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Effects of poultry litter and the residues of maggot's production on chemical fertility of a lixisol and maize (*Zea mays* L.) yield in western of Burkina Faso.

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ABSTRACT

Organic substrates have shown their importance in the sustainable management of soil fertility and crops production. A study was conducted during 2 years (2016 and 2017) at western of Burkina Faso to evaluate the effects of poultry litter (PL) and the residues of maggots' production (RMP) on soil chemical fertility and maize yield. The experimental design was a completely randomized block design with nine treatments and three replications. The treatments in 2016 included : *T0 : natural soil fertility (control) ; T1 = NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; T2 = PL (5000 g/25 m^2) ;T3 = RMP (5000 g/25 m^2) ; T4 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) ; T5 = PL (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T6 = RMP (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T7 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T8 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (375 g/25 m^2) + Urea (125 g/25 m^2).* In 2017, the same treatments received only *NPK (187.5 g/25 m²) and urea (62.5 g/25 m²).* Data collection concerned soil, pH_{H2O}, pH_{KCl}, total carbon (C), total nitrogen (N), total phosphorus (P-total), total potassium (K-total), available phosphorus (P-ass) and exchangeable potassium (K-ex). Crop measurement concerned maize grain and maize straw yields. The results show that organic substrates didn't have a significant effect on soil chemical parameters during 2016 cropping season. However, the treatment T6 has increased significantly ($P < 0.05$) maize yield during 2016 cropping season to 84 and 38 % compared to T0 and T1 respectively. Moreover, the treatment T6 induced a significant rear effect during the 2017 season on soil C, N, K-total and K-ex and C/N ratio. It was concluded that RMP could be considered as organic substrates which have a great agronomic value and could help to reduce mineral fertilizer quantity.

1.0. Introduction

Burkina Faso agriculture is facing many difficulties, among which low productivity of soil and climatic precariousness. Most of the soils are lixisol, characterised by bad structural stability of superficial horizons linked to their richness in silts and fine sands and their low organic matter content (Pieri,1989). According to Zoundi *et al.* (2006), agricultural land degradation constitutes one of the significant threat to food production. Facing this problem, many studies are done to improve soil fertility management (Bationo *et al.,* 2012; Blanchard *et al.,* 2014; Gomgnimbou *et al.,* 2016; Coulibaly *et al.,* 2018). The studies of Blanchard *et al.* (2014) showed that farms produce and use a diversity of organic substrates in real conditions. However, the quantities produced remain low and also cover 7 to 28 % of the needs of farms in western Burkina Faso (Vall *et al.,* 2012).

To mobilise other sources of organic substrates, the studies of chemical characterization of animal manures (cattle, sheep, goat, pig, poultry, ...) were done by Gomgnimbou *et al.* (2016). These authors got 33.07 and 2.58 % of carbon and nitrogen content, respectively in the poultry manure. In addition to that, Coulibaly *et al.* (2018) showed that poultry manure produced in farms of western of Burkina Faso could contribute from 26.46 to 35.72 % of the total organic manure produced of these farms. Various organic jvsubstrates are used to produce maggots which are used to feed poultry (Pomalégni *et al.,* 2016). Among these organic substrates, poultry manure is the most used for the production of maggots in the western conditions of Burkina Faso, because it is available, cheaper and give higher maggot output. (Sanou *et al.,* 2018; Sankara, 2017; Bamogo, 2017). In the maggots production process, there are organic residues which are also produced. These residues can be used to fertilize soil (Diener *et al.,* 2011; Zhu *et al.,* 2015).

This paper which focused on the use of organic substrates produced from poultry activity aimed to evaluate the effects of poultry litter and residues from maggots' production (combined or not) on soil chemical fertility and maize yield.

2.0. Materials and methods

2.1. Site description.

The experiments were carried out in the experimental field of Institut du Developpement Rural (Université Nazi BONI), located in Bobo-Dioulasso which is about 375 km far from Ouagadougou, the capital of Burkina Faso. The university is in the village of Nasso where the experimental site is located between 4° 25' West longitude and 11° 12' North latitude. The climate is south Sundanese type, characterised by annual rainfall between 800 and 1200 mm (Fontes and Guinko, 1995). The average of the last 10 years rainfall (2006-2015) is 1065.45 mm with the lowest in 2011 (775.4 mm) and the highest in 2014 (1278.3 mm). The 2016 rainfall during cropping season was not well distributed in time with 1190.6 mm and 85 days of rain. That of 2017 was only 747.9 mm for 82 days. The soil of the study area is a lixisol (IUSS Working Group WRB, 2015) with sandy texture in the surface horizons.

Table 1 : soil chemical characteristics before experimentation

pH_{H2O}	pH_{KCl}	C (%)	N (%)	C/N	P-total (mg/kg sol)	P-ass (mg/kg)	K-total (mg/kg sol)	K-ex (mg/kg)
5.89	4.65	0.37	0.03	13.96	51.63	2.00	329.54	36.01

Table 1 gives the chemical characteristics of the soil before the experiment. The sesame was the previous crops of the experiment.

2.2. Study Materials

The plant material used was maize (*Zea mays* L.), and FBC6 (Farako Bâ Composite n°6) was the variety. That variety has 91 days cycle with 5.6 t/ha potential yield (Sanou, 1993). The seeds were purchased with a company specialized in the sale of seeds at Bobo-Dioulasso.

Table 2: Chemical characteristics of poultry litter and residues of maggots' production used

	pH_{H2O}	C (%)	MM (%)	N (%)	C/N	P_total (mg/kg)	K_total (mg/kg)
PL	6.77	36.00	37.94	2.35	15	7680	10077
RMP	7.37	31.26	46.12	1.86	17	11145	10287

Legend: *PL: poultry litter; RMP: residues of maggots' production; MM: mineral matter; C: carbon; N: nitrogen ; P: phosphorus; K: potassium.*

The organic substrates used were residues of maggots' production (RMP) and poultry litter (PL). They are gotten on the same site. RMP is obtained after maggots' production. Table 2 gives its chemical composition. The mineral fertilizers used are the complex NPK (15-15-15) and urea (46 % N). These fertilizers were also purchased in a local market of Bobo-Dioulasso.

3.0. Experimental design

The experiment was a completely randomized block design (CRBD) with nine treatments. The total area of the experiment design was 935 m² (55 m x 17 m). The area of each plot was 25 m² (5 m x 5 m), and there were 3 blocks (replicates) the field. Between two blocks there was 2 m wide guard strip, and between two plots there was 1 m wide guard strip.

Table 3 gives the treatments formulated in 2016 cropping season. In 2017 cropping season only mineral fertilizers were applied to all plots at the doses of 187.5 g/25 m² for NPK and 62.5 g/25 m² for urea. The quantities of 375 and 125 g/25 m² correspond respectively to the doses of 150 and 50 kg/ha of NPK and urea popularized at Burkina Faso. The quantities of 187.5 and 62.5 g/25 m² correspond to the half-doses (75 and 25 kg/ha) of NPK and urea respectively. As to the quantities of

Table 3 : Quantities of organic substrates and fertilizers used

Treatments	NPK (g/25 m²)	Urea (g/25 m²)	PL (g/25 m²)	RMP (g/25 m²)
T0	0	0	0	0
T1	375	125	0	0
T2	0	0	5 000	0
T3	0	0	0	5 000
T4	0	0	2 500	2 500
T5	187.5	62.5	0	5 000
T6	187.5	62.5	5 000	0
T7	187.5	62.5	2 500	2 500
T8	375	125	2 500	2 500

Legend: PL: poultry litter; RMP: residues of maggots' production

5000 and 2500 g/25 m² of organic substrates, they correspond respectively to the doses of 2 and 1 t/ha of these substrates (respectively dose and half-dose recommended for organic fertilizer in Burkina Faso).

3.1. Crop establishment

In 2016, the experiment field was weeded, and after that, tillage was carried out with animal traction on 20 cm depth. The organic substrates were applied according to the quantities per treatment. The maize was planted 3 seeds per pocket 4 days after tillage (July 16, 2016). A reduction to 2 plants per pocket was carried out the 8th day after planting (DAP). The pockets were separated from 0.4 m, and the sowing lines were separated from 0.8 m. NPK was applied the 15th DAP and urea the 40th DAP according to the doses per treatment. Weeding was done manually twice at 25 and 61 DAP. In 2017, except the application of organic substrates, all production practices of 2016 were conducted, and the sowing was done June 21, 2017.

3.2. Soil sampling and analysis

Soil samples were collected each year after harvest from 0 -20 cm soil depth. Five samples per plot collected were mixed to constitute a sample per plot. So, 27 samples collected per year were used to determine chemical parameters such as pH_{H2O}, pH_{KCl}, total carbon (C), total nitrogen (N), total phosphorus (P-total), total potassium (K-total), available phosphorus (P-av) and exchangeable potassium (K-ex). The analysis was done at the laboratory of the Department of *Gestion des Ressources Naturelles et Système de Production (GRN-SP)* of *INERA (Institut de l'Environnement et de Recherches Agricoles)* at *Farako-Ba (Bobo-Dioulasso)*. Soil pH_{H2O} and pH_{KCl} were determined according to the ratio 1/2.5 through a suspension of the soil sample, respectively, in the distilled water and the solution of KCl (AFNOR, 1981). The total C was determined by Walkley and Black (1934) procedure. The total N and total P were determined by Kjeldhal digestion method, available P was determined by BRAY I extraction (Bray and Kurtz , 1945). K-total was dosed using flame photometer after mineralisation of soil samples. Exchangeable K was also determined using flame photometer by the method of Walinga *et al.* (1995).

3.3. Yield parameters of maize

Maize grain and straw yields were determined by harvesting the cobs and stems of maize of each useful plot (9 m^2). Grain and straw samples were dried at 105°C during 24 hours in the stone. The values gotten were extrapolated per kg/ha.

3.4. Statistical analysis

Data collected were subjected to analysis using Xlstat statistical software, 2018 version. Analysis of variance was done, and treatment means were compared using the Newman-Keuls test, and the Least significant different (LSD) was considered at a 95% confidence interval. It was also used for the correlation test of Pearson at $p = 0.05$.

4.0. Results

4.1. Effects of organic substrates on soil pH

The soil of the experiment site are acids with $pH_{H2O,}$ which has varied between 5.80 and 6.05 in 2016, and between 5.95 and 6.27 in 2017 (Table 4). The soil pH_{KCl} has varied in 2016 between 4.10 and 4.85, and 2017 between 4.70 and 5.15. The analysis of variance has shown that organic substrates have no significant effect (p > 0.05) on soil pH in 2016 as well as in 2017.

4.2. Effects of organic substrates on soil C, N and C/N

Table 4: Variation of soil pH of the treatments

	2016		2017*	
	pH_{H2O}	pH_{KCl}	pH_{H2O}	pH_{KCl}
T0	5.97 ± 0.14	4.85 ± 0.17	6.03 ± 0.11	4.90 ± 0.29
T1	5.90 ± 0.08	4.54 ± 0.12	6.08 ± 0.13	4.78 ± 0.11
T2	5.88 ± 0.09	4.63 ± 0.22	6.02 ± 0.08	4.70 ± 0.14
T3	5.91 ± 0.11	4.76 ± 0.17	6.07 ± 0.04	4.86 ± 0.12
T4	5.88 ± 0.11	4.69 ± 0.20	5.95 ± 0.06	4.70 ± 0.11
T5	5.92 ± 0.10	4.81 ± 0.12	6.03 ± 0.07	4.81 ± 0.11
T6	6.05 ± 0.30	4.10 ± 0.47	6.27 ± 0.19	5.15 ± 0.32
T7	5.80 ± 0.10	4.59 ± 0.25	6.10 ± 0.07	4.79 ± 0.18
T8	5.92 ± 0.08	4.69 ± 0.31	6.09 ± 0.02	4.80 ± 0.12
F	0.758	0.980	2.465	1.640
Pr > F	0.642	0.482	0.053	0.182
Significant	No	No	No	No

***Legend** : pH = potential hydrogen; H_2O = water; KCl = potassium chloride; T0 : Control ; T1 = NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; T2 = PL (5000 g/25 m^2) ;T3 = RMP (5000 g/25 m^2) ; T4 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) ; T5 = PL (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T6 = RMP (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T7 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T8 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; * = During 2017, the same treatments received only NPK (187.5 g/25 m²) and urea (62.5 g/25 m²) without organic substrates.*

ratio

Table 5 shows that in 2016, the soil C content varied between 0.29 and 0.41%, N content varied between 0.02 and 0.03%. The ratio of C/N was ranged from 12.65 to 13.63 in 2106. In 2017, C content varied from 0.24 to 0.43%, N content varied from 0.02 to 0.04% and C/N ratio from 10.06 to 13.72. The difference observed in 2016 between the treatments was not significant (p > 0,05) for the soil parameters considered. However, in 2017 the C and N contents and C/N ratio of T6 (*RMP (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2))* was significantly higher (p < 0,05).

Table 5: Variation of soil C, N and C/N ratio of the treatments

	2016			**2017***		
	C (%)	**N (%)**	**C/N**	**C (%)**	**N (%)**	**C/N**
T0	0.36 ± 0.02	0.03 ± 0.00	13.17 ± 0.20	$0.26^{a} \pm 0.03$	$0.03^{a} \pm 0.00$	$10.30^{a} \pm 0.56$
T1	0.39 ± 0.14	0.03 ± 0.01	12.75 ± 0.55	$0.27^{a} \pm 0.01$	$0.03^{a} \pm 0.00$	$10.86^{a} \pm 0.85$
T2	0.33 ± 0.05	0.03 ± 0.00	13.24 ± 0.72	$0.24^{a} \pm 0.05$	$0.02^{a} \pm 0.00$	$10.60^{a} \pm 0.91$
T3	0.29 ± 0.03	0.02 ± 0.00	12.65 ± 1.11	$0.29^{ab} \pm 0.05$	$0.03^{a} \pm 0.00$	$10.82^{a} \pm 0.42$
T4	0.35 ± 0.02	0.03 ± 0.00	13.57 ± 0.69	$0.31^{ab} \pm 0.05$	$0.03^{a} \pm 0.00$	$10.06^{a} \pm 1.44$
T5	0.41 ± 0.05	0.03 ± 0.00	13.63 ± 0.33	$0.30^{ab} \pm 0.04$	$0.03^{a} \pm 0.00$	$11.08^{a} \pm 0.13$
T6	0.40 ± 0.07	0.03 ± 0.00	13.11 ± 0.31	$0.43^{b} \pm 0.13$	$0.04^{b} \pm 0.01$	$13.72^{b} \pm 1.81$
T7	0.39 ± 0.04	0.03 ± 0.00	13.43 ± 0.59	$0.29^{ab} \pm 0.06$	$0.03^{a} \pm 0.01$	$10.94^{a} \pm 0.18$
T8	0.40 ± 0.06	0.03 ± 0.00	13.19 ± 0.06	$0.31^{ab} \pm 0.02$	$0.03^{a} \pm 0.00$	$10.97^{a} \pm 0.21$
F	1.158	1.027	0.958	2.591	3.845	4.049
Pr > F	0.375	0.451	0.497	0.045	0.008	0.007
Significant	No	No	No	Yes	Yes	Yes

***Legend** : C = carbon ; N = nitrogen ; T0 : Control ; T1 = NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; T2 = PL (5000 g/25 m^2) ;T3 = RMP (5000 g/25 m^2) ; T4 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) ; T5 = PL (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T6 = RMP (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T7 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T8 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; * = During 2017, the same treatments received only NPK (187.5 g/25 m²) and urea (62.5 g/25 m²) without organic substrates ; Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Newman-Keuls test.*

4.3. Effects of organic substrates on soil P and K

The results show that in 2016, P-total content varied from 49.54 to 60.82 mg/kg of soil, available P from 1.64 to 3 mg/kg, K-total from 353.55 to 418.93 mg/kg, and exchangeable K from 28.29 to 40.32 mg/kg (Table 6). In 2017, P-total varied from 48.42 to 66.91 mg/kg of soil, available P from 1.43 to 3.17 mg/kg, K-total from 315.26 to 455.82 mg/kg, and exchangeable K from 17.28 to 50.77 mg/kg. For these parameters, the differences observed between treatments were not significant at p = 0.05 in 2016. However, in 2017 the difference was significant (p < 0.05) between treatments for the same parameters excepted P-total. The highest available P (3.17 mg/kg of soil) was observed for the treatment T8. The treatments T4 (455.82 mg/kg of soil), T6 (432.00 mg/kg of soil) and T8 (442.20 mg/kg of soil) were statistically similar, but they had higher K-total compared to the other treatments. The highest exchangeable K was noted for the treatment T6 (50.77 mg/kg of soil).

4.4. Analysis of the correlation between C and N, available P and exchangeable K

Figure 2 gives the results of a correlation test between various parameters. C content and N content, available P content and exchangeable K content. The correlations between C and N (Figure 2a), and C and exchangeable K (Figure 2b) were significant (p < 0.0001) with R^2 = 0.7361 and 0.230 respectively (Figure 2a). On the other hand, no significant correlation was observed between C and available P (p = 0.480; R^2 = 0.0096) (Figure 2c).

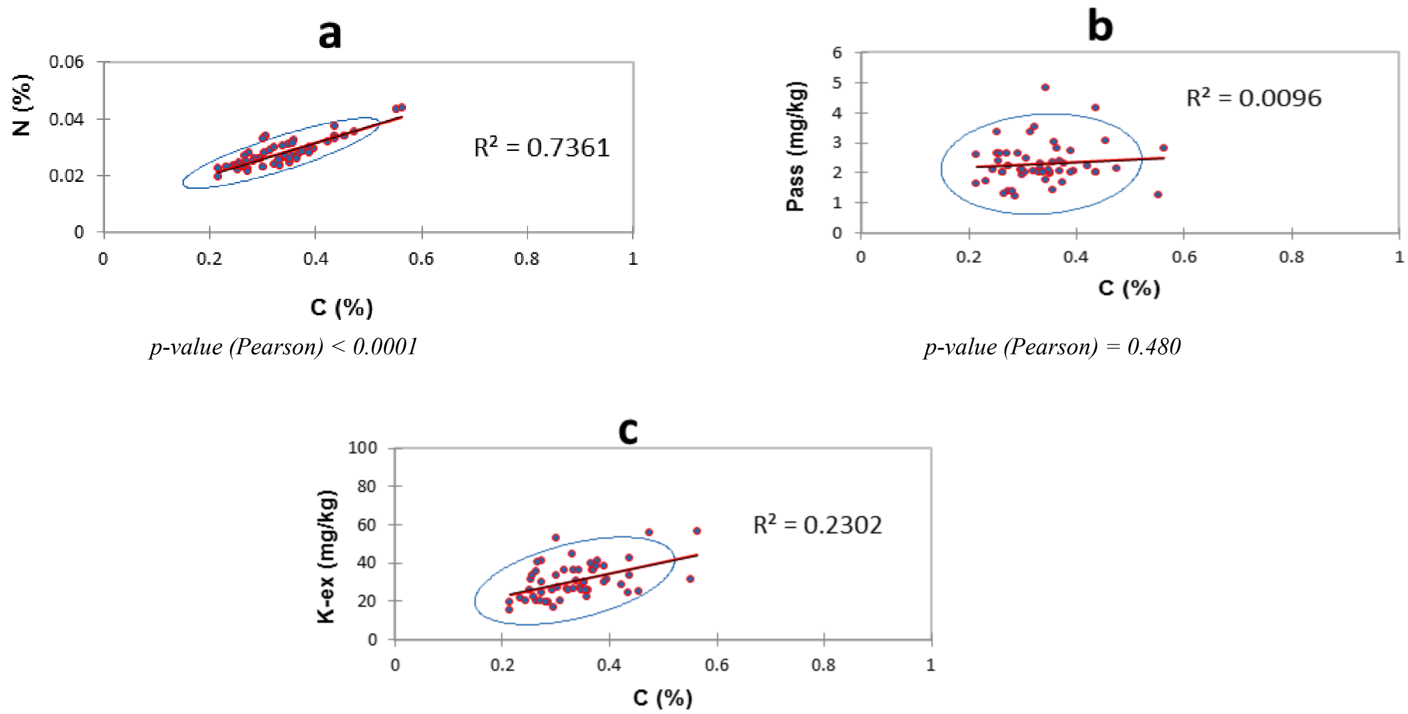
4.5. Effects of organic substrates on the maize yield

The data of the grain and straw yields of maize are presented in Table 7. The yields in 2016 varied from 157.46 to 1187.04 kg/ha for grain, and from 730.47 to 2751.60 kg/ha for straw. In 2017, the yields ranged from 111.65 to 946.89 kg/ha and from 640.40 to 2822.71 kg/ha respectively for grain and straw. On average, for the 2 years cropping season, the grain yields varied from 137.78 to 999.79 kg/ha while the straw yields varied from 685.43 to 2787.15 kg/ha. The analysis of variance showed a signifi-

Table 6: Variation of soil P and K of the treatments

	2016				2017*			
	P_total (mg/kg)	**P_av mg/kg)**	**K_total mg/kg)**	**K_ex mg/kg)**	**P_total (mg/kg)**	**P_ass mg/kg)**	**K_total mg/kg)**	**K_ex mg/kg)**
T0	49.54 ± 10.08	1.94 ± 0.41	377.85 ± 14.44	36.90 ± 1.02	48.42 ± 3.72	1.43^{a} ± 0.25	379.17^{ab} ± 25.20	27.20^{a} ± 11.49
T1	57.10 ± 8.99	1.64 ± 0.54	353.55 ± 14.62	31.54 ± 9.27	56.53 ± 10.51	1.61^{ab} ± 0.36	315.26^{a} ± 46.01	21.58^{a} ± 2.62
T2	60.82 ± 10.45	2.31 ± 0.05	426.66 ± 28.71	35.77 ± 5.37	59.23 ± 10.43	2.12^{ab} ± 0.49	362.11^{ab} ± 41.80	17.28^{a} ± 2.06
T3	58.57 ± 5.03	2.22 ± 0.39	418.93 ± 51.00	30.24 ± 3.52	64.64 ± 5.71	2.28^{abc} ± 0.31	372.16^{ab} ± 49.53	22.24^{a} ± 2.86
T4	52.16 ± 2.96	2.03 ± 0.05	402.38 ± 36.94	37.07 ± 7.36	59.94 ± 4.75	2.42^{bc} ± 0.08	455.82^{b} ± 17.39	26.53^{a} ± 6.50
T5	53.25 ± 2.81	2.67 ± 0.52	377.49 ± 28.32	32.19 ± 7.37	62.36 ± 9.75	2.02^{ab} ± 0.00	409.00^{ab} ± 40.58	31.16^{a} ± 4.01
T6	55.84 ± 9.53	3.00 ± 1.59	369.27 ± 37.06	40.32 ± 14.28	66.91 ± 4.73	2.31^{abc} ± 0.43	432.00^{b} ± 54.84	50.77^{b} ± 7.44
T7	55.03 ± 12.66	2.97 ± 1.10	361.43 ± 24.78	28.29 ± 3.37	52.52 ± 2.65	3.01^{cd} ± 0.35	398.93^{ab} ± 57.09	24.55^{a} ± 1.72
T8	59.70 ± 2.52	2.14 ± 0.13	394.30 ± 14.20	29.27 ± 3.52	56.53 ± 3.72	3.17^{d} ± 0.46	442.20^{b} ± 15.72	29.18^{a} ± 6.30
F	0.624	1.266	2.116	0.997	2.145	8.314	3.438	8.050
Pr > F	0.748	0.320	0.089	0.471	0.085	0.000	0.014	0.000
Significant	No	No	No	No	No	Yes	Yes	Yes

***Legend** : P-total = total phosphorus ; P_ass = available phosphorus; K-total = total potassium ; K_ex = exchangeable potassium ; T0 : Control ; T1 = NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; T2 = PL (5000 g/25 m^2) ;T3 = RMP (5000 g/25 m^2) ; T4 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) ; T5 = PL (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T6 = RMP (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T7 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2) ; T8 = PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (375 g/25 m^2) + Urea (125 g/25 m^2) ; * = During 2017, the same treatments received only NPK (187.5 g/25 m²) and urea (62.5 g/25 m²) without organic substrates ; Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Newman-Keuls test.*



p-value (Pearson) < 0.0001

p-value (Pearson) = 0.480

p-value (Pearson) = 0.000

Figure 2 : Correlation test between C and N, available P and exchangeable K

***Legend :** N = nitrogen ; C = carbon ; P_ass = available phosphorus ; K_ex = exchangeable potassium*

cant difference ($p < 0.05$) between treatments in 2016; T8 had the highest grain yield, and T6 the highest straw yield. This significant difference was maintained between the treatments when the average of the 2 years was done. In this order, the treatments T6 (999.79 kg/ha) and T8 (910.83 kg/ha) which gave the highest grain yield, were statistically similar. On the other hand, T6 had the highest straw yield (2787.15 kg/ha). No significant difference ($p > 0.05$) was observed between the treatments in 2017.

4.6. Analysis of correlation between grain yield and (a) N, (b) C, (c) available P and (d) exchangeable K of soil

The correlation between grain yield and N content was significant ($p < 0.0001$) with $R^2 = 0.2716$ (Figure 3a). Figure 3b shows also significant difference between grain yield and C content ($p < 0.0001$) with $R^2 = 0.2972$. On the

Table 7: Variation of the grain and straw yield of maize

	2016		2017*		Average 2016-2017	
	Grain (kg/ha)	Straw (kg/ha)	Grain (kg/ha)	Straw (kg/ha)	Grain (kg/ha)	Straw (kg/ha)
T0	$163.90^{a} \pm 98.20$	$730.47^{a} \pm 384.25$	111.65 ± 135.46	640.40 ± 407.19	$137.78^{a} \pm 109.62$	$685.43^{a} \pm 357.51$
T1	$648.24^{ab} \pm 74.75$	$1811.43^{abc} \pm 181.70$	313.85 ± 37.72	1722.54 ± 666.05	$481.05^{ab} \pm 190.65$	$1766.98^{ab} \pm 439.35$
T2	$157.46^{a} \pm 118.77$	$1069.72^{ab} \pm 343.72$	358.18 ± 209.39	1856.49 ± 683.08	$257.82^{a} \pm 187.80$	$1463.10^{ab} \pm 647.76$
T3	$245.69^{a} \pm 244.24$	$1114.79^{ab} \pm 153.75$	608.71 ± 231.13	1938.89 ± 337.05	$427.20^{ab} \pm 291.14$	$1526.84^{ab} \pm 508.57$
T4	$446.82^{ab} \pm 171.71$	$1243.29^{ab} \pm 191.63$	618.42 ± 371.16	2164.91 ± 357.22	$532.62^{ab} \pm 275.19$	$1704.10^{ab} \pm 566.17$
T5	$823.32^{ab} \pm 312.64$	$1876.76^{abc} \pm 495.85$	509.57 ± 234.82	1790.55 ± 104.04	$666.45^{ab} \pm 301.14$	$1833.65^{b} \pm 323.89$
T6	$1052.68^{ab} \pm 493.00$	$2751.60^{c} \pm 884.72$	946.89 ± 486.54	2822.71 ± 1380.74	$999.79^{b} \pm 441.89$	$2787.15^{c} \pm 1037.87$
T7	$768.22^{ab} \pm 255.50$	$896.30^{ab} \pm 637.94$	520.79 ± 295.26	1388.58 ± 320.45	$644.51^{ab} \pm 281.69$	$1142.44^{ab} \pm 525.89$
T8	$1187.04^{b} \pm 733.26$	$2331.50^{bc} \pm 1031.45$	634.62 ± 551.91	1680.26 ± 836.18	$910.83^{b} \pm 654.57$	$2005.88^{b} \pm 912.40$
F	3.699	4.535	1.612	2.284	4.092	5.062
Pr > F	0.010	0.004	0.190	0.069	0.001	0.000
Significant	Yes	Yes	No	No	Yes	Yes

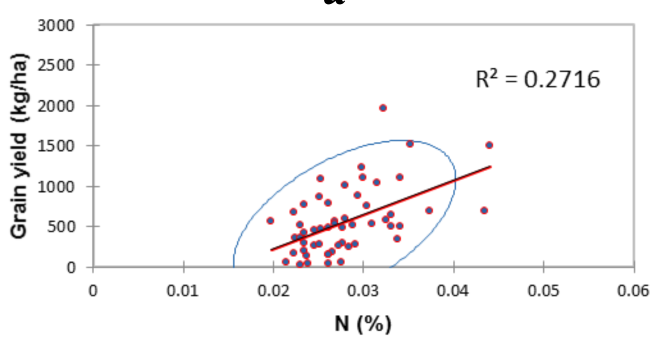
Legend : *T0 : Control ; T1 = NPK (375 g/25 m²) + Urea (125 g/25 m²) ; T2 = PL (5000 g/25 m²) ;T3 = RMP (5000 g/25 m²) ; T4 = PL (2500 g/25 m²) + RMP (2500 g/25 m²) ; T5 = PL (5000 g/25 m²) + NPK (187.5 g/25 m²) + Urea (62.5 g/25 m²) ; T6 = RMP (5000 g/25 m²) + NPK (187.5 g/25 m²) + Urea (62.5 g/25 m²) ; T7 = PL (2500 g/25 m²) + RMP (2500 g/25 m²) + NPK (187.5 g/25 m²) + Urea (62.5 g/25 m²) ; T8 = PL (2500 g/25 m²) + RMP (2500 g/25 m²) + NPK (375 g/25 m²) + Urea (125 g/25 m²) ; * = During 2017, the same treatments received only NPK (187.5 g/25 m²) and urea (62.5 g/25 m²) without organic substrates ; Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Newman-Keuls test.*

other hand, the correlation between grain yield and available P content was not significant ($p = 0.177$; $R^2 = 0.0347$) (Figure 3c). It is the same between grain yield and exchangeable K content ($p = 0.268$; $R^2 = 0.0716$) (Figure 3d).

5.0. Discussion

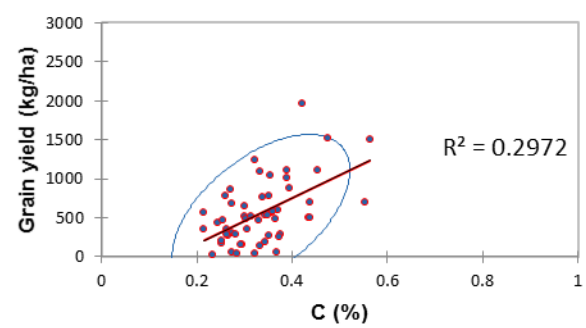
The effect of treatments on soil pH was not significant ($p > 0.05$). Those results indicate that using poultry litter and residues of maggots' production combined or separately at 2 t/ha do not influence soil pH significantly . The similar results were obtained by Habib *et al*. (2015) who were compared fertilizer and poultry waste combined with farm

a



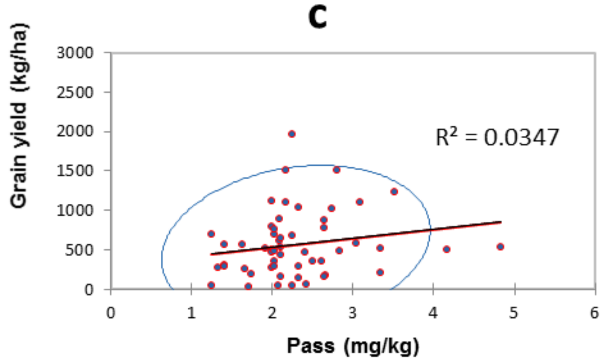
p-values (Pearson) < 0.0001

b



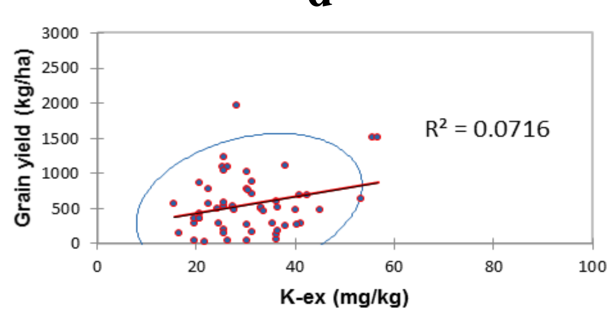
p-values (Pearson) < 0.0001

c



p-values (Pearson) < 0.0001

d



p-values (Pearson) = 0.268

Figure 3 : Correlation test between grain yield and (a) N, (b) C, (c) available P and (d) exchangeable K of soil
Legend : N = nitrogen ; C = carbon ; P_ass = available phosphorus ; K_ex = exchangeable potassium

waste, either municipal solid waste or well-decomposed cow dung.

In 2016, the treatments did not have a significant effect on soil C, N, C/N ratio, P-total, available P, K-total and exchangeable K. However a significant rear effect in 2017 of T6 *(RMP (5000 g/25 m^2) + NPK (187.5 g/25 m^2) + Urea (62.5 g/25 m^2))* was noted on C content, N content, K-total content, exchangeable K content and C/N ratio. The treatment T8 (*PL (2500 g/25 m^2) + RMP (2500 g/25 m^2) + NPK (375 g/25 m^2) + Urea (125 g/25 m^2)*) had also significant rear effect on available P and K-total content. The treatment T4 (*PL (2500 g/25 m^2) + RMP (2500 g/25 m^2)* also had a significant rear effect on K-total. Increasing of soil chemical parameters by poultry litter has been noted by previous studies (Agbede *et al.,* 2013; Adekiya *et al.,* 2014; Habib *et al.,* 2015; Adekiya *et al.,* 2016). For this study, it was the combination of organic substrates and fertilizer which influenced soil chemical fertility. The use of the same combination of organic substrates and fertilizer (T6 et T8) induced better maize yields compared to their separated use in 2016. This could be explained by the concentration of the nutrient of organic substrates used and added to those brought by fertilizers. The availability and absorption by maize plants of all those nutrients have been increased. The combined effect of organic matter and fertilizer on crop yields has been shown by other authors (Habib *et al.,* 2015; Koulibaly *et al.,* 2015; Akanza *et al.,* 2016). The yields obtained with T6 in 2016, in 2017 as well as the average of the 2 years, suggest that nutrients of residues of maggots' production (RMP) are easer available for plants than nutrients of poultry litter (PL). Those RMP behave like fertilizer than a soil amendment.

The correlation between C and N, as well as exchangeable K, was significant. The correlation between C and N was shown by Martel and Laverdiere (1976). The grain yield was also correlated to C content and N content. So, grain yield increases when C content and N content increase. Seremesic *et al.* (2011) reported a positive relation between C and wheat yield.

Overall, we can say that 2 t/ha of organic substrates used during that study are low to induce essential effects. Adekiya *et al.* (2016) showed that soil nutrients contents, as well as cocoyam yield, increase when the quantity of poultry manure increase. So, they have found on the one hand that soil chemical parameters, as well as cocoyam yield, were similar to those obtained with the control without poultry manure. On the other hand, the difference to the control became significant when the quantities of poultry manure reached 5 t/ha. The increasing of the quantity of PL and RMP will be a hypothesis for sustainable management of soil fertility like lixisol. However, it should be noted that the quantities of PL and RMP produced and collected in the farms of western Burkina Faso are insufficient (Coulibaly *et al.,* 2018) to consider this solution. So, we suggest the best combination of PL and RMP with other organic substrates like cattle, sheep or goat manure which are also produced in the farms (Blanchard *et al.,* 2014; Coulibaly *et al.,* 2018). This will help to increase farms coverage rate of organic matter needs and for their sustainable soil management. The combination of RMP and other organic substrates can reduce the quantity of fertilizers which are becoming expensive for small farms.

6.0. Conclusion

In western zone of Burkina Faso and on lixisol which has been the subject of this study, the treatment T6 which brings residues of maggots' production (RMP) combined to popularized half-dose fertilizer (75 kg/ha of NPK and 25 kg/ha of urea), is the technology which can improve maize production and induce a positive rear effect on soil chemical fertility. In 2016 cropping season, it has increased maize grain yield to 84 and 38 % compared respectively to T0 (control) and T1 (fertilizer popularized dose, 150 kg/ha of NPK and 50 kg/ha of urea). In 2017, this increase has been 88 and 67 % always compared to T0 and T1, respectively. So, the residues of maggots' production could be combined with other organic substrates in the farms with perspective to reduce fertilizers using.

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