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Planting Pits' Effects on Soil Nutrients in a Sorghum and Pigeon Pea Rotation in Semi-arid Areas of Eastern Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author RY designed the study, wrote the protocol, managed the literature searches, analyses of the study, performed the soil analysis, managed the experimental process and wrote the first draft of the manuscript. Author FKN identified the experimental sites. Authors PWM, GCM and FKN provided guidance throughout the experiment and writing process. All authors read and approved the final manuscript.

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ABSTRACT

Planting pits are rain water harvesting structures that trap water and nutrients in surface runoff and rain water falling directly into the pits. Planting pits have been promoted for improving crop yields without considering the nutrient dynamics. To contribute to this knowledge, a study was conducted to determine the soil nutrient content after four seasons of growing sorghum and pigeon pea in rotation in "Chololo" and "Five by Nine" pits. Two planting pits; "Five by Nine" and "Chololo" with a control without water harvesting replicated three times were arranged in a randomised complete block design. The study was done for four seasons in Embu and Tharaka-Nithi counties in semi-arid Eastern Kenya. Soil pH, total organic carbon, total nitrogen, available phosphorus,

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exchangeable potassium, calcium, magnesium and sodium were determined. "Chololo" pits significantly increased total organic carbon by 0.06 mg kg^{-1} and total nitrogen by 0.4 mg kg^{-1} relative to without water harvesting in Machang'a. The potassium content significantly increased by 0.4 $cmol_c$ kg^{-1} and 0.54 $cmol_c$ kg^{-1} in "Five by Nine" and "Chololo" pits in Machang'a relative to without water harvesting. There was an insignificant effect on soil phosphorus, calcium, magnesium and sodium. After four seasons of planting pits, total nitrogen, potassium and calcium increased in both soils and phosphorus in Machang'a relative to the beginning of the study. Total organic carbon significantly decreased in "Chololo" pits and without water harvesting in Machang'a. Phosphorus significantly decreased in Nkarini whereas magnesium and pH decreased in both soils. Nutrients in "Five by Nine" and "Chololo" pits depended on the soils and crops grown and should thus be promoted together with periodic soil testing.

Keywords: Water harvesting; "Chololo" pits; "Five by Nine" pits; "Zaï" pits.

ABBREVIATIONS

ANOVA : Analysis of variance
ASALs : Arid and semi-arid lands
Ca : Calcium
CAN : Calcium ammonium nitrate
CEC : Cation exchange capacity
K : Potassium
LR : Long rains
Mg : Magnesium
Na : Sodium
OC : Organic carbon
P : Available phosphorus
RWH : Rain water harvesting
SR : Short rains
TN : Total nitrogen
WWH : Without water harvesting

1. INTRODUCTION

Torrential rainfall in arid and semi-arid lands (ASALs) causes high runoff that usually results in up to 85% water being lost that would otherwise be harvested to increase crop production. This limits crop production by reducing available water resulting in crop losses every three in five years making farmers unwilling to invest in soil fertility management strategies [1,2]. Increasing crop production requires water management and improved nutrient management as noted by Zougmore et al. [3].

RWH techniques include harvesting water and storing it in a storage structure away from where it is harvested described by Critchley and Siegert [4] as macrocatchments.

Macrocatchments include hillside runoff utilization, floodwater harvesting, ephemeral stream diversion. RWH techniques that store water where it falls are described by Critchley and Siegert [4] as micro-catchments. Micro-catchments have different shapes and sizes and include Planting pits, Negarims, Contour bunds, Contour ridges, Trapezoidal bunds and Semi-circular bunds [4]. RWH combined with improved soil, nutrient and crop management creates synergies that further increase yields [1]. This has been demonstrated by several authors including Zougmore et al. [3] who found 800 kg ha^{-1} sorghum yield using semi-circular bunds and manure while without water harvesting (WWH) had crop failure. Fatondji et al. [5] also reported two to 69 times increased millet yield when fertilizers were applied in "Zaï" pits. Similarly, Amede et al. [6] found higher potato and bean yields on applying nitrogenous fertilizers whereas Fatondji et al. [7] observed two to 69 times higher millet grain yield when manure was applied to "Zaï" pits. Microcatchments have been advocated for increased soil moisture, soil fertility improvement and reduced soil erosion by [1] with Kabore and Reij [8] and Fatondji et al. [9] attributing the increased soil fertility in planting pits to increased decomposition of trapped organic material and sediment.

However, some studies on planting pits have found decreased soil nutrients at the end of the studies. For instance, Amede et al. [6] found no increase in organic carbon (OC), total nitrogen (TN), available phosphorus (P) and cation exchange capacity (CEC) in modified "Zaï" pits (45 cm deep x 50 cm diameter) relative to WWH. However, Wildemeersch et al. [10] found lower OC, increased pH and no effect on P, potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na). Amede et al. [6] and Wildemeersch et al. [10] attributed the nutrient decline to the high crop production in planting pits suggesting that applied nutrients are depleted within the season. This would suggest that planting pits need nutrient replenishment each season without which soil nutrients would be depleted resulting in soil degradation. Further studies in different crops and environments would help in providing more information that would help in improving crop management in planting pits. To contribute to this knowledge, this study hypothesized that planting sorghum and pigeon pea in planting pits for four seasons would affect soil chemical properties. To test this hypothesis, a study investigating the effect of sorghum and pigeon pea rotation on soil pH, soil TN, P, K, OC, Ca, Mg and Na and was conducted for four seasons in two sites in semi-arid Eastern Kenya.

2. MATERIALS AND METHODS

2.1 Study Area

The four season study was conducted in: short rains (SR) 2013, October 2013 to March 2014; long rains (LR) 2014, March 2014 to July 2014; SR2014, November 2014 to March 2015 and LR2015, April 2015 to August 2015. The study sites were Machang'a secondary school, 0º 46' S and 37º 39' E, Embu County, and a farmer's field in Nkarini village 0 28' S and 37º 76' E, Tharaka-Nithi County both in semi-arid areas of Eastern Kenya. Machang'a lies at 1100 m above sea level and Nkarini at 1220 m. The soils are sandy loam Plinthic Cambisols and clayey Rhodic Ferralsols according to [11]. According to [11], the rainfall ranges from 253 to 506 mm in the SR and 171 to 297 mm in the LR in Machang'a and 300-513 mm and 204 to 312 mm in Nkarini in the two seasons respectively. Soil characterization (Table 1) indicated that both soils were slightly acidic and low in TN and OC and high in K, Ca and Mg according to [12] and high in P using Heckman's [13] criteria.

2.2 Experimental Design and Measurements

Two planting pits; "Five by Nine" pits and "Chololo" pits with a control WWH replicated three times were arranged in a randomized complete block design (Fig. 1). "Five by Nine" pits were made by digging out the topsoil to make 60 cm long, 60 cm wide and 60 cm deep pits spaced 60 cm within the row and 75 cm between rows as described by Mati [14]. "Chololo" pits were made as described by Mati [14] at 22 cm diameter by 30 cm deep spaced 60 cm apart within rows and 90 cm between rows with rows running along the contour. In both pits, topsoil was separated from the subsoil, mixed with manure and the manure-topsoil mixture returned to the pits.

At the beginning of the study, soil samples from the 0-20 cm depth were collected from three random points in each plot and the samples bulked to make a composite sample. At the end of the four seasons, soil samples were collected inside three random pits per plot and from three points in each plot WWH. Samples from each plot were mixed to make a composite sample. The samples were air dried at room temperature before determining the physical and chemical properties after sieving the samples through a 2 mm mesh sieve as per the procedures of [15]. Soil pH was measured in suspension with a deionized water ratio of 1:2.5 [16]. OC was determined using the modified Walkley-Black method [17]. TN was measured using the modified Kjeldahl digestion-distillation-titration method [18] and P by the Mehlich 3 method [19]. Exchangeable bases were extracted with 1 N ammonium acetate solution at pH 7; available K and Na were determined by Flame photometer and available Ca and Mg by Atomic Absorption Spectrophotometer [20].

Soil analysis was conducted (Table 1) to determine the nutrient requirements for optimal yields. Fertilizers and manure were applied at the same rate in the SR with none added in the LR. Nutrients were applied in form of cattle manure (24,700 kg ha^{-1}) one month before planting in both sites. Sorghum variety *Gadam* was planted in a spacing of 75 x 20 cm and pigeon pea variety *KAT 60/8* at 75 x 50 cm in WWH treatment; five plants were planted per "Five by Nine" pit, in the pit diagonals and in the middle of the pit and two plants on each side of a "Chololo" pit. Plots planted to sorghum in the SR were planted to pigeon pea in the LR and plots planted to pigeon pea in the SR were planted to sorghum in the LR. At sorghum planting, inorganic fertilizers (23-23-0) were applied at 57 kg N ha^{-1} and 57 kg P ha^{-1} in Machang'a and 68 kg N ha^{-1} and 68 kg P ha^{-1} in Nkarini. Additional N was top dressed as calcium ammonium nitrate (CAN) three weeks after planting in both sites at a rate of 32 kg N ha^{-1} and 28 kg N ha^{-1} in Machang'a and Nkarini, respectively. At Pigeon pea planting inorganic fertilizers were applied at 45 kg N ha^{-1} and 45 kg P ha^{-1} per site in both sites. The fields were maintained weed free by hand weeding.

2.3 Data Analyses

Data was subjected to normality test before being subjected to analysis of variance (ANOVA) using GENSTAT version 14. The treatments were the planting pits ("Five by Nine", "Chololo") and WWH with each soil nutrient analysed separately. Where there was statistical significance between treatments, means were separated using Tukey's honest significant test at P =.05. Differences between the nutrient content at the beginning and the end of the study were compared using the student's t-test at P =.05.

Table 1. Selected soil physical and chemical properties at Machang'a and Nkarini, Kenya

Site	Soil properties								
	pH	TN	P	OC	K	Ca	Mg	Na	Texture
		mg kg^{-1}		cmol$_c$ kg^{-1}					
Machang'a	6.0	0.1	26.7	0.6	0.5	2.3	3.4	0.2	Sandy loam
Nkarini	6.5	0.1	18.3	1.1	0.8	3.3	2.2	0.3	Clay

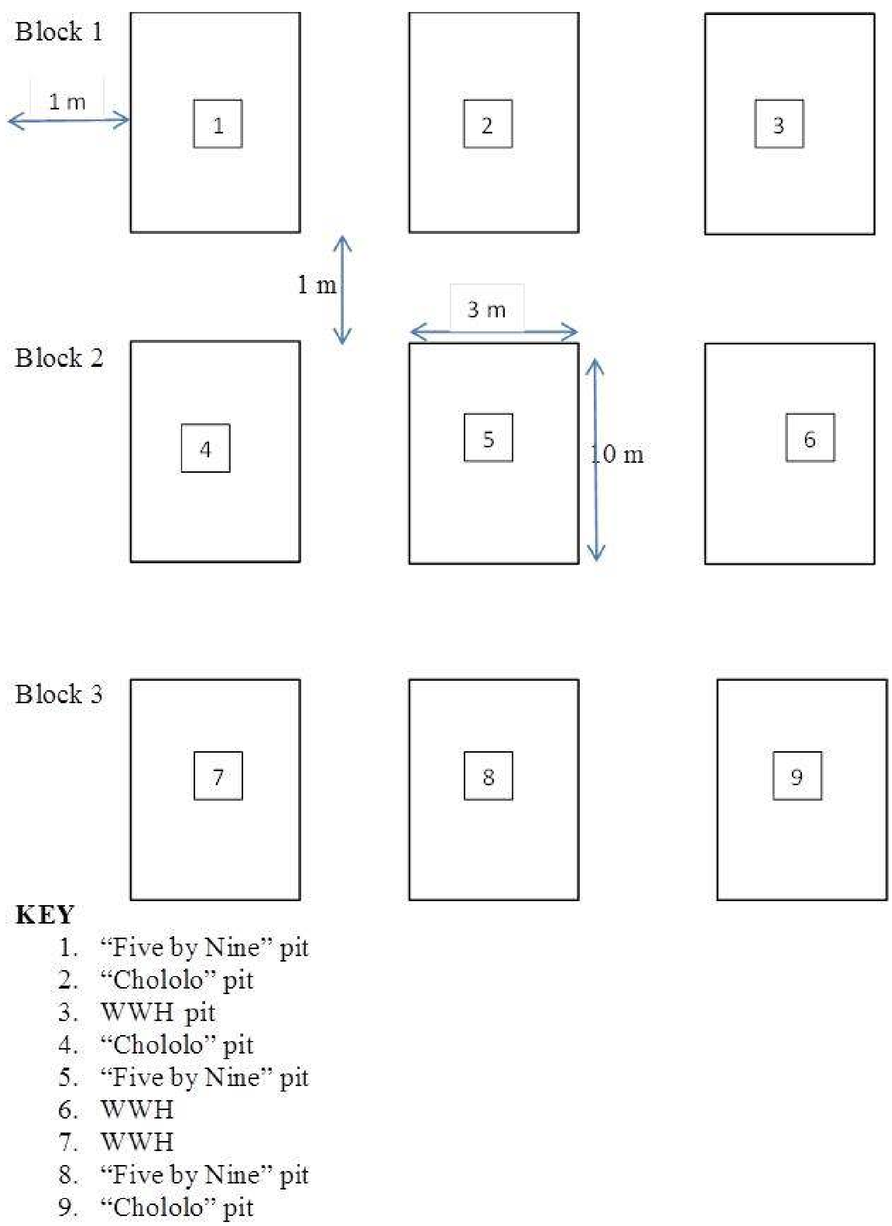

Fig. 1. Illustration of the experimental layout

3. RESULTS AND DISCUSSION

3.1 Planting Pit Effect on Soil Organic Carbon

OC >20 mg kg^{-1} was rated by [12] as very high, > 10-20 mg kg^{-1} as high, 4-10 mg kg^{-1} as medium and <2-4 mg kg^{-1} as low and <2 mg kg^{-1} as very low. Soil OC was 0.06 mg kg^{-1} higher (P =.05) in "Chololo" pits than WWH and statistically (P =.05) similar to that in "Five by Nine" pits in Machang'a sandy loams (Table 2). The OC in the Nkarini clay was statistically (P =.05) similar between the treatments (Table 2). The OC in Machang'a decreased significantly (P =.05) in "Chololo" pits and WWH and in all treatments in Nkarini at the end of the four seasons relative to that at the start of the study (Table 1). The decrease in "Five by Nine" pits in Machang'a was however statistically insignificant (P =.05). The decrease was by 0.22 mg kg^{-1}, 0.47 mg kg^{-1} and 0.48 mg kg^{-1} in "Chololo" pits, WWH and "Five by Nine" pits, respectively in Machang'a and 0.79 mg kg^{-1}, 0.82 mg kg^{-1} and 0.88 mg kg^{-1} WWH, in "Five by Nine" and in "Chololo" pits respectively, in Nkarini. The OC both at the start (Table 1) and at the end of the study (Table 2) was low as per the criteria of [11] which are expected in ASALs due to low biomass production and high decomposition rates as explained by Estefan et al. [21].

The increased OC in "Chololo" pits in the sandy loam Machang'a soil agrees with the findings of Kabore and Reij, [8] who found increased OC in "Zaï" pits and Ruto [22] who found increased OC in the lowest points in terraces attributed to sediment accumulation. In contrast, [6] and [10] found decreased OC in 45 x 50 cm and 15 x 20 cm dimension pits, respectively. The decreased OC in "Chololo" pits and WWH in the sandy loam Machang'a soil at the end of the present study relative to at the beginning of the study and in the clayey Nkarini soil agreed with Amede et al. [6] and Wildemeersch et al. [10] who attributed it to increased straw production. The OC decrease may also be as a result of increased mineralization as suggested by [23]. Interestingly, the decrease was insignificant in "Five by Nine" pits. This may require further studies on OC mineralization to establish if the different patterns are actually as a result of mineralization.

3.2 Planting Pit Effect on Soil Total Nitrogen

TN levels of >1.0 mg kg^{-1} are rated by [12] as very high, >0.5-1.0 mg kg^{-1} as high, 0.2-0.5 mg kg^{-1} as medium and 0.1-0.2 mg kg^{-1} as low and <0.1 mg kg^{-1} as very low. In the present study, the TN was 0.27 mg kg^{-1} and 0.4 mg kg^{-1} higher (P =.05) in "Chololo" pits than in "Five by Nine" pits and WWH in the Machang'a sandy loam soil (Table 2). There was no significant (P =.05) treatment effect in the clayey Nkarini soil (Table 2). The TN at the end of the four seasons increased significantly (P =.05) in all treatments in both soils relative to that at the beginning of the study (Table 1). The increase was by 0.83 mg kg^{-1} and 2.9 mg kg^{-1} in "Chololo" pits, 0.56 mg kg^{-1} and 2.62 mg kg^{-1} in "Five by Nine" pits and 0.43 mg kg^{-1} and 2.83 mg kg^{-1} WWH in Machang'a and Nkarini, respectively. The TN at the beginning of the study was low as per the criteria of Landon [12] increasing to high in Machang'a and very high in Nkarini after four seasons using Landon's [12] criteria (Table 2).

The increased TN found in this study in "Chololo" pits in the sandy loam Machang'a soil and at the end of the study agree with the finding of Kabore and Reij [8] in "Zaï" pits and Ruto [22] in terraces. However these results are different from those of Amede et al. [6] and Wildemeersch et al. [10] who did not find significant increase in TN under

Table 2. Planting pit effect on soil OC, TN, P and pH in Machang'a (M) and Nkarini (N), Kenya

Planting pit	OC		TN		P		pH	
	mg kg^{-1}							
	M	N	M	N	M	N	M	N
"Chololo" pit	0.19^{a}	0.31^{a}	0.93^{a}	3.00^{a}	73^{a}	13^{a}	5.5^{a}	5.8^{b}
"Five by Nine" pit	0.16^{ab}	0.28^{a}	0.66^{b}	2.72^{a}	64^{a}	10^{a}	5.5^{a}	5.8^{b}
WWH	0.13^{b}	0.31^{a}	0.53^{b}	2.98^{a}	82^{a}	14^{a}	5.5^{a}	5.9^{a}
l.s.d	**0.029**	**0.03**	**0.145**	**0.28**	**0.524**	**0.06**	**0.33**	**0.07**
F.pr	**≤0.001**	**0.09**	**0.001**	**0.078**	**0.524**	**0.06**	**0.938**	**≤0.001**
cv%	**9.5**	**2.5**	**13.9**	**2.4**	**29.8**	**3**	**2.5**	**0.3**

**Means with different superscripts within a column are significantly different P <0.05 M: Machang'a N: Nkarini*

"Zaï" pits. This difference may be due to the inclusion of pigeon pea in the rotation which has been reported to increase soil N by various authors including Hayat et al. [24], Phiri et al. [25] and Njira et al. [26].

The decreased TN in both pits in Nkarini and in "Five by Nine" pits in Machang'a agree with the findings of Amede et al. [6] and Wildemeersch et al. [10]. This decline may be due to TN resulting from decomposition of manure and fixation by pigeon pea being taken up by the crops during the growing season as suggested by Fatondji et al. [27] and Fatondji et al. [5]. The increased OC and TN observed in this study in the sandy loam soil and insignificant effect in clayey soil may be due to the higher OC and TN mineralization in the clayey soil by soil organisms due to wetting and drying cycles as the water is stored and used in the pits as proposed by Austin et al. [28] resulting in higher levels in the sandy loams at the end of the study.

3.3 Planting Pit Effect on Soil Phosphorus

Mehlich-3 available P of 0-12 mg kg^{-1} is rated by Heckman (13) as very low, 13-23 mg kg^{-1} as low, 24-45 mg kg^{-1} as medium, 72-137 mg kg^{-1} as high and < 138 mg kg^{-1} as very high. In the present study, available soil P was statistically insignificant (P =.05) between the treatments in both sites (Table 2). The available soil P in Machang'a significantly (P =.05) increased by 55.3 mg kg^{-1} WWH; 46.3 mg kg^{-1} in "Chololo pits" and 37.3 mg kg^{-1} in "Five by Nine" pits after four seasons of the experiment. Available soil P in Machang'a was medium at the start of the study (Table 1) remaining medium in "Five by Nine" pits and increasing to high in "Chololo" pits and WWH at the end of the study (Table 2) following Heckman's [13] criteria. In Nkarini however, available soil P decreased significantly (P =.05) after four seasons (Table 2) relative to the initial content (Table 1) being low as per the criteria of [12] both at the start and end of the study. The decrease was by 4.3 mg kg^{-1}, 5.3 mg kg^{-1} and 8.3 mg kg^{-1} WWH, in "Chololo" and in "Five by Nine" pits, respectively.

The increased available soil P at the end of the study in the sandy loam Machang'a soil agree with the finding of Neugschwandtner [23] who found available soil P accumulating under no tillage and Ruto [22] who found increased available soil P under terraces attributed to accumulated sediment P. The increased available soil P in the present study may also be due to the inclusion of pigeon pea in the rotation which has been shown by Ae et al. [29] to exude piscidic acid in its roots which accelerates release of P from iron phosphates by chelating Fe and by Otani et al. [30] to exude malonic acid that releases aluminium bound P or due to residue decomposition as suggested by [23] and [22]. The significant decrease of available P in the Ferralitic Nkarini soil may be due to fixation by iron and aluminium oxides likely to be high in this soil. It may suggest that the effect of pigeon pea in this soil is not as effective as it is in the Machang'a Cambisols. The significant effect of planting pits found in this study differs from the insignificant effect observed by [6] and [10] highlighting the effect of pigeon pea in this study considering the former study was on potatoes and beans and the latter on millet.

3.4 Planting Pit Effect on Soil Potassium

Exchangeable K values of 0.4-0.8 $cmol_c$ kg^{-1} are rated by Landon [12] as high, 0.2-0.4 $cmol_c$ kg^{-1} as medium and 0.03-0.2 $cmol_c$ kg^{-1} as low for tropical soils. Exchangeable soil K in Machang'a was 0.4 $cmol_c$ kg^{-1} and 0.54 $cmol_c$ kg^{-1} higher (P = 0.05) WWH than in "Five by Nine" and "Chololo" pits and statistically insignificant (P =.05) in Nkarini (Table 3). The available soil K increased significantly (P =.05) in both sites after four seasons of water harvesting (Table 3) relative to the initial content (Table 1). The increase was by 63.5 $cmol_c$ kg^{-1}, 72.5 $cmol_c$ kg^{-1} and 83.5 $cmol_c$ kg^{-1} and 9.2 $cmol_c$ kg^{-1}, 12.2 $cmol_c$ kg^{-1} and 13.2 $cmol_c$ kg^{-1} in "Five by Nine", in "Chololo" pits and WWH, respectively in Machang'a and Nkarini. The available K was high in both sites as per the criteria of Landon, [12] both at the beginning of the study and at the end of four seasons.

The lower available K content in planting pits relative to WWH observed in this study is comparable to the findings of Wildemeersch et al. [10]. The increase in K in both sites after four seasons of this study agrees with the findings of Neugschwandtner et al. [21] who observed K accumulation under reduced tillage. The increased K may be attributed to K released from the decomposition of plant residues, manure and accumulated sediment.

3.5 Planting Pit Effect on Soil Calcium

Planting pits did not significantly (P =.05) affect the soil Ca in both sites (Table 3). After four seasons of planting pits, the soil Ca content (Table 3) significantly increased (*P* =.05) compared to the initial levels (Table 1) in both soils. Ca increased by 1.16 $cmol_c\ kg^{-1}$, 1.26 $cmol_c\ kg^{-1}$ and 1.36 $cmol_c\ kg^{-1}$ WWH, in “Five by Nine” and “Chololo” pits, respectively in Machang’a and 2.71 $cmol_c\ kg^{-1}$, 3.95 $cmol_c\ kg^{-1}$ and 4.32 $cmol_c\ kg^{-1}$ in “Chololo”, “Five by Nine” pits and WWH, respectively in Nkarini. The soil Ca content was low as per the criteria of Landon [12] at the start of the study in both sites (Table 1) and in Machang’a at the end of the study increasing to moderate levels in Nkarini at the end of the study as shown in Table 3. The insignificant effect of planting pits on soil Ca found in this study concur with the findings of Wildemeersch et al. [10] and may be attributed to low contribution of planting pits on soil Ca. The increase at the end of the study may be attributed to Ca released due to decomposition of manure and crop residues after four seasons of growing sorghum and pigeon pea.

3.6 Planting Pit Effect on Soil Magnesium

Exchangeable Mg levels of <0.2 $cmol_c\ kg^{-1}$ are rated by [12] as low, 0.2-0.5 $cmol_c\ kg^{-1}$ as medium and >0.5 $cmol_c\ kg^{-1}$ as high. Planting pits did not significantly (*P* =.05) affect the Mg content in both soils (Table 3). At the end of four seasons, the soil Mg significantly (*P* =.05) decreased by 1.43 $cmol_c\ kg^{-1}$, 1.56 $cmol_c\ kg^{-1}$ and 1.83 $cmol_c\ kg^{-1}$ in “Five by Nine”, “Chololo” pits and WWH, respectively in Machang’a. Though statistically insignificant (*P* =.05) the decrease in Nkarini after four seasons was 0.14 $cmol_c\ kg^{-1}$, 0.23 $cmol_c\ kg^{-1}$ and 0.37 $cmol_c\ kg^{-1}$ in “Five by Nine”, “Chololo” pits and WWH, respectively (Table 2). The non-significant effect of planting pits on soil exchangeable Mg content in this study concur with the findings of Wildemeersch et al. [9] and may be attributed to low contribution of planting pits on soil Mg. The decrease at the end of four seasons may suggest that decomposition of manure and crop residues did not release significant magnesium to both soils or all added Mg was taken up by sorghum and pigeon pea.

3.7 Planting Pit Effect on Soil Sodium

Planting pits did not significantly (*P* =.05) affect the soil Na content in both sites (Table 3). The soil Na content did not change (*P* =.05) relative to the initial amounts (Table 1) in both sites after four seasons of planting pits (Table 3). This may suggest that planting pits did not affect soil Na in these soils and residue and manure decomposition did not release Na into both soils.

3.8 Planting Pit Effect on Soil pH

Soil pH in water of >8.5 is rated by [12] as very high, 7.0-8.5 as high, 5.5-7.0 as medium and <5.5 as low. The soil pH was statistically similar (*P* =.05) in all the treatments in Machang’a and 0.1 units higher (*P* =.05) in Nkarini WWH than in planting pits (Table 1). The soil pH decreased (*P* =.05) by 0.5 units in all treatments in Machang’a and by 0.7 units WWH and 0.6 units in planting pits in Nkarini after four seasons (Table 2) relative to the initial level (Table 1). The decreased pH observed in this study in the clayey Nkarini soils differs with the increase observed by Fatondji et al. [9] in a sandy soil. Since the pH decline in this study still resulted in the range being within that suitable for availability of plant nutrients (> 5.5) as per the criteria of [12], it may not have had a negative effect on the crops. The decreased pH may be due to release of organic acids as a result of decomposition as explained by Brady and Weil [31] whose effect may have been higher than that of the accumulated exchangeable bases attributed for the pH increase in the study by [9] which were insignificantly affected by planting pits in the present study. A summary of the effect of planting pits on soil nutrients is shown in Fig. 2.

Table 3. Planting pit effect on soil calcium, magnesium and sodium

Planting pit	K		Mg		Na		Ca	
	$cmol_c\ kg^{-1}$							
	M	N	M	N	M	N	M	N
“Chololo”	0.63^b	1.15^a	1.84^a	1.97^a	0.21^a	0.32^a	3.66^a	6.01^a
“Five by Nine”	0.77^b	1.01^a	1.97^a	2.06^a	0.21^a	0.31^a	3.56^a	7.25^a
WWH	1.17^a	1.24^a	1.57^a	1.65^a	0.20^a	0.31^a	3.46^a	7.62^a
l.s.d	**0.145**	**0.2046**	**0.503**	**0.3608**	**0.073**	**0.0664**	**0.86**	**2.046**
F.pr	**<0.01**	**0.726**	**0.278**	**0.067**	**0.882**	**0.971**	**0.897**	**0.265**
cv%	**6.4**	**9.7**	**11.2**	**16.3**	**5.2**	**4**	**4**	**41.1**

Means with different superscripts within a column are significantly different P = 0.05; number of replicates n=3
M: Machang’a; N: Nkarini

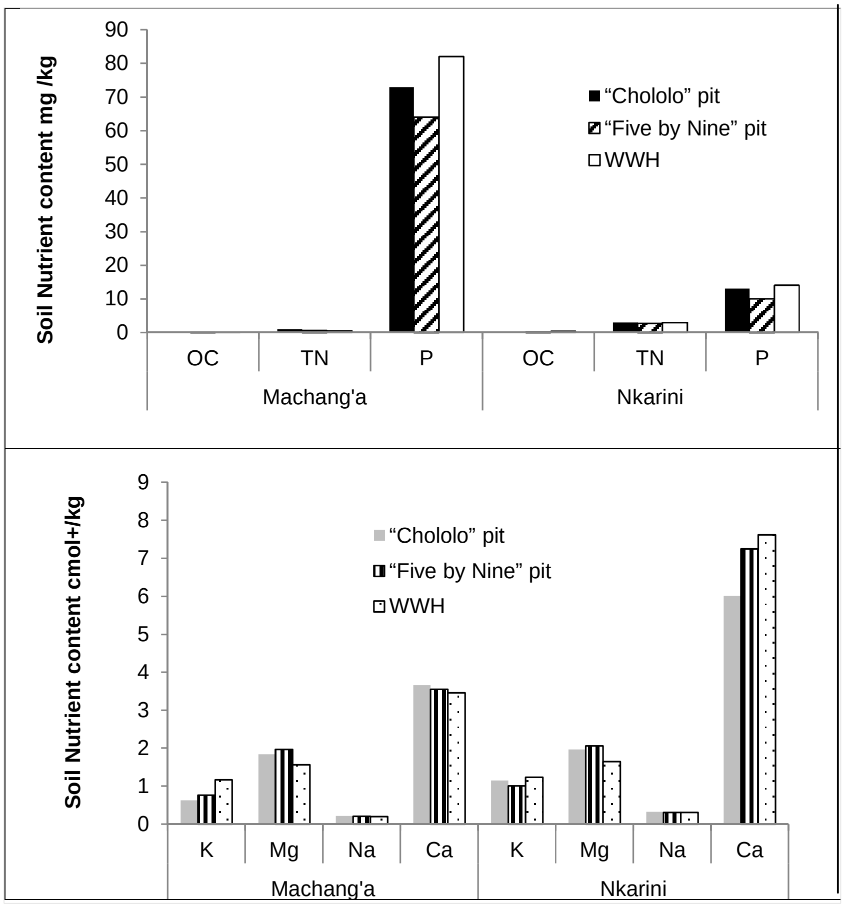

Fig. 2. Summary of the effect of planting pits on soil nutrients in semi-arid areas of Eastern Kenya

4. CONCLUSION

This study sought to establish the effect of "Five by Nine" and "Chololo" pits on soil nutrients. The results show that:

- "Chololo" pits significantly increased TN and OC relative to WWH in the Machang'a sandy loams.
- The K content significantly increased in planting pits relative to WWH in the Machang'a sandy loams.
- Soil P, Ca, Mg, Na contents were not significantly affected by planting pits in both soils.
- After the four seasons of the study, TN, K and Ca significantly increased in planting pits and WWH relative to that at the beginning of the study in both soils; P increased in Machang'a and decreased in Nkarini whereas OC decreased in "Chololo" pits in "Machang'a and in both pits and WWH in Nkarini and Mg and pH significantly decreased in both pits and WWH in both soils.

These results show that the effect of "Chololo" and "Five by Nine" pits differs depending on the soil properties and crops grown. This study therefore recommends promoting "Chololo" and "Five by Nine" pits together with periodic soil testing to facilitate nutrient replenishment in cases of deficit and to avoid excess nutrients in case of surplus. Further work needs to be done to establish the nutrient uptake of sorghum and pigeon pea to explain the nutrient dynamics in the pits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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