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Influence of Integrated Weed Management and Tillage Methods on Soil Physical and Chemical Properties in Maize Production

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Authors' contributions

This work was carried out in collaboration among all authors. Author GCM designed the study, wrote the proposal, performed the statistical analysis, and wrote the first draft of the manuscript. Authors SAG, SOD and ADM managed the literature and revised the draft. All authors read and approved the final manuscript.

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ABSTRACT

A two year field experiments were conducted at the College of Agriculture Teaching and Research Farm, Jalingo, Taraba State, Nigeria, to evaluate the integrated use of 25% rates of selected herbicides mixtures (atrazine-pendimethalin (AP_1) or primextra (PX_1) and cover crops (a vegetable cowpea, "Akidi" (A), Melon (M) and Sweet potato (S) planted sole or mixed at 20,000 stands/ha ($_1$) or 40,000 stands/ha ($_3$) under manual (MT) and tractor tillage (TT) methods used primarily for weed control on soil properties and maize production. The experimental design was a split plot arrangement in a randomized complete block design replicated three times. Tractor Tillage (TT) and Manual Tillage (MT) were the main treatments. The sub treatments included ten integrated weed management (IWM), AP_1A_l, AP_1AS_1, AP_1S_3, AP_1MS_3, AP_1AMS_3, PX_1A_1, PX_1AS_1, PX_1S_3, PX_1MS_3, PX_1AMS_3 in addition to Weeded 3+6 Weeks After Planting (WAP) (C_1) and unweeded(C_2) as controls. Descriptive statistics and Analysis of Variance were used to analyze data and the

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treatment means were compared using standard error at 5%. The level of Na, organic carbon, TN, %clay and %fine sand were higher in MT than TT during the experimental period while Mg, pH, %silt and clay were higher in TT than in MT. Herbicide groups did not significantly influenced soil properties in this study. The Ca^{2+}, K^+ and A-VP in all IWM treated plots were higher than the value in C_2 . Treatments having Akidi (A_1, AS_1, AMS_3) recorded higher OC than those without (S_3, MS_3). Therefore, MT improves soil condition and should be used in small scale farming and where TT is used, special consideration of soil type and frequency of use should be moderated. Use of IWM ameliorates fertility losses observed, with preference for mixture with at least a leguminous component.

Keywords: Maize; soil properties; tillage; integrated weed management; cover crop; herbicide mixtures.

1. INTRODUCTION

Despite the great potential of maize, both for human consumption and livestock feed, as well as industrial processing, the average yield obtained on farmers field is very low, about 1 t ha^{-1} (in Africa), 1.13 t ha^{-1} (in Nigeria) compared with the world average of 4.04 t ha^{-1} [1]. In Taraba State, about 61.2% of the farmers harvest less than 1 t ha^{-1} [2], which is far below the actual yield of 1 – 2 t ha^{-1} (open pollinated) and 3.5t ha^{-1} (hybrid) expected in the Savanna [3]. The low yield obtained by farmers may be due to factors including low soil fertility, pest's infestation, weed and diseases infection beyond the threshold level, change and loss of biodiversity [4,5]. Among the various problems limiting maize production, weed appears to have the most deleterious effect [6,7] causing yield reduction of between 40-100% [8,9,10,11] and in some serious cases resulting in abandonment of farmers' fields [12]. Soil tillage, as a necessary practice in crop production, can affect the soil physical properties that are important for plant growth [13,14]. Improvements of root penetration, water infiltration and soil moisture storage, weed control, and supply of nutrients from rapid decomposition of organic matter are considered the most beneficial contributions of tillage to crop production [15,16].

No or minimum tillage is a sustainability strategy for enhancing soil, water and crop performance [17,18]. Cover crop used is key determinant of success in no/minimum tillage system as it keeps the soil surface covered, recycle nutrients, making such available through gradual decomposition of organic residue. Limited adoption by farmers because of cost of implementation and inadequate information about its economic analysis [19]. Cover crops influence soil's physical, chemical and biological properties when grown alone with the major crop or as a mixture [20]. The positive impact of cover crop in reducing erosion, rainfall erosivity, weed suppression and organic matter enhancement has been documented [21]. Cover crops planted in association with maize have been reported to influence soil physico-chemical properties, with a decline in exchangeable cations, P, pH, exchangeable acidity, effective cation exchange capacity (ECEC) and the silt proportion; however organic carbon, N, fine sand increased in all the treatments over the years [22]. Conservative tillage promotes chemical and physical qualities of soil than conventional approach [23]. Integrated Weed Management (IWM) is the best, as no one single weed control method can give adequate solution. The most appropriate IWM system is integrating crop competitiveness with reduced herbicidal mixture and optimum dosage which could control weed in maize effectively without environmental pollution and soil erosion [24].

Sustainable, long-term weed management strategies need to provide adequate weed control to protect crop yield, prevent increases in weed populations, ensure profitability for the grower, and minimize the risk of environmental impact. The recommended rates of broad-spectrum herbicide programs are generally very effective at protecting yield and controlling weeds. Reductions in the rate or frequency of herbicide application could lessen the environmental impact of weed management and reduce input costs but may also lead to steady increases in the weed seed bank, jeopardizing long-term profitability [25,26].

Not much is known about the combined effects of low herbicide dosage, cover crops and tillage on soil properties in maize in the study area. Hence, this study was carried out to determine the effects of integrated use of 25% rates of selected herbicides mixtures (atrazine-pendimethalin (AP_1) or primextra (PX_1) and cover crops (a vegetable cowpea, "Akidi" (A), Melon (M) and Sweet potato (S) planted sole or mixed at 20,000 stands/ha ($_1$) or 40,000 stands/ha ($_3$) under manual (MT) and tractor tillage (TT) methods used primarily for weed control on soil properties and maize production.

2. MATERIALS AND METHODS

2.1 Experimental site

The Field trials were conducted at the Teaching and Research Farm of Taraba State College of Agriculture (08° 50' N, 11° 50' E) Jalingo in the northern Guinea savanna ecological zone. Jalingo has a wet and dry tropical climate with rainy season of about 150 days and an average annual rainfall of about 700 mm – 1000 mm. Mean annual temperature of Jalingo is about 28°C with maximum temperature ranges between 30°C and 39.4°C and minimum temperature range between 15°C to 23°C. Annual rainfall was 808.9 mm and 1063.2 mm for 2008 and 2009, respectively. The rainy season is between May and October while the dry season is from November to April.

2.2 Experimental Materials

Maize variety 95-TZEE-W1, an open pollinated and extra early maturing used as the test crop was obtained from International Institute of Tropical Agriculture (IITA), Ibadan.

2.3 Experimental Design and Layout

The experiment was laid out in a randomized complete block design with a split plot arrangement and replicated three times. Tillage methods; Tractor Tillage (TT) and Manual Tillage (MT) were the main plots. The sub-plot factors were various integrated weed management treatments viz: AP_1A_l, AP_1AS_1, AP_1S_3, AP_1MS_3, AP_1AMS_3, PX_1A_1, PX_1AS_1, PX_1S_3, PX_1MS_3, PX_1AMS_3, hand-weeded at 3 and 6 WAP (C_1) and weedy check (C_2) treatments were subplots (Table 1).

Table 1. Tillage and integrated weed management treatments

Tillage	IWM Treatment	Symbols
Manual	25 % atrazine + pendimethalin + Akidi at 20,000 plants ha^{-1}	AP_1A_1
Manual	25 % atrazine + pendimethalin + Sweet potato at 40,000 plants ha^{-1}	AP_1S_3
Manual	25 % atrazine + pendimethalin + Akidi/Sweet potato at 20,000 plants ha^{-1}	AP_1AS_1
Manual	25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants ha^{-1}	AP_1MS_3
Manual	25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants ha^{-1}	AP_1AMS_3
Manual	25 % Primextra + Akidi at 20,000 plants ha^{-1}	PX_1A_1
Manual	25 % Primextra + Sweet potato at 40,000 plants ha^{-1}	PX_1S_3
Manual	25 % Primextra + Akidi/Sweet potato at 20,000 plants ha^{-1}	PX_1AS_1
Manual	25 % Primextra + Melon/Sweet potato at 40,000 plants ha^{-1}	PX_1MS_3
Manual	25 % Primextra + Akidi/Melon/Sweet potato at 40,000 plants ha^{-1}	PX_1AMS_3
Manual	Hand-weeded control	C_1
Manual	Unweeded control	C_2
Tractor	25 % atrazine + pendimethalin + Akidi at 20,000 plants ha^{-1}	AP_1A_1
Tractor	25 % atrazine + pendimethalin + Sweet potato at 40,000 plants ha^{-1}	AP_1S_3
Tractor	25 % atrazine + pendimethalin + Akidi/Sweet potato at 20,000 plants ha^{-1}	AP_1AS_1
Tractor	25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants ha^{-1}	AP_1MS_3
Tractor	25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants ha^{-1}	AP_1AMS_3
Tractor	25 % Primextra + Akidi at 20,000 plants ha^{-1}	PX_1A_1
Tractor	25 % Primextra + Sweet potato at 40,000 plants ha^{-1}	PX_1S_3
Tractor	25 % Primextra + Akidi/Sweet potato at 20,000 plants ha^{-1}	PX_1AS_1
Tractor	25 % Primextra + Melon/Sweet potato at 40,000 plants ha^{-1}	PX_1MS_3
Tractor	25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha	PX_1AMS_3
Tractor	Hand-weeded control	C_1
Tractor	Unweeded control	C_2

2.4 Field Establishment

The field was cleared manually using cutlass to reduce shrubs on the land. The fields were laid out in two strips, Manual Tillage (MT) and Tractor Tillage (TT). Ploughing was done on strips in alternate replicates. The commonly available tractor, Massey Ferguson (MF) 375, a two-wheel drive (2WD) with gross weight of about 2355 kg was used in the tractor tillage main plots. Manual tillage was accomplished using big hand-held hoes to make 4 ridges per plots of 4m x 4m. Maize seeds (95-TZEE-W1, an open pollinated and extra early maturing variety was obtained from International Institute of Tropical Agriculture (IITA), Ibadan were sown on 30th and 13th June in 2008 and 2009 respectively. Three seeds per hole at 25cm x 100cm spacing, to give a population of 40,000 plants ha^{-1} in all the plots and the seedlings were later thinned to one plant per stand.

Cover crops were planted in 8 rows (2 rows of cover crop to 1 row of maize). Akidi and melon seeds were sown 4 seeds/hole, while 2-3 sweet potato vines/hole, spaced 50 cm x 100 cm and latter thinned to give the required population densities of 20,000 or 40,000 plants ha^{-1}. The number of rows or stands was shared evenly in the mixed cover crop plots. However, sweet potato vines were planted after 48 hours of application of the herbicides.

2.5 Herbicide Application

Atrazine (6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine) formulation used was 50% SC (500g L^{-1}), pendimethalin (N- (1- ethylpropyl)- 3,4- dimethyl-2,6-dinitrobenzenamine) 500 EC and Primextra (atrazine (290g L^{-1}) + metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)-acetamide (370g L^{-1})) 660g a.i. L^{-1} were used. Low rate (25% of recommended rates) of the preemergence herbicides, 0.5 + 0.5 kg a.i. ha^{-1} atrazine +pendimethalin (AP_1) or 0.625 kg a.i. ha^{-1} Primextra (PX_1) was applied to appropriate plots within 48 hours of planting of maize, akidi and melon with a CP 15 knapsack sprayer calibrated to deliver 300 L ha^{-1} spray solution.

2.6 Trial Management and Harvesting

Manual weeding was carried out twice at 3 and 6 WAP on hoe-weeded control plots, other treatments were not weeded at all. Fertilizer was applied to maize at 120 kgN ha^{-1} in two splits at 5 and 7 WAP. NPK 20-10-10 and Urea were used. Maize cobs were harvested dry on 12th (14 WAP) and 2nd (16 WAP) October of 2008 and 2009 respectively, and shelled.

2.7 Data Collection

2.7.1 Soil sampling and analysis

Prior to planting, 40 surface soil samples were collected from different plots with soil auger at 0-15 cm depth. These were bulked together, air-dried at room temperature, crushed in a mortar to break the soil aggregates and sieved with a 2 mm sieve to remove large particles, debris and pebbles as described by Food and Agriculture Organisation [27]. Routine analysis was carried out to determine some physical and chemical properties of the soils. Soil pH was measured with the glass electrode pH meter in a 1:1 soil to water ratio and 1:2 soil to $CaCl_2$ ratio [28]. The organic carbon was determined by the Walkley and Black wet oxidation method [29]. Total N was determined by the micro Kjeldahl digestion method by heating the samples at 360-410^{0}C with concentrated sulphuric acid (H_2SO_4), distilled with NaOH as described by Bremner [30], while AV-P was extracted by Bray's 1 method [31] and read from the spectrophotometer. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) were determined by repeated extraction procedure with neutral 1M NH_4OAc (pH7) solution. The $Ca^{2+}$and Mg^{2+} in solution were read on an atomic absorption spectrophotometer while K^+, Na^+ were read on the flame photometer [32]. Soil particle-size distribution was determined by the hydrometer method using sodium hexametaphosphate (Calgon) as the dispersant; as described by Gee and Or [33]. Exchangeable acidity (H^+) of the soils was determined by titration method. Effective cation exchange capacity (ECEC) was calculated as the sum of the exchangeable bases (K^+, Na^+, Ca^{2+} and Mg^{2+}) [34].

The pre-cropping physical and chemical characteristics of the soils of the experimental site are shown in Table 2. The result of the soil study before planting showed that the soils were sandy loam, slightly acidic to neutral (6.1-6.5 to 6.6-73) and organic carbon value was low (<1%). Also, Total N value of 0.098 was low (0-0.15%) and available phosphorus value of 4.75 was low (0-10 mg kg^{-1}). Calcium value of 2.36 cmol kg^{-1} was medium (2-5 cmol kg^{-1}) and magnesium value of 0.57 cmol kg^{-1}was also medium (0.3-1.0

cmol kg^{-1}), while value for potassium 0.18 cmol kg^{-1} was high (>0.3 cmol kg^{-1}). These results indicate that the soils have good potentials to support agricultural cultivation with proper soil management practices. At harvest in 2008 and 2009, ten Core samples were collected from each treated plots, bulked together on treatment basis and analysed for soil physical and chemical properties as in the pre-cropping soil study.

Table 2. Pre-cropping soil physical and chemical properties of the experimental site

Soil Properties	Values
(A) Physical Properties	
Particle size (%)	
Sand	73.3
Silt	14.0
Clay	12.7
(B) Chemical Properties	
pH 1:1 (H_2O)	6.720
pH 1:2 ($CaCl_2$)	6.450
Organic Carbon (%)	0.741
Total N (%)	0.098
Avail. P (mg kg^{-1})	4.750
Exchangeable Cations (cmol kg^{-1})	
Ca^{2+}	2.36
Mg^{2+}	0.57
Na^{+}	0.21
K^{+}	0.18

2.7.2 Data collection (Maize)

These were collected from 10 tagged maize plants selected from the two middle rows, exempting the boarder plants, in each plot. The dry cob and grain yield per hectare, as well as 100 seeds weight was used to assess the yield performance.

2.7.3 Data analysis

Descriptive statistics and Analysis of Variance using the generalized model of SAS [35] were used to analyse data. Treatment means were compared using the standard error at 5% probability level [36,37].

3. RESULTS AND DISCUSSION

The pre-cropping physical and chemical characteristics of the soils of the experimental site are shown in Table 2. The result of the soil study before planting showed that the soils were sandy loam, slightly acidic and organic carbon was less than critical levels according to Enwenzor et al. [38]. Total N (0.1%) and available phosphorus (4.8 mg kg^{-1}) were low. The exchangeable cations ranged from 0.18 $cmol^{-1}$ for K to 2.36 $cmol^{-1}$ for Ca.

3.1 Calcium and Magnesium

The effect of tillage and integrated weed management (IWM) on Ca^{2+} and Mg^{2+} in 2008 and 2009 are presented in Table 3. In 2008, Ca^{2+} was not significantly influenced by tillage method, though MT recorded slightly higher Ca^{2+} value. Across tillage, Ca^{2+} ranged from 1.5 in PX_1AMS_3 to 2.195 in AP_1A_1, which is similar to Ca^{2+} in C_1 (2.08). These results might be due to increase decomposition and mineralization rates of Ca as the result of the presence of Akidi and melon, with high plant population thereby increasing the Ca^{2+} in the soils, Arévalo-Gardini et al. [39] supports these findings. The Ca^{2+} in all IWM treated plots were higher than the value in C_2 (1.675) except PX_1AMS_3 and AP_1AS_1 respectively and this might be attributed to calcareous parent materials present in the soils and the MT having more ability for soil texture and structure improvement than TT. The Ca^{2+} was more in PX-CC>C_2>AP-CC/C_1. Generally, there was a significant increase in Ca^{2+} between 2008 and 2009 and this might be due to continuous crop cover which protected the soil surface from erosion and leaching activity; thereby increasing soil Ca^{2+} values. The reduction in Ca^{2+} values in 2009 from Ca^{2+} values in 2008 in MT in PX_1AMS_3, AP_1A_1, AP_1S_3 and AP-CC plots could be as a result of leaching activities which reduced Ca^{2+} content in the soils as a result of fast decomposition of melon component when compared to other treatments; this is in agreement with Michael et al. [22] who reported decrease in Ca^{2+} level in akidi, melon or sweet potato with maize. This was in contrast with Beck et al. [40] who reported increase in Ca^{2+} over two years.

The effect of tillage method and IWM on Mg^{2+} followed trend similar to Ca^{2+} (Table 3). In 2008, Mg^{2+} in TT was higher than MT by 12.5%. Across the tillage, IWM significantly influenced Mg^{2+}, Khormalia et al. [41] found significant values for soil Mg in their studies. All IWM treated plots except PX_1AMS_3, AP_1AS_1 and AP_1AMS_3 recorded Mg^{2+} that was significantly higher than C_2 (0.29), but less than the Mg^{2+} recorded in C_1 (0.41). This corroborates the findings of Simone et al. [42] who reported increase in Mg^{2+} content in mixed cover crop in Brazil. It seems C_1, hand weeding enhances Mg^{2+} compared to C_2 or other treated plots. The AP and PX groups had similar effect. In 2009, Mg^{2+} in TT was 14.3% higher than in MT. Across the tillage methods, Mg^{2+} in C_2 and PX-CC were similar (0.4 each) but higher than in C_1 and AP-CC plots. There was a general increase in Mg^{2+} in all IWM treated plot and C_2 but a decrease in C_1 plot over the years. These attributes might not be unconnected with Mg bearing mineral in the weathering environment encouraged by the action of erosion and deposition similar to the report by Freitas et al. [43].

3.2 Potassium and Sodium

The effect of tillage methods and IWM on K^+ and Na^+ is presented in Table 4. Tillage method did not significantly influence K^+ in 2008, though TT was slightly higher. This could be attributed to the disturbance of the soils or pedoturbation by TT which allowed the potassium to slightly increase in TT for the soil. Across the tillage methods, K^+ ranged from 0.145 in C_2 to 0.215 in PX_1MS_3 respectively. All treated plots recorded significantly higher K^+ status than C_2 except AP_1AS_1. The order PX-CC>C_1>AP-CC>C_2 was observed. These results might be linked to higher pulverisation which might have led to release of more K^+ in all the tillage methods, and less release in C_2 plots and with minimal inter-tillage and PX_1MS_3 plot, this is in line with Beck et al. [40] who reported decrease K^+ in all cover crop treated plots. In 2009, tillage effect was similar in K^+; however, the order was reversed in favour of AP-CC>C_1>PX-CC>C_2. There was a decrease in K^+ value in PX-CC, C_1 and C_2 but K^+ in AP-CC was unchanged leading to a general decrease over the years, perhaps due to increase in rainfall which led to loses from leaching activity. In 2008, tillage method significantly influenced Na^+ level. The Na^+ level in MT was 22.2% higher than in TT. This result might be attributed to less disturbed soils in MT than in the TT leading to higher percentage of soil Na values. The IWM across tillage showed that PX-CC and AP-CC had similar effect on Na^+ which were comparable to Na^+ in C_2 plot (0.325). These were significantly higher Na^+ in plots than C_1 i.e. C_2/PX-CC/AP-CC>C_1. In 2009, tillage effect followed the 2008 pattern, MT>TT. The order AP-CC>PX-CC/C_1>C_2 was observed for Na^+. There was a general decrease in Na^+ status over the years except in C_1 and the decrease was highest in C_2. This result suggests the possibility of using melon, akidi and sweet potato for bioremediation of soils high in sodium, having been able to reduce Na^+ level in the soils. The low values and reduction in Na^+ in melon, akidi and sweet potato reflected the high diversity in such system making it more sustainable, this is in agreement with Sharma et al. [44] and Michael et al. [22] who reported decrease in Na^+ in cover crop plots than the control.

3.3 Exchangeable Acidity (EA) and Organic Carbon (OC)

The effect of tillage methods and IWM on EA and OC is presented in Table 5. In 2008, tillage effect was not significant, though TT>MT. The PX-CC and AP-CC had similar effect on EA. The EA was highest in C_2, followed by C_1 and PX-CC but lowest in AP-CC respectively. The control plots recorded EA that was higher than all IWM plots except the AMS_3 plots in both herbicide groups (4.1– 4.55). This suggests that diversity might enhance EA compared with less diverse CC plots. Furthermore, the reduction in EA in all IWM could be as a result of the integrated crop mixture through their root penetration and increased gaseous exchange at the soil exchange cites, leading to increase soil microbial activity and cation/anion exchange than the lower crop population or bare surfaces of the study plots. In 2009, tillage effect was not significant on EA of the soils though MT>TT. Across, tillage methods, EA ranged from 2.5 in MS_3 to 4.9 in A_1 and 2.6 in A_1 to 3.45 in AS_1 in PX and AP plots respectively when compared with 3.2 (C_1) and 3.0 (C_2), no significant influence of IWM treatments on EA over the two years. There was general decrease in EA in the controls and most treatments. This is in agreement with Legesse et al. [45] who reported a reduction in EA in a limed soil cultivated with common beans. This is also in line with the report of Yuan et al. [46] who reported higher reduction in EA in soil treated with leguminous biochar than non-leguminous biochar because the legumes have higher alkalinity and thus neutralized more exchangeable acidity of the soil. The decrease was highest in AMS_3 plots. However, an increase in EA was observed in PX_1A_1, PX_1S_3, AP_1AS_1, AP_1MS_3.

Tillage methods significantly influenced Organic Carbon (OC) in 2008. The OC in MT plot was 21.5% more than in TT plots. Across tillage systems, the OC ranged between 7.7 in MS_3 to 9.22 in A_1 and 7.3 in AS_1 to 8.3 in A_1 in PX and AP respectively. The order C_2>PX-CC>C_1/AP-CC. Treatments having Akidi (A_1, AS_1, AMS_3) seem to have higher OC than those without (S_3, MS_3). Sharma et al. [47] observed that the inclusion of continuous cover cropping resulted in small increases of organic C and total N only in the top 0 to 5 cm soil depth in the mixed cover crop treatment. The MT recorded high OC could be attributed to TT wheel traffic which lowers the macroporosity of the soils; thereby reducing microorganism activities which controls the organic matter decomposition and mineralization resulting to the low OC rates in the soils. The TT plots get easily compacted over the years, further degrading the soil texture and structure especially at the soil surface; this could reduce soil infiltration rates and microbial population. In contrast, MT ensures more microbial activities which improve the OC of the soils. This result is supported by Brady and Weil [48] who reported the effect of tractor tillage on soil properties. In 2009, tillage effect on OC was similar, though MT>TT slightly. PX_1AS_1, AP_1AS_1, AP_1MS_3, AP_1AMS_3 had significantly more OC than C_1 and the order AP-CC>C_2>PX-CC/C_1. These results might not be unconnected to the presence of akidi/sweet potato combination which improved OC and the increases in cover plant population observed in the combination of melon/sweet potato and akidi/melon/sweet potato by increasing more plant biomass and improve soil fertility which resulted in high OC. Furthermore, labile constituents of crop residues are used more efficiently by the soil microbial population, generating microbial products responsible for soil aggregation and stabilization of soil organic matter through strong connections with the soil mineral matrix [49].

3.4 Soil pH (water) and pH KCl

The effect of tillage methods and IWM on pH (water) and pH KCl is presented in Table 6. Tillage method significantly influenced pH (water) in 2008. Soil pH (water) in TT (5.78) was higher than in MT plots (5.6). Across the tillage methods, treatments with mixed cover crop in PX and AP_1A_1 recorded significantly higher pH than the controls. The order PX-CC>AP-CC/C_1/C_2 was observed. In 2009, pH (water) value in TT (5.78) was greater than MT value of 5.45. Soil pH (water) in all PX-CC-AS_1 (5.5)–A_1 (6.15) and AP_1A_1 recorded significantly higher pH value (water) when compared with C_1 (5.35) and the order C_2 >PX-CC>AP-CC>C_1 was observed. These results suggest the TT loses up the soil surface cohesion and adhesion thereby increasing soil erosion and leaching; washing the basic cation which then increases H^+ and Al^{2+} concentration. Hence the soil acidity is enhanced. Perreira et al. [50] reported the number of nitrogen fixation was enhanced under acidic conditions. There was a general decrease in soil pH (water) in AP-CC and C_1 but increased in C_2 plot over the year. Legesse et al. [45] reported decrease in pH in water after common bean genotypes treatments. The pH KCl followed similar trend as pH (water). Tillage method influenced pH KCl in 2008. The pH KCl in TT>MT. Across the tillage methods, pH KCl value in AP-CC (5.21)>PX-CC/C_2> C_1 (4.9) indicating increase in soil pH. In 2009, pH KCl in was TT>MT. The pH KCl value in PX-CC was higher than C_2 and AP-CC respectively showing acidic condition of the plots. A general increase in pH KCl was observed in all treatments which suggested that the exchangeable bases of the soils were leached thereby increasing soil acidity. This was in contrast with Arévalo-Gardini et al. [39] who reported that soil pH increased due to perennial vegetative cover with abundant foliage, which provides a permanent soil cover and abundant yearly addition of leaf litter that protects the soil from erosion and minimizes the nutrient loss by surface run-off and leaching.

3.5 Total Nitrogen (TN) and Available Phosphorus (A-VP)

The influence of tillage methods and IWM on TN and A-VP is presented in Table 7. The MT significantly increased TN by 21.50% when compared with TT in 2008. Across tillage, TN ranged between 0.76 (AP_1AS_1) to 1.19 (C_2). This variation could be as a result of high demand for nitrogen by the crop mixture plots than the C_2 plot, hence the trend. The TT disturbed the surface soil and nitrogen is highly volatile and easily washed by the action of downward gradient. In each herbicide-cover crop treatments, A_1 recorded the highest TN (0.87–0.96) which was significantly better than TN in C_1. The effect of PX-CC on TN was slightly higher than AP-CC. In 2009, tillage did not significantly influence TN of the soil. However, TN in PX_1AS_1, AP_1A_1, AP_1AS_1, AP_1MS_3 was significantly higher than in C_1 respectively. This is contrary to Mubiru and Coyne [51] who reported that all improved fallows produced significantly more N than the natural fallow. The order AP-CC/C_2>PX-CC was observed. These results indicated the cover crop mixture used; akidi, melon and sweet potato increased TN in the soils and increased plant population resulted in better results. Mixing crops of distinct families as in AMS has been tested by research and could result in intermediate C:N ratio and combine N input and soil protection [52,53].

Table 3. Effects of tillage methods and integrated weed management on calcium and magnesium status of soil in maize in 2008 and 2009

Treatments	Ca^{2+} cmol kg^{-1}									Mg^{2+} cmol kg^{-1}								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	1.76	1.63	1.695	2.61	1.98	2.295	48.30	21.47	35.40	0.30	0.36	0.33	0.35	0.36	0.355	16.67	0.00	7.58
PX_1S_3	1.96	2.22	2.09	2.70	2.50	2.6	37.76	12.61	24.40	0.34	0.39	0.365	0.41	0.45	0.43	20.59	15.38	17.81
PX_1AS_1	1.96	2.14	2.05	3.26	2.30	2.78	66.33	7.48	35.61	0.31	0.43	0.37	0.45	0.44	0.445	45.16	2.33	20.27
PX_1MS_3	2.19	1.84	2.015	1.89	2.26	2.075	-13.70	22.83	2.98	0.40	0.38	0.39	0.33	0.39	0.36	-17.50	2.63	-7.69
PX_1AMS_3	1.56	1.44	1.5	1.84	2.58	2.21	17.95	79.17	47.33	0.24	0.27	0.255	0.32	0.49	0.405	33.33	81.48	58.82
PX-CC	1.88	1.86	1.87	2.46	2.32	2.39	30.85	24.73	27.81	0.32	0.37	0.345	0.37	0.43	0.4	15.63	16.22	15.94
AP_1A_1	2.53	1.86	2.195	2.14	2.39	2.265	-15.42	28.49	3.19	0.39	0.39	0.39	0.35	0.38	0.365	-10.26	-2.56	-6.41
AP_1S_3	1.95	1.62	1.785	1.64	1.63	1.635	-15.90	0.62	-9.17	0.34	0.36	0.35	0.29	0.32	0.305	-14.71	-11.11	-12.86
AP_1AS_1	1.64	1.27	1.455	1.68	2.31	1.995	2.44	81.89	37.11	0.24	0.27	0.255	0.34	0.40	0.37	41.67	48.15	45.10
AP_1MS_3	1.71	2.28	1.995	2.23	2.56	2.395	30.41	12.28	20.05	0.35	0.44	0.395	0.38	0.46	0.42	8.57	4.55	6.33
AP_1AMS_3	1.72	1.43	1.575	1.72	1.83	1.775	0.00	27.97	12.70	0.30	0.25	0.275	0.33	0.35	0.34	10.00	40.00	23.64
AP-CC	1.91	1.69	1.8	1.88	2.14	2.01	-1.57	26.63	11.67	0.32	0.34	0.33	0.34	0.38	0.36	6.25	11.76	9.09
C_1	1.52	2.64	2.08	2.04	1.99	2.015	34.21	-24.62	-3.13	0.33	0.49	0.41	0.34	0.36	0.35	3.03	-26.53	-14.63
C_2	1.75	1.60	1.675	2.05	2.42	2.235	17.14	51.25	33.43	0.33	0.25	0.29	0.36	0.44	0.4	9.09	76.00	37.93
Mean	1.85	1.83	1.84	2.15	2.23	2.19	17.06	26.63	20.01	0.32	0.36	0.34	0.35	0.40	0.375	11.97	18.45	14.35
S.E.M.	0.083	0.119	0.101	0.140	0.088	0.114	7.09	7.92	4.77	0.014	0.023	0.0185	0.012	0.015	0.0135	5.32	8.82	6.10

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Table 4. Effects of tillage methods and integrated weed management on potassium and sodium status of soil in maize in 2008 and 2009

Treatments	K^{+} cmol kg^{-1}									Na^{+} cmol kg^{-1}								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	0.21	0.20	0.205	0.17	0.13	0.15	-19.05	-35.00	-26.83	0.35	0.36	0.355	0.25	0.23	0.24	-28.57	-36.11	-32.39
PX_1S_3	0.20	0.14	0.17	0.17	0.12	0.145	-15.00	-14.29	-14.71	0.36	0.25	0.305	0.27	0.26	0.265	-25.00	4.00	-13.11
PX_1AS_1	0.17	0.21	0.19	0.18	0.14	0.16	5.88	-33.33	-15.79	0.35	0.30	0.325	0.27	0.24	0.255	-22.86	-20.00	-21.54
PX_1MS_3	0.20	0.23	0.215	0.14	0.15	0.145	-30.00	-34.78	-32.56	0.35	0.33	0.34	0.28	0.27	0.275	-20.00	-18.18	-19.12
PX_1AMS_3	0.20	0.13	0.165	0.13	0.12	0.125	-35.00	-7.69	-24.24	0.24	0.23	0.235	0.28	0.25	0.265	16.67	8.70	12.77

Treatments	K^+ cmol kg^{-1}									Na^+ cmol kg^{-1}								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX-CC	0.20	0.18	0.19	0.16	0.13	0.145	-20.00	-27.78	-23.68	0.33	0.29	0.31	0.27	0.25	0.26	-18.18	-13.79	-16.13
AP_1A_1	0.19	0.14	0.165	0.13	0.18	0.155	-31.58	28.57	-6.06	0.32	0.24	0.28	0.28	0.30	0.29	-12.50	25.00	3.57
AP_1S_3	0.14	0.17	0.155	0.12	0.18	0.15	-14.29	5.88	-3.23	0.42	0.30	0.36	0.28	0.26	0.27	-33.33	-13.33	-25.00
AP_1AS_1	0.14	0.15	0.145	0.15	0.15	0.15	7.14	0.00	3.45	0.26	0.32	0.29	0.30	0.28	0.29	15.38	-12.50	0.00
AP_1MS_3	0.15	0.18	0.165	0.15	0.18	0.165	0.00	0.00	0.00	0.35	0.28	0.315	0.25	0.25	0.25	-28.57	-10.71	-20.63
AP_1AMS_3	0.14	0.18	0.16	0.14	0.14	0.14	0.00	-22.22	-12.50	0.36	0.19	0.275	0.26	0.28	0.27	-27.78	47.37	-1.82
AP-CC	0.15	0.16	0.155	0.14	0.17	0.155	-6.67	6.25	0.00	0.34	0.27	0.305	0.27	0.27	0.27	-20.59	0.00	-11.48
C_1	0.13	0.23	0.18	0.15	0.15	0.15	15.38	-34.78	-16.67	0.31	0.18	0.245	0.24	0.28	0.26	-22.58	55.56	6.12
C_2	0.13	0.16	0.145	0.13	0.15	0.14	0.00	-6.25	-3.45	0.35	0.30	0.325	0.25	0.25	0.25	-28.57	-16.67	-23.08
Mean	0.17	0.18	0.175	0.15	0.15	0.15	-10.23	-12.53	-12.59	0.33	0.27	0.3	0.27	0.26	0.265	-18.32	-0.05	-11.56
S.E.M.	0.009	0.010	0.0095	0.005	0.006	0.0055	4.38	5.46	3.16	0.014	0.016	0.015	0.005	0.006	0.0055	4.31	7.32	3.76

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), ,PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Table 5. Effects of tillage methods and integrated weed management on exchangeable acidity and organic carbon status of soil in maize in 2008 and 2009

	Exchangeable Acidity									Organic Carbon g kg^{-1}								
	2008			2009			%Change			2008			2009			%Change		
Treatments	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	1.50	4.00	2.75	2.9	6.90	4.9	93.33	72.50	78.18	8.51	9.92	9.215	7.63	7.43	7.53	-10.34	-25.10	-18.29
PX_1S_3	2.60	3.10	2.85	5.3	1.80	3.55	103.85	-41.94	24.56	8.30	8.30	8.3	8.61	7.02	7.815	3.73	-15.42	-5.84
PX_1AS_1	2.40	3.40	2.9	2.8	3.00	2.9	16.67	-11.76	0.00	9.32	7.70	8.51	5.48	13.50	9.49	-41.20	75.32	11.52
PX_1MS_3	2.80	3.30	3.05	2.4	2.60	2.5	-14.29	-21.21	-18.03	10.53	4.86	7.695	4.69	11.74	8.215	-55.46	141.56	6.76
PX_1AMS_3	5.50	3.60	4.55	2.8	2.40	2.6	-49.09	-33.33	-42.86	9.72	7.49	8.605	7.82	7.82	7.82	-19.55	4.41	-9.12
PX-CC	2.96	3.48	3.22	3.2	3.34	3.27	8.11	-4.02	1.55	9.28	7.65	8.465	6.85	9.50	8.175	-26.19	24.18	-3.43
AP_1A_1	3.40	2.90	3.15	2.4	2.80	2.6	-29.41	-3.45	-17.46	9.52	7.09	8.305	8.22	8.80	8.51	-13.66	24.12	2.47
AP_1S_3	3.00	2.90	2.95	3.3	2.50	2.9	10.00	-13.79	-1.69	7.90	7.90	7.90	8.02	3.91	5.965	1.52	-50.51	-24.49
AP_1AS_1	2.10	2.40	2.25	3.6	3.30	3.45	71.43	37.50	53.33	9.52	5.06	7.29	11.74	9.58	10.66	23.32	89.33	46.23
AP_1MS_3	2.40	3.40	2.9	3.8	2.40	3.1	58.33	-29.41	6.90	8.10	8.30	8.20	10.17	9.98	10.075	25.56	20.24	22.87
AP_1AMS_3	4.80	3.40	4.1	2.8	3.10	2.95	-41.67	-8.82	-28.05	8.10	8.10	8.10	9.98	9.39	9.685	23.21	15.93	19.57

	Exchangeable Acidity									Organic Carbon g kg^{-1}								
	2008			2009			%Change			2008			2009			%Change		
Treatments	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
AP-CC	3.14	3.00	3.07	3.1	2.82	2.96	-1.27	-6.00	-3.58	8.63	7.29	7.96	9.63	8.33	8.98	11.59	14.27	12.81
C_1	4.00	3.40	3.7	3.6	2.80	3.2	-10.00	-17.65	-13.51	8.71	7.29	8.00	8.80	6.65	7.725	1.03	-8.78	-3.44
C_2	4.00	4.40	4.2	3.1	2.90	3	-22.50	-34.09	-28.57	13.16	9.72	11.44	11.93	5.67	8.80	-9.35	-41.67	-23.08
Mean	3.21	3.35	3.28	3.23	3.04	3.135	13.82	-8.25	0.77	9.28	7.64	8.46	8.59	8.46	8.525	-6.13	19.13	2.47
S.E.M.	0.338	0.150	0.244	0.229	0.369	0.299	13.71	8.39	9.09	0.422	0.440	0.431	0.630	0.759	0.6945	6.72	14.61	5.41

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Table 6. Effects of tillage methods and integrated weed management on pH in water and KCl of soil in maize in 2008 and 2009

Treatments	pH (H_2O)									pH (KCl)								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	5.60	5.60	5.6	6.20	6.10	6.15	10.71	8.93	9.82	5.00	4.90	4.95	4.90	4.80	4.85	-2.00	-2.04	-2.02
PX_1S_3	5.40	5.80	5.6	5.30	6.10	5.7	-1.85	5.17	1.79	5.10	5.10	5.1	4.90	5.00	4.95	-3.92	-1.96	-2.94
PX_1AS_1	5.90	5.90	5.9	5.10	5.90	5.5	-13.56	0.00	-6.78	5.10	5.20	5.15	4.80	4.90	4.85	-5.88	-5.77	-5.83
PX_1MS_3	5.70	5.90	5.8	6.20	5.80	6	8.77	-1.69	3.45	4.90	5.10	5	4.70	4.90	4.8	-4.08	-3.92	-4.00
PX_1AMS_3	5.70	5.90	5.8	5.60	5.70	5.65	-1.75	-3.39	-2.59	4.90	5.10	5	4.70	4.90	4.8	-4.08	-3.92	-4.00
PX-CC	5.66	5.82	5.74	5.68	5.92	5.8	0.35	1.72	1.05	5.00	5.08	5.04	4.80	4.90	4.85	-4.00	-3.54	-3.77
AP_1A_1	5.80	6.00	5.9	5.50	5.90	5.7	-5.17	-1.67	-3.39	5.30	5.00	5.15	4.70	5.00	4.85	-11.32	0.00	-5.83
AP_1S_3	5.60	5.70	5.65	5.10	5.50	5.3	-8.93	-3.51	-6.19	4.90	5.00	4.95	4.40	4.60	4.5	-10.20	-8.00	-9.09
AP_1AS_1	5.90	5.50	5.7	5.20	5.60	5.4	-11.86	1.82	-5.26	5.00	5.90	5.45	4.70	4.90	4.8	-6.00	-16.95	-11.93
AP_1MS_3	5.60	5.90	5.75	5.10	5.70	5.4	-8.93	-3.39	-6.09	5.10	5.10	5.1	4.90	4.90	4.9	-3.92	-3.92	-3.92
AP_1AMS_3	5.30	5.40	5.35	5.00	5.60	5.3	-5.66	3.70	-0.93	4.90	5.90	5.4	4.70	4.70	4.7	-4.08	-20.34	-12.96
AP-CC	5.64	5.70	5.67	5.18	5.66	5.42	-8.16	-0.70	-4.41	5.04	5.38	5.21	4.68	4.82	4.75	-7.14	-10.41	-8.83
C_1	5.20	6.00	5.6	5.10	5.60	5.35	-1.92	-6.67	-4.46	4.70	5.10	4.9	4.90	4.70	4.8	4.26	-7.84	-2.04
C_2	5.50	5.80	5.65	6.00	5.90	5.95	9.09	1.72	5.31	4.90	5.10	5	4.70	4.80	4.75	-4.08	-5.88	-5.00
Mean	5.60	5.78	5.69	5.45	5.78	5.615	-2.78	0.15	-1.34	4.98	5.21	5.095	4.75	4.84	4.795	-4.75	-6.75	-5.87
S.E.M.	0.064	0.056	0.06	0.130	0.058	0.094	2.16	1.13	1.39	0.044	0.096	0.07	0.042	0.036	0.039	1.02	1.60	0.98

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), ,PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Table 7. Effects of tillage methods and integrated weed management on nitrogen and available phosphorus of soil in maize in 2008 and 2009

Treatments	TN (g kg^{-1})									A-VP (mg kg^{-1})								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	0.88	1.03	0.955	0.79	0.77	0.78	-10.23	-25.24	-18.32	5.68	1.52	3.6	2.08	3.0	2.54	-63.38	97.37	-29.44
PX_1S_3	0.86	0.86	0.86	0.89	0.73	0.81	3.49	-15.12	-5.81	3.47	0.42	1.945	4.71	1.3	3.005	35.73	209.52	54.50
PX_1AS_1	0.97	0.80	0.885	0.57	1.40	0.985	-41.24	75.00	11.30	5.41	2.08	3.745	5.41	3.6	4.505	0.00	73.08	20.29
PX_1MS_3	1.09	0.50	0.795	0.49	1.22	0.855	-55.05	144.00	7.55	6.66	4.02	5.34	4.85	2.2	3.525	-27.18	-45.27	-33.99
PX_1AMS_3	1.01	0.78	0.895	0.81	0.81	0.81	-19.80	3.85	-9.50	4.30	2.08	3.19	2.22	0.2	1.21	-48.37	-90.38	-62.07
PX-CC	0.96	0.79	0.875	0.71	0.99	0.85	-26.04	25.32	-2.86	5.10	2.02	3.56	3.85	2.1	2.975	-24.51	3.96	-16.43
AP_1A_1	0.99	0.74	0.865	0.85	0.91	0.88	-14.14	22.97	1.73	5.13	2.63	3.88	1.80	8.5	5.15	-64.91	223.19	32.73
AP_1S_3	0.82	0.82	0.82	0.83	0.41	0.62	1.22	-50.00	-24.39	4.71	0.42	2.565	0.69	2.4	1.545	-85.35	471.43	-39.77
AP_1AS_1	0.99	0.52	0.755	1.22	0.99	1.105	23.23	90.38	46.36	2.77	2.08	2.425	1.66	2.6	2.13	-40.07	25.00	-12.16
AP_1MS_3	0.84	0.86	0.85	1.06	1.04	1.05	26.19	20.93	23.53	2.63	1.39	2.01	1.52	2.3	1.91	-42.21	65.47	-4.98
AP_1AMS_3	0.84	0.84	0.84	1.04	0.97	1.005	23.81	15.48	19.64	1.94	1.66	1.8	1.52	0.5	1.01	-21.65	-69.88	-43.89
AP-CC	0.90	0.76	0.83	1.00	0.86	0.93	11.11	13.16	12.05	3.44	1.64	2.54	1.44	3.3	2.37	-58.14	101.22	-6.69
C_1	0.90	0.76	0.83	0.91	0.69	0.8	1.11	-9.21	-3.61	2.08	2.49	2.285	2.36	1.2	1.78	13.46	-51.81	-22.10
C_2	1.37	1.01	1.19	1.24	0.59	0.915	-9.49	-41.58	-23.11	1.11	0.42	0.765	0.55	2.0	1.275	-50.45	376.19	66.67
Mean	0.96	0.79	0.875	0.89	0.88	0.885	-6.13	19.28	2.47	3.82	1.77	2.795	2.45	2.48	2.465	-34.07	99.22	-6.95
S.E.M.	0.044	0.046	0.045	0.066	0.078	0.072	6.73	14.75	5.43	0.503	0.305	0.404	0.471	0.617	0.544	9.19	46.77	10.52

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), ,PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Available P followed the trend of TN. The A-VP in MT was 115.8% higher than in TT in 2008. All treated plots recorded significantly higher A-VP (1.95 (PX_1S_3) – 5.34 (PX_1MS_3)) when compared with C_2 (0.77). The order PX-CC>AP-CC/ C_1>C_2 was observed. In 2009, tillage effect on A-VP was not significant. Across the tillage methods, all PX-CC plots except PX_1AMS_3 and AP_1A_1 recorded significantly higher A-VP than the controls. The higher AV-P values observed in MT than TT could be due to less soil pedoturbation which reduces soil AVP loses when compared to deep TT method of soil tillage. In their study, Khairul et al. [54] found AVP in zero tillage was 41.90% higher than deep plough tillage in soils of Bangladesh. The order PX-CC>AP-CC> C_1>C_2 was also observed. There was a reduction in A-VP over the two years by 16.4%, 6.7% and 22.1% in PX-CC, AP-CC and C_1 plots respectively, whereas an increase in C_2. Weerasekara et al. [20] observed that P content decreased with time in all soil types, possibly due to uptake of nutrients by the cover crops.

3.6 ECEC and %Silt and Clay

The influence of tillage methods and IWM on ECEC and %Silt and Clay is presented in Table 8.

In 2008, tillage method did not significantly influence ECEC. Across tillage, all the IWM treatments except PX_1AMS_3 recorded significantly less ECEC when compared with the control plots. The order C_2/C_1>PX-CC>AP-CC was observed. These results suggest that crop removal of essential nutrients might have contributed to the reduction of the ECEC in the soils and higher ECEC value in PX_1AMS_3 plot might be due to increase in population of akidi/melon mixtures that improved the soil condition. The ECEC has the ability to influence soil structure stability, nutrient availability, soil pH and soil's reaction to fertilizers and other ameliorants [55]. In 2009, tillage effect was similar on ECEC. Across the tillage, ECEC ranged from 5.27 (AP_1S_3) to 7.95 (PX_1A_1). The ECEC in PX-CC was higher than in AP-CC, C_1 and C_2. Also, PX-CC>C_2/C_1/AP-CC order was observed. There was an increase in ECEC in IWM treated plots but, decrease in the control plots. A 9.40% and 2.40% ECEC increase in PX-CC and AP-CC respectively. This corroborates the findings of Degu et al. [56] that rotation with legume recorded ECEC and total nitrogen because of continuous deposits of sediments. This however, is in contrast with Hulugalle [57] who reported that total ECEC was not significantly affected by cover crop. Soil ameliorative ability of cover crop was primarily related to rapidity of formation of ground cover and subsoil root density.

The %silt and clay was not significantly influenced by tillage methods in 2008. However, in 2009, %silt and clay was significantly higher in TT than MT respectively. This could be due to the ability of TT to improve infiltration, aeration and microbial activity thereby increasing silt/clay content of the soils. Across tillage, all the treated plots except PX_1AS_1 recorded low %silt and clay when compared with C_2 in 2008. Similar trend was observed in 2009. Most treated plots except PX_1A_1, PX_1AMS_3 and AP_1AMS_3 recorded less %silt and clay than C_2. There was a general increase in %silt and clay in treated plots, but a slight decrease in the controls as observed in ECEC status. These results might be partly due to the sandy loose nature of the soils, soil nutrients depletion by the crop mixtures leading to removal of clay and silt materials encouraged by disturbance of soils by the tractor tillage. This is in contrast with Hulugalle [57] who reported that sand and silt contents were not significantly affected by cover crop.

3.7 %Clay and %Silt

Table 9 shows the effect of tillage methods and IWM on %clay and %silt. In 2008, there was no significant effect of tillage on %clay, but, in 2009, %clay in MT was 91.9% higher than in TT. This result could be attributed to TT created way path ways on the soils surface which led to increase in surface erosion; washing away the silt/clay component of the soils leaving a more coarse soil fraction. In addition to that, leaching of soil nutrients contributed to weak surface soils easily degraded when soils were exposed to more. This suggests that pulverization reduces clay content. Across the tillage, in 2008, %clay in PX_1AS_1, AP_1A_1, AP_1AMS3 (7.4% each) was higher than the control plots (6.4%). Hulugalle [57] reported significant increase in clay content following cover crop treatment. The pooled analysis showed no significant difference in %clay in PX-CC, AP-CC and the controls. In 2009, C_2 recorded the highest %clay (6.7%) which was significantly higher than the %clay in the rest of the treatments. Degu et al. [56] reported that rotation with legume reported that clay content in conserved system is greater than un-conserved system because of continuous deposits of sediments. A general reduction in %clay was observed in all the treated plots including C_1 but a slight increase in C_2. This general decrease over the years in most CCM plots is in contrast with the findings from the evaluation of impact of cover crops on soil in two maize farms where Mahama et al. [58] observed an increase in % clay after two growing seasons.

The %silt was not significantly influenced by tillage methods in 2008. However, in 2009, %silt in TT>MT by 36.20%. The increase in %silt might have resulted from increase in soil activity by decomposition action of microorganisms after the soils tilt by the disc plough. This process led to improved biding ability of the soils, reduced erodibility of clay and silt from the soil fraction. Furthermore, any deposition of clay and silt materials by moving water was accommodated due to improved soil conditions. Across the tillage, the order C_2>C_1/PX-CC>AP-CC was observed in 2008. However, in 2009, %silt was in the order PX-CC (14.8%)>AP-CC>C_2>C_1. Over the two years, there was an observed increase in %silt in PX-CC (11.4 – 14.8) and AP-CC (10.6 – 13.7) plots when compared to decrease in C_2 plot. This is in contrast with the findings of Mahama et al. [58] who reported decrease in % silt (55 to 49% and 39 to 38% respectively) in two maize farms planted with cover crops over two growing seasons. Michael et al. [22] in their evaluation of sole planted akidi, melon or sweet potato in association with maize on soil physico-chemical properties observed that there was a decline in the silt proportion; but fine sand increased in all the treatments over the years.

3.8 %Fine Sand

The effect of tillage methods and IWM on %fine sand is presented in Table 10. Tillage did not significantly influence %fine sand in 2008, but in 2009, %fine sand in MT was higher than in TT (1.4%). Similar result of no statistical significance of soil properties under tillage methods was reported by Fuentes et al. [59]. Across tillage methods, in 2008, all the treated plots except PX_1AS_1 recorded significantly higher %fine sand than C_2. This might have been due to the nature of the soils and pedogenic process that formed the soils from its origins. Fine sand is characteristic of sandy loam soils and clay content might have been washed from the soil surface as a result of erosion hazard. All AP-CC plots except the sole plant cover crop plots; A_1, MS_3 and AMS_3 in PX-CC plots recorded higher %fine sand than C_1. In 2009 however, C_1 recorded the highest %fine sand. The order C_1>AP-CC/PX-CC/C_2 was also observed. There was a general decrease in %fine sand in PX-CC, AP-CC but slight increase in the control plots. Thus, %fine sand was reduced by IWM. The reduction in fine sand increased coarse sand fraction due to low clayey contends in soil particle fraction mix. This is in contrast with the findings of Michael et al. [22] in their evaluation of sole planted cover crops in association with maize on soil physico-chemical properties who observed that fine sand increased in all the treatments over the years. The present study however agrees with the findings of Hulugalle [57] and Seguel et al. [60] who reported that sand content was not significantly affected by preceding cover crop.

3.9 Comparative Evaluation of Tillage Methods

Comparable evaluation of tillage methods in Table 11 shows that in manual tilled system, there was a general decrease in the values of K^+ (9.3%), Na^+ (18.3%), pH (H_2O) (2.6%), pH (KCl) (4.6%), organic carbon (5.9%), AV-P (32.9%), TN (5.9%), clay (0.3%) and fine sand (0.7%). These results seem to be linked to the effect of tillage which encouraged erosion of already fragile sandy soil surface by action of water, nutrient losses as a result of crop removal and leaching; further reduced the clay/silt component of the soils which increased soil acidity. Since the soil pH increased, other soil properties were significantly affected; hence the observed trend. However, a slight increase was observed in Ca^{2+} (17.5%), Mg^{2+} (11.9%), exchangeable acidity (15.5%), ECEC (9.6%), silt and clay (5%) and silt (12.4%). This change is expected due to the Ca-Mg^{2+} bearing parent materials in the study site. Changes in magnitude of various soil parameters in TT showed that there was equally a decrease in K^+ (11.9%), pH (KCl) (6.7%), exchangeable acidity (8.8%), clay (44.1%) and fine sand (1.42%). However, an increase was observed in Ca^{2+} (26.7%), Mg^{2+} (19.5%), Na^+ (1.1%), pH (H_2O) (0.09%), organic carbon (19.1%), TN (19.3%), AV-P (41.2%), ECEC (2.8%), silt and clay (11.6%) and silt (44.4%) contents. The integrated crop mixtures of akidi/melon and sweet potato improved the soil texture and structure thereby the observed change in soil values. In their study, Khairul et al. [54] found tillage practices showed positive effects on Soil Properties and crop yields. They observed highest OM accumulation, maximum root mass density and improved physical and chemical properties in the conventional tillage practices. This supports findings were there was significant changes in soil properties in this study.

Table 8. Effects of tillage methods and integrated weed management on cation exchange capacity and % silt and clay of soil in maize in 2008 and 2009

Treatments	CEC									%Silt and Clay								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	4.12	6.56	5.34	6.28	9.61	7.945	52.43	46.49	48.78	18.80	14.80	16.8	18.80	22.80	20.8	0.00	54.05	23.81
PX_1S_3	5.46	6.10	5.78	8.85	5.13	6.99	62.09	-15.90	20.93	14.80	20.80	17.8	18.80	14.80	16.8	27.03	-28.85	-5.62
PX_1AS_1	5.19	6.49	5.84	6.96	6.12	6.54	34.10	-5.70	11.99	16.80	24.80	20.8	18.80	18.80	18.8	11.90	-24.19	-9.62
PX_1MS_3	5.93	6.09	6.01	5.03	5.67	5.35	-15.18	-6.90	-10.98	16.80	14.80	15.8	15.40	20.80	18.1	-8.33	40.54	14.56
PX_1AMS_3	7.73	5.67	6.7	5.37	5.85	5.61	-30.53	3.17	-16.27	18.80	14.80	16.8	19.40	20.80	20.1	3.19	40.54	19.64
PX-CC	5.69	6.18	5.935	6.50	6.48	6.49	14.24	4.85	9.35	17.20	18.00	17.6	18.24	19.60	18.92	6.05	8.89	7.50
AP_1A_1	6.82	5.54	6.18	5.30	6.05	5.675	-22.29	9.21	-8.17	18.80	18.80	18.8	15.40	20.80	18.1	-18.09	10.64	-3.72
AP_1S_3	5.84	5.36	5.6	5.64	4.89	5.265	-3.42	-8.77	-5.98	18.80	18.80	18.8	17.40	18.80	18.1	-7.45	0.00	-3.72
AP_1AS_1	4.39	4.41	4.4	6.06	6.44	6.25	38.04	46.03	42.05	14.80	14.80	14.8	19.40	18.80	19.1	31.08	27.03	29.05
AP_1MS_3	4.96	6.58	5.77	6.80	5.85	6.325	37.10	-11.09	9.62	18.80	14.80	16.8	17.40	16.80	17.1	-7.45	13.51	1.79
AP_1AMS_3	7.31	5.44	6.375	5.25	5.70	5.475	-28.18	4.78	-14.12	14.80	16.80	15.8	19.40	20.80	20.1	31.08	23.81	27.22
AP-CC	5.87	5.46	5.665	5.81	5.79	5.8	-1.02	6.04	2.38	17.20	16.80	17	17.80	19.20	18.5	3.49	14.29	8.82
C_1	6.29	6.94	6.615	6.37	5.57	5.97	1.27	-19.74	-9.75	18.80	16.80	17.8	15.40	16.80	16.1	-18.09	0.00	-9.55
C_2	6.56	6.70	6.63	5.88	6.16	6.02	-10.37	-8.06	-9.20	16.80	22.80	19.8	19.40	18.80	19.1	15.48	-17.54	-3.54
Mean	5.89	5.99	5.94	6.15	6.09	6.12	9.16	3.17	5.04	17.30	17.80	17.55	17.92	19.13	18.525	4.99	11.62	6.90
S.E.M.	0.323	0.211	0.267	0.304	0.344	0.324	8.52	5.62	5.68	0.500	1.000	0.75	0.482	0.644	0.563	4.62	6.87	3.84

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), ,PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Table 9. Effects of tillage methods and integrated weed management on %clay and %silt clay of soil in maize in 2008 and 2009

Treatments	% CLAY									% SILT								
	2008			2009			%Change			2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	5.40	5.40	5.4	7.40	1.40	4.4	37.04	-74.07	-18.52	13.40	9.40	11.4	11.40	21.40	16.4	-14.93	127.66	43.86
PX_1S_3	5.40	7.40	6.4	5.40	1.40	3.4	0.00	-81.08	-46.88	9.40	13.40	11.4	13.40	13.40	13.4	42.55	0.00	17.54
PX_1AS_1	7.40	7.40	7.4	5.40	1.40	3.4	-27.03	-81.08	-54.05	9.40	17.40	13.4	13.40	17.40	15.4	42.55	0.00	14.93
PX_1MS_3	7.40	5.40	6.4	6.00	3.40	4.7	-18.92	-37.04	-26.56	9.40	9.40	9.4	9.40	17.40	13.4	0.00	85.11	42.55
PX_1AMS_3	7.40	3.40	5.4	6.00	3.40	4.7	-18.92	0.00	-12.96	11.40	11.40	11.4	13.40	17.40	15.4	17.54	52.63	35.09
PX-CC	6.60	5.80	6.2	6.04	2.20	4.12	-8.48	-62.07	-33.55	10.60	12.20	11.4	12.20	17.40	14.8	15.09	42.62	29.82
AP_1A_1	7.40	7.40	7.4	6.00	3.40	4.7	-18.92	-54.05	-36.49	11.40	11.40	11.4	9.40	17.40	13.4	-17.54	52.63	17.54
AP_1S_3	5.40	7.40	6.4	6.00	3.40	4.7	11.11	-54.05	-26.56	13.40	11.40	12.4	11.40	16.40	13.9	-14.93	43.86	12.10
AP_1AS_1	5.40	3.40	4.4	6.00	3.40	4.7	11.11	0.00	6.82	9.40	11.40	10.4	13.40	15.40	14.4	42.55	35.09	38.46
AP_1MS_3	7.40	5.40	6.4	6.00	3.40	4.7	-18.92	-37.04	-26.56	11.40	9.40	10.4	11.40	13.40	12.4	0.00	42.55	19.23
AP_1AMS_3	7.40	7.40	7.4	6.00	5.40	5.7	-18.92	-27.03	-22.97	7.40	9.40	8.4	13.40	15.40	14.4	81.08	63.83	71.43
AP-CC	6.60	6.20	6.4	6.00	3.80	4.9	-9.09	-38.71	-23.44	10.60	10.60	10.6	11.80	15.60	13.7	11.32	47.17	29.25
C_1	5.40	7.40	6.4	6.00	3.20	4.6	11.11	-56.76	-28.13	13.40	9.40	11.4	9.40	13.40	11.4	-29.85	42.55	0.00
C_2	5.40	7.40	6.4	8.00	5.40	6.7	48.15	-27.03	4.69	11.40	15.40	13.4	11.40	13.40	12.4	0.00	-12.99	-7.46
Mean	6.40	6.23	6.315	6.18	3.22	4.7	-1.48	-45.00	-24.65	10.90	11.57	11.235	11.73	15.98	13.855	12.53	44.48	26.02
S.E.M.	0.302	0.458	0.38	0.218	0.386	0.302	6.32	7.28	4.65	0.557	0.757	0.657	0.482	0.701	0.5915	8.49	9.89	5.57

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), ,PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2=unweeded control

Table 10. Effects of tillage methods and integrated weed management on %fine sand of soil in maize in 2008 and 2009

Treatments	% Fine Sand								
	2008			2009			%Change		
	MT	TT	AV	MT	TT	AV	MT	TT	AV
PX_1A_1	81.20	85.20	83.2	81.2	77.20	79.2	0.00	-9.39	-4.81
PX_1S_3	85.20	79.20	82.2	81.2	85.20	83.2	-4.69	7.58	1.22
PX_1AS_1	83.20	75.20	79.2	81.2	81.20	81.2	-2.40	7.98	2.53
PX_1MS_3	83.20	85.20	84.2	84.6	79.20	81.9	1.68	-7.04	-2.73
PX_1AMS_3	81.20	85.20	83.2	80.6	79.20	79.9	-0.74	-7.04	-3.97
PX-CC	82.80	82.00	82.4	81.7	80.40	81.05	-1.33	-1.95	-1.64
AP_1A_1	81.20	81.20	81.2	84.6	79.20	81.9	4.19	-2.46	0.86
AP_1S_3	81.20	81.20	81.2	82.6	81.20	81.9	1.72	0.00	0.86
AP_1AS_1	85.20	85.20	85.2	80.6	81.20	80.9	-5.40	-4.69	-5.05
AP_1MS_3	81.20	85.20	83.2	82.6	83.20	82.9	1.72	-2.35	-0.36
AP_1AMS_3	85.20	83.20	84.2	80.6	79.20	79.9	-5.40	-4.81	-5.11
AP-CC	82.80	83.20	83	82.2	80.80	81.5	-0.72	-2.88	-1.81
C_1	81.20	83.20	82.2	84.6	83.20	83.9	4.19	0.00	2.07
C_2	83.20	77.20	80.2	80.6	81.20	80.9	-3.13	5.18	0.87
Mean	82.70	82.20	82.45	82	80.87	81.435	-0.74	-1.56	-1.22
S.E.M.	0.500	1.000	0.75	0.482	0.644	0.563	0.90	1.48	0.76

A= Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), ,PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%)
A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands ha^{-1}, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1},
MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, $^{2+}$ =unweeded control

Table 11. Comparative effect of tillage methods on soil properties

Properties	2008			2009				%Change			
	MT	TT	Average	MT	TT	Average	Se	MT	TT	Average	Se
Ca cmol kg^{-1}	1.85	1.83	1.84	2.15	2.23	2.19	0.07	16.22	21.86	19.02	1.33
Mg cmol kg^{-1}	0.32	0.36	0.34	0.35	0.40	0.375	0.01	9.37	11.11	10.29	0.41
K cmol kg^{-1}	0.17	0.18	0.175	0.15	0.15	0.15	0.01	-11.76	-16.67	-14.29	1.16
Na cmol kg^{-1}	0.33	0.27	0.3	0.27	0.26	0.265	0.01	-18.18	-3.70	-11.67	3.42
Exch. Acidity	3.21	3.35	3.28	3.23	3.04	3.135	0.04	0.62	-9.25	-4.42	2.33
pH (H_2O)	5.6	5.78	5.69	5.45	5.78	5.615	0.05	-2.68	0.00	-1.32	0.63
pH (KCl)	4.98	5.21	5.095	4.75	4.84	4.795	0.07	-4.62	-7.10	-5.89	0.59
O.C g kg^{-1}	9.28	7.64	8.46	8.59	8.46	8.525	0.19	-7.44	10.73	0.77	4.29
TN g kg^{-1}	0.96	0.79	0.875	0.89	0.88	0.885	0.02	-7.29	11.39	1.14	4.41
AV-P mg kg^{-1}	3.82	1.77	2.795	2.45	2.48	2.465	0.25	-35.86	40.11	-11.81	18.31
ECEC	5.89	5.99	5.94	6.15	6.09	6.12	0.04	4.41	1.67	3.03	0.65
%Silt and Clay	17.3	17.8	17.55	17.92	19.13	18.525	0.25	3.58	7.47	5.56	0.92
%Clay	6.4	6.23	6.315	6.18	3.22	4.7	0.48	-3.44	-48.31	-25.57	10.58
%Silt	10.9	11.57	11.235	11.73	15.98	13.855	0.74	7.61	38.12	23.32	7.19
%Fine Sand	82.7	82.2	82.45	82	80.87	81.435	0.25	-0.85	-1.62	-1.23	0.18

The Na^+, organic carbon, TN, %clay and %fine sand were higher in MT than TT during the experimental period while Mg^{2+} pH, %silt and clay and %silt were higher in TT than in MT.

With continuous usage of a particular tillage method, over the years, the following were observed;

i. in both tillage methods, Ca^{2+}, Mg^{2+}, ECEC, %silt and clay and %silt increased.
ii. in both tillage methods, K^+, Na^+, pH (KCl), %clay, %fine sand decreased.
iii. MT increased exch. acidity, while TT decreased exch. acidity.
iv. MT decreased pH (H_2O), organic carbon, TN, AV-P; while TT increased organic carbon, TN and AV-P.

3.10 Effect of Tillage Method and Integrated Weed Management on Maize Grain Yield (MGY)

The effects of tillage and IWM treatments on maize grain yield (MGY) is presented in Table 12a and 12b.

There was no significant tillage effect on MGY throughout the experimental periods, though MGY was higher in TT plot. In 2008, MGY in PX_1MS_3 plot was significantly higher than in PX_1AMS_3 by 60.3%. In 2009, MGY in AP_1A_1 was the highest (3.4 tha^{-1}), which was significantly ($p<0.05$) higher than in unweeded and all PX-CC treatments, except PX_1S_3 and PX_1AS_1.The two-year average shows no significant tillage by treatment interaction on MGY. The MGY in AP_1 A_1 treated plots was significantly higher (61.1%) than in PX_1AMS_3. All the IWM treatments

Table 12a. Effect of tillage methods and herbicide-cover crop treatments on maize grain yield (kg ha^{-1})

	2008	2009	Average
Tillage			
MT	2273.0a	1873.1a	2073.1a
TT	2256.0a	2281.3a	2268.6a
Treatments			
AP_1A_1	2172.6abcd	3410.6a	2791.6a
AP_1S_3	2261.2abcd	2028.7abc	2144.9abc
AP_1AS_1	2296.3abcd	2011.3abc	2153.8abc
AP_1MS_3	2580.2abc	2158.8abc	2369.5ab
AP_1AMS_3	2038.2abcd	2318.2abc	2178.2abc
PX_1A_1	2482.4abc	1485.1bc	1983.8abc
PX_1S_3	1913.4bcd	2004.3abc	1958.9abc
PX_1AS_1	2436.1abc	2126.0abc	2281.0ab
PX_1MS_3	2869.3ab	1690.4bc	2279.8ab
PX_1AMS_3	1790cd	1674.9bc	1732.4bc
C_1	2916.7a	2879.7ab	2898.2a
C_2	1417.8d	1138.6c	1278.2c
Tillage X Treatment	*	NS	NS

Table 12b. Interaction of tillage and integrated weed management treatments on maize grain yield in 2008

	2008	
	TT	MT
Treatments		
AP_1A_1	1985.7bcd	2359.4abcd
AP_1S_3	2148.8abcd	2373.5abcd
AP_1AS_1	2443.7abcd	2148.8abcd
AP_1MS_3	2126.7abcd	3033.6abc
AP_1AMS_3	2464.8abcd	1611.6cd
PX_1A_1	2935.3abc	2029.5bcd
PX_1S_3	1033.3d	2793.4abc
PX_1AS_1	3096.8ab	1775.3bcd
PX_1MS_3	3501.3a	2237.3abcd
PX_1AMS_3	1305.1d	2274.9abcd
C_1	2995.7abc	2837.7abc
C_2	1034.3d	1801.2bcd

Means followed by the same letter (s) in the same column are not significantly different by DMRT at 5 probability A=Atrazine, P= Pendimethalin AP_1 = 0.5 + 0.5 kg a.i. ha^{-1} (25 %), PX = Primextra, PX_1 = 0.625 kg a.i. ha^{-1} (25%),A_1= Akidi at 20,000 stands ha^{-1}, S_3 = Sweet potato at 40,000 stands/ha, AS_1 =Akidi + Sweet potato at 20,000 stands ha^{-1}, MS_3 = Melon + Sweet potato at 40,000 stands ha^{-1}, AMS_3 = Akidi + Melon + Sweet potato at 40,000 stands ha^{-1}, C_1=weeded control, C_2 =unweeded control (3 + 6 WAP) MT= Manual Tillage TT=Tractor Tillage except PX_1AMS_3 had MGY that were comparable to C_1. The MGY in AP_1A_1, AP_1MS_3, PX_1AS_1, PX_1MS_3 significantly higher than unweeded by 118.4, 85.4, 78.5 and 78.4% respectively.

The similarity in the yield in most IWM and hand-weeded controlled plots suggests that low herbicide rates whose effects keep the field clean in the earlier phase of maize growth was further complemented by the ground cover achieved through various cover crops. However, in 2009, the nitrogen fixing potential of akidi, which could increase N available through the process of decomposition of its litter at peak of the growing phase of maize plants might be responsible for higher maize grain yields in 2009 in AP_1A_1 compared with the 2008 yield in line with the findings of Choudhary and Choudhary [61]. This could also explain, the significantly higher MGY in AP_1A_1 than PX_1AMS_3 and unweeded plots. Leguminous cover crop has been reported to increase yield of associated maize [62].

4. SUMMARY

This study evaluated the secondary or additional impact of integrated weed management on soil physical and chemical properties. The influence of tillage methods which constituted the main treatments shows that the Na^+, organic carbon, TN, %clay and %fine sand were higher in MT than TT during the experimental period while Mg^{2+} pH, %silt and clay and %silt were higher in TT than in MT. The effect of the herbicide grouping indicates that PX-CC on TN was slightly higher than AP-CC. All treated plots recorded significantly higher K^+ status than C_2 except AP_1AS_1. The order PX-CC>C_1>AP-CC>C_2 was observed.

The Ca^{2+}, K^+in all IWM treated plots were higher than the value in C_2 (1.675) except PX_1AMS_3 and AP_1AS_1. All treated plots recorded significantly higher A-VP. Treatments having Akidi (A_1, AS_1, AMS_3) seem to have higher OC than those without (S_3, MS_3)

There was a general increase in Mg^{2+} in all IWM treated plot and C_2 but a decrease in C_1 plot over the years.

The control plots recorded EA that was higher than all IWM plots except the AMS_3 plots in both herbicide groups (4.1– 4.55). No significant influence of IWM treatments on EA over the two years. Treatments having Akidi (A_1, AS_1, AMS_3) seem to have higher OC than those without (S_3, MS_3)

In each herbicide-cover crop treatments, A_1 recorded the highest TN (0.87–0.96) which was significantly better than TN in C_1. However, TN in PX_1AS_1, AP_1A_1, AP_1AS_1, AP_1MS_3 was significantly higher than in C_1 respectively.

All treated plots recorded significantly higher A-VP (1.95 (PX_1S_3) – 5.34 (PX_1MS_3)) when compared with C_2 (0.77).

Across tillage, all the IWM treatments except PX_1AMS_3 recorded significantly less ECEC when compared with the control plots.

Across tillage, most treated plots except PX_1A_1, PX_1AMS_3 and AP_1AMS_3 recorded less %silt and clay than C_2. There was a general increase in %silt and clay in treated plots.

5. CONCLUSION AND RECOMMENDATION

Most significant enhancement in soil properties were recorded in plots treated with akidi (A_1, AS_1, AMS_3) in both herbicide groups under manual tillage and thus recommended for maize production in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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