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Effects of Nitrogen Fertilizer Rates and Soybean Residue Management on Nitrate Nitrogen in Sorghum-Soybean Intercropping System

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Authors' contributions

This work was carried out in collaboration between all authors. Author SJK designed the study, collected field data, performed statistical analysis and wrote the first draft of the manuscript. Authors JMRS and WKN reviewed the experimental design and monitored the field trials. Authors JMRS, BMM and DKC carried out the literature review. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out in Busia County, Kenya at Emalomba (N 00°25′28.8″ E 034°15′ 51.9″), Nambale District to assess the effects of nitrogen fertilizer rates and legume management options on nitrate nitrogen (NO_3-N) under intercropping system. Six soybean residue management options were considered: Sole sorghum, sorghum + soybean left to maturity, sorghum + soybean mulched, sorghum + soybean incorporated, sorghum + soybean exsitu and sorghum + soybean exsitu and plot tilled. Three levels of nitrogen (0kg N ha^{-1}, 40kg N ha^{-1}, and 80kg N ha^{-1} as urea were applied as top-dress and treatments arranged in randomized complete block design. Soil NO_3-N was significantly high (P<0.0010) in topsoil with a notable leaching to subsoil due to precipitation. Control treatments had low soil NO_3-N in comparison to other treatments implying that, use of inorganic fertilizers to supplement soil N is important. Fertilizer application at 40kg N ha^{-}

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[1] with respect to on-farm soybean residue management was in relation to NO_3-N supply was in the order: sorghum + soybean left to maturity > sorghum + soybean mulched = sorghum + soybean incorporated. Experimental plots with legume residues removed had significantly (P<0.001) low NO_3-N. High leaf NO_3-N observed points to transfer of N to sorghum by nitrogen fixation signifying importance of intercropping. There was no significant difference between nitrogen fertilizers applied at 40kg N ha^{-1} and 80kg N ha^{-1} irrespective of field managed legume residues. Sorghum intercropped with soybean left to maturity with nitrogen fertilizer applied at 40 kg N ha^{-1} reflected high (P< 0.001) soil NO_3-N in comparison to the other management options. It is therefore recommended as a possible optimum rate and legume residue management option to improve soil NO_3-N among small scale households with stretched socio-economic ability in Busia County.

Keywords: Nitrate nitrogen levels; sorghum-soybean intercropping; residue management; n fertilizer rates.

1. INTRODUCTION

Nitrogen (N) is the most deficient nutrient in the soil and more nitrogenous fertilizers are applied annually than other fertilizers [1,2]. Nitrogen is an essential plant nutrient required in large quantities [3] and as a major component of plant protein and enzymes [2,4,5,6]. The nutrient element is abundant in the atmosphere. However, it is inert and cannot be chemically combined with other elements into usable forms by plants [3]. Of the three forms of nitrogen; nitrate, ammonium, and dinitrogen, nitrate is the primary form of mineral N taken up from the soils by many crops [7,8]. This explains why soil testing for nitrate-nitrogen is better than testing for ammonium-nitrogen to predict the sufficiency of soil mineral N supply to crops [8].

Soil fertility improvement has been noted as a basic prerequisite to achieve long term food security and improve farmers' living standards [9,10]. Reports by many authors [11,12,13] pointed out the significance of inorganic fertilizer use to replenish nutrients into the soil. Studies by [1,2] indicated that, application of nitrogen fertilizers improve soil fertility and increase crop productivity. According to [14], nitrogen fertilizer application increased grain yield (43-68%) and biomass (25-42%) in maize. This notwithstanding, crop nitrogen requirements cannot be optimally met solely through use of mineral fertilizer. Further to this, economic constraints among small scale farmers in Western Kenya limit sole inorganic fertilizer use [15]. According to [16], it is necessary to find an additional source of N that would embrace the smallholder socio-economic status.

In addition to inorganic fertilizer use, management of crop residues is an important aspect in improving inherent soil fertility status and can contribute to increase in nutrient recycling and crop yield [17]. Studies by [18,19] pointed out that incorporation of crop residues results to increase in crop growth and yields. Findings by [20] showed that soybean residues returned to the field after harvest contained total N up to as much as 30kg N ha^{-1}. The authors further found out that litter fall that occurs from planting to physiological maturity of the soybean legume constituted a fixed N of 8.2 to 11.8kg N ha^{-1}. Other workers [21] indicated the significance of legumes (alfalfa) as internal input to add N to the soil. On the contrary, burning and removal of residues from the field causes direct loss of plant nutrient and dispossess the soil organic matter which is the sink of these nutrients and a habitat of soil microbes [22]. Though this is so, the norm among the smallholder farmers is to remove the crop, in particular the legumes to shell in the homes and later burn the residues or feed to livestock.

The authors; [23,24] were of the opinion that intercropping is a possible option to improve low inherent soil fertility status in order to enhance crop yields. According to [25], cereal - legume crop intercropping is an alternative and sustainable way of improving soil nitrogen among smallholder production households. Other researchers [26,27,28], have shown that cereal-legume crop farming system results in increased soil fertility, N economy and consequent productivity of the cereal crop. Soybean (*Glycine max*) is among the nitrogen-fixing legumes intercropped with cereals [29]. Grain sorghum (*Sorghum bicolor [r* L. Moench) is a cereal crop that serves as a source of food for most of the world's population [2,10] and has been ranked the third most important staple food in Kenya [30,31].

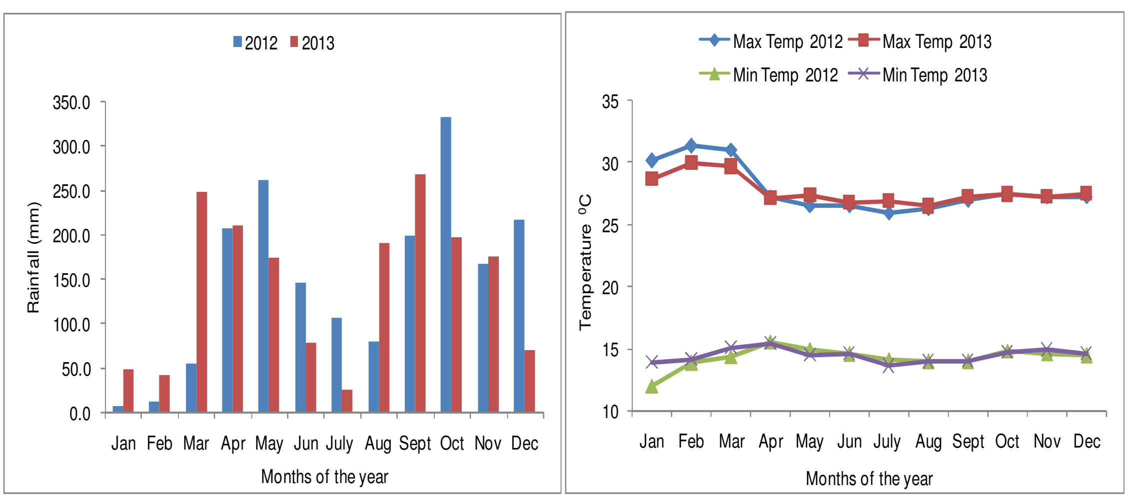
In Western Kenya, the soils are highly weathered, acidic and low in native nutrient status with nitrogen and phosphorus as the most limiting plant nutrients [32,33,34]. Taking into consideration the low inherent soil fertility level and the economic status of the smallholder households [16], it is imperative to find alternative options that can improve the soil nutrient levels and crop yields. An integrated use of nitrogen fertilizer, cereal-legume intercropping and residue management is probably an option to achieve this. However, the outstanding challenge is the economic status, residue management and importance as well as the contribution of nitrogen fixing leguminous intercrops to soil fertility improvement, which is not well understood by smallholder farmers in the region [35]. A better understanding, therefore, is required to optimize nitrogen fertilizer rate and residue management option under cereal-legume intercropping that can improve soil mineral N and sustain crop productivity. In this perspective, the study envisaged to assess effects of nitrogen fertilizer rates and legume residue management options on soil nitrate nitrogen, leaf N contents and yields in sorghum-soybean intercropping system with the specific objectives hereunder:

(i) To determine the effects of nitrogen fertilizer rates and soybean residue management options on soil NO_3-N.
(ii) To determine the effects of nitrogen fertilizer rates and soybean residue management options on leaf NO_3-N contents.
(iii) To assess the yield response of sorghum to nitrogen fertilizer rates and management of intercropped soybean residues.

2. MATERIALS AND METHODS

2.1 Experimental Site

The study was carried out in Busia County, Kenya at Emalomba (N 00°25′28.8″ E 034°15′ 51.9″) Nambale District. The site elevation is 1222m above sea level. Mean monthly rainfall and temperature of the experimental site over a two year period are presented in Fig. 1. The average annual precipitation in the year 2012 was 1784 mm while in the year 2013 it was 1718 mm. The mean maximum temperatures ranged between 26.3°C to 31.3°C in comparison to mean monthly minimum temperature that varied from 12.0°C to 15.5°C in the year 2012. In the year 2013, mean maximum temperature ranged between 26.5°C to 29.9°C in comparison to mean monthly minimum temperatures that varied from 13.6°C to 15.4°C. The experimental site experiences bimodal rainfall with the long rains beginning in March and the short rains in August/September. The rainfall data indicate variation in both the mean monthly amounts received in the years of study as well as the distribution.



(a) Precipitation (2012-2013) **(b) Max. and min. temperature (2012-2013)**

Fig. 1. Climatic data for the experimental site [36]

In the year 2013, more rainfall amounts were experienced at the onset of the long rainy season with a peak in March compared to the year 2012 when lower precipitation amounts were experienced with a peak in the month of May. The short rains in the year 2013 were higher in amount as compared to 2012 though the short rains in the later was prolonged to the end of the year.

Prior to the start of the study, soil samples taken from 0 - 15cm, 15 - 30cm and 30 – 45cm depths were characterized and their physico-chemical properties are presented in Table 1.

The soils depicted sandy clay texture in the plough layer and clayey in the subsoil. Soil pH is strongly acidic with low available phosphorus below the critical value of 7mg/kg. Organic carbon is rated medium and organic matter high [37]. Nitrate nitrogen values were more less the same in the plough layers. This was attributed to the variation of clay with soil depth. Exchangeable calcium is low, while exchangeable magnesium is moderate and exchangeable potassium rated low in 0-15 cm depth and very low in the subsoil [37,38] and has negative implications on soil pH, CEC and nutrient uptake [3]. Initial soil NO_3-N concentration was 23 ppm which was below the critical concentration of 25mg/kg recommended [39,40,41].

The soil is classified as *Kanhaplic Haplustults* in USDA Soil Taxonomy [42] correlating with *Haplic Cutanic Acrisols* in WRB [43].

2.2 Experimental Description

Field experimentation was conducted during the long rains in 2012 and 2013. Each experimental plot measured 3.0m x 4.5m with inter-plot distance of 0.5 m and 2 m between blocks. An outer allowance path of 2m around the experimental plots was considered. Sorghum variety KARI Mtama II, suitable to the climatic conditions of the experimental site was sown at the spacing of 75 cm inter-rows and 15 cm between plants. Soybean variety SB 19 inoculated with Biofix® inoculants and was planted in between the sorghum rows at a spacing of 10cm. Six treatment options were considered;

(i) Sole sorghum (SS),
(ii) Sorghum + soybean left to maturity (SS + SB (maturity),
(iii) Sorghum + soybean residue mulched (SS + SB (maturity),
(iv) Sorghum + soybean residue incorporated (SS + SB (incorporated),
(v) Sorghum + soybean ex-situ (SS + SB (ex-situ) and
(vi) Sorghum + soybean ex-situ and plot tilled (SS + SB (ex-situ and plot tilled).

Table 1. Physico-chemical properties of the experimental site

Parameter	**Soil depth (cm)**		
	0 – 15	**15 – 30**	**30-45**
Clay (%)	30.50	54.10	64.50
Silt (%)	19.20	10.10	3.80
Sand (%)	50.30	35.80	31.70
Textural class	SC	C	C
pH 1:2.5 water	5.45	5.43	5.40
Electrical conductivity ($mScm^{-1}$)	28.00	17.00	17.00
Organic carbon (%)	2.58	2.49	2.49
Total nitrogen (%)	0.29	0.26	0.26
C/N ratio	8.90	9.58	9.58
Organic matter	4.45	4.29	4.29
Nitrate nitrogen (mg/kg)	23.00	19.20	20.7
Avail. P Mehlich-3 ($mgkg^{-1}$)	1.44	0.49	0.44
CEC NH4OAc cmol(+)kg^{-1} soil	14.6	11.20	11.60
Exch. Ca (cmol(+) kg^{-1}	3.00	2.28	2.32
Exch. Magnesium (cmol(+) kg^{-1}	1.31	1.00	1.03
Exch. Potassium (cmol(+) kg^{-1}	0.23	0.07	0.08

SC= Sandy clay, C= Clay
Source: Field experimentation data, 2012

The term ex-situ is used in reference to removal of soybean residues from the experimental plots while in-situ revfers to soybean residues being managed within the experimental plots. Triple super phosphate ($Ca(H_2PO_4)_2.H_2O$) was applied uniformly to all the treatments during planting by broadcasting and mixing with soil at rate of 20kg Pha^{-1}. Three levels of nitrogen (0kg N ha^{-1} = N_0, 40kg N ha^{-1} = N_{40}, and 80 kg N ha^{-1} = N_{80}) as urea ($CO(NH_2)_2$ was applied 42 days after emergence to sorghum plants as a top dress by banding. The treatments were arranged in a randomized complete block design with three replications. Soybean residue management options as described in the treatments were carried out 55 days after emergence before pod formation by soybeans.

2.3 Field Determination of Soil and Leaf Nitrate Nitrogen

To estimate nitrate-nitrogen (NO_3-N) concentrations in the soil and leaf blade of sorghum, on-farm measurement using ion selective electrode (ISE) as described by [44, 45, 46] was adopted. According to [47], ISE has a clear potential for use in rapid on-farm determination of soil NO_3-N.

Three soil samples from each plot were randomly collected by augering at three depths i.e. 0 - 15 cm, 15-30cm and 30-45cm and each time putting in sealed plastic bags. The respective samples were then mixed thoroughly to obtain a representative sample for determination of soil NO_3-N concentrations. The composite soil samples in sealed plastic bags were placed in cooler box to protect from heat. Soil solution of each composite was extracted by mixing soil with water at the ratio of 1:5 (10 g of soil + 50 mls of water) and 10mls of calcium chloride was added. The sample was thoroughly shaken for 2 minutes until all the soil clumps had thoroughly dispersed. The sample was left to settle until a clear zone of solution formed at the top of the tube. The ISE meter was calibrated with two standard solutions for NO_3-N which was included in the kit. Using a dropper, 2 - 3 drops of the clear solution was put on the meter sensor. Once the meter reading stabilized (after 30 - 40 seconds) the value for NO_3-N concentration was recorded. Determination of soil NO_3-N concentrations was performed in duplicate for each treatment and average recorded.

Leaf nitrate nitrogen was determined by selecting randomly, recently matured leaves from the sorghum plants. From each experimental plot, three sorghum leaf blades were selected, placed in sealed plastic bags and put in cooler boxes until leaf samples from all experimental plots had been collected. At the end of the sample collection, the leaves were rinsed with distilled water and blot dried with a paper towel. Direct sunlight and/or high temperatures were avoided during meter reading. With a sharp knife and on a cutting board, leaf blades were chopped and put in a plastic bag. The samples were then punched using a hand hammer to extract the juice. The corner of the bag bottom was cut to puncture the plastic bag then squeezed to obtain juice. The juice was then dropped to the nitrate meter sensor (about 0.3ml) to cover the sensor. The measurement values were then read off and recorded once the meter reading stabilized. Leaf NO_3-N concentrations were determined in duplicate for each treatment and average recorded. A forth-night sampling interval starting from 20 days after emergence up to physiological maturity of sorghum was undertaken to monitor the trends of both soil and leaf nitrate nitrogen. Prior to harvest, an area of 2x2m was demarcated for measurement of crop yields.

2.4 Statistical Data Analysis

All data were analyzed using ANOVA in GenStat software [48]. Significant treatment effects were tested using the least significant difference at an alpha level of 0.05.

3. RESULTS AND DISCUSSION

3.1 Effects of Nitrogen Fertilizer Rates and Soybean Legume Residue Management Options on Soil NO_3-N

3.1.1 Soil NO_3 -N concentrations as affected by soil depth during the growing season of 2012 and 2013

3.1.1.1 Top soil (0 – 15 cm)

The trends of soil NO_3-N concentration over the growing period to physiological maturity for the years 2012 and 2013 are presented in Fig. 2. The background soil NO_3-N concentration (Table 1) in the plough layer was 23mg kg^{-1} that is below the recommended critical concentration of 25mg/kg [39,40]. In the first sampling (20 days after emergence) NO_3-N concentration increased by more than two times the initial concentration in the year 2012. Before the onset of rains, soil contains mostly organic nitrogen (N) as well as some ammonia and a little inorganic NO_3-N [3]. Thus, the increase in NO_3-N is attributed to nitrogen flush that probably occurred after the onset of the rains. Between the first and second sampling soil NO_3-N indicated a plateau in the year 2012. This was thought to be as a result of sustained soil NO_3-N derived from decomposition and mineralization of organic materials from previous crop. The site soils had C/N ratio ranging from 8.9 to 9.6 which indicates good quality organic matter [37]. Through decomposition of organic matter, nutrients; nitrogen, phosphorus, potassium and sulphur are recycled into the soil [3].

Sampling at 48 days after emergence shows a notable increase in soil NO_3-N in both years with a lower rate of increase, however in 2013 compared to 2012. The increase was attributed to nitrogen fertilizer application as a top dress to sorghum crop at 42 days after emergence. According to [13], application of inorganic fertilizers increases plant nutrients in the soil. As the crop growth and development continued in the growing season, demand for NO_3-N increased (Fig. 5) thus, reducing the concentration of the nutrient in the soil.

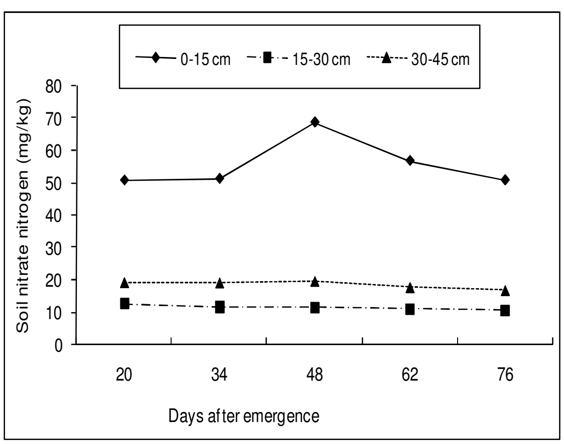
In the year 2013, the results of soil NO_3-N concentration showed a sharp drop at second sampling period. This was attributed to the amount of precipitation that was received in the months of March and April (Fig. 1) that probably resulted to leaching of the nutrient to lower soil depths as observed in the recorded NO_3-N in the subsoil. The decrease is also presumed to be as a result of under-developed plant root system, thus, NO_3-N losses could have occurred at this period of sampling.

3.1.1.2 Subsoil (15 – 30 cm and 30 – 45 cm)

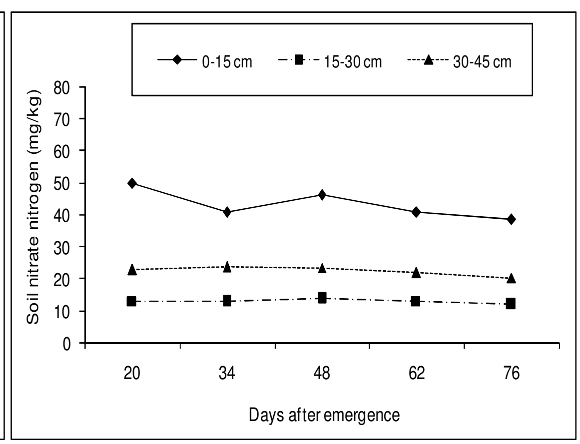
Taking into consideration the soil NO_3-N in the subsoil both years show leaching from the plough layer, further leaching from 15–30cm and consequent accumulation in 30–45cm depth. The accumulation in the subsoil is attributed to the texture of the soils in the site that had more sand in the plough layer in contrast to the clay content in the subsoil of which higher content is noted in the 30–45cm depth. Similar findings of soil NO_3-N in the subsoil were reported by [49]. Studies by [50] indicated that sand content in the soil has negative implication on the retention capacity of soil.

3.1.2 Nitrate-nitrogen (NO_3-N) as Affected by Soil Depth, Nitrogen Fertilizer Rates and Soybean Residue Management options During the Growing Season of 2012 and 2013

The comparison of effects of nitrogen fertilizer rates and soybean residue management options with respect to soil depth in the years 2012 and 2013 are given in Table 2.



(a) Year 2012



(b) Year 2013

Fig. 2. Soil NO_3-N concentrations over the sampling period with respect to soil depths in the years 2012 and 2013

3.1.2.1 Topsoil (0 – 15cm)

Soil NO_3-N concentrations increased with increased nitrogen fertilizer application rates under the intercropping system. The control treatments recorded the lowest soil NO_3-N concentrations implying the importance of use of inorganic fertilizers with respect to soil N. Nitrogen fertilizer application at 40kg N ha^{-1} with respect to legume residue management was in the order: sorghum + soybean left to maturity > sorghum + soybean residue mulched > sorghum + soybean residue incorporated > sorghum + soybean exsitu > sorghum + soybean exsitu and till > sole sorghum. It is imperative to note that experimental plots with soybean residues removed had significantly ($P<0.001$) lower NO_3-N concentrations. At 80kg N ha^{-1} the experimental plots with residues removed had the same trend. However, the trend in relation to soybean residue management was: sorghum + soybean left to maturity < sorghum + soybean mulched < sorghum + soybean incorporated. The reversed trend at higher N fertilizer application is attributed to synergistic effects of immediate legume residue decomposition and nitrogen fertilizer applied which perhaps improved the efficiency of each other [51].

Sole sorghum as well as sorghum with soybean residue removed from the experimental plots at flowering and those with plots tilled thereafter recorded the lowest concentrations of NO_3-N. The results from sole sorghum treatments suggest that intercropping has a positive influence on soil N. The findings confirm report by other workers [23,24,28,49] on the role intercropping plays in introducing N into the soil. Removal of the soybean residues from the experimental plots decreased the concentration of soil NO_3-N and agrees with the report of [22] that residue removal from the field causes direct loss of plant nutrients.

There were significant ($P<0.001$) differences between soybean left to maturity, residue mulched and residue incorporated in the order: sorghum + soybean residue left to maturity > sorghum + soybean residue mulched > sorghum + soybean residue incorporated. The findings on soybean left to maturity and those mulched agree with those reported by [20] who reported on the significance of litter fall of soybean that occur from planting to physiological maturity.

Soil NO_3-N concentrations was improved with incorporation of legume residue at flowering. The results are in agreement with work reported by [52] who indicated legume residue incorporation improved soil N due to immediate decomposition. The findings are comparable with results of [21] who pointed out that incorporation of alfalfa increased soil N. In the year 2013, sorghum + soybean left to maturity indicated significant ($P<0.001$) NO_3-N but much lower compared to the year 2012. Mulched and incorporated legume residues had no significant difference on NO_3-N concentrations. The low NO_3-N concentrations in the year 2013 is attributed to rainfall amounts (Fig. 1) that probably led to more leaching of NO_3-N as indicated in 30 - 45 cm depth (Fig. 2). These results are supported by other researchers e.g. [49], who pointed out the influence of soil moisture (precipitation) on soil NO_3^--N concentrations in the soil profile.

Table 2a. Soil NO_3-N in relation to soil depth, nitrogen fertilizer rates and soybean residue management options in the year 2012

Soybean residue management option	0 - 15 cm			Soil depth 15 - 30 cm			30 - 45 cm		
	Fertilizer rate (kg N ha^{-1})								
	0	40	80	0	40	80	0	40	80
Sole sorghum	47.15	49.58	50.22	10.74	11.44	11.74	17.36	18.24	19.28
Sorghum+soybean (Maturity)	55.42	61.80	65.26	11.20	11.50	11.70	17.40	18.62	19.48
Sorghum+soybean (residue mulched)	55.62	60.06	65.72	11.33	11.30	11.59	17.29	17.84	18.52
Sorghum+soybean (residue incorporated)	53.29	59.56	66.52	10.76	11.16	10.93	17.06	17.64	17.89
Sorghum+soybean (residue exsitu)	50.08	53.67	57.36	10.59	10.57	11.27	17.44	18.70	20.19
Sorghum+soybean (residue exsitu +Till)	50.62	49.73	51.02	10.85	11.02	11.10	17.38	18.60	19.68

P value <.001;L.s.d $_{(0.05)}$ (Soybean residue management option) 0.31

Table 2b. Soil NO_3-N in relation to soil depth, nitrogen fertilizer rates and soybean residue management options in the year 2013

Soybean residue management option	0 - 15 cm			Soil depth 15 - 30cm			30 - 45cm		
	Fertilizer rate (kg N ha^{-1})								
	0	40	80	0	40	80	0	40	80
Sole sorghum	41.33	42.17	42.64	10.34	11.38	12.15	20.31	21.21	21.58
Sorghum+soybean (Maturity)	43.15	44.14	44.88	12.91	14.47	15.73	22.39	23.74	24.60
Sorghum+soybean (residue mulched)	43.32	44.53	43.83	13.26	14.84	13.82	22.65	23.97	23.19
Sorghum+soybean (residue incorporated)	42.32	43.61	43.92	11.79	13.60	14.00	21.36	22.95	23.38
Sorghum+soybean (residue exsitu)	41.69	43.22	43.46	10.78	13.06	13.43	20.69	22.52	22.78
Sorghum+soybean (residue exsitu +Till)	42.02	42.47	42.75	11.02	12.02	12.30	20.96	21.47	21.72

P value ;<.001;L.s.d.$_{(0.05)}$ (Soybean residue management option) 0.28

There was no significant difference between incorporation and mulching of the legume residues in the year 2013 and this is attributed to rapid loss of released N via decomposition through percolation of water to deeper soil depths.

3.1.2.2 Subsoil (15 – 30 cm, 30 – 45 cm)

Leaching of NO_3-N to lower soil depths was evident in all the treatments indicating a linear increase with increased N fertilizer rate applied. The loss of NO_3-N to subsoil was attributed to leaching via percolating water due to the sand content of the topsoil in the study site. The findings point out the need to emphasize use of organic fertilizers and intercropping to build above and below ground biomass to improve ion retention capacity of the topsoil.

3.1.3 Soil Nitrates Response to Interactive Effects of Days After Emergence, Nitrogen Rates and Legume Residue Management Options During The Growing Season of 2012 and 2013

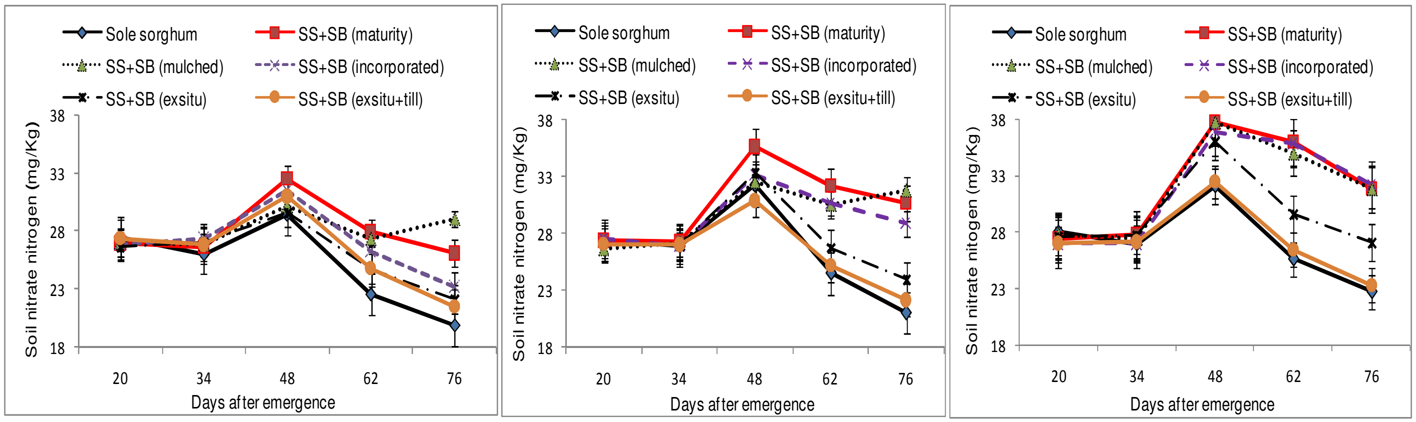
The interactive effects of days after emergence, nitrogen fertilizer rates and legume residue management options on soil NO_3-N for both years are presented in Fig. 3. Soil NO_3-N concentration varied significantly ($P<0.01$) with sampling time as well as between treatment and reflected a similar trend as presented in Fig. 1 and as reported in 3.1.2. It is notable however that sorghum with mulched soybean showed higher concentrations at late days of plant growth at 40 and 80kg N ha^{-1} indicating that mineralization of the residues continues even as the crop approaches physiological maturity.

Nitrogen fertilizer application at 40kg N ha^{-1} and 80 kg N ha^{-1} indicated no significant differences in soil NO_3-N concentrations with respect sorghum + soybean left to maturity. These findings suggest nitrogen fertilizer application at 40kg N ha^{-1} with soybean left to maturity to be a potential optimum rate and soybean residue management option to improving soil N among small scale households with stretched socio-economic ability as reported by [15].

In the year 2013, sorghum + soybean residue mulched recorded slightly higher NO_3-N concentrations though not significantly different from the soybean residues left to maturity and incorporated. The trend of results obtained probably can help in determining the NO_3-N concentrations at different stages of plant growth and assessing the supply of NO_3-N from soil under cereal-legume intercropping and the break-even where NO_3-N concentrations translate to yields.

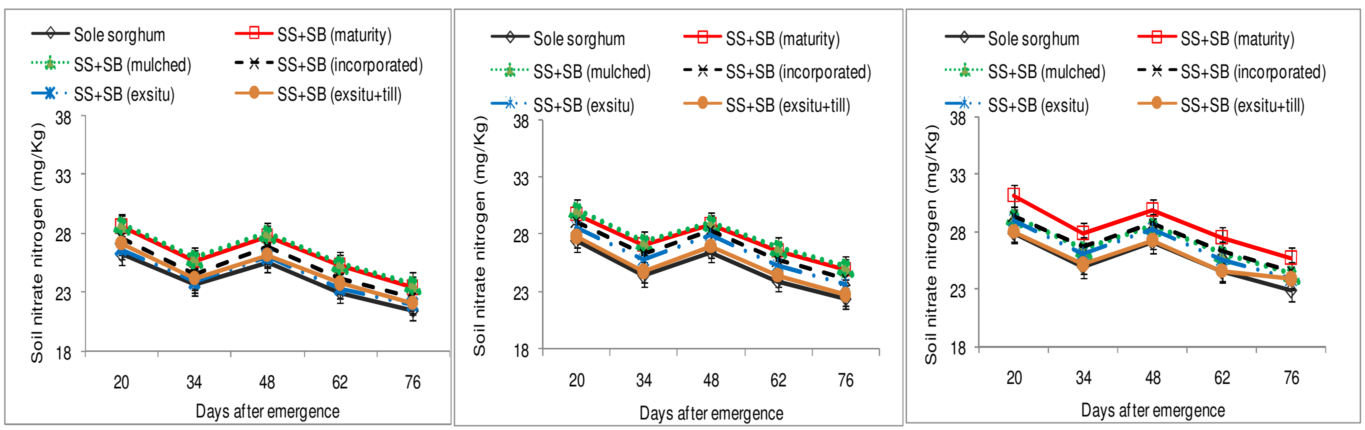
3.1.4 Effects of Nitrogen Fertilizer Rates on Soil NO_3-N with Respect to Soybean Residue Management Options During the Growing Season of 2012 and 2013

Combined effects of three rates of N fertilizer and soybean residue management options on soil NO_3-N concentrations in the years 2012 and 2013 are presented in Fig. 4. The data indicate increase in NO_3-N concentrations with increase in nitrogen fertilizer rates in both years.



(a) 0kg N ha^{-1} (b) 40kg N ha^{-1} (c) 80kg N ha^{-1}

Fig. 3a. Soil NO_3-N response to days after emergence, soybean residue management options and nitrogen rates in year 2012



(a) 0kg N ha^{-1} (b) 40kg N ha^{-1} (c) 80kg N ha^{-1}

Fig. 3b. Soil NO_3^--N response to days after emergence, soybean residue management options and nitrogen rates in year 2013

The results further highlight significant ($P \leq 0.001$) difference in nitrogen fertilizer rates applied as top dress. The control treatments had lower nitrate values with sole sorghum giving lower values compared to the other controls. This implies that intercropping plays a role in addition of nitrates to the soil during the growing period of the current crop and this is in agreement with the findings of [51,21].

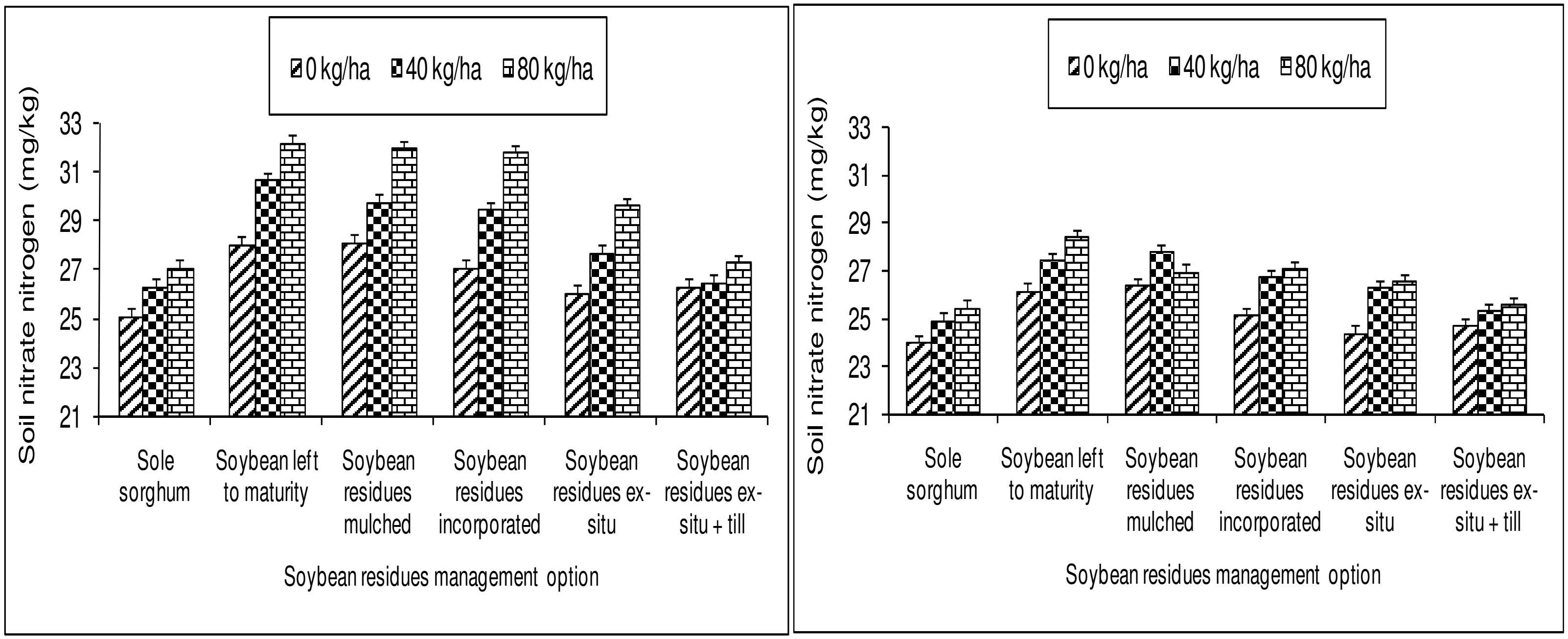
Intercropped sorghum with soybean left to maturity showed high ($P \leq 0.001$) NO_3-N concentrations in all the treatments in both years. There was no significant difference between incorporated and mulched soybean residue at 40 kg N ha^{-1} in comparison to exsitu soybean residue at 80kg N ha^{-1} in year 2012. Sorghum intercropped with soybean left to maturity at 40 kg N ha^{-1} resulted into higher ($P \leq 0.001$) soil NO_3-N concentration than the other management options at same N fertilizer levels. The results further indicate that sole sorghum as well as soybean residue removal from the fields has negative implications on soil fertility improvement and management as shown by the levels of soil NO_3-N recorded. The lower soil NO_3-N concentrations recorded in the year 2013 compared to the year 2012 gives a reflection of soil NO_3-N dynamics and the influence of climatic conditions as reported by [49].

It is worth noting that in the year 2012, soil NO_3-N concentration above 29mg kg^{-1}, had no significant differences irrespective of N fertilizer rates in respect to insitu soybean residue management options (soybean residues mulched, left to maturity and incorporated). At 80kg N ha^{-1} there was more less a plateau as soil NO_3-N concentration approached 33 mg kg^{-1} in reference to insitu soybean residue management options. The findings indicate that soil NO_3-N concentration at 29mg kg^{-1} meets the crop demand for soil N during the cropping season and nutrient concentrations above 33 mg kg^{-1} may result to leaching of the nitrates. The findings of this study agrees with report by [40] who reported that 31mg kg^{-1} was probably the optimum soil NO_3-N concentration that meets the crop N demand during the growing season and that concentrations above this optimum level does not translate to yield increase but supports N over application. In the year 2013, rainfall amounts and distribution had an influence on observed soil NO_3-N concentrations and this is in agreement with report by [53] who pointed out the influence of environmental factors on NO_3-N.

3.2 Effects of Days after Emergence, Nitrogen Fertilizer Rates and Soybean Residue Management Options on leaf NO_3^--N Concentrations during the year 2012 and 2013

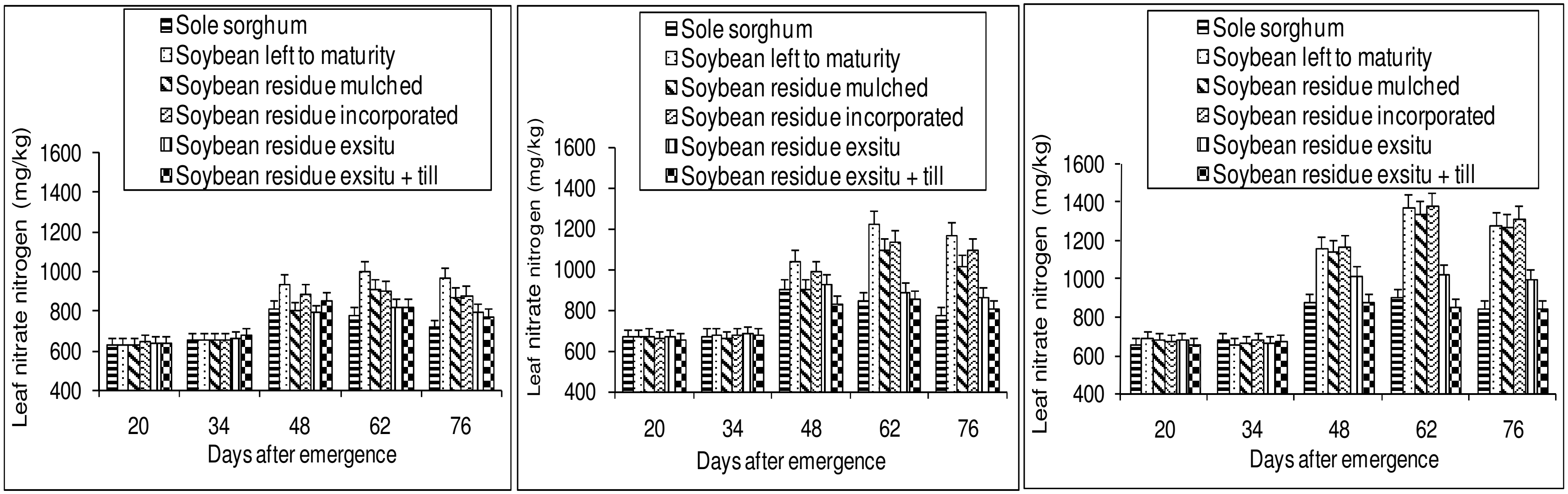
Variations of leaf NO_3-N concentrations in response to days after emergence, nitrogen fertilizer rates and soybean residue management options is given in Fig. 5. The findings depict lower leaf NO_3-N concentrations at the early stage of development and this is attributed to underdeveloped plant rooting system. The leaf nitrate values increased with progressive sampling periods with a decrease noted as the crop leaf senesced. The increase in concentration was presumed to be as a result of fertilizer application as well as supply from soybean residues. The findings agree with report by [54] that was of the opinion that legumes have a potential to transfer N to cereal crop during the growing season and probably result to increased fixing ability of the soybean and the transfer from the legume to cereal as suggested by [55]. Other researchers [18,19,20] pointed out the significance of return of crop residues to the field after harvest to take advantage of the total N through nutrient recycling which can be up to as much as 30 kg N ha^{-1}. The authors further found out that litter fall that occur from planting to physiological maturity of the soybean legume constituted a fixed N of 8.2 to 11.8kg N ha^{-1}. In addition, [21] reported on the contribution of nitrogen fixing legumes to soil N improvement.

Variation of leaf NO_3-N concentrations in the year 2012 and 2013 is evident indicating the difference in supply of soil N via inorganic fertilizers and that derived from soybean residues with respect to rainfall amounts and distribution (Fig. 1) in the years of study. Lower leaf NO_3-N concentrations (highest: approximately 1000 mg/kg) in the year, 2013 were attributed to more precipitation in comparison to the year, 2012 where the highest leaf NO_3-N concentration was approximately 1200mg/kg. The rainfall is presumed to have probably washed away soil N supplied via mineral fertilizer and soybean residues was presumed to have decomposed slowly to supply the plant required N. The findings are in agreement with [56] who showed that rainfall has a negative influence on soil N through leaching.



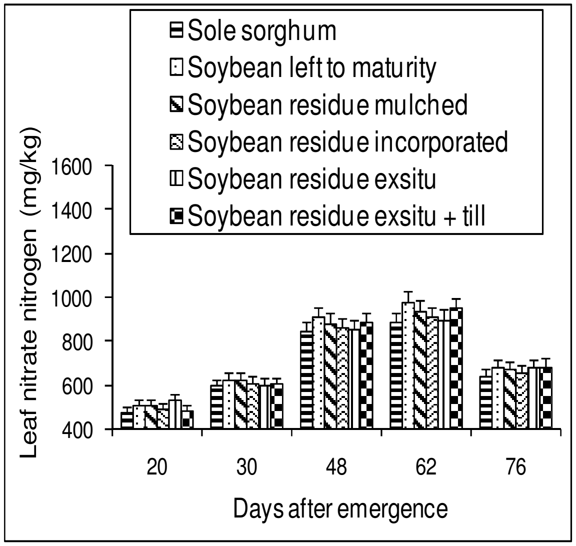
(a) Year 2012 **(b) Year 2013**

Fig. 4. Soil nitrate-nitrogen concentrations in response to nitrogen fertilizer rates and soybean residue management options in the years 2012 and 2013

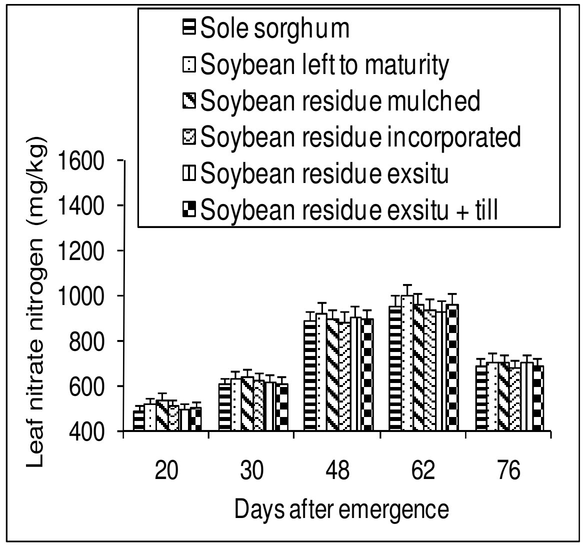


(a) 0 kg N ha^{-1} **(b) 40 kg N ha^{-1}** **(c) 80 kg N ha^{-1}**

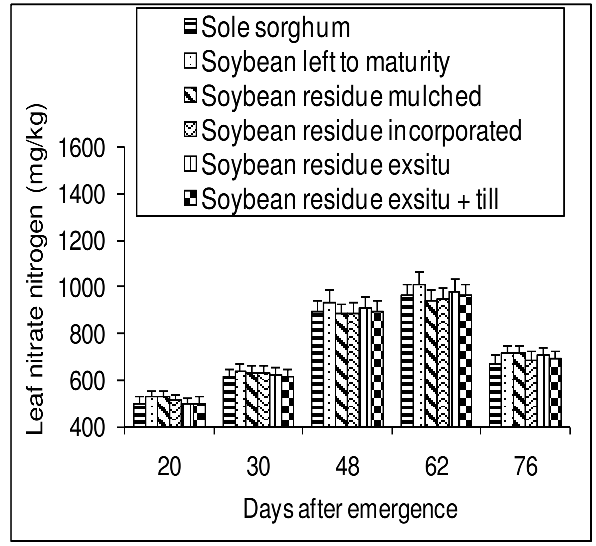
Fig. 5a. Leaf nitrate levels in respect to fertilizer rates and soybean residue management options in year 2012



(a) 0 kg N ha^{-1}



(b) 40 kg N ha^{-1}



(c) 80 kg N ha^{-1}

Fig.5b. Leaf nitrate levels in respect to fertilizer rates and soybean residue management options rates in year 2013

The decrease in NO_3-N concentrations as the crop senesced is in agreement with report by other workers [57,58] who reported a decrease in NO_3-N under intercropping at harvest. The results further indicated variation of nitrate levels in the years of study with the year 2012 showing higher NO_3-N concentrations in comparison to the year 2013 suggesting the possible effects of precipitation amounts and distribution on leaf uptake.

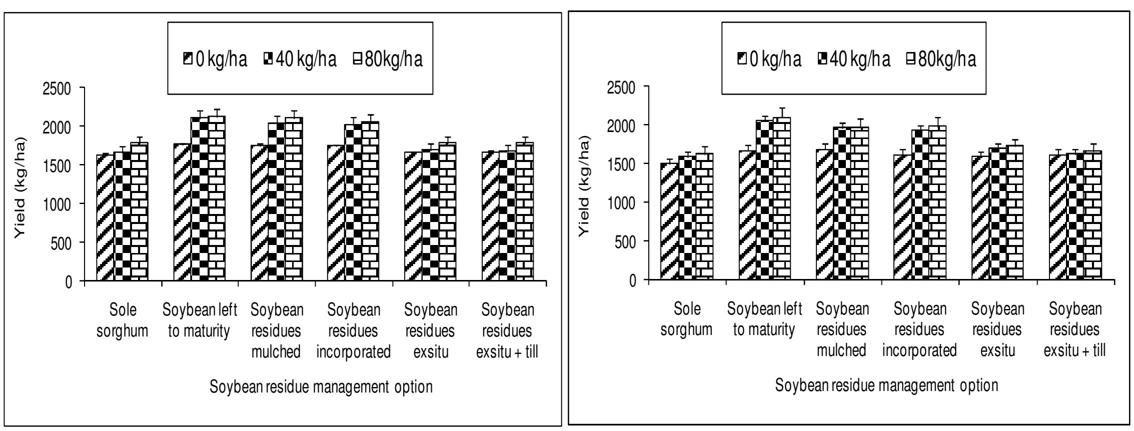
3.3 Yield Response of Sorghum to Nitrogen Fertilizer Rates and Soybean Residue Management Options during the Growing Season of 2012 and 2013

Sorghum yield data in response to soybean residue management and N fertilizer rates are given in Fig. 6. The control and treatments where soybean residues were removed gave lower yields than where residues were retained and with no significant differences with rate of nitrogen fertilizer applied.

In both years plots with soybean residues left to maturity, mulched or incorporated had significantly ($P<0.01$) higher yields compared to control and experimental plots with sole sorghum and those whose residues were removed off field. The results are in agreement with report of other researchers [18,19,28] who reported increase in yield under intercropping.

The results on yield shows no significant difference between nitrogen fertilizers applied at 40kg N ha^{-1} and 80kg N ha^{-1} irrespective of soybean left to maturity, legume residues mulched or incorporated in both years of study. The yields in the year 2013 however, were lower compared to year 2012.

The results thus, point out that in terms of food security and soil fertility improvement intercropping of sorghum + soybean left to maturity in combination with application of nitrogen fertilizer at 40 kg N ha^{-1} application could be probable option for adoption by the smallholder farmers in Busia County. It is worth noting however that though N fertilizer application at 40 kg N ha^{-1} with soybean left to maturity has a potential to supply the plant required NO_3-N, N supply through this management option does not translate to optimum sorghum yield (3 tonnes) in western Kenya according to [59]. There is speculation, therefore that other nutrients inter-related to nitrogen could be deficient. Researchers [60, 61] indicated that there is a strong relationship between sulphur and nitrogen nutrition. The researchers pointed out that both nutrients are inter-related and play significant role in protein synthesis and that lack of sulphur limits efficiency of added N implying that S addition might be necessary to achieve optimum efficiency of N supply in the study sites.



(a) Year 2012 **(b) Year 2013**

Fig. 6. Sorghum yields (kg ha^{-1}) in response to soybean residue management options and nitrogen fertilizer rates in year 2012 and 2013

4. CONCLUSION

The following conclusions were derived from the results of the study:

- Soil NO_3-N is dynamic and is influenced by soil particle distribution, soil depth, precipitation amounts and distribution and it varies during crop growth and development.
- Application of nitrogen fertilizer in combination with soybean residue management have synergistic effects of increasing soil NO_3-N and yield while removal of residues off the field dispossess the soil of the nutrient.
- Intercropped sorghum with soybean left to maturity indicated high NO_3-N concentrations in all the treatments in both years. In addition, sorghum intercropped with soybean left to maturity with nitrogen fertilizer applied at 40 kg N ha^{-1} reflected higher soil NO_3-N concentration in comparison to the other management options.
- Leaf NO_3-N is influenced by rainfall amounts and distribution and fertilizer supply via mineral fertilizer should be synchronized with crop demand during growing season to reduce leaching of soil N.
- In terms of food security and soil fertility improvement, intercropping of sorghum + soybean left to maturity in combination with application of nitrogen fertilizer at 40 kg N ha^{-1} application could be probable option for adoption by the smallholder farmers in Busia County.

5. RECOMMENDATIONS

The conclusions given leads to the following recommendations;

- Nitrogen fertilizer application at 40kg N ha^{-1} with soybean left to maturity under sorghum-soybean intercropping is recommended as an optimum rate and legume residue management option to improve soil NO_3-N among small scale households with stretched socio-economic ability in Busia County.
- A shorter assessment interval of NO_3-N during the growing season of crops is recommended as a further research to establish NO_3-N concentration that translates to expected yields.
- Further research on sulphur in relation to nitrogen be carried out to provide a balanced fertilizer recommendation for optimum sorghum yields in Busia County.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Habtegebrial K, Singh BR, Haile M. Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef *Eragrostis*, *Trotter* and soil properties. Soil and Tillage Research. 2007;94:55-63.
2. Soil Science Society of America. Know soil know life. Edited by Lindbo DA, Kozlowski DA, Robinson C. United States of America; 2012.
3. Brady NC, Weil RR. The nature and properties of soils. 14th Edition. Pearson Education, Inc; 2008.
4. Zhao D, Reddy KR, Kakani VG, Reddy VR. Nitrogen deficiency effects on plant growth, leaf photosynthesis and hyper spectral reflectance properties of sorghum. European Journal of Agronomy. 2005;22:391-403.
5. Barker AV, Pilbeam D. Handbook of plant nutrition. Taylor and Francis, London, New York. 2007;662.
6. Taiz L, Zeiger E. Plant Physiology, 5th Edn. Sinauer Associates Inc. Sunderland, MA, USA; 2010.
7. Miller AJ, Fan X Shen Q, Smith SJ. Amino acids and nitrate as signals for the regulation of nitrogen acquisition. Journal of Experimental Botany. 2008;59(1):111-119.
8. Uwah EI, Abah J, Ndahi NP, Ogugbuaja VO. Concentration levels of nitrate and nitrite in soils and some leafy vegetables obtained in Maiduguri, Nigeria. Journal of Applied Science in Environmental Sanitation. 2009;4(3):233-244.
9. International Food Production Research Institute. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system; 2010.
10. Jensen ES, Peoples MB, Boddey RM, Gresshoff PM, Hauggaard-Nielsen et al. Legumes for mitigation of climate change and provision of feedstock for biofuels and biorefineries. Agronomy for Sustainable Development. 2012;32:329-364.

11. Okalebo JR, Othieno CO, Woomer PL, Karanja NK, Semoka JRM, et al. Available technologies to replenish soil fertility in East Africa. Nutrient Cycling Agro ecosystems. 2006;76:153-170.
12. Vanlauwe B, Tittonell P, Mukalama J. Within-farm soil fertility gradients affect response of maize to fertilizer application in western Kenya. Nutrient Cycling Agro ecosystems. 2006;76:171-182.
13. Ngome AF, Becker M, Mtei KM, Mussgnug M. Fertility management for maize cultivation in some soils of Kakamega, Western Kenya. Soil Tillage Research. 2011a;117:69-75.
14. Ogola JBO, Wheeler TR, Harris PM. Effects of nitrogen and irrigation on water use of maize crops. Field Crop Research. 2002;78:105-117.
15. Ministry of Agriculture. Adaptation to Climate Change and Insurance. Climate risk and vulnerability profiles for Homa Bay and Busia Counties, Kenya. Government Printers, Nairobi. 2013;37.
16. Kiani MJ, Abbasi MK, Rahim N. Use of organic manure with mineral nitrogen fertilizer increases wheat yield at Rawalakot Azad Jammu and Kashmir. Archives of Agronomy and Soil Science. 2005;51:299-309.
17. Johnson JMF, Karlen DL, Andrews SS. Conservation considerations for sustainable bioenergy feedstock production: If what, where, and how much? Journal of Soil and Water Conservation. 2010;65(4): 88a-91A.
18. Rachid M. Effects of residue management and cropping systems on wheat yield stability in a semi-arid Mediterranean clay soil. American Journal of Plant Sciences. 2011;2(2): 202-216.
19. Jan MT, Khan MJ, Khan A, Arif M, Farhatullah Jan D, Afridi MZ. Increasing wheat productivity through source and timing of nitrogen fertilization. Pakistan Journal of Botany. 2011;43(2): 905-913.
20. Kihara J, Martius C, Bationo A, Vlek PLG. Effects of tillage and crop residue application on soybean fixation in a tropical Ferrasol. Agriculture. 2011;1:22-37.
21. Kamkar B, Akbari F, Da Siliva JAT, Naeni SAM. The effect of crop residue on soil nitrogen dynamics and wheat yield. Advances in Plants and Agriculture. 2014;1(1):00004:1-7.
22. Blanco-Canqui H, Lal R. Crop residue removal impacts on soil productivity and environmental quality. Critical review. Plant Science. 2009;28(3):139-163.
23. Sanginga N, Woomer PL (eds). Integrated soil fertility management in Africa: Principles, practices and developmental process. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 2009;263.
24. Mucheru-Muna M, Pypers P, Mugendi D, Kung'u J, Merckx R, et al. Staggered maize-legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. Field Crops Research. 2010;115:132-139.
25. Fustec J, Lesuffleur F, Mahieu S, Cliquet JB. Nitrogen rhizodeposition of legumes. A review. Agronomy Sustainable Development Journal. 2010;30:57-66.
26. Gosh PK, Bandypadhyay KK, Wanjari RH, Manna MC, Mishra AK, et al. Legume effect for enhancing productivity and nutrient use efficiency in major cropping systems – An Indian perspective: A review. Journal of Sustainable Agriculture. 2007;30 (1):61-86.
27. Sharma AR, Behera UK. Recycling of legume residues for nitrogen economy and higher productivity in Maize (*Zea mays*) – wheat (*Triticum aesticum*) cropping system. Nutrient Cycling Agro Eco Systems. 2009;83:197-210.
28. Lithourgidis AS, Dordas CA, Damals DA, Vlachotergios DN. Annual intercrops: An Alternative Pathway for Sustainable Agriculture. Australian Journal of Crop Science. 2011;5(4): 396-410.
29. Kadam GL. Yield and monetary returns from sorghum and soya bean intercropping. Karnataka Journal of Agricultural Sciences. 2010;18(13):112-123.
30. Alliance for a Green Revolution in Africa. Africa agriculture; Focus on staple crops. Nairobi, Kenya. 2013;204.
31. Ministry of Agriculture. Food security assessment report. Government printers, Nairobi; 2013.
32. Kifuko MN, Othieno CO, Okalebo JR, Kimenye LN, Ndungu KW, et al. Effect of combining organic residues with Minjingu phosphate rock on sorption and availability of phosphorus and maize production in acid soils of western Kenya. Experimental Agriculture. 2007;43:51-66.
33. Opala PA, Othieno CO, Okalebo JR, Kisinyo PO. Effects of combining organic

materials with inorganic phosphorus sources on maize yield and financial benefits in Western Kenya. Journal of Experimental Agriculture 2009;46(1):23 – 34.
34. Kisinyo PO, Gudu SO, Othieno CO, Okalebo JR, Opala PA, et al. Effects of lime, phosphorus and rhizobia on *Sesbania sesban* performance in a Western Kenyan acid soil. African Journal of Agricultural Research. 2012;7(18):2800-2809.
35. Mahasi JM, Vanlauwe B, Mursoy RC, Mbehero P, Mukalama J. Increasing productivity of soybean in Western Kenya through evaluation and farmer participatory variety selection. Proceedings of the 12th Kenya Agricultural Research Institute Biennial Scientific conference, 8th -12th November, 2010, Nairobi, Kenya; 2011. Available: [http://www.kari.org/biennialconference/.htm] site visited on 12/06/2014.
36. Kenya Meteorological Department. Rainfall and temperature data for the period 2012 – 2013. Nairobi, Kenya; 2014.
37. Landon JR. Booker tropical soils manual: A Handbook for soil survey and agricultural land evaluation in the Tropics and Subtropics. New York: John Wiley & Sons; 1991.
38. Pam H, Murphy B. Interpreting soil test results: What do all the numbers mean? CSIRO publishing. 2007;160.
39. Blackmer AM, Pottker D, Cerrato ME, Webb. Correlation between soil nitrate concentration in late spring and corn yields in Iowa. Journal of Production Agriculture. 2013;2(2):103-109.
40. Bast LE, Mullen RW, Eckert DJ, Thomson PR. Evaluation of Pre-side dress soil nitrate test in Ohio. American Society of Agronomy. 2012;11(1).
41. Heckman JR. Monitoring plant and soil nitrogen status in high yield corn environment Mid-Atlantic. Grain and Forage Journal; 2006.
42. Soil Survey Staff. Keys to soil taxonomy. 11th edition. United States Department of Agriculture. NRCS, Washington DC. 2006;346.
43. IUSS Working Group World Reference Base. World reference base for soil resources 2006, first update 2007. World soil resources reports No. 103, FAO, Rome; 2007.
44. Hartz TK, Smith RF, Schulback KF, LeStrange M. On-farm nitrogen tests improve fertilizer efficiency, protect ground water. California Agriculture 1994;48(4):29-32. Univ. Cal., DANR.
45. Hartz TK, Bendixen WE, Wierdsma L. The value of preside dress soil nitrate as a nitrogen management tool in irrigated vegetable production. Horticultural Science 2000;35:651–656.
46. Westervert SM, McKeon AW, McDonald MR, Scott-Dupree CD. Assessment of nitrate meter for nitrogen tests in mineral and organic soils. Journal of Vegetable Science 2005;1(1):17-32.
47. Shaw R, Williams AP, Miller A, Jones DL. Assessing the potential for ion electrodes and Dual wavelength UV spectroscopy as a rapid on-farm determination of soil nitrate concentration. Agriculture 2013;3:327-341.
48. GENSTAT. Introduction to Gen Stat version 13.2 for windows. Statistical Services Centre. University of Reading, United Kingdom. 2010;39.
49. Phiri AT, Weil RR, Yobe G, Phiri K, Msaky JJ, Mrema J, Grossman J, Harawa R. Insitu assessment of soil nitrate-nitrogen in the pigeon pea-groundnut intercropping-maize rotation system: Implications on nitrogen management for increased maize productivity. International Research Journal of Agriculture and Soil Science. 2014;4(2):13-29.
50. Vagen TG, Winowieck LA. Mapping of soil organic carbon stocks for spatially explicit assessments of climate change mitigation potential. Environmental Research Letters 2012;(8): 9-10.
51. Jan T, Jan MT, Arif M, Akbar H, Ali S. Response of wheat source, type and time of nitrogen application. Sarhad Journal of Agriculture. 2007;23:871-879.
52. Malhi SS, Lemke R, Wang ZH, Chhabra BS. Tillage, nitrogen and crop residue effects on crop yield, nutrient uptake, soil quality and green-house gas emissions. Soil and Tillage Research. 2006;90:171-183.
53. Xue Z, Cheng M, An S. Soil nitrogen distribution for different land uses and landscape positions in a small water shed on Loess plateau, China. Ecological Engineering. 2013;60:2004-2013.
54. Arif M, Jan MT, Khan MJ, Saeed M, Munir I, et al. Effect of cropping system and residue management on maize. Pakistan Journal of Botany. 2011;43(2):915-920.

55. Ning T, Zheng Y, Han H, Jiang G, LZ. Nitrogen uptake, biomass yield and quality of intercropped spring - and summer – sown maize at different nitrogen levels in the northern China plain. Biomass Bionergy. 2012;47:91-98.
56. Forrestal PJ, Kratochvil RJ, Meisinger J. Late-season corn measurements to assess soil residual nitrate and nitrogen management. Agronomy Journal. 2012;104:148–157.
57. Ye YL, Li L, Sun JH. Effect of intercropping three legume crops with maize on soil-N accumulation and distribution in the soil profile. China. Journal of Ecological Agriculture. 2008;16(4):818-823.
58. Matusso JMM Mugwe JN and Mucheru-Muna M. Effect of different maize (*Zea mays* L.) – soybean (*Glycine max*(L) Merril) intercropping patterns on yields, light interception and leaf area index in Embu West and Tigania East sub Counties. Academic Research Journal of Agricultural Science. 2014;2(1):6-21.
59. Jaetzold R, Schmidt H, Hornetz B, Shisanya C. Natural Conditions and Farm Management Information. 2nd Edn. Part A: West Kenya. Sub Part AI Western Province. 2007;319.
60. Fazli IS, Jamal A, Ahmmad S, Masoodi M, Khan JS, Abdin MZ. Interactive effect of sulphur and nitrogen on nitrogen accumulation and harvest in oilseed crops differing in nitrogen assimilation potential. Journal of Plant Nutrition. 2008;31:1203-1220.
61. Jamal A, Moon YS, Abdin MZ. Enzyme activity assessment of peanut (*Arachis hypogeal*) under slow-release sulphur fertilization. Australian Journal of Crop Science. 2010;4(3):169-174.

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