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REVIEW ARTICLE

EFFECTS OF ORGANO-MINERAL FERTILISERS ON SOIL CHEMICAL PARAMETERS AND ON THE RICE YIELDS (*ORYZA GLABERRIMA*STEUD) UNDER IRRIGATED CONDITIONS IN THE SOUTH SUDANIAN ZONE OF BURKINA FASO

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ABSTRACT

About 53% of rice production in Burkina Faso comes from irrigated rice cultivation. However, national average paddy yields remain low, due mainly to inherient soils fertility conditions of rice soils. The current study was initiated to solve low rice land soils fertility issues and was conducted on the irrigate rice land of the southern Sudanese zone of Burkina Faso. The objective was to evaluate the effects of four fertilization options on soil chemistry properties and rice paddy yield (during the dry season of year 2022-2023. A Fisher block experimental design was set up, with five treatments in four replicates: (T1) Control without fertilization, (T2) Compost + Urea recommended, (T3) Compost + NPK + Urea recommended, (T4) NPK + Super granulated Urea and (T5) NPK + Urea recommended. During this study, soil chemistry, rice agro-morphological and yield parameters were assessed. The results show significant difference between treatments for K and P avaiable. Treatments T2 to T5 show also significant effect on the growth and development of rice plants. The best paddy yield (5544 kg/ha) was obtained with treatment T2 ("compost + Urea recommended)" compared to the other treatments and the control showed the lowest low paddy yield (1848 kg/ha). The current study should be repeated to also assess the short and medium term effects on soils and rice yield productivity.

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INTRODUCTION

Burkina Faso, is an agricultural country where crop production is still dominated by cereals, which are the basis of the population's diet. Rice is ranked as the fourth cereals produced in the country, and after sorghum, millet and maize (INERA, 2008). The national production of paddy rice increased rapidly, from 85.090 to 270.658 tons between 2001 and 2010 (Kaboré *et al.,* 2011). Annual per capita consumption has followed the same trend, rising from 18.2 kg in 1999 to 21 kg in 2008 and even 50 kg per person in large urban centers (DGPER, 2011). Despite this strong growing enthusiasm, national rice production remains below the national needs estimated to more than 300.000 tons of milled rice per year (DGPER, 2011), resulting in massive imports each year to meet -increasing demand (FAO, 2012).

Rice accounts for 8.6% of household food expenditure in Burkina Faso. Since the cereal crisis in 2008, new projects/plans were initiated to increase national rice production through the National Strategy for the Development of Rice Cultivation (SNDR), which aims to make agriculture as one of the levers for achieving food security in Burkina Faso. Irrigated rice cultivation occupies 10% of total rice area and provides only 5% of the national rice production with an average yield of 1 t/ha (DGPER, 2009). However, the poor level pf of production technique of rice farmers (Traoré *et al.,* 2015), accentuated by high climatic variability, including recurrent droughts and soil nutrient poverty, lead to uneven yield from years. It is well known that rice production requires availability of nitrogen, phosphorus and potassium (Traore 2016). Given the current soil ferticilty conditions in Burkina irrigated lands there is a need to initiate research activities on efficient and accessible fertilization options that can improve soils nutrients content of nitrogen, phosphorus and potassium. It is in this perspective that the current study was conducted. The overall objective of this study was to improve the productivity of irrigated rice in the south soudanian zone of Burkina Faso.

MATERIALS AND METHODS

Presentation of the study site: The trials were conducted in the irrigated perimeter of vallee du Kou. in the Houet province, (30) km northwest from the city of Bobo-Dioulasso heaquater of the province, The irrigated perimeter is located in the Kou River watershed between latitudes 11.35° and 11.41° North and longitudes 4.36° and 4.50° West with an altitude of 300 m. Soils of the site are oxisols with little leaching (Wellens *et al.,* 2003). The vegetation of the site is a shrubby and wooded savannah type (Sauret, 2008). The climate is South Sudanian (Segda *et al.,* 2001) with average annual rainfall around 1,100 mm (Traoré, 2012).

Material

The rice variety used is FKR 62N developed by the national research Institute of Burkina Faso. with growing cycle of 118 days with yield potential of 5-7t/ha. The mineral fertilizers used in our trial are formulation NPK (14-23-14), Urea (46% N). Compost used was made of cotton straw.

Methods

Experimental design: The trials were conducted during the dry season of year 2022-2023 on an experimental plot with a total area of 282 m^2. The experimental design was a randomized bloc. with five (05) treatments and four (04) repetitions. The treatments were randomly distributed to the plots. The five (05) treatments are summarized in Table 1:

Table 1. Description of treatments used

Treatment	Description
T1	control (without fertilizer)
T2	Compost (5 t/ha) + urea (100 kg/ha)
T3:	Compost (5 t/h) + NPK (150 t/ha) + urea (100 t/ha)
T4:	NPK (150 t/ha) +super granulated urea (100 t/ha)
T5:	NPK (150 t/ha) + urea (100 t/ha)

Trials implementation: A total quantity of 200 g of seeds of the variety FKR 62N was planted in a nursery prepared by making two raising beds of 6 m length g and 1.5 m wide. The duration of the plants in the nursery was 7 days, the compost was applied in the nursery by incorporation into the soil one day after the seedbed was prepared. Transplantation was done in the trials site at one stand per pit. The space between pits was 25 cm and 25cm between lines. Weeding was done manually as needed. The compost was applied as a basic fertilizer during ploughing at rate of 5 t/ha. The chemical fertilizer NPK (14-23-14) was at 15th days after transplanting at rate of 200 kg/ha. Urea (46% N) was applied two times at dose of 37.5 kg/ha on the 30th days after transplanting and 37.5 kg/ha on the 45th days after transplanting.

Data collection

Soil sampling: In each plot, soil samples were taken with an auger at different growth stages along the diagonal of the plot at 3 points to make a composite sample by treatment and replication, making a total of sixty (60) samples. The 1st sampling was done before ploughing, the second at 30 days after transplantation which corresponds to the panicle initiation growth stage and the last sampling was done after harvest. The samples were taken at soil the depth of 0-20 cm, which generally corresponds to the layer of soil used by the rooting system in the tropical zones. The samples were analyzed in the Soil-Water-Plant laboratory of GRN/SP of INERA at the Farako-Bâ research station in Burkina Faso.

Soil Chemical properties analysis: The soils samples taken were air dried and oven dried, grounded and sieved at 2mm. 2 g of each sample were collected for soil properties analysis. The analyses concerned soil pH, the assimilable phosphorus, the organic carbon (C), the total nitrogen (N) and the available potassium (K). pH H_2O was measured from a soil suspension in water by the glass electrode pH meter electrometric method (AFNOR, 1999). The organic carbon content was determined according to the method of Walkley and Black (1934). Determination of total nitrogen (Nt) was done by digestion in a mixture of sulphuric acid, selenium and hydrogen peroxide (H_2SO_4-Se-H_2O_2) at 450°C for 4 hours, according to the method of Walinga *et al.,* (1995). The available phosphorus was extracted using the Bray-1 method (Bray and Kurtz, 1945). available potassium (K) tested by was extraction with a solution of oxalic acid ($H_2C_2O_4$) 4 N and hydrochloric acid (HCl) 0.1N, then the determination done by flame emission spectrophotometry.

Yields components and determination: The straw and paddy rice yield were measured from data collection on a yield estimation area of 1 m2. Yield components such as the number of panicles per plant, the number of grains per panicle were also evaluated on the area.

Data analysis: All data collected were recorded in Excel spreadsheet and analysis of variance done using XLSTAT version 2007 software. The averages were separated using the Newman-Keuls test at 5% confidence.

RESULTS

Chemical parameters of the soil before application of fertilization options: The results presented in Table 1show the chemical compositions of the soils before application of fertilization options. The soils are homogeneous in terms of pH, organic C and N content, as well as available K and assimilable P content.

Effects of fertilisers options on soil chemical properties at 30 days after sowing: Table 2 shows the contents of soil chemical parameters (pH, water, organic C, Nt, K available and P available) at 30 days after sowing. The soil pH water values varied from 6.26 (T5: NPK + Urea) to 6.44 (T2: compost + Urea). Soil Organic C values ranged from 1.04% for control treatment to1.09% for treatment T2: Compost + Urea and T3: compost + NPK + Urea). For all the treatments, the total N values was 0.09%. the results show available K content between 39.70 mg/kg for T5 (NPK + Urea) to 80.13 mg/kg for T3 (compost + NPK + Urea treatment). For soil assimilable P, the values varied between 6.99 mg/kg for T2(compost + Urea) and the highest values 11.64 mg/kg was obtained with T4(NPK + super granulated urea).no significant difference was observed between the treatments for soil pH,

Table 1. Chemical parameters of the soil before application of fertilization options

Soil before application of fertilization	Water pH	C (%)	N (%)	Available K (mg/Kg)	Assimilable P (mg/Kg)
	6.42 ± 0.32	0.80 ± 0.07	0.07 ± 0,01	37.47 ± 6.53	4.15 ± 0.92

The values are the mean ± standard deviation. NS = Not significant.

Table 2. Soil chemical properties at 30 days after sowing

Treatments	Water pH	C organic (%)	N (%)	Available K (mg/Kg)	Assimilable P (mg/Kg)
T1	6.37 ± 0.17	1.04 ± 0.25	0.09 ± 0.03	59.30^{ab} ±4.86	6.99^{b} ± 3.21
T2	6.44 ± 0.07	1.09 ± 0.24	0.09 ± 0.02	73.45^{a} ±26.49	8.04^{bc} ± 2.62
T3	6.41 ±0.19	1.09 ± 0.14	0.09 ± 0.02	80.13^{a} ±12.15	11.64^{a} ± 4.65
T4	6.33 ± 0.56	1.05 ± 0.19	0.09 ± 0.02	60.29^{ab}±10.15	9.71^{ab} ± 3.03
T5	6.26 ± 0.05	1.05 ± 0.00	0.09 ± 0.00	39.70^{b} ± 8.16	9.42^{ab} ± 2.47
Probability	*0.900*	*0.993*	*0.995*	*0.012*	*0.038*
Signification	*NS*	*NS*	*NS*	*S*	*S*

The values are the mean ± standard deviation. NS = Not significant. S = Significant.

Table 3. Effects of fertilisers options on soil chemical properties at harvest

Treatments	Water pH	Organic C (%)	N (%)	Available K (mg/Kg)	Assimilable P (mg/Kg)
T1	6.25 ± 0.24	0.80 ± 0.18	0.07 ± 0.01	38.46 ± 9.41	2.69 ± 0.86
T2	6.41 ± 0.13	0.66 ± 0.09	0.06 ± 0.01	35.24 ± 7.74	2.20 ± 0.57
T3	6.27 ± 0.07	0.79 ± 0.13	0.07 ± 0.01	33.75 ± 5.46	3.27 ± 0.92
T4	6.48 ± 0.39	0.81 ± 0.09	0.07 ± 0.01	40.99 ± 9.09	3.10 ± 1.12
T5	6.43 ± 0.17	0.81 ± 0.11	0.07 ± 0.00	39.45 ±10.59	2.55 ± 0.19
Probability	***0.547***	***0.457***	***0.378***	***0.748***	***0.369***
Signification	***NS***	***NS***	***NS***	***NS***	***NS***

The values are the mean ± standard deviation. NS = Not significant.

Table 4. Number of panicles per plant and grains per panicle

Treatments	Number of panicles per plant	Number of grains per panicle
T1 (control)	7^{b} ± 0.98	91^{c} ± 4.26
T2 (Compost + Urea)	11.61^{a} ± 1.62	150^{a}± 14.98
T3 (Compost + NPK + Urea)	13^{a}± 1.78	143^{a} ± 16.97
T4 (NPK + granulated Urea)	9.21^{ab} ± 1.60	104^{bc} ± 11.39
T5 (NPK + Urea)	10^{ab} ± 0.98	118^{b} ± 9.56
Probability	*0.002*	*0.0001*
Signification	*S*	*HS*

The values are the mean ± standard deviation. Values followed by the same letter in each column are not significantly different at the 5% probability level. S = significant; HS = Highly Significant.

Table 5. Paddy yield and straw weight as a function of fertilizer option

Treatments	Paddy yield (kg/ha)	Straw yield (kg/ha)
T1(control)	1848^{c} ± 11.,69	7219^{b} ± 1552.46
T2 (Compost + Urea)	5544^{a} ± 1317.22	13657.75^{a} ± 1568.35
T3 (Compost + NPK + Urea)	4205.75^{b} ± 359.32	15882.75^{a} ± 3223.55
T4 (NPK + Super granulated Urea)	3187.75^{b} ± 268.45	13405.25^{a} ± 3413.22
T5 (NPK + Urea)	3214.25^{b} ± 734.38	6231.75^{b} ± 1101.95
Probability	*0.0001*	*0.0001*
Signification	*HS*	*HS*

The values are the mean ± standard deviation. Values followed by the same letter in each column are not significantly different at the 5% probability level. HS = Highly Significant.

organic C and total N at 30 days after sowing. But, for the content of available K and P, the results show a significant difference between treatments.

Effects of fertilisers options on soil chemical properties at harvest: Table 3shows the results of the effect of fertilization options on soil chemical properties at the end of the cropping period. The results show soil pH values between 6.25 (T1=control) and 6.48 (T4: NPK + Super granulated urea treatment). Organic C values ranged0.66% (T2: compost + Urea treatment) and 0.81% (T4: for NPK + Super granulated Urea treatment and T5: NPK + Urea treatment).Soil Ntotal, contents varied between 0.06% for the "T2: (compost + Urea)" and 0.07% for the other treatments. Available K content varies between 33.75 mg/kg (T3: Compost + NPK + Urea treatment) and 40.99 mg/kg (T4: NPK + Super granulated Urea treatment). For available P, the values varied between 2.20 mg/kg (T2:compost + urea) and 3.27 mg/kg (T3:compost + NPK + urea).The analysis of variance did not show any significant difference between the treatments for all the measured parameters at harvest.

Effects of fertilization options on Yield Components

Effects of fertilization on the formation of panicles and grains of rice: The variation in the average number of panicles per plant and the number of grains per panicle are recorded in Table 4.

The average number of panicles per plant varied between 7 (T1: control) and 13 (T3: compost + NPK + Urea). The average number of grains per panicle is between 91 (T1: control) and 150 (T2: compost + urea). The analysis of variance show a significant difference between treatments for the average number of panicles and a highly significant for the number of grains per panicle. The highest number of panicles was obtained with treatment T3 the "compost + NPK + Urea " statistically equivalent to that of T2: Compost + Urea. For the average number of grains, the highest value was obtained wiht treatment T2: compost + Urea and statistically similar to that of treatment T3: compost + NPK + Urea.

Effects of fertilization options on paddy and straw weight yields: The effect of fertilizers on paddy yield and straw weight is reported in Table 5. The paddy yield varied between 1848 kg/ha (T1: control) and 5544 kg/ha (T2: compost + Urea). As for the paddy yields the straw yields, varied between 7219 kg/ha (T1:control) and 15882.75 kg/ha (T3:compost + NPK + Urea).Statistical analyses show a highly significant difference between the treatments for paddy yield and straw weight. The paddy yield of treatment T3: compost + NPK + Urea is statistically equivalent to treatment T5: NPK + Urea and treatment T4: NPK + Super granulated Urea". For straw yield, the treatment T2: compost + Urea and treatment T4: NPK + Super granulated Urea are statistically equivalent to treatment T3compost + NPK + Urea.

DISCUSSION

Effects of fertilization options on soil chemical properties: The results show, no significant difference between treatments for soil pH, organic C and total nitrogen, at 30 days after sowing as well as after the harvest. These results, show that fertilization options tested did not affect these parameters. As far as pH is concerned, our results are in line with those of Ouédraogo (2016) who reported that organo-mineral fertilization does not have a significant affect soil pH. The long-term use of mineral fertilizers, especially nitrogen, acidifies the soil (Hien *et al.,* 2004; Ouattara *et al.,* 2006; Zhang *et al.,* 2008). Our results on total nitrogen, are opposite to those reported by Traoré (2016) indicating that organo-mineral fertilization has a positive impact on the nitrogen content of the soil. The difference in results can be explained by the difference in agro ecological conditions of the site of the two trials. For available Kand available P, there is a significant difference between the treatments after applying 30 days after sowing fertilizers. Fertilisers options therefore affected the level of Pand Klevels during cropping period. in fact, all the fertilization options had a positive effect on the available K content and available P. The treatment T3"compost + NPK + Urea" and treatment T2"compost + Urea" treatment showed the highest level of available Kand available P.

Our results are in line with those of Ouédraogo (2016) who showed that organic amendments and mineral addition are important sources of available P. This shows that the fertilizer applied in the soil during ploughing added phosphorus to the soil. These results are also in line with those obtained by Traoré *et al.* (2007) and Héma (2016) who stipulate that the soil is better enriched in potassium and phosphorus by organo-mineral fertilization. In addition, this could be explained by the fact that compost mineralization in the soil with NPK application, increased the amount of P and Kin the soil. Hafner *et al.,* 1993 also reported that addition of NPK in the presence of compost improves the amount of phosphorus in solution in the soil and also the uptake of phosphorus by plants.

Effects of Fertilization options on yields components: Our results show that the application of fertilizers positively affects the yield of irrigated rice through the high number of panicles, number of grains per panicle but also the paddy and the straw yields.in fact, all the fertilization options gave higher paddy rice yields compared to the control without any fertilizer. However, among all the treatments, treatment T2: "Compost + Urea " showed the highest yields of paddy rice. For Diallo (2002) and Lompo (2005), organo-mineral fertilization ensures good supply of soluble and available nutrients leading to higher yields. Our results are in line with those of Bougma (2013) and Héma (2016) who stipulate that the best paddy and rice straw yields are obtained with organo-mineral fertilizers.

Similarly, the results of Segda *et al.,* (2013) showed that the application of organo-mineral fertilization contributes to stabilizing paddy yields. These fertilization options s allow better N, P and K supply which are essential nutrients for mineral nutrition of rice (Traoré, 2016). The importance of N, for paddy rice production, was reported by Fageria (2007) who showed that nitrogen significantly increases the yield components of rice. Meena *et al.,* (2003) also highlighted the importance of nitrogen in rice nutrition, showing that the use of increasing doses of nitrogen would lead to an increase in paddy rice yields. However, the treatment T3"compost + NPK + Urea ", obtained lower yield of paddy rice compared to treatment T2"compost + urea ". Those results show that the addition of NPK to organo-mineral fertilization (T2=compost + urea) in irrigated rice cultivation has no additional effect on paddy rice yield. Our results are in agreement with those of Ouédraogo (2016) who showed that the simple combination of organic manure and urea fully contributes to an increase in paddy yields.

CONCLUSION

The current study conducted in South Sudanian zone of Burkina Faso show that yield parameters (number of tillers per plant and number of grains per panicle) as well as grain and straw yields are higher with the combination of organic and chemical fertilizers. It appears that the treatment T3"compost + NPK + urea" and treatment T2"compost + urea " had significant effects only on the available P and K of the soil. Organo-mineral fertilization (compost + urea) obtained the highest yield of paddy rice. This study show that it is not necessary to combine NPK withT2 "compost + Urea" fertilizer to for higher yields of paddy rice. However, compost must be incorporated in the soil before or during ploughing so that it can provide nutrients to rice plants at the right time because its mineralization is slow. It would be interesting to repeat this study in different agro ecological zones and soils conditions for final recommendation on organo-mineral fertilization option able to increase paddy yields and soil fertility. The final decision on option will require economic evaluation.

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