

1 **INFLUENCE OF SOYBEAN RESIDUE MANAGEMENT ON NITRATE**
2 **NITROGEN ACCUMULATION AND SUBSEQUENT SORGHUM YIELD IN**
3 ***KANHAPLIC HAPLUSTULUS* OF WESTERN KENYA**

4
5 **ABSTRACT**

6 Crop residues are overlooked when making fertilizer recommendations, yet have
7 potential to contribute to soil nitrogen in addition to mineral fertilizer use. A study
8 was carried out in western Kenya to establish the contribution of soybean residues
9 under varied management options and nitrogen fertilizer rates on nitrogen supply to
10 subsequent sorghum crop. Six soybean residue management options were evaluated;
11 sole sorghum, sorghum + soybean left to maturity, sorghum + soybean mulched,
12 sorghum + soybean incorporated, sorghum + soybean exsitu and sorghum + soybean
13 exsitu and plot tilled. Three levels of nitrogen (0 kg N ha⁻¹, 40 kg N ha⁻¹, and 80 kg
14 N ha⁻¹) as urea were applied as top-dress and treatments arranged in randomized
15 complete block design. Soybean left to maturity at 40 kg N ha⁻¹ indicated significant
16 (P < 0.001) increase (56%) in soil NO₃-N. Removal of soybean residues resulted in
17 significantly (P < 0.001) lower soil NO₃-N increase while control treatment and sole
18 sorghum indicated the lowest soil NO₃-N accumulation irrespective of nitrogen
19 fertilizer rates. Soybean left to maturity indicated significant (P < 0.001) increase
20 (43%) in leaf NO₃-N accumulation at 40 kg N ha⁻¹ while treatments with soybean
21 residues mulched showed 39% increase and those with residues incorporated, 25%
22 increase. Soybean residues *ex-situ* and *ex-situ* and till indicated a decrease (- 6% and
23 -7%) in leaf NO₃-N accumulation, respectively. Sole sorghum had a uniform NO₃-N
24 increase of 4% irrespective of nitrogen fertilizer rates. It was observed that *insitu*
25 soybean residues and nitrogen fertilizer application had no significant (P < 0.05)
26 influence on sorghum yield. In conclusion, soil and leaf NO₃-N accumulation by
27 soybean residues in addition to nitrogen fertilizer does not translate to optimum nor
28 potential research sorghum yields. There is need to research on sulphur and nitrogen
29 to establish their interactive effects on sorghum yields.

30 *Key words: Soybean residue management options, nitrogen fertilizer rates, nitrate*
31 *accumulation and build up, subsequent sorghum yields.*

33 1. INTRODUCTION

34 Soil organic nitrogen is transformed into mineral nitrogen through mineralization
35 which is the most important process of soil nitrogen cycling [1]. Nitrogen is an
36 essential element required for successful plant growth [2]. Inorganic nitrogen
37 compounds exist as ammonium, nitrite and nitrate [2] and of the three, nitrate is the
38 principal N source for plant growth irrespective of inorganic or organic N source [3].
39 In addition to mineral fertilizer which is the prime source of N for crops [4],
40 legumes contribute appreciable amounts of N through symbiotic nitrogen fixation
41 [5]. The authors [6] pointed out that cereal-legume intercropping increases the
42 amount of nitrogen, phosphorus and potassium contents compared to monocropping.
43 According to [7], legume species and several cultivars have potential to adequately
44 contribute N for corn growth. For example, hairy vetch (*Vicia villosa*), and crimson
45 clover (*Trifolium incarnatum*,) were found to contribute 204 kg ha⁻¹ and 163 kg ha⁻¹
46 respectively [8]. Other researchers [9] showed that soybean litter fall over the
47 growing period of the crop contributed 8.2 to 11.8 kg N ha⁻¹ from N fixation while
48 residues returned to the field after harvest had total N content of up to 30 kg N ha⁻¹.

49

50 Crop residues have been reported to play a significant role in terms of soil fertility
51 improvement [10] and have direct roles on nutrient cycling and crop yields [11].
52 Leguminous residues undergoing decomposition have potential to supply adequate
53 plant available nitrogen to the subsequent crop depending on management and soil
54 conditions [12]. In addition, [13] were of the opinion that legume residue
55 decomposition provides long-term supply of N for subsequent crop. The findings
56 reported by [14] indicated that removal of crop residues negatively impacted on soil
57 nitrate nitrogen (NO₃-N) while residue covered soil showed accumulation of NO₃-N.
58 Other studies [15] showed that incorporation of legume residues from velvet bean
59 and sun hemp led to accumulation of N in the soil, high absorption by corn and
60 ultimate increase in corn yields.

61

62 According to [16], 55% of overall nitrogen applied in agricultural systems can be
63 recovered; out of this percentage, 35% is in harvested products and 20% is in crop
64 residues. However, crop residues are under-estimated in nutrient recycling and often

overlooked when making fertilizer recommendations. Further to this, [17] reported that legumes have potential to contribute to build up of soil NO₃-N to meet and/or exceed the plant nitrogen requirement during the cropping season and consequently increase yields. Findings by [18] showed that crop residues' contribution to soil nitrogen need to be considered in nitrogen fertilizer management and factored in to reduce mineral fertilizer rates. In the light of the findings and opinions of these researchers, this study sought to establish the potential of integrated soybean residue management options and nitrogen fertilizer rates on nitrogen supply to the subsequent sorghum crop and their influence on grain yield in *Kanhaplic Haplustults* of Western Kenya.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was carried out in Busia County, Emalomba area (N 00°25'28.8" E 034°15' 51.9"), Agro-ecological zone: LM 1 [19]. The site elevation is 1222 m above sea level. Table 1 presents the mean monthly rainfall and temperature of the experimental site over a two year period (2012 – 2013).

Table 1. Rainfall amounts (mm) and maximum and minimum temperatures (°C) for the years 2012 and 2013

Month	Rainfall (mm)		Max. Temp (°C)		Min. Temp (°C)	
	2012	2013	2012	2013	2012	2013
Jan	7.2	47.1	30.1	28.6	12	13.9
Feb	12.1	40.7	31.3	29.9	13.8	14.1
Mar	54.2	248.0	31.0	29.6	14.3	15.1
Apr	206.6	209.0	27.2	27.1	15.5	15.4
May	261.2	172.9	26.5	27.4	14.9	14.5
June	146.0	77.2	26.5	26.8	14.5	14.5
July	105.3	24.3	25.9	26.9	14.1	13.6
Aug	79.8	190.5	26.3	26.5	13.9	13.9
Sept	197.4	268.0	26.9	27.2	13.9	14.0
Oct	332.6	196.7	27.4	27.4	14.8	14.7
Nov	166.1	174.6	27.2	27.2	14.6	14.9
Dec	215.8	68.6	27.2	27.5	14.4	14.5

Source: [20]

86 The average annual precipitation of the study area ranges between 1718 – 1784 mm
87 while the mean maximum temperatures ranged between 26.3°C and 31.3°C in
88 comparison to mean monthly minimum temperature that vary from 12.0°C to
89 15.5°C. The experimental site experiences bimodal rainfall with the long rains
90 beginning in March and the short rains in August/September. The soil is classified as
91 *Kanhaplic Haplustults* in USDA Soil Taxonomy [21] correlating with *Haplic*
92 *Cutanic Acrisols* in WRB [22].

93

94 **2.2 Field Experimentation**

95 The experimental site was prepared preceding the onset of long rains in March, 2012
96 and 2013. In the year 2013, a study was carried out in the previous experimental
97 plots with respective treatments to establish the contribution of soybean residues
98 under varied management options and nitrogen fertilizer rates on nitrogen supply to
99 the subsequent sorghum crop and on yield. Additionally, in same year, 2013, new
100 experimental site with similar experimental treatments as the previous
101 experimentation in the year 2012 were prepared alongside that of the year, 2012.
102 This was done to allow a comparison on effects of soybean residue management
103 options and N fertilizer rates on NO₃-N accumulation and build up both in the soil
104 and sorghum leaves in the year 2012 and that of year 2013. Each experimental plot
105 measured 3.0 m x 4.5 m with inter-plot distance of 0.5 m and 2 m between blocks.
106 An outer allowance path of 2 m around the experimental plots was considered.
107 Sorghum variety; KARI Mtama II, recommended to the climatic conditions of the
108 experimental site, was sown at the spacing of 75 cm inter-rows and 15 cm between
109 plants. Soybean variety SB 19 inoculated with Biofix ® inoculants was planted in
110 between the sorghum rows at a spacing of 10 cm. Six treatment options were
111 considered;

- 112 (i) sole sorghum(SS),
- 113 (ii) sorghum + soybean left to maturity (SS + SB [maturity]),
- 114 (iii) sorghum + soybean residue mulched (SS + SB [mulched]),
- 115 (iv) sorghum + soybean residue incorporated (SS + SB [incorporated]),
- 116 (v) sorghum + soybean ex-situ (SS + SB [*ex-situ*]), and
- 117 (vi) sorghum + soybean ex-situ and plot tilled (SS + SB [*ex-situ* and plot tilled]).

118 Triple super phosphate ($\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$) was applied uniformly to all the
 119 treatments during planting by broadcasting and mixing with soil at rate of 20 kg P
 120 ha^{-1} . Three levels of nitrogen ($0 \text{ kg N ha}^{-1} = \text{N}_0$, $40 \text{ kg N ha}^{-1} = \text{N}_{40}$, and 80 kg N ha^{-1}
 121 $= \text{N}_{80}$) as urea ($\text{CO}(\text{NH}_2)_2$) was applied 42 days after emergence to sorghum plants as
 122 a top dress. The treatments were arranged in a randomized complete block design
 123 with three replications. Soybean residue management options as described in the
 124 treatments were carried out before pod formation by soybeans. A schematic lay-out
 125 of the field experiment was as given below and was replicated in three blocks;

1 SS + N_{40}	2 SS + SB (maturity) + N_{80}	3 SS + SB (<i>exsitu</i> and plot tilled) + N_{40}	4 SS + SB (incorporated) + N_0	5 SS + SB (<i>mulched</i>) + N_{40}	6 SS + SB (<i>exsitu</i>) + N_0
12 SS + SB (incorporated) + N_{40}	11 SS + SB (<i>exsitu</i> and plot tilled) + N_{80}	10 SS + SB (maturity) + N_0	9 SS + SB (<i>exsitu</i>) + N_{40}	8 SS + N_0	7 SS + SB (<i>mulched</i>) + N_{80}
13 SS + SB (<i>exsitu</i>) + N_{80}	14 SS + SB (<i>mulched</i>) + N_0	15 SS + N_{80}	16 SS + SB (incorporated) + N_{80}	17 SS + SB (<i>exsitu</i> and plot tilled) + N_0	18 SS + SB (maturity) + N_{40}

126

127 2.3 Determination of on-site soil and leaf nitrate nitrogen

128 Supply of mineralized N was investigated over a sequence of dates as recommended
 129 by [23] using extractable inorganic soil- and leaf- nitrate-nitrogen and quantified by
 130 direct measurement in the field [24,25]. Three soil samples from every plot were
 131 collected by augering at 0 - 15 cm and each time putting in sealed plastic bags. The
 132 respective samples were then mixed thoroughly to obtain a representative sample for
 133 determination of soil NO_3^- -N concentrations. The composite soil samples in sealed
 134 plastic bags were placed in cooler box to protect them from heat. Soil solution of
 135 each composite was extracted by mixing soil with water at the ratio of 1:5 (10 g of
 136 soil + 50 ml of water) and 10 ml of calcium chloride was added. The sample was
 137 thoroughly shaken for 2 minutes until all the soil clumps had thoroughly dispersed.
 138 The sample was left to sit until a clear zone of solution formed at the top of the tube.
 139 The ISE meter was calibrated with two standard solutions for NO_3^- -N which was
 140 included in the kit. Using a dropper, 2 - 3 drops of the clear solution was put on the
 141 meter sensor. Once the meter reading stabilized (after 30 - 40 seconds) the value for

142 NO₃-N concentration was recorded. Determination of soil NO₃-N concentrations
143 was performed in duplicate for each treatment and the average recorded.

144

145 Leaf nitrate nitrogen was determined by selecting randomly, appropriate sizes from
146 recently matured leaves of the sorghum plant on a fortnight interval. From each
147 experimental plot, three sorghum leaf blades were selected, placed in sealed plastic
148 bags and put in cooler boxes until leaf samples from all experimental plots had been
149 collected. At the end of the sample collection, the leaves were rinsed with distilled
150 water and blot-dried with a paper towel. Direct sunlight/high temperatures were
151 avoided during meter reading. With a sharp knife and on a cutting board, leaf blades
152 were chopped and put in a plastic bag. The samples were then punched using a hand
153 hammer to extract the juice. The corner of the bag bottom was cut to puncture the
154 plastic bag then squeezed to collect the juice. The juice was then dropped to the
155 nitrate meter sensor (about 0.3 ml) to cover the sensor. The measurement values
156 were then read off and recorded once the meter reading stabilized. Leaf NO₃-N
157 concentrations were determined in duplicate for each treatment and the average
158 recorded. Concentrations of NO₃-N in the soil and leaf was evaluated over time
159 during the growing period from 20 days after emergence at an interval of 2 weeks up
160 to physiological maturity of sorghum plants to monitor the trends of both soil and
161 leaf nitrate nitrogen. Prior to harvest, an area of 2 x 2 m was demarcated for
162 measurement of crop yields.

163

164 **2.4 Statistical data analysis**

165 Data on concentrations of NO₃-N in the soil and leaf as well as sorghum yields were
166 subjected to analysis of variance using GenStat software version 13.2 [26]. To test
167 the differences between different soybean residue management options and N
168 fertilizer rates, the means were analyzed using Tukey's Test at 95 per cent of
169 significance level ($P < 0.05$). Pearson Correlation Coefficient (r) was used to show
170 correlation between leaf nitrates and period of sampling during growing period of
171 sorghum.

172

173 **3. RESULTS AND DISCUSSION**

174 **3.1 Accumulation of Soil NO₃-N as Influenced by Soybean Residue**
175 **Management Options and N Fertilizer Rates in Year 2012 and 2013**

176 Accumulation of soil NO₃-N with respect to soil depth (0 – 15 cm) as influenced by
177 soybean residue management options and nitrogen fertilizer rates is presented in
178 Table 2. A comparison of soil NO₃-N accumulation with respect to years of study
179 showed significant ($P < 0.001$) difference between treatments. A significant
180 ($P < 0.001$) difference was noted in treatments with soybean left to maturity at
181 fertilizer application rates of 0 kg N ha⁻¹, 40 kg N ha⁻¹ and 80 kg N ha⁻¹ that indicated
182 28%, 56% and 38% soil NO₃-N, respectively, in the year 2013 as compared to 2012.

184 **Table 2. Accumulation and build-up of soil NO₃-N as influenced by soybean**
185 **residue management options and N fertilizer rates**

Soybean residue management option	Year 2012			Year 2013		
	Fertilizer rate (kg N Ha ⁻¹)			Fertilizer rate (kg N Ha ⁻¹)		
	0	40	80	0	40	80
Sole sorghum	25.08	26.28	27.08	28.23	29.75	30.70
Soybean left to maturity	28.01	30.64	32.15	34.88	41.08	39.18
Soybean residues mulched	28.08	29.73	31.94	31.14	38.10	40.79
Soybean residues incorporated	27.04	29.45	31.78	32.37	37.68	38.27
Soybean residues ex-situ	26.04	27.64	29.61	28.36	34.41	34.68
Soybean residues ex-situ + till	26.28	26.45	27.27	28.23	32.49	34.55
P value	0.001			0.001		
LSD _(0.05)	0.18			0.67		

189 At 40 kg N ha⁻¹, treatments with soybean residues mulched or incorporated indicated
190 an increase in soil NO₃-N but were not significantly different and the concentration
191 levels were lower than that of soybean residues left to maturity. In the year 2013,
192 fertilizer N at 40 kg N ha⁻¹ with soybean left to maturity and soybean residues
193 mulched at 80 kg N ha⁻¹ had significant difference ($P < 0.001$).

195 A comparison of nitrogen fertilizer application at 80 kg N ha⁻¹ in the year 2012 and
196 2013 indicated significant ($P < 0.001$) difference in soil NO₃-N accumulation
197 between the treatments (i.e. soybean left to maturity, soybean residues mulched and
198 soybean residues incorporated. The findings indicate the role soybean litter and

199 residue incorporation play in nutrient cycling and in particular NO₃-N accumulation
200 for use by the subsequent crop.

201

202 The study findings are supported by [9] who demonstrated the contribution of
203 soybean litter to soil N build up. The findings are further in agreement with the
204 findings of [27] who reported an increase in NO₃-N with residues incorporated and
205 N application at 40 kg ha⁻¹. The results also agree with [15] who showed that crop
206 residues contribute to NO₃-N accumulation and soil N improvement.

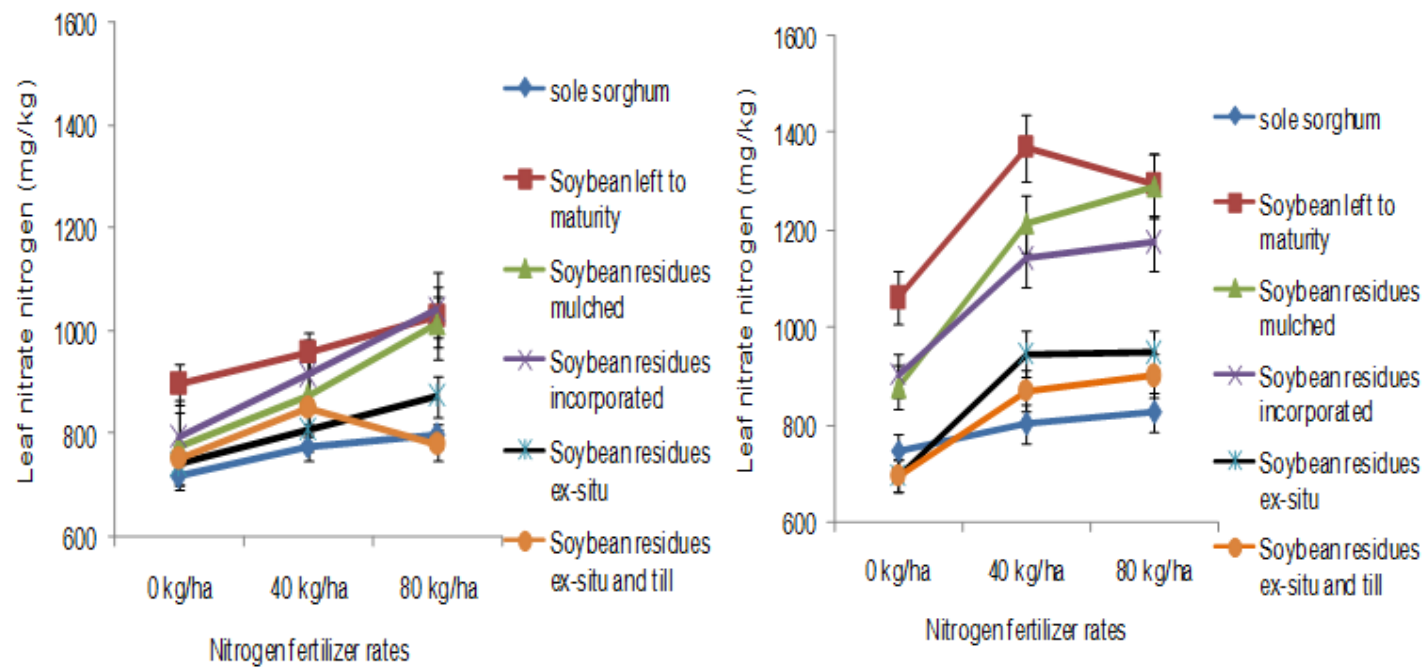
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208 In comparison with *in-situ* soybean residue management, the experiments with
209 soybean residues removed showed significantly ($P < 0.001$) lower soil NO₃-N
210 accumulation. In response to nitrogen fertilizer application. The control experiment
211 with sole sorghum indicated still lower soil NO₃-N accumulation. The findings are
212 in agreement with those pointed out by [14] and [6] indicating negative implications
213 of residue removal on soil N improvement and signifying that intercropping cereals
214 and legumes improves soil fertility.

215

216 **3.2 Accumulation of Leaf NO₃-N as Influenced by Soybean Residue** 217 **Management Options and N Fertilizer Rates during the Year 2012 and** 218 **2013**

219 Leaf NO₃-N accumulation evaluated followed similar patterns of increase with
220 increase in nitrogen fertilizer application in the year 2012 (Figure 1a)



(a) Year 2012 **(b) Year 2013**
Fig. 1. Comparison of leaf NO₃-N accumulation in the year 2012 and 2013

227 In the year 2013 (Figure 1b), there were significant ($P < 0.001$) differences in $\text{NO}_3\text{-N}$
 228 accumulation with soybean left to maturity, indicating 43% increase from the
 229 previous $\text{NO}_3\text{-N}$ concentrations when N was supplied at 40 kg ha^{-1} . Treatments with
 230 soybean residues mulched resulted in 39% increase while those with residues
 231 incorporated had 25% increase in $\text{NO}_3\text{-N}$ accumulation at 40 kg ha^{-1} . Treatments
 232 with soybean residues removed, removed and tilled and sole sorghum recorded
 233 increase of 17%, 2% and 4%, respectively.

234

235 The control treatments (0 kg N ha^{-1}) with soybean left to maturity showed 18%
 236 increase in leaf $\text{NO}_3\text{-N}$ accumulation in comparison with that of the previous year
 237 while soybean residues mulched and incorporated each indicated an increase of
 238 13%. In contrast, the control treatments with soybean residues ex-situ and ex-situ
 239 and till indicated a negative influence of residue removal on $\text{NO}_3\text{-N}$ accumulation
 240 (- 6% and -7%, respectively). Percentage change in leaf $\text{NO}_3\text{-N}$ concentration in sole
 241 sorghum in the year 2013 in comparison with the observed levels in the year 2012
 242 indicated a uniform increase of 4% irrespective of nitrogen fertilizer rates.

243

244 The results on leaf $\text{NO}_3\text{-N}$ accumulation with respect to some soybean residues
 245 management options (soybean left to maturity, mulched or incorporated) are in
 246 agreement with report by [28] who pointed out that mineralization of soil organic
 247 matter always provides a surplus of nitrate to the plant. Other findings [29] also
 248 showed an increase in plant N when rice was grown in rotation with winged bean,
 249 attributing the increase to addition of above ground plant parts and below ground
 250 plant residues of legumes.

251

252 The authors [6] were of the opinion that cereal-legume intercropping increases the
 253 amount of nitrogen, phosphorus and potassium contents compared with mono-
 254 cropping and this has been demonstrated by the findings of this study in relation to
 255 nitrogen. Removal of soybean residues indicated a negative effect on leaf $\text{NO}_3\text{-N}$
 256 accumulation and these findings are in agreement with [14] who observed that crop
 257 residue removal negatively impacted on soil $\text{NO}_3\text{-N}$, which has direct relation with
 258 leaf $\text{NO}_3\text{-N}$ as shown in Figure 2.

3.3 Accumulation of Soil- and Leaf - NO₃-N with Respect to Days after Emergence in the Year 2012 and 2013

The relationship between soil and leaf NO₃-N accumulation during the sorghum growing season indicates a similar pattern of increase in both years as shown in Figure 2. In the year 2013, there was a significant ($P < 0.001$) increase in NO₃-N accumulation than in the year 2012. This was attributed to soybean residue mineralization and subsequent plant absorption resulting in NO₃-N accumulation in the sorghum leaves [28,29]. The results are supported by [13,15] and [7] who showed that legume species have potential to adequately contribute N for corn growth.

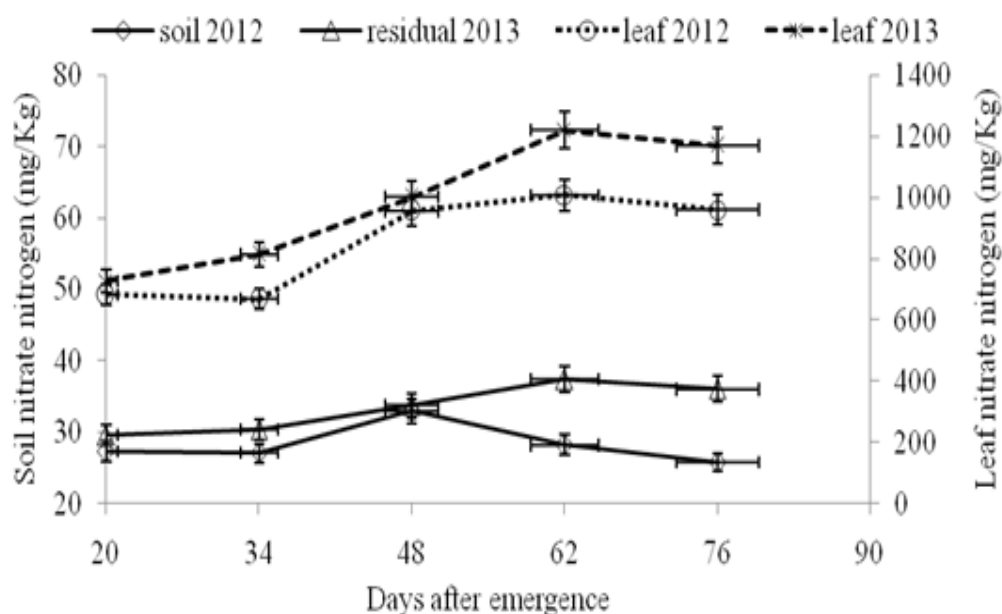


Fig. 2. Relationship between soil and leaf NO₃-N accumulation during sorghum growing season

3.4 Relationship between Days after Emergence and Leaf NO₃-N Accumulation in the Year 2012 and 2013

When leaf NO₃-N accumulation is plotted versus the data sampling period in the year 2012 and 2013 (Figure 3) a polynomial increase was noted, with the previous year indicating lower increase. The regression equation further indicated that the highest leaf NO₃-N accumulation occurred between 60 - 70 days. The results suggest

the need to apply mineral fertilizer much earlier (approximately 30 - 35 days) after emergence to meet N demand during vegetative stage and not late in the season.

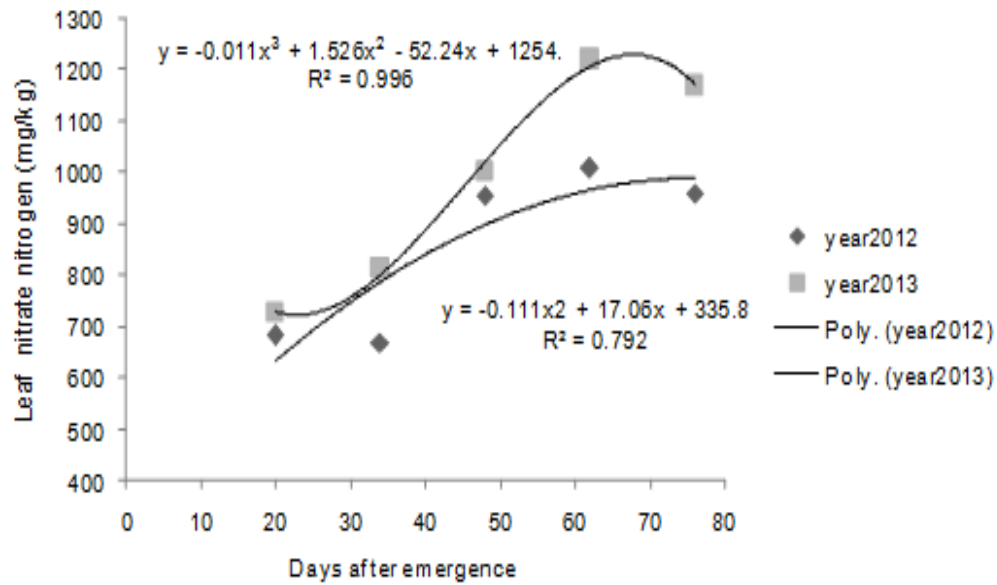
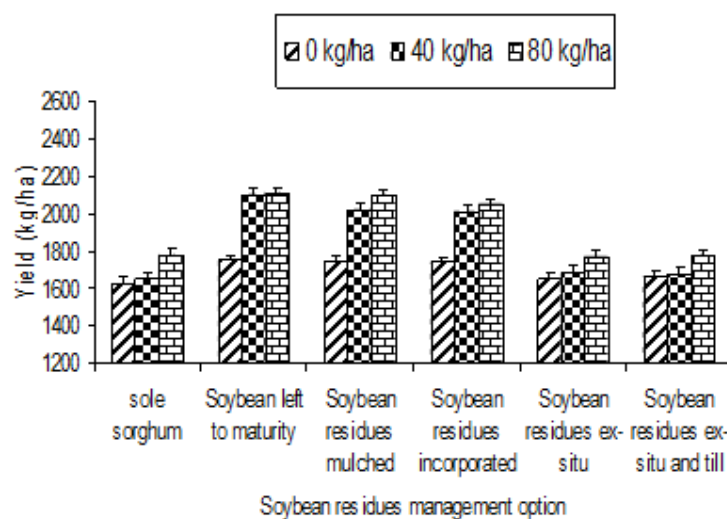


Fig. 3. Regression equation of the relationship between sampling times over the growing seasons (2012 and 2013) and leaf NO₃-N accumulation.

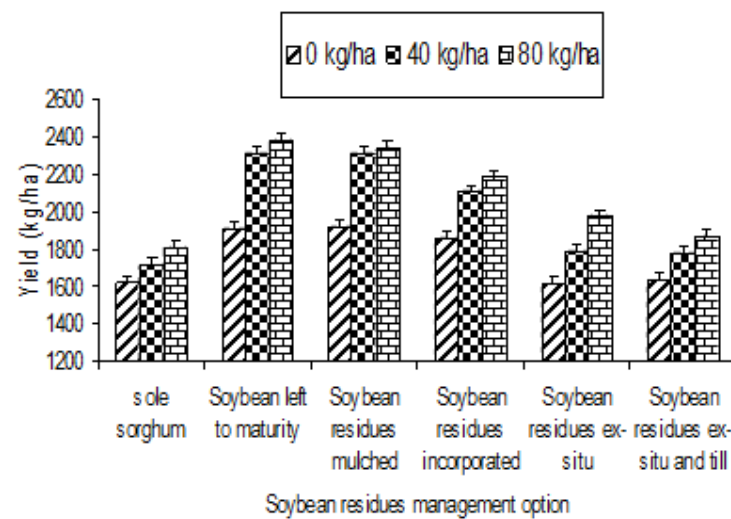
The findings of the study agree with [4] who indicated that mineral fertilizer is prime in N supply and report by [7] and [29] on the important role legume residues play in soil N contribution. Researchers [30] also pointed out positive contribution of legumes on wheat N uptake, maturity and yield.

3.5 Sorghum Yield Response to NO₃-N Accumulation as Influenced by Soybean Residue Management Options and N Fertilizer Rates

The response of sorghum yields with respect to NO₃-N accumulation as influenced by soybean residue management options and N fertilizer rates are presented in Figure 4.



(a) Year 2012



(b) Year 2013

Fig. 4. Effects of soybean residue management options and nitrogen fertilizer rates on sorghum yields in the year 2012 and 2013.

From the data values, percentage increase of sorghum yields in the year 2013 up from the yields of the year 2012 in reference to soybean management options and nitrogen fertilizer rates is presented in Table 3.

Table 3. Percentage change in sorghum yield between 2012 and 2013 growing seasons

Soybean residues management option	Nitrogen fertilizer rates		
	0 kg/ha	40 kg/ha	80 kg/ha
Sole sorghum	-0.3	4	2
Soybean residues left to maturity	9	10	13
Soybean residues mulched	10	14	12
Soybean residues incorporated	7	5	7
Soybean residues ex-situ	-2	6	11
Soybean residues ex-situ + till	-2	6	5

The data derived indicated that the preceding soybean residues and nitrogen fertilizer application had significant ($P < 0.05$) influence on yield increase of sorghum in the year 2013 in comparison to year 2012. The increase in yield in the year 2013 suggests carry over soil $\text{NO}_3\text{-N}$ from decomposing soybean residues and probably below ground biomass in the case of treatments with residues removed. The results on yield are in agreement with report by [29] who observed an increase in rice grain yield due to influence of legume residues and N fertilizer application.

The results further indicate that in the year 2012, there was no significant difference in sorghum yields between soybean left to maturity, soybean residues mulched and soybean residues incorporated at 40 and 80 kg N ha^{-1} . However, in the year 2013, soybean left to maturity and soybean residues mulched had no significant difference in sorghum yield at 40 kg N ha^{-1} or 80 kg N ha^{-1} but indicated significantly higher yield than when soybean residues were incorporated. The results are supported by [9,15,27] who emphasized the potential contribution of soybean litter, mulch or incorporation of residues to soil N build up.

From the results obtained, the need for N fertilizer application cannot be over emphasized. The removal of residues from the field and sole sorghum cropping with no nitrogen fertilizer application showed a significant ($P < 0.001$) decrease in sorghum grain yield (lower than the previous yields). The results point out the need to supply inorganic nitrogen during the cropping season to meet the nutrient crop demand in the *Kanhaplic Haplustults* of Western Kenya.

Though there is appreciable accumulation of soil and leaf $\text{NO}_3\text{-N}$ with respect to soybean residue management and nitrogen fertilizer rates to meet the crop N demand as reported by [17], it does not translate to research potential sorghum yields of 4 000 – 5 000 kg ha^{-1} [31]. It is, thus, speculated that other plant essential nutrients inter-related with nitrogen could have influenced the obtained sorghum grain yield. For example, [32,33]

indicated that there is a strong relationship between sulphur (S) and nitrogen (N) nutrition. The authors reported that the assimilatory pathways of S and N are functionally convergent i.e. sulphur is an essential component of enzymes involved in the metabolism of nitrogen (nitrate and nitrite reductase) and that the availability of one of the elements regulates the other.

4. CONCLUSIONS

From the results of the study, it can be concluded that:

- Fertilizer N application at 40 kg N ha^{-1} with soybean residues left to maturity has the potential to accumulate soil and leaf $\text{NO}_3\text{-N}$ accumulation for use during the growing season of grain sorghum.
- N fertilizer application at 40 kg N ha^{-1} with sorghum soybean left to maturity increases soil N by 56% but does not lead to optimal sorghum yields in the *Kanhaplic Haplustults* of Western Kenya, Busia County.
- Previous soybean residue removal and sole cropping in the year 2012 had negative influence on soil and leaf $\text{NO}_3\text{-N}$ accumulation in the year 2013.

5. RECOMMENDATIONS

In the perspective of the above conclusions, the following recommendations are made:

- Growing of grain sorghum intercropped with soybean left to maturity in combination with nitrogen fertilizer application at 40 kg ha⁻¹ improves soil NO₃-N and is recommended be adopted to build up soil nitrogen, in the long term.
- Removal of soybean residues from the field should be discouraged as this has a negative influence on soil nitrate nitrogen and yields of grain sorghum.
- Further research on sulphur is recommended to be carried out in order to establish whether the nutrient element is limiting in the studied soils in order to optimize sorghum grain yields.

COMPETING INETERST

Authors have declared no competing interests exit.

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