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RESEARCH ARTICLE

EFFECTS OF IMPROVED BURKINA PHOSPHATE (ROCH) AND ORGANIC AMENDMENTS ON SOIL CHEMICAL PROPERTIES AND MAIZE (*ZEAMAYS L.*) YIELD IN WESTERN BURKINA FASO

Adama TRAORÉ^{1*}, Shinya IWASAKI², Olivier DJINDIERE³, Check Kaled Serge TRAORÉ³, Karim TRAORÉ¹ and Pascal BAZONGO⁴

¹Institute of Environment and Agricultural Research (INERA), Department of Natural Resources Management and Production System, Farako-Bâ. Soil Water Plant Laboratory, Bobo-Dioulasso, Burkina Faso; ² Japan International Research Center for Agricultural Sciences; ³Nazi BONI University/ Rural Development Institute (UNB/IDR), Bobo-Dioulasso, Burkina Faso; ⁴Yembila Abdoulaye TOGUYENI University (University of Fada N'Gourma), High Institute for Sustainable Development, Fada N'Gourma, Burkina Faso

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*Corresponding author:
Ignacio Bonasa Alzurria

ABSTRACT

The soils of Burkina Faso are poor in major nutrients, with a particularly pronounced deficiency in phosphorus. However, the country has enormous deposits of natural phosphate (Burkina phosphate), but these are little used in agricultural production because of their slow solubilization. Phosphate rock was therefore processed to make the phosphorus more readily available to crops. This processing involved partial acidification and calcination. The objective of the study was to test the effectiveness of partially acidified (BPA) or calcined (BPC) Burkina phosphate on soil chemical properties and maize yield. A completely randomized Fisher block design with seven treatments and four replicates was therefore set up in western Burkina Faso. The treatments consisted of T0: (urea)+P (TSP)+K (KCl); T1: N (urea)+(TSP)+K (KCl)+BP; T2: N (urea)+P (BPC)+K (KCl); T3: (urea)+(BPA)+(KCl); T4: compost+T1; T5: compost+T2; T6: compost+T3. The data collected were soil chemical parameters and maize yield. At harvest, high pHwater values (5.4 ± 0.08), high organic carbon ($0.47 \pm 0.08\%$) and total nitrogen ($0.043 \pm 0.006\%$) contents were observed with treatment T6. The same treatments T4 (116.99 ± 1.70 mg/kg) and T6 (16.77 ± 3.70 mg/kg) had the highest levels of available phosphorus. For grain yields, treatments T4 (2964 ± 210 kg/ha) and T6 (2809 ± 150 kg/ha) recorded the highest values. The use of BPA + compost can increase soil phosphorus content and sustainably increase maize yields in Burkina Faso compared to commercial phosphate fertilizers.

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INTRODUCTION

Soils under crops in Burkina Faso are facing declining productivity. Among the causes are poor farming practices that reduce nutrient content. Indeed, agriculture in Burkina Faso uses very little fertilizer due to high costs and organic restitution. This leads to soils that are not only poor in major nutrients but also in organic matter. Among the limiting factors, phosphorus deficiency is at the top of the list. In fact, 93% of cultivated soils have total phosphorus contents of less than 0.06% and low levels of phosphorus that can be assimilated by crops (Koulibaly *et al.*, 2014). Among the crops produced, maize, long ranked third in cereal production, has moved to the top of the list since 2020 (MAAH, 2021). However, like nitrogen, phosphorus is one of the nutrients essential for maize growth and yields (Nsimba *et al.*, 2019). It promotes good root development, plant vigor that enables them to withstand drought, rapid flowering and fruiting, and

good grain filling (Bourama and Laouali, 2020). To increase the phosphorus content of soils with a view to sustainably increasing agricultural production in Burkina Faso, Bikienga (2011) and Lompo (2009) recommended regular and sufficient inputs of Burkina phosphate (BP). Despite its availability, BP is rejected by most producers because of its very slow phosphorus release characteristics. This is mainly due to its low chemical reactivity, which makes it unsuitable for direct application (Nakamura *et al.*, 2013; Bikienga, 2014). However, processes involving acidification or calcination of Burkina phosphate (BP) have proven effective in both solubilizing BP and improving agricultural yields (Nakamura *et al.*, 2016; Nakamura *et al.*, 2019; Fukuda *et al.*, 2021). One solution for improving the availability of phosphorus in BP is to add it to an organic fertilizer source (Pouya, 2008; Traore, 2016). However, most studies conducted on acidified (BPA) or calcined (BPC) phosphate rock in Burkina Faso have not paid much attention to their effectiveness when combined with organic fertilizer (FO), and even less so on maize cultivation.

The addition of organic fertilizer to BPA or BPC could improve phosphate nutrition of crops and organic status of soils, leading to increased maize yields in Burkina Faso.

MATERIALS AND METHODS

MATERIAL:

Study site: The study was conducted during two agricultural seasons from 2021 to 2022 at the Farako-Bâ environmental and agricultural research station. The geographical coordinates are 11°06' north latitude and 4°20' west longitude at an altitude of 405 m. The climate of the area is South Sudanese, characterized by alternating dry (October to April) and rainy (May to November) seasons. Average temperatures range from 17 to 37°C during the dry season and 10 to 32°C during the rainy season. The annual rainfall recorded in 2021 and 2022 in the area was 1031.3 mm and 1281.5 mm, respectively. The soils at the site are leached tropical ferruginous soils characterized by high acidity and low organic matter and mineral content (Traore *et al.*, 2020).

Plant material: *Barkamaize* variety was used as the plant material for the study. It's a white variety with a potential yield of 5.5 t/ha and an average semi-maturity cycle of 84 days. This variety is not very sensitive to drought.

Fertilizers: Organic fertilizer: The organic fertilizer used was compost. It was obtained at the research station using maize residues and cattle manure through the pile composting technique. Table 1 shows the chemical composition of the compost. This composition indicates a pH close to neutrality and a very high total element content according to the standards of the National Soil Office of Burkina Faso. (BUNASOLS, 1990).

METHODS

Experimental design: The experimental design used was Fisher's completely randomized block design with seven (07) treatments repeated four (04) times. The treatments were assigned randomly, with each representing one elementary plot (EP), for a total of 28 EPs. The EPs measured 5 m x 4 m, with an area of 20 m² each. The elementary plots were 0.5 m apart, and the blocks were separated by a 1 m aisle.

The different treatments were:

- T0: 74 kg/ha N (urea) + 46 kg/ha P₂O₅ (TSP) + 28 kg/ha K₂O (KCl); (recommended dose)
- T1: 74 kg/ha N (urea) + 46 kg/ha P₂O₅ (TSP) + 28 kg/ha K₂O (KCl) + 400 kg/ha BP
- T2: 74 kg/ha N (urea) + 46 kg/ha P₂O₅ (BPCalcined) + 28 kg/ha K₂O (KCl);
- T3: 74 kg/ha N (urea) + 46 kg/ha P₂O₅ (BPAcidulate) + 28 kg/ha K₂O (KCl);
- T4 : compost (5 t/ha) + T1 ;
- T5 : compost (5 t/ha) + T2 ;
- T6 : compost (5 t/ha) + T3.

Maize sowing and fertilizer application: Sowing: Maize was sown at a spacing of 0.80 m between rows and 0.40 m between holes. One week after sowing, thinning was carried out, leaving two (02) maize plants per hole.

Fertilizer doses and application: Compost and Burkina phosphate (BP) rock were applied as base fertilizer at doses of 5 t/ha and 400 kg/ha, respectively, depending on the treatment. The recommended doses for maize production in Burkina Faso are based on the NPK complex formulation 14-23-14 at a dose of 200 kg/ha and urea (46% N) at a dose of 100 kg/ha. These doses are equivalent to 74 kg/ha (N); 46 kg/ha (P₂O₅) and 28 kg/ha (K₂O). These quantities of elements were applied in the various treatments in urea for N; in TSP, BPC, or BPA for P; and KCl for K.

- Urea (46% N) was applied in three (03) fractions, on the 14th, 30th and 45thDAS at respective doses of 60.86 kg/ha; 50 kg/ha and 50 kg/ha, i.e. a total of 160.86 kg/ha for the equivalent of 74 kg/ha of N.
- KCl (60% K₂O) was applied at a dose of 46.66 kg/ha, or 28 kg/ha of K₂O;
- TSP (45% P₂O₅) was applied at a dose of 102.22 kg/ha, or 46 kg/ha of P₂O₅. BPA (21.1% P₂O₅) was applied at a rate of 218 kg/ha, or 46 kg/ha of P, and BPC (15.5% P₂O₅) was applied at a rate of 296.77 kg/ha, or 46 kg/ha of P₂O₅.

KCl, TSP, BPA, and BPC were applied by burying them in a single fraction on the 14thDays after sowing (DAS), depending on the treatments.

Soil sampling and laboratory analysis: Soil samples were taken at a depth of 0-20 cm before planting and at harvest on each elementary plot. Composite samples were prepared. The soil pH was measured using the potentiometric method in a soil/distilled water ratio of 1/2.5 (AFNOR, 1981). Total phosphorus was measured on the mineralization condensate (Anderson and Ingram, 1989) and assimilable phosphorus was extracted using the Bray I method (Bray and Kurtz, 1945). Total nitrogen was measured using the Kjeldahl method (Hillebrand *et al.*, 1953) and organic carbon (OC) was determined using the Walkley and Black method (Walkley and Black, 1934).

Data processing: The Excel 2016 spreadsheet was used for data entry and the development of tables and graphs and statistical analyses were carried out using the XLSTAT 2016 software. An analysis of variance was performed for the parameters whose data followed a normal distribution. In this case, Fisher's test was used to test for significant differences between means at the 5% significance level. The Kruskal-Wallis test was used for the parameters whose data did not follow a normal distribution.

RESULTS

Effect of manure on the chemical characteristics of the test soil: The analysis of variance indicated that the different treatments had highly significant effects (p=000) on soil pH, total and available phosphorus content, and total and available potassium content after cultivation (Table 2). At harvest, soil acidity had decreased significantly in all treatments compared to the soil before the trial was set up, which had a pHwater value of 4.4. This decrease was greater with treatment T6 (pHwater=5.44±0.08), followed by treatments T5 (pHwater=5.31±0.07) and T4 (pHwater=5.24±0.06). Significant increases in total phosphorus content were observed with treatments T4 (124.84±9.22 mg/kg) and T6 (116.99±6.38 mg/kg), which also had the highest assimilable phosphorus contents, with 21.12±1.70 mg/kg and 16.76±3.70 mg/kg,

Table 1. Chemical composition of compost

Chemical parameters						
pHwater	C (%)	OM (%)	N	C/N	P total (mg/kg)	K total (mg/kg)
6,54	19,7	33,9	1,4	14,07	1674,3	1012, 8

Legend : OM : Organic Matter ; N : Azote ; C : Carbone ; P : Phosphorus ; K : Potassium

Mineral fertilizer: It consisted of:

- urea ($\text{CO}(\text{NH}_2)_2$) at 46% N; potassium chloride (KCl) at 60% K_2O ; triple superphosphate (TSP) at 45% P_2O_5 ; Burkina phosphate (BP) rockat 26.6% P_2O_5 ; Burkina phosphate acidulate (BPA) at 21.1% P_2O_5 ; Burkina phosphate calcined (BPC) at 15.5% P_2O_5

Table 2. Variation of soil chemical parameters according to treatment

Traitements	pHwater	OC (%)	N_total (%)	C/N	P_total (mg/kg)	P_avail. (mg/kg)	K_total (mg/kg)	K_avail. (mg/kg)
SS	4,40 ^e ±0,01	0,41 ^{abc} ±0,02	0,039 ^{ab} ±0,001	10,54±0,36	68,33 ^d ±3,06	5,28 ^d ±1,28	949,31 ^a ±16,95	52,95 ^{bc} ±3,17
T0	5,04 ^e ±0,05	0,35 ^{bc} ±0,01	0,032 ^{bc} ±0,001	10,71±0,37	88,18 ^{bc} ±10,61	5,76 ^d ±1,05	689,96 ^{bc} ±36,94	35,76 ^c ±6,21
T1	5,08 ^e ±0,04	0,32 ^{bc} ±0,02	0,030 ^c ±0,002	10,46±0,21	101,28 ^b ±4,94	6,97 ^d ±2,74	675,28 ^{bc} ±33,90	33,3 ^c ±1,23
T2	5,10 ^e ±0,16	0,30 ^c ±0,07	0,029 ^c ±0,004	10,65±0,79	86,72 ^c ±4,39	5,90 ^d ±0,34	691,59 ^{bc} ±39,55	57,55 ^{bc} ±21,83
T3	4,93 ^d ±0,04	0,32 ^{bc} ±0,04	0,029 ^c ±0,004	11,17±0,40	90,36 ^{bc} ±5,77	6,63 ^d ±1,58	616,56 ^c ±45,90	35,76 ^c ±12,17
T4	5,24 ^b ±0,06	0,38 ^{abc} ±0,02	0,034 ^{abc} ±0,003	10,99±0,30	124,84 ^a ±9,22	21,12 ^a ±1,70	641,03 ^{bc} ±79,31	101,13 ^b ±18,72
T5	5,31 ^b ±0,07	0,42 ^{ab} ±0,08	0,038 ^{ab} ±0,005	10,92±0,74	94,73 ^{bc} ±10,42	11,34 ^c ±2,28	716,87 ^b ±81,24	192,38 ^a ±71,29
T6	5,44 ^a ±0,08	0,47 ^a ±0,08	0,043 ^a ±0,006	10,97±0,39	116,99 ^a ±6,38	16,77 ^b ±3,70	641,03 ^{bc} ±76,23	119,62 ^b ±13,43
Pr > F	0,000	0,015	0,013	0,613	0,000	0,000	0,000	0,000
Significance	HS	S	S	NS	HS	HS	HS	HS

Within the same column, values assigned the same letter are not significantly different according to Newman Keuls' multiple means comparison test at the 5% probability threshold.

Legend : T0: N (urea) + P (TSP) + K (KCl); T1: N (urea) + P (TSP) + K (KCl) + (BP, Phosphate rock); T2: N (urea) + P (BP Calcined) + K (KCl); T3: N (urea) + P (BP Acidulate) + K (KCl); T4: compost + T1; T5: compost + T2; T6: compost + T3; Pr: Probability; HS: Highly significant; S: Significant; NS: not significant; OC: Organic Carbone; N_total: Total Nitrogen; C: Carbone; N: Azote; P_total: Total Phosphorus; P_avail.: Available Phosphorus; K_total: Total Potassium; K_avail.: Available Potassium; SS: Starting soil; TSP: Superphosphate triple; BP: Burkina phosphate rock.

Table 3. Effects of treatments on maize grain and straw yields

Treatments	Grain yield (kg/ha)	Straw yields (kg/ha)
T0: N (urea) + P (TSP) + K (KCl)	1368 ^c ±406	1488 ^{cd} ±405
T1: N (urea) + P (TSP) + K (KCl) + (BP, Phosphate rock)	1469 ^c ±196	1918 ^{bc} ±376
T2: N (urea) + P (BP Calcined) + K (KCl)	920 ^d ±165	967 ^d ±149
T3: N (urea) + P (BP Acidulate) + K (KCl)	1332 ^c ±164	1323 ^{cd} ±303
T4: compost + T1	2964 ^a ±210	2629 ^a ±367
T5: compost + T2	2098 ^b ±77	1885 ^{bc} ±100
T6: compost + T3	2809 ^a ±150	2447 ^{ab} ±376
Pr > F	0,000	0,000
Significance	HS	HS

Within the same column, values assigned the same letter are not significantly different according to Newman Keuls' multiple means comparison test at the 5% probability threshold.

Legend : T0: T0: N (urea) + P (TSP) + K (KCl); T1: N (urea) + P (TSP) + K (KCl) + (BP, Phosphate rock); T2: N (urea) + P (BP Calcined) + K (KCl); T3: N (urea) + P (BP Acidulate) + K (KCl); T4: compost + T1; T5: compost + T2; T6: compost + T3; Pr: Probability; HS: Highly significant

respectively. In contrast, treatment T2, with 86.72±4.39 mg/kg, had the lowest total phosphorus content among the treatments. With regard to total K, the analysis results indicated a sharp decline in levels across all treatments after cultivation. Compared to other treatments, this decrease was still lower with the T5 treatment (716.87±81.24 mg/kg), which also accumulated the highest available K content (192.38±71.29 mg/kg). Analysis of the organic carbon (OC) and total nitrogen (TN) contents of the soil samples revealed significant differences ($p=0.015$ and 0.013 , respectively) between treatments.

Treatment T6 (0.47±0.08%) was followed by treatments T5 (0.42±0.08%) and T4 (0.38±0.02%) and the soil before the trial was set up (0.41±0.02%) recorded the highest OC contents. With regard to N_total, the same treatments T6 (0.043±0.006%) followed by T5 (0.038±0.005%); T4 (0.034±0.003%) and the soil before the trial was set up (0.039±0.001%) also performed best. On the other hand, the lowest levels of these elements (OC and total N) were found in treatments T0, T1, T2, and T3.

Effects of treatments on maize grain and straw yields: The fertilizers tested had a significant impact on maize yields (Table 3). In fact, the analysis of variance revealed highly significant differences ($p=0.000$) between treatments for both maize grain and straw yields. Treatments T4 and T6, with 2964±210 kg/ha and 2809±150 kg/ha respectively, ranked first in terms of maize grain yield performance. Treatment T5, with 2098±77 kg/ha, ranked second. For straw yields, treatments T4 and T6, with respective yields of 2629±367 kg/ha and 2447±376 kg/ha, were also the most effective. They were followed by treatments T1 (1918±376 kg/ha) and T5 (1885±100 kg/ha). In contrast, treatment T2 was the least effective in terms of both grain yields (920±165 kg/ha) and straw yields (967±149 kg/ha).

DISCUSSION

In general, the fertilizers applied significantly altered the chemical properties of the soil after two years experimentation. Before the trial was set up, soil pH and total and available phosphorus content were very low, but improved significantly

after the experiment according to BUNASOLS (1990) standards. This improvement was more significant with treatments based on BPA (Burkina phosphate acidulate), TSP, or BPC (Burkina phosphate calcined) combined with compost (T6, T4, and T5, respectively), which significantly increased the soil pH compared to treatments that were not combined with compost (T0, T1, T2, and T3). These results could be attributed to the liming power of Burkina phosphate rock due to its high calcium oxide (CaO) (34%) and magnesium oxide (MgO) (0.18%) content, but also to the buffering capacity of compost associated (soil pH = 6.54). Similar results were obtained by Sanou *et al.* (2021), who observed a very significant increase in soil pH during the first and second years of application of Burkina phosphate rock combined with compost compared to their application alone. The same findings were done by Dabr  t *et al.* (2017), who showed that Burkina phosphate (BP) combined with compost significantly raised the soil's pHwater. According to these authors, BP is rich in calcium oxide (CaO) and, when combined with compost, neutralizes the soil's active acidity. The dissolution of CaO and MgO releases Ca^{2+} and Mg^{2+} ions, which are basic ions capable of reacting with the ions that generate soil acidity (H^+ , Al^{3+}) and lowering their concentration in the soil solution (Lambers *et al.*, 2020).

As for organic matter, it forms the "clay-humic complex" with the clay fraction of the soil, which, thanks to its negative surface charges, has the ability to adsorb the H^+ ions responsible for the acidity of the soil solution (Lefevre, 2015). The significant improvement in the soil's available phosphorus content observed with the same T4, T5, and T6 treatments can be attributed in part to the significant increase in pHwater indicated above with these treatments. The decrease in acidity would therefore have promoted a high solubilization of phosphorus that was already present in the soil well before cultivation, but which had been rendered unavailable due to the high acidity of the test soil. This phosphorus, now available, would therefore be added to the phosphorus released by the solubilization of the associated TSP, BPC (Burkina phosphate calcined), or BPA (Burkina phosphate acidulate). In fact, in acidic soils, phosphorus is most often rapidly converted into insoluble and non-assimilable forms either by adsorption or through precipitation or retrogradation reactions (Naci *et al.*, 2022). Similar results were obtained by Ch'ng *et al.*, (2020), who observed a very significant increase in total and available phosphorus content in acidic tropical soils in Malaysia when natural phosphate (NP) was applied in combination with compost, compared to NP applied alone without compost. These authors found that as the soil pH increased with NP+ compost treatments, exchangeable aluminum and iron were retained by the negative charges of the organic matter, thereby increasing the availability of phosphorus in the soil. According to them, compost, due to its large specific surface area and pool of negative charges, significantly reduces the fixation and insolubility of phosphorus in acidic soils. Indeed, by complexing aluminum and iron oxides, compost promotes the release and retention of phosphate ions in the soil solution (Hassimi *et al.*, 2017).

On the other hand, the significant increase in soil phosphorus content recorded with treatments T4, T5, and T6 would be intrinsically linked to the high total phosphorus content (1674.3 mg/kg) of the compost associated with them. This corroborates the results of Ouattara *et al.*, (2017) in Ivory Coast, who observed a significant improvement in soil

phosphorus content with the application of compost (5 t/ha) + 122 kg/ha of P_2O_5 + mineral fertilizer (FM) compared to the application of the same dose of P_2O_5 + FM (without compost). Among the treatments that received compost, our analysis results indicated a very significant improvement in total and assimilable phosphorus content with TSP and BPA (T4 and T6 respectively) compared to BPC (T5). These results are likely related to the high total phosphorus content of TSP (45%) and BPA (21.1%) compared to BPC (15.5%). Our results are consistent with those of Fukuda *et al.*, (2021), who observed a significant increase in soil assimilable phosphorus content with TSP (3.57 mg/kg) and BPA (3.07 mg/kg) compared to BPC (2.92 mg/kg). According to them, the high total phosphorus content and high water solubility of TSP and BPA compared to BPC, as indicated by their chemical analysis results, would explain the results observed. However, our results indicated a high accumulation of potassium in the soil with the BPC treatment combined with compost (T5) compared to TSP and BPA combined with compost (T4 and T6). These results can be attributed in part to the reagents used during calcination. During the calcination process of Burkina phosphate rock, potassium carbonate (K_2CO_3) is used as an additive. Our results corroborate those of Nakamura *et al.*, (2019), who observed a high accumulation of potassium in the soil with the application of BPC (63.9 mmol/kg) compared to TSP and BP crushed, which accumulated only 4.9 and 3.9 mmol/kg, respectively. On the other hand, our results could be attributed to the effect of calcination. Ognalaga *et al.*, (2016) showed that calcined organic compounds produce ash with a high potash content, which increases the potassium content of soils. With regard to maize grain and straw yields, treatments combining TSP, BPA, or BPC with compost (T4, T5, and T6) performed better than their counterparts without compost (T0, T1, T2, and T3). The significant improvement in nitrogen and available phosphorus content revealed by our soil chemical analyses with treatments T4, T5, and T6 would explain our results. In this regard, Zongo *et al.*, (2021) showed a positive and significant correlation between improved soil nitrogen and phosphorus content and sorghum and cowpea grain yields. Indeed, compost as a soil amendment would have provided nitrogen, while phosphate fertilizers would have made phosphorus more available, both of which are the main factors limiting maize growth and yield (Nsimba *et al.*, 2019). Our results corroborate those of Traor   (2009) in Mali, who obtained growth rates of 66% and 68% respectively in millet grain and straw yields with the application of 5 t/ha of manure + 300 kg/ha of natural phosphate (NP) compared to the same dose of NP without manure. These authors found higher nitrogen and phosphorus contents in millet grains and biomass with the application of NP + manure, thus demonstrating good availability of mineral elements for plants compared to NP applied without manure. Sanou *et al.*, (2021) also obtained significantly higher grain and straw yields from rain-fed rice in western Burkina Faso when using crushed Burkina phosphate (BP) combined with compost compared to the same dose of BP without compost. Organic matter improves the availability of nutrients in the soil, creates physical conditions conducive to good root development, and significantly improves maize yields (Gomgnimbou *et al.*, 2019).

Our analysis results also revealed good performance of TSP and BPA combined with compost (T4 and T6) on maize grain and straw yields compared to BPC+ compost (T5). These results can be attributed, on the one hand, to the high availability of phosphorus in the soil with our T4 and T6

treatments compared to the T5 treatment, as indicated by our soil analysis results. Phosphorus promotes fruit set and good grain filling (Bennai *et al.*, 2007). Our results are similar to those of Fukuda *et al.*, (2021), who obtained the lowest rice grain and straw yields with BPC (3.4 t/ha and 6.63 t/ha for grain and straw, respectively) compared to treatments based on BPA (4.05 t/ha and 7.42 t/ha) and TSP (4.0 t/ha and 7.32 t/ha). According to these authors, BPA is as effective as commercial phosphate fertilizers (TSP and SSP) in terms of phosphorus release, regardless of soil type, texture, and fertility level. However, BPC is only effective on fine-textured, base-rich soils. The low fertility of the soils at our study site in terms of exchangeable bases (Ilboudo, 2019) may therefore have limited the performance of BPC. In western Burkina Faso, Wasaki *et al.*, (2022) also recorded lower sorghum and cowpea yields with BPC compared to TSP and BPA, which they attributed to the low phosphorus content of BPC. Our results also corroborate those of Nakamura *et al.*, (2016), who found low maize and rice yields with BPC compared to TSP when applied at high doses.

They attributed their results to the alkaline property of the calcined product, but also to an accumulation of sodium in the soil with BPC, which inhibited growth and limited crop yields. Nakamura *et al.*, (2019) also observed in a greenhouse pot experiment a very significant reduction in rice and maize yields with calcined BP compared to TSP. While the maize straw yield was 8.6 g/pot with TSP, it was only 1 g/pot with BPC. This time, the authors attributed the low yields recorded with BPC-based treatments to the high accumulation of potassium observed in the soil with the application of these treatments. In their view, BPC can easily damage crops, especially when applied at high doses, and may even contain phytotoxic substances in such cases. The available potassium content (192.38 mg/kg) of the soil recorded in our case with the BPC+compost treatment (T5) was well above that observed by Nakamura *et al.*, (2019) (63.9 mmol/kg). This would also explain the low maize yields recorded with this treatment (T5) compared to treatments T4 (TSP+ compost) and T6 (BPA+ compost). Indeed, excess potassium prevents the plant from absorbing nutrients, particularly magnesium and calcium (Ballot *et al.*, 2016), which are essential for maize yield (Traoré *et al.*, 2020).

CONCLUSION

Fertilizers based on triple superphosphate (TSP), partially acidified Burkina phosphate (BPA) or calcined Burkina phosphate (BPC) combined with compost significantly improved soil chemical properties and associated maize yields. Among these fertilizers, TSP and BPA combined with compost performed best in terms of total and available phosphorus in the soil. In terms of organic carbon, total nitrogen, and soil pH, BPA proved to be very effective when combined with compost.

In terms of grain yields, TSP (2964±210 kg/ha) and BPA (2809±150 kg/ha) combined with compost were the most effective. These two fertilizers also performed best in terms of straw yields. BPA combined with compost produced yields that were statistically similar to those of commercial phosphate fertilizers (TSP). Given the poverty of our rural producers and the very high prices of commercial phosphate fertilizers, these results reveal the socio-economic and agro-ecological importance that acidified phosphate could have in rural areas of Burkina Faso.

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