partial Factor Productivity (Pfp) of Maize as Affected by Tillage and Phosphorus Application

Tillage did not significantly ($p < 0.05$) affect the PFP of maize at both sites Walungu and Kabare (Table 8). Under the different rates of P applied, 30 kg P_2O_5 ha^{-1} consistently recorded the highest PFP, except at Kabare where the application of 60 kg P_2O_5 ha^{-1} recorded a significantly higher PFP than the other application rates. There were significant ($p < 0.05$) tillage x phosphorus interaction effect on PFP at both Walungu and Kabare. Generally, PFP were highest under CTP30 on both soils. The agronomic efficiency (PAE) of maize under tillage followed the same trend at both study sites. The different rates of P applied had significant influence on the PAE of maize (Table 8). Plants under P60 application recorded higher PAE than the other rates of P applied. P_{90} generally has the lowest PAE.

Table 8. PAE and PFP of Maize under tillage and P application

Treatment	PAE (kgkg^{-1} P_2O_5 ha^{-1})		PFP (kgkg^{-1} P_2O_5 ha^{-1})	
	Walungu	**Kabare**	**Walungu**	**Kabare**
Tillage				
NT	24.25	34.23	71.08	95.67
CT	33.64	39.68	75.84	90.55
LSD (0.05)	NS	NS	NS	NS
Rates of P application (kg P_2O_5 ha^{-1})				
P_0	28.94	25.11	73.46	51.51
P_{30}	29.62	36.95	107.74	87.53
P_{60}	34.89	46.01	66.04	141.81
P_{90}	22.32	23.76	46.60	89.78
LSD (0.05)	10.70	13.5	6.07	17.07
Interaction				
NTP_0	24.24	27.67	42.17	73.59
NTP_{30}	26.52	35.59	106.23	118.74
NTP_{60}	29.61	40.12	71.08	92.72
NTP_{90}	26.63	38.99	64.83	91.62
CTP_0	28.01	30.39	75.84	71.03
CTP_{30}	32.71	38.31	109.24	116.18
CTP_{60}	40.18	42.84	67.24	90.16
CTP_{90}	33.65	41.72	51.03	89.04
CV (%)	7.82	3.21	6.24	7.45
LSD (0.05)	19.25	18.34	12.08	29.75

Values are means of four replicates. CT=Conventional tillage, NT=No-tillage, P_0=0 kg P_2O_5 ha^{-1}, P_{30}=30 kg P_2O_5 ha^{-1}, P_{60}=60 kg P_2O_5 ha^{-1}, P_{90}=90 kg P_2O_5 ha^{-1}, LSD=Least significant differences of means, CV=Coefficient of variation, NS=Not significant at $p > 0.05$

Table 9. Values cost ratio of Maize under tillage and P application

Treatment	Economic analysis (VCR)	
	Walungu	Kabare
Tillage		
NT	1.86	1.98
CT	2.00	2.12
LSD (0.05)	NS	NS
Rates of P application (kg P_2O_5 ha^{-1})		
P_0	1.78	1.65
P_{30}	1.67	1.86
P_{60}	2.04	2.17
P_{90}	1.62	1.68
LSD (0.05)	0.33	0.27
Interaction		
NTP_0	1.71	1.54
NTP_{30}	1.65	1.84
NTP_{60}	2.01	2.01
NTP_{90}	1.47	1.75
CTP_0	1.85	1.64
CTP_{30}	1.69	1.91
CTP_{60}	2.08	2.07
CTP_{90}	1.78	1.82
CV (%)	5.5	7.8
LSD (0.05)	0.22	0.34

Values are means of four replicates. CT=Conventional tillage, NT=No-tillage, P_0=0 kg P_2O_5 ha^{-1}, P_{30}=30 kg P_2O_5 ha^{-1}, P_{60}=60 kg P_2O_5 ha^{-1}, P_{90}=90 kg P_2O_5 ha^{-1}, LSD=Least significant differences of means, CV=Coefficient of variation, NS=Not significant at p > 0.05

Table 10. Pearson correlation coefficient (r) showing the linear interrelationships among plant parameters of maize as affected by tillage and phosphorus amendments at Walungu

	PAE	PFP	Grain yield	VCR	Dry matter
PAE	1				
PFP	0.05055257^{ns}	1			
Grain yield	0.71669235*	-0.0438807^{ns}	1		
VCR	0.63008329*	-0.1476267^{ns}	0.30898186^{ns}	1	
Dry matter	0.68801224*	-0.2103804^{ns}	0.88999049*	0.59944992*	1

*n = 24, NS = not significant, *represents statistical significance at 5 % level of probability*

Table 11. Pearson correlation coefficient (r) showing the linear interrelationships among plant parameters of maize as affected by tillage and phosphorus amendments at Kabare

	PAE	PFP	Grain yield	VCR	Dry matter
PAE	1				
PFP	0.4310265^{ns}	1			
Grain yield	0.9442105*	0.33644817^{ns}	1		
VCR	0.8602780*	0.52556634*	0.90062189*	1	
Dry matter	0.9403081*	0.25434616^{ns}	0.93066888*	0.8964231*	1

*n = 24, NS = not significant, *represents statistical significance at 5 % level of probability*

3.3 Economic Analysis (VCR)

Tillage did not significantly ($p < 0.05$) affect the values cost ratio of maize at both sites Walungu and Kabare (Table 9). Under the different rates of P applied, 60 kg P_2O_5 ha^{-1} consistently recorded the highest VCR above 2 (2.04 in Walungu and 2.17 Kabare). There were significant ($p < 0.05$) tillage x phosphorus interaction effect on VCR at both Walungu and Kabare.

3.4 Relationship among Measured Plant and Soil Parameters

The interrelationship among total above ground biomass dry matter, grain yield, PAE, PFP and VCR in the two agro-ecological zones are presented in Tables 10 and 11. Significant positive correlations were observed among dry matter, grain yield, PAE, PFP and VCR at both sites. However, in Walungu, grain yield, VCR and dry matter of maize were negatively correlated with PFP (Table 9). There was a very strong positive correlation between the rates of phosphorus fertilizer applied and the grain yield at both locations (Figs 1 and 2). The coefficient of correlation (r) were comparable for both sites.

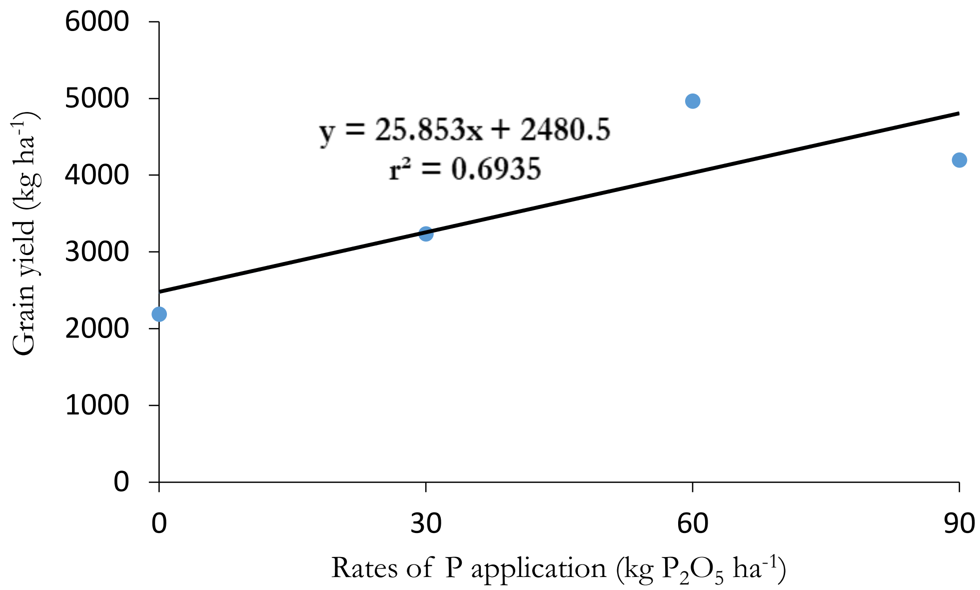

Fig. 2. Correlation between phosphorus application and grain yield at Walungu

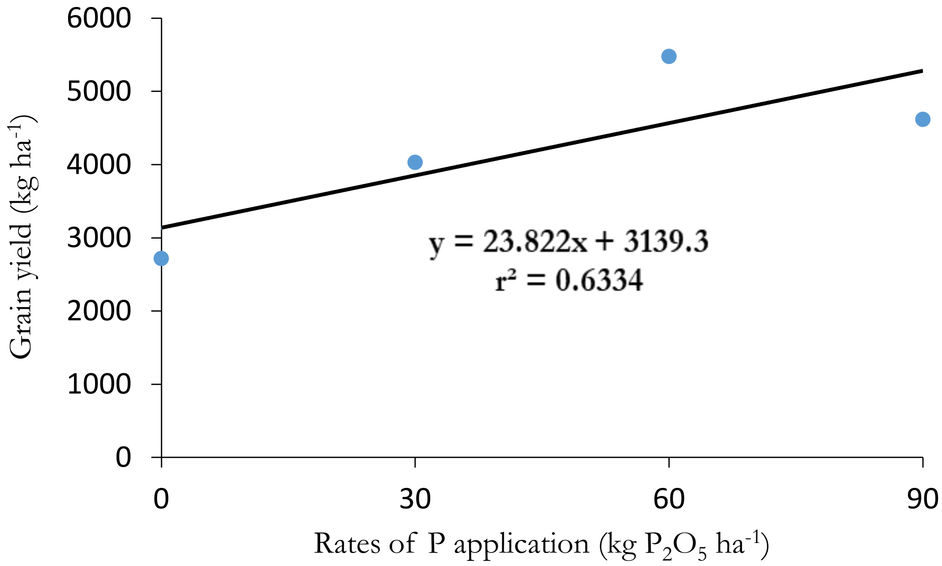

Fig. 3. Correlation between phosphorus application and grain yield at Kabare

4. DISCUSSION

Overall, maize yield responses to mineral fertilizer were lower in Walungu than in Kabare. The significant interaction between tillage system and rates of P application suggest that, on average, crop response to fertilizer was affected by tillage systems for all traits measured or calculated for maize. There were significant increases in maize grain yield with the conventional tillage treatment at all study sites. Although not statistically significant, mean grain yield of maize tended to increase with the use of conventional tillage.

According to Essel [26] and Yin et al. [27], plant height and leaf area index are a key indicator of plant growth and is linked to plant nutrition more especially during the vegetative growth stage of maize plants. Tillage practices have been reported to optimize the physical, chemical or biological conditions of soils for germination, seedling establishment and crop growth [28]. Significant ($p < 0.05$) tillage x phosphorus interactions were observed on plant height and leaf area index of the maize at both sites (Tables 4 and 5). The higher results were observed under conventional tillage plots as compared to the lower in no-tillage plots could be due to the loosening effect and improved soil aeration produced under the conventional tillage system thereby creating favourable soil conditions for maize growth, nutrient translocation and use by the crops. Phosphorus in addition to the adequate N and K applied possibly enhanced balanced nutrition and nutrient absorption by maize plants resulting in significant impact on the overall performance of the plants.

Maize plants under conventional tillage system had significantly greater biomass dry matter than those cultivated under no-tillage system. Zorita [29] reported a higher biomass dry matter in conventionally tilled plots as compared to no-tilled plots on a sandy loam soil. Dry matter of maize plants increased with increased rates of P fertilizer applied at both experimental sites. Colomb et al. [30] and Pellerin et al. [31] reported that increase in dry matter production following application of P fertilizers is as a result of improved root system, increased leaf area index and its subsequent effect on photosynthetically active radiation absorption and carbohydrate nutrition of plants. The extensive root system possibly developed under the higher rates of application enhanced the ability of the maize plants to absorb more water and nutrients from the soil, which consequently influenced the production of more assimilates and the resultant higher biomass.

Grain yields of maize were further increased with fertilizer application, regardless of tillage system. Averaging over tillage systems, fertilizer application resulted in 227 and 202 % increases in maize grain yield in Walungu and Kabare, respectively. The greater grain yields with fertilizer application compared with no fertilizer input are consistent with previous results [32,33]. Indeed, poor kernel formation, increased abortion and ultimately lower grain yield under N stress have been reported widely [34,35]. No-till recorded lower yields at both study sites as compared to conventional tillage. This could be due to the lack of soil loosening under the NT system to provide conditions favourable to crop growth And also, there is a reduction of labor, but it increase soil compact which negative affect the root development. These results lend credence to previous findings by Ishaq et al. [36] that higher yields were obtained under conventional tillage. Agbede et al. (2008) however reported that zero tillage was most suitable for cereals in the forest-savannah transition zone of Nigeria in the medium term over three seasons from 2004 to 2006. No-tillage is a potentially profitable option for maize production in the mountain of Kivu even if in this study, it doesn't give the expected results on this cropping season. Water conservation was probably improved with no-tillage, especially as significant soil water was probably lost with ploughed tillage and the extra weeding. Farmers weeded only once with no-tillage, as compared to twice with conventional tillage, and achieved better weed control. Labour is scarce and costly during major weeding times, and farmers give priority to weeding cash crops, resulting in late and inadequate weed control in maize. Any delay in field preparation results in delayed planting, which may result in reduced yield.

Okalebo and Probert (1992) and Sahoo and Panda [37] reported that P application to maize increased yield and yield components over the control plots. The highest grain yields observed in this study were produced by maize crops which received 60 kg P_2O_5 ha^{-1} (Table 7). This observation followed a pattern similar to that of the dry matter yields suggesting that increasing P application to 90 kg P_2O_5 ha^{-1} on both soil types might be excessive and uneconomical to maize production since P application at this rate resulted in no yield advantage. Maize responded positively to P application with the control plots producing the least yield. The lowest hundred seed weight was observed on the control plots (0 kg P_2O_5 ha^{-1}) compared to the treated plots. Phosphorus directly influenced 100-seeds weight of maize grains due to the function it plays in grain formation and filling in cereal crops. Because the control plots did not receive any P amendment, crop uptake was basically from the native P in the soil. This resulted in lower uptake and hence the least 100-seeds weight in plots which did not receive any P.

Although the input cost of conventional tillage system, on average, was US$2.00–US$2.12 VCR more than for the no-tillage system for maize production. The cost saving associated with no-tillage is consistent with results of Ribera et al. [38], whose data from two years of on-farm studies on conservation agricultural practices showed cost savings due to reduced labour and machinery time, despite an increase in agro-chemical usage, that also calls for sensitizing and training of farmers on safe and efficient use of agrochemicals. The monetary returns were greatest with no-tillage and least for conventional tillage system. The cost of labour for weed control in no-tillage maize was lower compared to conventional tillage systems because the frequency of weeding on no-tillage plots was reduced to one weeding as against two weedings for the conventional tillage system. It has been reported that chemical weed control is a cheaper and more effective option [39], which improves crop yields and grain quality (Schnelle and Hensley, 1990). However, overuse of herbicides may have adverse effects on beneficial soil microorganisms as well as detrimental long-term effects on the environment. The reliance on glyphosate with the same mode of action for extended period can contribute to weed shifts and the selection of biotypes with resistance to glyphosate. These glyphosate-resistant weeds survive application of glyphosate and reproduce to increase their numbers in a population. To prevent weeds from growing and to keep glyphosate-resistant weeds under control, it is critical to integrate as many weed management strategies as possible into a weed management plan.

Partial factor productivity of the maize generally declined with increasing levels of P application at both experimental sites (Table 8). Bagayoko [40] observed a similar trend on his rice experimental plots in Mali where the highest PFP of rice (105.5 kg) was observed with minimum P application and the lowest PFP (12.3 kg) with the highest fertilizer rate. According to Yadav [41], PFP is a useful measure of nutrient use efficiency as it enhances an integrative index that quantifies total output relative to the utilization of all nutrient resources in the farming system. With this, it can be inferred that the lower rates of P applied were beneficial in producing a higher yield relative to the higher rates of P applied. This could probably be due to the fact that as maize biomass and grain yields increased with increasing amounts of P applied, P was less efficiently assimilated and utilized by the maize plants. Singh et al. [42], Bagayoko [40] and Essel [26] reported that if a unit of fertilizer does not increase the yield enough to cover its cost, then its application becomes uneconomical. It is pertinent to note that the tillage systems used and the different rates of phosphorus applied on the treatment plots consistently and interdependently influenced the PFP of maize.

As already reviewed, agronomic efficiency is a measure of nutrient use efficiency that quantifies total output in terms of yield difference relative to the utilization of all nutrient resources in the farming system [41]. It is a production efficiency index, giving an estimate of the marginal response in production in response to added fertilizer estimated by difference to the control treatments (Norton et al., 2012). From the results obtained, the different rates of P applied generally had a significant influence on the PAE of maize, with the application of 60 kg P_2O_5 ha^{-1} recording a higher PAE than the other rates of P applied (Table 8). This was due to the fact that P_{60} generally produced a higher dry matter at both Walungu and Kabare, which translated into greater yields making P_{60} produce a higher economic output relative to the control. These results are contrary to results obtained by Panayotova et al. [43] that the agronomic efficiency of durum wheat decreased with increasing levels of triple superphosphate application in Bulgaria. They also reported that the soil application of P at rates exceeding 80 kg P_2O_5 ha^{-1} was inefficient.

5. CONCLUSION

The results of these studies showed that Conventional tillage with fertilizer of maize, generally resulted in the highest grain yields that no-tillage. Conventional tillage also gave the highest economic returns. Farmers can get better returns to the money invested in P fertilizer for producing maize with their traditional practice even on degraded soils with low levels of plant available nutrients. The various indices (PAE and PFP) of estimating use efficiencies of P in maize were generally higher at lower rates of P than at higher rates. Significant tillage x phosphorus interactions ($p < 0.05$) were recorded among treatment combinations, with regards to PFP and PAE at Walungu and Kabare. Phosphorus was more efficiently utilized by the maize crops at 60 kg P_2O_5 ha^{-1} than at 90 kg P_2O_5 ha^{-1}. Under the different rates of P applied, whereas the application of 60 kg P_2O_5 ha^{-1} led to significantly higher PRE and PAE, the highest PFP was recorded under 30 kg P_2O_5 ha^{-1}. Growth and yield components of maize on at the two locations were significantly affected by the rate of P applied under tillage systems. Generally, the highest biomass dry weight, grain yield and hundred seed weight were recorded under CTP_{60} in both study sites. The study has added to knowledge on the impact of tillage and phosphorus application on P uptake and use efficiencies of maize at Eastern of DRC [44,45].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yeboah S. Yield gap analysis in maize production from stakeholders perspective in Ejura-Sekyedumase District of the Ashanti Region of Ghana. A thesis submitted to the Department of Materials Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, in partial fulfilment of the requirement for the degree of Master of Science in Environmental Resources Management. 2013;151.
2. FAO. Fertilizer use by crops in Ghana. Land and Plant Nutrition management Service, Land and Water Development Division, Food and Agriculture Organization of the United Nations, Rome. 2005;39.
3. Camara O. and Heinemann ED. Overview of fertilizer situation in Africa. Background paper prepared for the African Fertilizer Summit. Abuja, Nigeria; 2006.
4. Bumb BL, Baanante CA. Policies to promote environmentally sustainable fertilizer use and supply to 2020. International Food Policy Research Institute. 2020 Brief 40, October. 1996;6.
5. Roberts TL. Improving nutrient use efficiency. Turk J For Agric. 2008;32:177-182.
6. Ryan I. Efficient use of phosphate fertilizers for sustainable crop production in WANA. Phosphate Newsletter. 2002;2-5.
7. Gupta PK. Major plant nutrient. In: Soil, Fertilizer and Manure. (ed.): Gupta, P.K. 2nd edition, Agrobios. India. Physiology. 2003;84:835-840.
8. Marschner H. Mineral nutrition of higher plants. Academic press. Inc. London, San Diego, New York. 1995;270-277.
9. Kogbe JOS, Adediran JA. Influence of nitrogen, phosphorus and potassium application on the yield of maize in the savannah zone of Nigeria. African Journal of Biotechnology. 2003;2(10):345-349.
10. Bashagaluke BJ, Masimane MJ, Nshobole MN, Kabakaba BC, Walangululu MJ. Phosphorus application based on time and different fertilizer's sources effect on maize (*Zea mays L.*) productivity in Democratic Republic of Congo. International Journal of Current Research. 2015;7(11):22424-22428.
11. Bert Thienpondt. Increasing soil fertility and crop yield in the Democratic Republic of Congo through implementation of an integrated soil fertility management approach. A thesis submitted to the Faculty of Bioengineering, Gent University, Gand, in partial fulfilment of the requirement for the degree of Master of of Science in the life sciences: Agriculture and horticulture. 2016;102.
12. Nyamekye A. Effect of placement on the utilization of phosphorus by maize (Zea mays) in northern Ghana. Nyankpala Agriculture Experimental Station Annual Report; 1989.
13. Issaka RN, Dennis EA, Buri MM. Management of phosphate rock in Maize - cowpea cropping system. Soil Sci. Plant Nutr. 2003;49(4):481-484.
14. Bouyoucos GJ. Hydrometer Method Improved for Making Particle-Size Analysis of Soils. Agronomy Journal. 1962;54:464-465.
15. Page AL, R H. Miller, DR. Keeney. Methods of soil analysis; 2. Chemical and microbiological properties, 2. Aufl. 1184 S., American Soc. of Agronomy (Publ.), Madison, Wisconsin, USA, gebunden 36 Dollar; 1982.

16. Nelson DW, Sommers LE. Total carbon, organic carbon and organic matter: In: A.L. Page, R.H. Miller and D.R. Keeney) Methods of Soil Analysis; 1982.
17. SLS (Soils Laboratory Staff). Analytical methods of the service laboratory for soil, plant and water analysis. Part 1: Methods for soil analysis. Royal Tropical Institute. Amsterdam; 1984.
18. Bray RH, Kurtz LT. Determination of total, organic and available forms of phosphorus in soil. Soil Science 1945;59:39-45.
19. Black CA. Methods of soil analysis. Part I. Physical and mineralogical properties including statistics of measurement and samplings Part II. Chemical and Microbiological properties. Agronomy series. ASA. Madison. Wis. USA; 1986.
20. McLean EO. Aluminium. In: Black, C.A. (Ed.). Methods of soil analysis. Part 2. Chemical and microbiological properties. First edition, American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin USA. 1965;978–998.
21. Adeoye PA, Adebayo SE. and Musa JJ. Growth and yield response of cowpea (*Vigna unguiculata* L.) to poultry and cattle manures as amendments on sandy loam soil plot. Agriculture Journal. 2011;5:218–221.
22. Donald CM. Competition among crop and pasture plants. Advanced Agronomy. 1963;15:1–118.
23. Dobbermann A. Nitrogen use efficiency– state of the art. IFA International workshop on enhanced– efficiency fertilizers. Frankfurt, Germany.2005;28-30.
24. Noronha R. The World Bank Research Observer. 1987;2(2):143–169. Available:https://doi.org/10.1093/wbro/2.2.143.
25. GenStat. GenStat Release 12.1 (PC/Windows Vista), GenStat Procedure Library Release PL20.1, VSN International Ltd;2009.
26. Benedicta Essel. Impact of tillage and phosphorus application on phosphorus uptake and use efficiency of maize (*Zea mays L.*). Master thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. 2014;106.
27. Yin X, McClure MA, Jaja N, Tyler DD, Hayes RM. In-season prediction of corn yield using plant height under major production systems. Agron. J. 2011; 103:923–929.
28. Lal R. No-till farming: Soil and water conservation and management in the humid and sub-humid tropics. IITA Monograph No. 2. Ibadan, Nigeria; 1983.
29. Zorita DM. Effect of deep-tillage and nitrogen fertilization interactions on dry land corn (*Zea mays L.*) productivity. Soil and Tillage Res. 2000;54:11-19.
30. Colomb B, Kiniry JR, Debaeke P. Effect of soil phosphorus on leaf development and senescence dynamics of field-grown maize. Agronomy Journal. 2000;92:428-435.
31. Pellerin S, Mollier A, Plenet D. Phosphorus deficiency affects the rate of emergence and number of maize adventitious nodal roots. Agronomy Journal. 2000;92:690-697.
32. Aflakpui GKS, Vyn TJ, Hall MR, Anderson GW, Swanton CJ. Effect of tillage on nitrogen response in corn (*Zea mays L.*) after established alfalfa. Can J Plant Sci. 1993;73:73–81.
33. Buah SSJ, Polito TA, Killorn R. No-tillage corn response to placement of fertilizer nitrogen, phosphorus, and potassium. Commun Soil Sci Plant Anal. 2000; 31:3121–33.
34. Ngwira AR, Aune JB, Mkwinda S. On-farm evaluation of yield and economic benefit of short-term maize legume intercropping systems under conservation agriculture in Malawi. Field Crops Res. 2012;132:149–57.
35. Andrade FH, Ortegiu ME, Vega C. Intercepted radiation at flowering and kernel number in Maize. Agron J. 2000; 92:92–7.
36. Ishaq M, Ibrahim, M. and Lal, R. Tillage effect on nutrient uptake by wheat and cotton as influenced by fertilizer rate. Soil and Tillage Research. 2001;62(1–2):41–53.
37. Sahoo SC, Panda M. Effect of P and de-tasseling on yield of baby corn. Indian J. of Agri. Sci. 2001;71:21-22.
38. Ribera LA, Hons F, Richardson JW. An economic comparison between conventional and no- tillage farming systems in Burleson County, Texas. Agron J. 2004;96(2):415–24.
39. Chikoye D, Schulz S, Ekeleme F. Evaluation of integrated weed management practices in maize in northern Nigeria. Crop Prot. 2004;23:895–900.

40. Bagayoko M. Effects of plant density, organic matter and nitrogen rates on rice yields in the system of rice intensification (SRI) in the “Office du Niger” in Mali. Journal of Agricultural and Biological Science. 2012;7(8):620-632.
41. Yadav RL. Assessing on-farm efficiency and economics of fertilizer N, P and K in rice wheat systems of India. Field Crops Research. 2003;18:39-51.
42. Singh NP, Sachan RS, Pandey PC, Bisht PC. Effect of decade long-term fertilizer and manure application on soil fertility and productivity of rice-wheat system in a Mollisol. Journal of the Indian Society of Soil Science. 1999;47:72-80.
43. Panayotova G, Kostadinova S, Almaliev M. Agronomic efficiency of fertilization at durum wheat under contrast climate conditions. IV International Symposium “Agrosym. 2013;114-118.
44. Nezomba H, Tauro TP, Mtambanengwe F, Mapfumo P.Indigenous legume fallows (indifallows) as an alternative soil fertility resource in smallholder maize cropping systems. Field Crops Res. 2010;115:149–57.
45. Okalebo JR. Gathua KW, Woomer PL. Laboratory methods of soil and plant analysis: A working manual Tropical S., Nairobi/Kenya: Soil Science Society of East Africa;1993.

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