

**EFFECTS OF COWPEA RESIDUES, CHICKEN
MANURE AND PARTIALLY ACIDULATED
PHOSPHATE ROCK ON THE FERTILITY OF TWO
ACID SOILS FOR MAIZE PRODUCTION IN LUSAKA-
ZAMBIA**

ABSTRACT

Aim: To assess the use of chicken manure pellets, partially acidulated phosphate rock (PAPR) and cowpea residues to enhance the fertility and productivity of two Kandustalfts in Zambia.

Methodology: Six treatments; chicken manure, PAPR, cowpea residues, chicken manure with PAPR, cowpea residues with PAPR and no amendment (control) were assigned to 4 m x 4 m plots on each soil. The PAPR was applied at a rate of 40 kg P₂O₅/ha, chicken manure at 20 kg N/ha and cowpea was planted in rows 45 cm apart. Cowpeas or weeds were allowed to grow on each plot for four months when cowpea pods matured. Plants were cut, incorporated into the soil and left to decompose for six weeks. Soil samples were then collected for analysis of organic matter, N, P, K and greenhouse maize trials.

Results: Cowpea residues, chicken manure and chicken manure with PAPR significantly increased levels of organic matter. Cowpea residues and cowpea residues with PAPR significantly increased levels of available N than the control. Available P levels significantly increased with application of cowpea residues and chicken manure with PAPR. Application of cowpea residues, cowpea residues with PAPR and chicken manure significantly increased levels of K than the control. Cowpea residues and cowpea residues with PAPR significantly increased maize dry matter yields than the control. The relative agronomic effectiveness (RAE) of cowpea residues was 66 % on Chakunkula soil and 37 % on Choma soil respectively.

Conclusion: Cowpea residues are potential means of improving the fertility and productivity of acidic

8

9 *Key words: amendment, soil organic matter, nitrogen, phosphorus, residue.*

10 **1. INTRODUCTION**

11 Many soils in sub-Saharan Africa are acidic and have low levels of organic matter (OM), nitrogen (N)
 12 and phosphorus (P) [1]. Deficiency of any plant nutrient results in poor crop establishment, reduced
 13 plant growth and sometimes, total crop failure. To achieve acceptable yields on degraded land,
 14 farmers apply chemical fertilizers to supply the deficient nutrients. In Zambia, majority of farmers are
 15 small scale farmers and resource poor who cannot afford to purchase adequate quantities of chemical
 16 fertilizers to sustain acceptable crop yields [2]. Continuous cultivation of land without adequate
 17 replenishment of nutrients removed through crop harvest results in reduced levels of nutrients and
 18 organic matter in soils [3].

19 Under traditional farming systems, farmers relied on 10 – 15 year fallows to restore the fertility of soils.
 20 Because of the increase in population and its associated increased demand on land, fallow periods
 21 have reduced to 1 - 2 years resulting in soil degradation and its associated reduction in productivity
 22 [4]. If this trend is to be arrested, there is need to find ways of improving the fertility of fields left fallow
 23 using potential locally available soil amendments. The need to use amendments such as phosphate
 24 rocks, animal manures and annual leguminous crops such as cowpea is quite urgent.

25 Cowpea is crop widely grown by small scale farmers in Zambia. It is known to form mycorrhizal
 26 associations with fungi in the soil that enhances the uptake of phosphorus [5]. It also forms symbiotic
 27 relationships with *Rhizobium* bacteria that enable it to fix nitrogen [6]. When cowpea is used as a
 28 cover crop, it can contribute as much as 145 kg N/ha into a cropping system [7]. After harvesting
 29 cowpea grain, the stover can be incorporated into the soil, where the nitrogen and other nutrients
 30 contained in the stover can be mineralized into the soil, since it has a low C/N ratio. Recent studies
 31 have shown that the effect of incorporating cowpea stover into the soils on maize yield is similar to
 32 that of applying chemical fertilizer [8] [9]. Incorporating cowpea residues was also reported to
 33 significantly increase soil nitrogen levels in the soil and rice yields [10].

34 According to [11] Poultry manure is the most easily decomposable animal manure, because it
 35 contains uric acids which are easily decomposed. It is a readily available source of nitrogen for plants
 36 when applied to soils. Poultry manure has been reported to increase N, moisture, exchangeable

37 bases and to reduce the bulk density when applied to soils [12]. It has also been cited to significantly
38 increase levels of organic matter, total and available N, available P and exchangeable K in soils [13
39 [14] [15].

40 Phosphate rocks (PR) are an important source of P, a nutrient which is commonly deficient in most
41 highly weathered soils. There are a number of PR deposits in Zambia which are not currently utilized
42 as sources of P for crop production. These deposits are at Chilembwe, Mumbwa, Nkombwa Hill,
43 Kaluwe Hill [16] and Sinda (V. Shitumbanuma, University of Zambia, Unpublished results). The use of
44 PR as sources of P for crop production has been well investigated across the world [17]. In Zambia,
45 trials have been conducted on the agronomic effectiveness of some PR products.

46 The suitability of Partially Acidulated Phosphate rock (PAPR) from Mumbwa and Chilembwe as
47 sources of P for growing soya beans, finger millet and maizewas assessed by [18]. They found that
48 PAPR from both Mumbwa and Chilembwe were effective sources of P for the three crops. Chilembwe
49 PAPR was found to had greater soil residual P than mono-ammonium phosphate and recommended
50 it as a suitable amendment for improving levels of P in deficient soils [19]. The PAPR from Sinda was
51 as effective as Single Super Phosphate fertilizer in providing P to maize (V. Shitumbanuma, University
52 of Zambia, unpublished results).

53 The above cited benefits of applying cowpea residues, chicken manure and phosphate rock to soils
54 intended for crop production prompted an investigation to assess the potential of using these
55 materials alone and in combination as amendments for improving the fertility and productivity of
56 degraded cultivated soils. This paper presents results of a study that was conducted to assess the
57 effects of incorporating cowpea residues, chicken manure and PAPR into the soil, on the levels of
58 organic matter, available N, available P and exchangeable K in the soil and on the dry matter yield of
59 maize on two cultivated acid soils.

60 **2. MATERIAL AND METHODS**

61 **2.1 Location**

62 The study was carried out in the 2015/2016 agricultural season. It involved field studies and
63 greenhouse pot trials. The field studies were conducted on two sites at the University of Zambia farm
64 in Lusaka, Zambia. The sites were Agricultural Technology Demonstration Centre (ATDC) located at
65 15° 21' 25.2" S and 28° 27' 25.2" E, at 1140 m above sea level and Liempe Farm located at 15° 23'

13.2° S and 28° 29' 13.2" E at 1160 m above sea level. Both sites are located in Agro-ecological zone II of Zambia. This zone has a subtropical continental climate that receives unimodal rainfall between the months of November and April. The long term mean annual rainfall is between 800 and 1200 mm while the mean annual air temperature is around 19 °C. During the study period, the sites received 729 mm of rainfall while the average monthly temperature was 21.9 °C indicating that the season had lower than normal rainfall and was hotter the long term average. The soil at the ATDC was a Typic Kandiusalf [20] locally classified as Choma Soil Series, while the soil at Liempe was also a Typic Kandiusalf [20] belonging to Chakunkula Soil Series. Greenhouse pot trials were carried out at the School of Agricultural Sciences of the University of Zambia in Lusaka, Zambia at latitude 15° 23' 40.4" S and longitude 28° 20' 04" E at an altitude of 1260 metres above sea level.

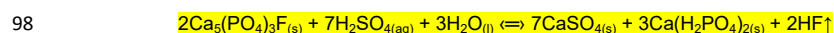
2.2 Soil sampling and analysis

At each study site, suitable locations with cultivated acid soils were selected. Selected locations at both sites were generally uniform in terms of their slope and surface properties. The land at each site was demarcated into rectangular quadrants. Surface (0-20 cm) soil samples were randomly obtained using an auger and mixed to make composite samples. Four composite samples were taken from each site for the initial characterization of soils.

Soil samples from the field were air dried, disaggregated and passed through a 2 mm sieve. Portions passing through the 2 mm sieve were retained for laboratory analysis of selected properties. The properties tested included; particle size analysis using the hydrometer method [21]; soil pH in 0.01M CaCl₂ at a soil to solution ratio of 1:2.5 [22]; organic carbon content by the Walkely and Black method [23]; available N extracted in 2M KCl and determined by distillation [24]; available P extracted using the Bray 1 method [25] and determined colorimetrically by measuring at a wavelength of 882 nm after developing molybdenum blue colour; exchangeable bases extracted in 1N NH₄O_{AC} buffered at pH 7.0 using a 1:5 (w/v) suspension and the concentrations in the extracts determined on Atomic Absorption Spectrophotometer (AAS) [26]

2.3 Production of PAPR and Analysis of nutrient contents of PAPR and chicken manure pellets

94 Partially acidulated phosphate rock (PAPR) was produced by adding concentrated commercial grade
 95 sulphuric acid to finely ground phosphate rock from Sinda district. The amount of acid used was
 96 calculated to be sufficient to convert 50 % of the phosphates in the rock into water soluble form. The
 97 calculation used was based on the following stoichiometric equation:



99 About 5 kg of phosphate rock powder was reacted with 250 mL of 10M H_2SO_4 and two litres of tap
 100 water and mixed under open air. The acid-rock mixture was left to cure for a few days and then
 101 allowed to dry. After drying, the product was ground into a powder.

102 To determine the concentrations of total P and Ca in the PAPR, samples of the PAPR were digested
 103 in Aqua-Regia for 30 minutes. Aqua regia was prepared by mixing one part concentrated HNO_3 to
 104 three parts concentrated HCl. The concentrations of P and Ca in the extract were determined
 105 colorimetrically and by AAS respectively.

106 To determine concentrations of Ca, Mg, K, Mn, Fe, Cu and Zn in the chicken manure pellets, the
 107 manure samples were ashed at 500 °C for 3 hours. The ash was then digested in 1N HNO_3 .
 108 Concentrations of the metals in the extract were determined by AAS. The total N content of the
 109 chicken manure was determined using the modified macro Kjeldhal method [27]. The total P content
 110 was determined using the dry ashing method [28] and concentrations determined colorimetrically at a
 111 wavelength of 882 nm after developing the molybdenum blue colour.

112 2.4 Experimental set up

113 At each site, the land was ploughed and disced with tractor drawn equipment after which six 4 m x 4
 114 m plots were demarcated. The treatments (i) a control where no amendment was applied, (ii) PAPR,
 115 (iii) chicken manure pellets (CM), (iv) cowpea residues (CP), (v) CM with PAPR and (vi) CP with
 116 PAPR were randomly assigned to each plot without replication. For the treatments with cowpea
 117 residues, a cowpea variety, LT 11-3-3-12 from the Department of Plant Science at the University of
 118 Zambia was used. The cowpea was planted in rows 45 cm apart with an intra row spacing of 20 cm.
 119 Four seeds were planted per planting station and thinned to two plants per station two weeks after
 120 emergence. Chicken manure pellets and PAPR were banded in rows 45 cm apart similar to those
 121 used for planting cowpea. On each of the plots, weeds were allowed to grow.

122 At the ATDC, plots in which cowpeas were grown were weeded 3 weeks after planting, following a
123 severe infestation of the weed *Richardia scabra*. This was done to prevent the crop from being
124 outgrown by the weeds. Four months after planting; when cowpea pods had formed and matured,
125 plants growing on each plots were cut, spread across the surface of the plots and left to dry for three
126 days. The plant residues on each plot were then arranged into four rows and covered with surface
127 soils to form ridges using hand hoes. The ridges were left for six weeks to allow the organic residues
128 to decompose. The ridges were then dismantled and the soils were thoroughly mixed with the
129 decomposed plant residues. Soil samples were collected from each plot for use in greenhouse maize
130 trials and for further soil analysis to determine the levels of organic matter, available N, available P
131 and exchangeable K using the methods outlined earlier.

132 A greenhouse pot trial was conducted to assess the effects of the treatments used in the field study
133 on the dry matter yield of maize. The experiment was laid out as a Completely Randomised Design
134 with 7 treatments and four replicates on each of the two soils. The extra treatment to the six used in
135 the field study, was the addition of chemical fertilizer; compound D (10 % N : 20 % P₂O₅ : 10 % K₂O)
136 at the rate of 4.5 g fertilizer per pot corresponding to the local recommended basal fertilizer
137 application rate of 200 kg Compound D per hectare for maize. Three kilograms of soil was added to 3
138 litre plastic pots in which four ZMS 402 maize seeds were planted and thinned to one plant per pot a
139 week after emergence. The maize plants were grown for six weeks after which the above ground
140 biomass was harvested, air-dried and weighed to determine the dry matter yield.

141 The Relative Agronomic Effectiveness (RAE) of the amendments used was then calculated using the
142 formula:

$$RAE(\%) = \frac{(\text{yield from amendment}) - (\text{yield from control})}{(\text{yield from fertilizer}) - (\text{yield from control})} * 100$$

143 Where:

- 144 - Yield from control is dry matter yield of maize grown on soils from control plots and NPK
145 fertilizer was not added
- 146 - Yield from fertilizer is dry matter yield of maize grown on soils from control plots and NPK
147 fertilizer was added
- 148 - Yield from amendment is dry matter yield of maize grown on soils obtained from plots treated
149 with different amendments

150

151 2.5 Statistical Analysis

152 To determine whether there were significant differences due to the effect of the amendments on
 153 selected soil properties and maize dry matter yield, an Analysis of Variance was conducted. Mean
 154 separation was carried out using Duncan's Multiple Variance Range Test was used. All tests were
 155 compared at a significance level of 0.05. The statistical analyses were conducted using SAS software
 156 version 9.0 for windows.

157 3. RESULTS AND DISCUSSION

158 3.1 Characteristics of soils used in the study

159 Results of selected initial chemical and physical properties of the soils used in the study are
 160 presented in Table 1. Both soils were very strongly acid. Chakunkula soil was a sandy loam soil and
 161 Choma soil was loamy sand.

162 The critical levels for maize production in tropical soils have been reported to be 12 mg/kg for
 163 available P [29], 0.15 % for total N [30] and 0.12 cmol/kg for K [31]. Based on these levels,
 164 Chakunkula soil had low levels of organic matter, total N, available P and K. On the other hand,
 165 Choma soil had low levels of N and K and moderate levels of organic matter and available P. This
 166 implied that the productivity of the two soils for maize was thus likely to be low if amendments were
 167 not applied to remedy the identified limitations to crop production.

168 Table 1: Selected physical and chemical properties of the soils used in the study

Soil	pH 0.01M CaCl_2	OC	N	Avail N	Avail P	Ca^{2+}	Mg^{2+}	K^+	Sand	Silt	Clay
		%		mg/kg soil		cmol+/kg soil			%		
Chakunkula	4.02	1.08	0.06	180	6.55	0.92	0.37	0.11	53.5	13.2	34
Choma	4.32	0.49	0.03	161	22.19	0.26	0.04	0.13	77	6	17

169 Avail = available; OC = Organic Carbon

170 The compositions of chicken manure and PAPR are presented in Table 2. The PAPR used in this
 171 study was produced from a PR that was predominantly composed of the phosphate mineral
 172 fluorapatite ($\text{Ca}_5(\text{PO}_4)_3\text{F}$). It therefore contained relatively high amounts of Ca and P. The PR was an
 173 inorganic material in which carbon, N and most other nutrients found in chicken manure were not

174 expected to occur in appreciable amounts. The PAPR was therefore not analysed for N, K and the
 175 micronutrients determined in the chicken manure. It was applied as a source of while of Ca and P, but
 176 not N and K.

177 Table 2: Composition of chicken manure and PAPR used in the study

Amendment	OC	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
	%						mg/kg			
Chicken manure	28.8	2.1	3.59	1.78	6.18	0.86	23	105	592	111
PAPR	-	-	5.95	-	22.74	-	-	-	-	-

178 OC = Organic Carbon

179 The chicken manure had relatively high levels of C, N, P, K, Ca and the metal micronutrients Cu, Zn,
 180 Fe and Mn. The C:N ratio of the chicken manure was 14:1 which is lower than 20:1 below which
 181 nitrogen present in organic materials is expected to be mineralized upon decomposition of the organic
 182 materials in the soil. Similarly, the P in the manure was readily mineralizable as the carbon to
 183 phosphorus (C:P) ratio of the manure was 8:1, which was much lower than 200:1 below which P in
 184 organic materials is expected to be mineralized upon decomposition of the organic materials [32].

185 3.2 Effects of amendments on selected soil properties

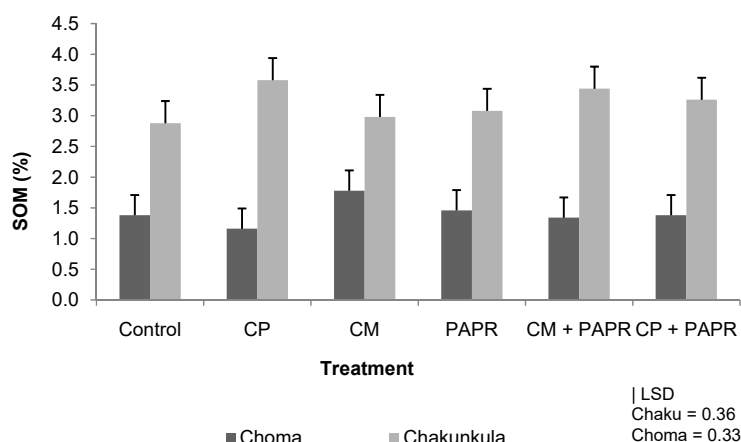
186 The mean values of organic matter, available N, available P, and K in plots treated with different
 187 amendments are presented and discussed in this section.

188 3.2.1 Organic Matter

189 The levels of SOM in plots treated with different amendments on the two soils are presented in Figure
 190 1. On Chakunkula soil, plots with cowpea residues and CM with PAPR had significantly ($P < .001$)
 191 higher levels of organic matter than the control while on Choma soil, only plots with CM had
 192 significantly higher levels of organic matter than the control.

193 Generally, soils from all the plots in the experiments including the control showed increases in the
 194 levels of organic matter compared to the initials levels in both soils. A significant amount of the
 195 organic matter measured in the soils at the end of experiment most likely originated from organic
 196 residues from plants that grew on the plots. According to [33], retaining plant residues and
 197 incorporation them into the soil increases the levels of soil organic matter. This may explain why

198 levels of organic matter in all plots at the end of the field experiment were generally higher than the
 199 initial levels of organic matter in soils at the two sites.



200

201 **Figure 1: SOM levels in plots treated with different amendments on the two soils**

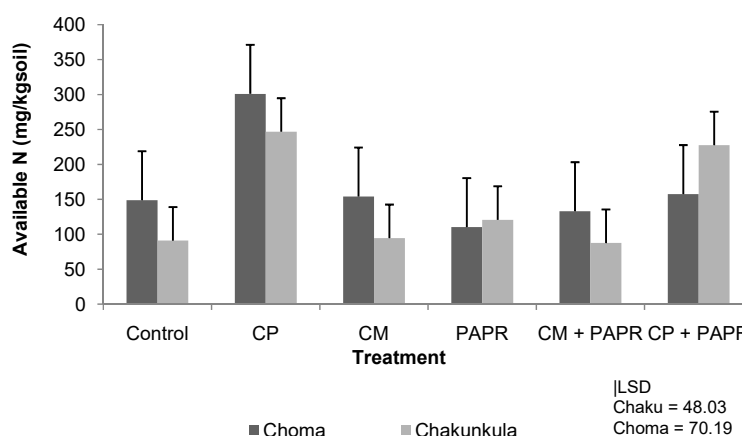
202 On Chakunkula soil, the levels of N, P and K were initially low for maize growth. It was therefore
 203 anticipated, that adding amendments containing these nutrient would results in enhanced plant
 204 growth. Results of correlation analysis showed highly significant ($p < 0.0001$) positive linear
 205 relationships between SOM and available P ($r = 0.83$). This could explain the significantly high levels
 206 of SOM associated with treatments like cowpea residues and chicken manure with PAPR which had
 207 significantly higher levels of available P than the control.

208 On Choma soil where K was low, significant ($p < 0.005$) positive relationships were also established
 209 between SOM and K. This means application of K containing amendments probably enhanced plant
 210 growth. This probably explains the highest levels of SOM observed in plots amended with chicken
 211 manure which had high levels of K in addition to other nutrients. These results are consistent with
 212 findings of other researchers on the effect of poultry manure on SOM levels in African soils which
 213 indicate that applying poultry manure increases the levels of soil organic matter [13][14] [15].

214 3.2.2 Available Nitrogen

215 The levels of available N associated with different treatments on the two soils are presented in Figure
 216 2. On Chakunkula soil, plots with cowpea residues and cowpea residues with PAPR had significantly

217 higher levels of available N than the control while on Choma soil; only plots with cowpea residues had
 218 significantly higher levels of available N than the control. These results are in agreement with findings
 219 of other researchers [10] [34] who reported significant increases in the levels of total N in the soil
 220 following the incorporation of cowpea residues into the soil. Cowpea is a legume that fixes nitrogen
 221 biologically and therefore accumulates N in its biomass [6]. According to [35], cowpea biomass has an
 222 average N content of 1.4 % and a C:N ratio of 21:1 which makes it a suitable source of N in soil.



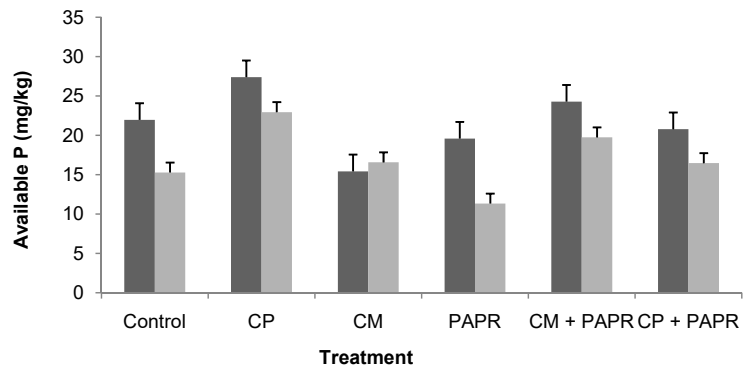
223

224 **Figure 2: Available N levels in plots treated with different amendments on two soils**

225 Plots that received CM did not have higher levels of N than the control. This could be attributed to the
 226 fact that N in chicken manure is usually in a form that is readily available for plant uptake and also
 227 susceptible to leaching [12] especially on sandy soils. On medium to heavy soils, the N mineralized
 228 from the manure may be retained if it is not nitrified.

229 **3.2.3 Available phosphorus**

230 Figure 3 presents the levels of available P in plots treated with different amendments on the two soils.
 231 On both soils, plots on which cowpea residues and chicken manure with PAPR were applied had
 232 significantly ($P < 0.05$) higher levels of available P than the control plots. The high levels of available
 233 P in soils treated with chicken manure with PAPR could be attributed to the fact that the two
 234 amendments making up this treatment contained relatively high amounts of P as shown in Table 2.



235

236

Figure 3: Available P levels in plots treated with different amendments on the two soils

237

The high amounts of P in soils from plot where cowpea residues were applied could be attributed to

238

the fact that cowpeas are known to take up significant amounts of P from soils. According to [5],

239

cowpea forms mycorrhizal associations with soil fungus which increase the uptake of P from the soil.

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The P taken up accumulates in the cowpea biomass and is mineralized when the biomass is

241

decomposed in the soil. This view is corroborated by the findings of [34] who observed an increase in

242

levels of available P in soils as a result of incorporating crop residues from food legumes in the soil.

243

3.2.4 Exchangeable Potassium

244

The levels of K in plots treated with different amendments on the two soils are presented in Figure 4.

245

Generally, all the treatments resulted in a significant increase in levels of K compared to the levels of

246

K before application of the treatments to the soil. The treatments that had significantly higher levels of

247

K than the control plot were cowpea residues alone and cowpea residues with PAPR on Chakunkula

248

soil and chicken manure and cowpea residues with PAPR on Choma soil.

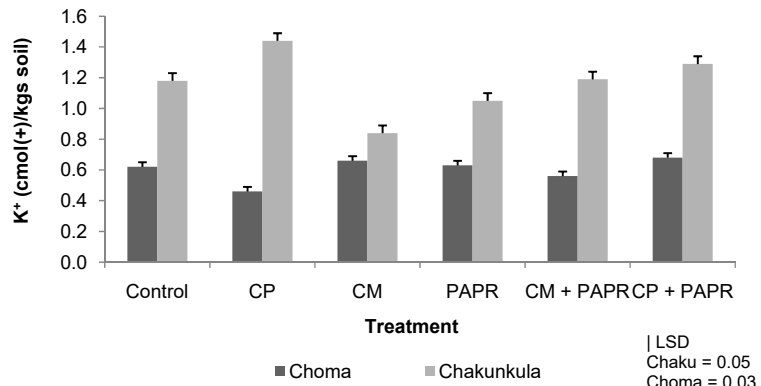


Figure 4: K levels in plots treated with different amendments on the two soils

On both soils, cowpea residues with PAPR had high levels of K. According to [36], phosphorus enhances root development which in turn possibly increased K uptake by the plant. Legumes take up a lot of K for nodule development and functioning [37]. This increases K accumulation in the crop biomass which is released into the soil upon decomposition of the plant residues. This could explain the increased K levels observed in plots with cowpeas residues. These results are in agreement to the findings of [34] who reported that incorporation of residues from food legumes significantly increased levels of Mg, Ca and K compared to natural fallow plots.

Generally, cowpea residues improved most of soil properties used to assess the fertility status of both soil. This indicates that cowpea residues were the best amendment in improving soil fertility of both soils.

3.3 Effect of Soil Amendments on the Dry Matter Yield of Maize

The dry matter yields of maize from soils treated with different amendments on the two soils without the application of chemical fertilizer are presented in Table 3. On both soils, plots with cowpea residues and CP with PAPR had significantly ($p < 0.05$) higher maize dry matter yields than the control. On Chakunkula soil, PAPR also had significant higher yields than the control plots, while on Choma soil, chicken manure also had significantly higher dry matter yield of maize compared to the control.

Table 3: Mean dry matter yield of maize on Choma and Chakunkula Soil Series with different treatments without application of compound D fertilizer.

Amendment	Maize dry matter yield (g/pot)	
	Chakunkula	Choma
Control	2.37 ^d	3.14 ^c
Cowpea residues	8.47 ^a	5.58 ^a
Chicken manure	2.43 ^d	4.23 ^b
PAPR	3.92 ^c	3.63 ^{bc}
Chicken manure + PAPR	3.73 ^{cd}	3.07 ^c
Cowpea residues + PAPR	5.58 ^b	5.42 ^a
LSD (0.05)	1.29	0.89

**Means followed by the same letter in a column are not significantly different from each other at 5 % significant levels

It was observed that available N had the greatest influence on maize dry matter yield, indicating that N was probably the most limiting nutrient to maize growth on both soils. There were highly significant ($p < 0.005$) linear relationships between available N and maize dry matter on both soil. This may explain the high dry matter yield associated with plots treated with cowpea residues and CP with PAPR which had higher levels of available N on both soils. Evidence in support of this, was that, no symptoms of N deficiency were observed on maize plants grown on soils with treatments of cowpea residue and CP with PAPR. Similar observations have been reported by [8] [9] who observed significant increases in maize grain yields on plot that received applications of cowpea residues compared to control plots. Reference [10] also reported significant increases in rice yields in plots where cowpea residues were incorporated into the soil compared to natural traditional fallows plots. On the other hand, very low maize dry matter yields were obtained where chicken manure was applied. Maize plants grown on soils treated with chicken manure also showed deficiency symptoms of N and P three weeks after emergence. It is probable that in these plots, most of the N released from the chicken manure may have been leached and partially utilised by the plants that grew on the plots during the fallow period.

3.4 Relative agronomic effectiveness of the amendments

Results of the Relative Agronomic Effectiveness (RAE) of the amendments on the two soils relative to Compound D fertilizer are presented in Table 4. On both soils, cowpea residues had the highest RAE followed by the treatments with CP with PAPR. On Chakunkula soil the RAE of cowpea was 66 %, while on Choma soil it was 36.6 %. These results are similar to those of reference [34], who found that grain yield of maize on plots on which stove of food legumes was incorporated into the soil ranged from 42.5 to 61.4 % of that obtained from plots that received applications of chemical fertilizers.

Table 4: Relative agronomic effectiveness of the amendments relative to compound D on the two soils

Amendment	RAE (%)	
	Chakunkula	Choma
Cowpea residues	66.4 ^a	36.6 ^a
PAPR	16.9 ^c	7.3 ^{bc}
Chicken manure	0.7 ^d	16.4 ^d
Chicken manure + PAPR	14.6 ^{cd}	-1.2 ^c
Cowpea residues + PAPR	35.1 ^b	34.3 ^a
LSD (0.05)	15.35	13.94

* Means followed by the same letter in a column are not significantly different from each other at 5 % levels of significance

It is evident from the results of this study that CP was the most effective treatment in increasing the productivity of the two soils for maize production. Results of the RAE of the amendments are consistent with those of the effects of the amendments on the fertility of the soils, which showed that on both soils CP improved the status of more soil fertility parameters than any other amendment. It is therefore not surprising that results of the agronomic effectiveness also showed CP to be superior to the other amendments. It should be noted that the evaluation of the agronomic effectiveness of the amendments used in this study was carried based on a pot study under greenhouse conditions and on the dry matter yield of maize rather than on the grain yield. It would therefore be necessary to carry out the same study under field conditions where maize would be grown to maturity and where the grain yield would be used to calculate the agronomic effectiveness. This however does not diminish the value of the present findings based on the greenhouse pot study studies.

310 4. CONCLUSION

311 Results of this study show that cowpea residues were the most effective amendment in increasing the
312 fertility status of the soils as indicated by greater number improvements in the fertility indicators used
313 on both soils. Furthermore cowpea residues were most effective in increasing the productivity of the
314 two soils for maize production. It was therefore concluded that among the amendments used, cowpea
315 residues were had the greatest potential for improving the fertility and productivity of the two the two
316 acidic, low fertility Kandiusstals for maize production. Growing cowpea and incorporating its residues
317 into the soil after harvest could therefore be a means of restoring the productivity of soils with low
318 fertility for maize production that resource poor resource farmers with limited access to chemical
319 fertilizers can use in agro-ecological environments similar to those used in this study.

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