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RESEARCH ARTICLE

VALORIZING DEGRADED LANDS USING INNOVATIVE BIOFERTILIZERS FOR TOMATO CROPPING: RESPONSE TO BOKASHI, EFFECTIVE MICROORGANISMS AND COMPOST IN THE SUDANESE ZONE OF BURKINA FASO (BOBO-DIOULASSO)

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Abstract

In order to improve food security and sustainable land management at relatively low cost, this study evaluates the effect of biofertilizers on soil chemical properties and on tomato yield in 2020 and 2022 in Bobo-Dioulasso (Burkina Faso). A Fisher randomized design compares six treatments: T1: compost at 30 kg ha⁻¹, T2: Bokashi at 30 kg ha⁻¹, T3: Effective Microorganisms at 500 l ha⁻¹, T4: T1 + T3, T5: T2+T3, T6: mineral fertilizer at 300 kg ha⁻¹ of compound fertilizer NPK (15-15-15) + 200 kg ha⁻¹ of urea 46% N. Results show that compost and Bokashi have the potential to improve the availability of phosphorus and exchangeable bases in soil compared to mineral fertilizer. They enable the stabilization of pH value and nitrogen content, which decrease if only mineral fertilizer is applied. Bokashi increases tomato yield by 23-58% compared to mineral fertilizer. Effective microorganisms alone are less efficient than mineral fertilizer. Combining Bokashi, whether enriched or not with effective microorganisms and a minimal amount of mineral fertilizer, could help optimize crop yields in the transitional phase of soil fertility recovery. This study suggests that biofertilizers can be used to improve food production while stabilizing soil quality.

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Introduction:-

The sustainability of agricultural systems and livelihoods is severely compromised by land degradation in sub-Saharan Africa (SSA) ([1]; [2]; [3]; [4]). Indeed, land degradation affects roughly 46% of the African continent's arable lands and 65% of the population [5]. According to a United Nations report on drought and desertification in Africa [6], land degradation results in an average annual loss of more than 3% of agricultural GDP in SSA. Accordingly, it is widely agreed that loss of soil nutrients is the main driver of the declining food production in this region. A study on the economics of land degradation in 42 African countries estimates soils nutrient losses between 49.6 and 56.2 kg ha⁻¹ year⁻¹ [4]. The same study estimates that a 1% decrease in nutrients on depleted cultivated soils results in a decrease in grain production of 1.3 kg ha⁻¹. Moreover, studies such as [7], estimate that maize yield stagnation has been more widespread in Africa since the 1990s because of land degradation. Thus, land degradation

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contributes to increase food insecurity, poverty and pressure on agricultural resources [3]. In Burkina Faso, it is noted that land degradation has accelerated, from 113,000 ha year⁻¹ between 1983 and 1992 to 360,000 ha year⁻¹ between 1992 and 2000, and to 469,000 ha year⁻¹ between 2002 and 2013 [8]. This is a major issue, given the strong dependence on agricultural resources, the high demographic pressure [9] and a changing climate.

Given this situation, irrigated market gardening plays a major socioeconomic role, especially in Burkina Faso, where 87% of cultivated lands is located in semi-arid area [10]. Indeed, the market gardening sector provided employment for up to 700,000 people and generated income estimated at over 389 billion in 2018 [11]. This represents 94% of the total income of market gardeners and contributes 30.6% to food expenditures [12].

However, conventional gardening practices threaten agrosystem sustainability due to the massive and inefficient use of synthetic mineral fertilizers ([13]; [14]). These large inputs contribute to highly positive nutrient balances (688 kg N ha⁻¹ yr⁻¹, 251 kg P ha⁻¹ yr⁻¹, 189 kg K ha⁻¹ yr⁻¹) in Bobo-Dioulasso, Burkina Faso [15]. Similarly, [16] observed high risks of nitrogen (in both mineral and organic form) leaching (236 to 990 kg ha⁻¹ yr⁻¹) into groundwater. Due to the lack of crop-specific recommendations for vegetable crops, compound fertilizers (NPK) used by farmers are very diversified and designed for cereals or cotton crops ([13]; [14]). Market gardeners use alternative sources of organic materials, such as solid urban waste and waste water, which can contain high amounts of heavy metals and pathogens [17]. This is a threat to the environment and public health. In addition, due to the income-generating and market-oriented nature of gardening, which allows investment in inputs, farmers use intensively imported synthetic fertilizers to increase production. Because of this dependence, farmers have become vulnerable to exogenous shocks such as international trade restrictions caused by the Covid 19 pandemic and the current war in Ukraine. The high cost of mineral fertilizers and their low accessibility are therefore limiting factors for vegetable farming [18].

While market gardening has the potential to increase food production in cities, and contribute to the reduction of food insecurity, it also presents high risks of environmental degradation, with negative effects on human and animal health. In response, agroecology, which involves cropping practices that are more respectful of human and environmental health, appears as an alternative capable of ensuring environmental sustainability as well as the resilience of vegetable farming systems [19]. This practice relies on natural ecosystem functionalities, which can be enhanced, in order to limit as much as possible, the pressure on the environment, preserving its renewal capacity. In this perspective, the adoption of biofertilizers based on natural microorganisms presents an interesting trade-off. The present study focuses on biofertilizers that are called "biostimulants", "growth and/or development stimulators", "soil activators" or even "phytostimulants" [20]. They are used as alternatives to the high input of synthetic fertilizers and to ordinary compost, which has lost the preference of farmers (compared to mineral fertilizers) due to the slow release of its nutrients and the arduousness of the composting labor [13]. This paper aims to contribute to the valorization of Bokashi and effective microorganisms by improving knowledge of their potential for local farming systems.

Originating from Japan, the term Bokashi means "fermented organic matter" [21], because it is derived from the fermentation of various organic matter, enhanced by the presence of effective microorganisms [22]. Bokashi was first developed in 1980s at Ryukyu University (Okinawa, Japan). It was then improved and adopted in many countries in Asia and Latin America [23], and nowadays in Burkina Faso. The technology of effective microorganisms known as EM (Effective Microorganisms) was also initiated in the 1980s in the same Japanese university. EMs are made up of a mixture of strains of beneficial microorganisms including photosynthetic bacteria, nitrogen-fixing bacteria, acid-lactic bacteria, actinomycetes, yeasts and filamentous fungi [24]. The chemical and biochemical composition of these biofertilizers endows them with the broad potential to improve soil productive capacity and health, and plant growth and development ([25]; [21]; [26]; [27]; [28]). Researches on these adapted biofertilizers made from locally available resources are needed to evaluate the quality and effects, especially in the perspective of making relevant recommendations for efficient farming and their use by farmers. The specific objectives of this experimental study are thus to evaluate the effects of using different formulations of compost, Bokashi and EM on soil chemical parameters and tomato yields under semi-controlled conditions.

Materials And Methods:-

Location and description of the study site

The trial was carried out at the experimental site of the "Institut de Recherche en Sciences Appliquées et Technologies (IRSAT)" located in Nasso (11°19'N, 04°38'W, figure 1). This site has a southern Sudanese climate, alternating a short rainy season (June-October) and a longer dry season (November-May). Average rainfall over the

last ten years is 1086 ± 215 mm with an average of 91 ± 8 rainy days. Rainfall was 1033.2 mm for 78 rainy days in 2020 and 1284 mm for 64 rainy days in 2022. The trial was laid out on a tropical ferruginous soil with a sandy-loam texture. Soil fertility was depleted by more than four decades of cereal (sorghum, millet) and legume (cowpeas, peanuts) cropping. These crops were grown with no use of synthetic mineral fertilizers. Since land was considered degraded and not favorable for agriculture, it had been abandoned and have not been cultivated during the three years preceding the trials.

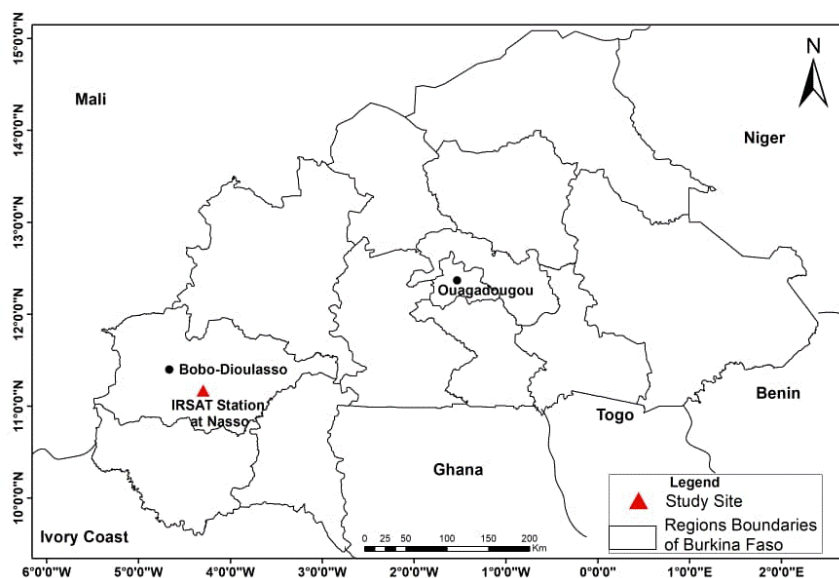


Figure 1:- Study site location.

Materials:-

Plant material

Trials were conducted on the F1 hybrid tomato variety cobra 26. It has an early cycle of 65 - 70 days and an average yield of over 25 tons per hectare. It is a vigorous variety, adapted to all seasons and appreciated by local market gardeners for various reasons, including its high yield potential and its tolerance to bacterial wilt.

Biofertilizers

Compost was made up with rice straw and animal waste, using the anaerobic heap composting process over a three-month period. Bokashi was produced in 15 days by aerobic fermentation of various substrates in following ratios: 150 kg of clay soil, 25 kg of rice husks (or dry plant mix, straw, dry leaves), 20 kg of poultry dung (or rabbit dung, pig dung, cow dung), 25 kg of rice bran (or other cereal), 20 kg of charcoal powder, 2 kg of brown sugar (or 2 liters of honey), 1 kg of baker's yeast, water without chlorine, 2.5 kg of ash, 30 kg of Burkina phosphate and 50 kg of crushed bones. The effective microorganisms (EM) were obtained in solid form in 21 days using: 30 kg of plant litter (source of EM), 50 kg of rice bran, 2 kg of sugar and 1 liter of honey. EM were activated by diluting 1 kg of solid EM in a mixture of 1 liter of milk, 1 liter of honey and 1 kg of sugar. This mixture was stored during 7 days before use. Use involved the dilution of 1 liter of the activated EM in 15 liters of water.

Various formulations of Bokashi and EM ([30]; [31]) have been adapted elsewhere, especially in Latin America [29], depending on inputs availability. The main chemical characteristics of the products used in the present study are summarized in Table 1. EM substrates appeared particularly rich in organic matter, nitrogen and phosphorus. The amount of Potassium was particularly high in the compost treatments. Bokashi and compost were clearly alkaline, whereas the EM were slightly acidic. The C/N ratios were relatively high. Therefore, the basal fertilization was done at least seven (07) days before transplanting. In addition, the activation phase of the EM by dilution likely reduced the C/N ratio before application.

Table 1:- Chemical characteristics of compost, Bokashi and solid EM.

Parameters	Unit	Compost	Bokashi	EM
Organic Matter	[%]	37.37	18.75	67.53

Carbon	[%]	21.67	10.88	39.17
Nitrogen	[%]	1.27	0.55	1.75
C/N	[---]	17	19.69	22.31
P-Total	[mg/kg]	1164	1729	2533
K-Total	[mg/kg]	1784	6221	8557
pH water	[---]	8.84	8.7	5.71

Methods:-

Experimental design

The trial was carried out on a randomized Fisher block design, with six treatments and four replications. Each elementary plot (EP) measured 6.4 m² (3.2 m x 2 m), with a total of 25 plants spaced 80 cm x 40 cm. The total area covered by the design was 238.7 m². Five biofertilizer formulas were compared with the recommended mineral fertilization (based on compound fertilizer NPK 15-15-15 and Urea 46% N) for vegetable crops (Table 2).

Table 2:- Comparative biofertilizer and mineral fertilizer treatments.

Treatments (T)	Applied rate	Mode of Application	Frequency / splitting
T1	Compost alone [30 t ha ⁻¹]	Basal dressing before ploughing	S.S
T2	Bokashi alone [30 t ha ⁻¹]	Basal dressing (B.D) and cover dressing (C.D)	B.D : 15 kg/ha C.D : 7.5 kg/ha à 15 et 30 JAR
T3	EM alone [500 l ha ⁻¹]	Post-tillage spraying + foliar spraying	W.S from transplanting to fruit maturity
T4	T1 [30 t ha ⁻¹] + T3 [500 l ha ⁻¹]	B.D + foliar spraying	S.S for T1 + W.S for T3
T5	T2 [30 t ha ⁻¹] + T3 [500 l ha ⁻¹]	B.D + C.D + foliar spraying	C.D for T2 + W.S for T3
T6	NPK [300 kg ha ⁻¹] + Urea [200 kg ha ⁻¹]	C.D inside the stingrays	NPK: 300 kg/ha at 15 DAP + Urea : 150 kg/ha at 30 DAP + 50 kg/ha at 45 DAP

NB: S.S: Single Supply; W.S: Weekly Supply; DAP: Day after transplanting

Crops management

The plots were laid out on June 16, 2020 and on June 15, 2022 after a 20 cm depth ploughing. A basal dressing of a single dose of compost and a half-dose of Bokashi was applied on June 23, 2020 and on June 16, 2022. On the same dates, EM was sprayed at 500 l/ha. Transplanting took place on June 30, 2020 and on June 23, 2022 using 20- and 26-days old plants, respectively. Density was 1 plant/pod. As a cover dressing, Bokashi was applied 15 and 30 days after transplanting, at a rate of 7.5 t/ha. It was applied at a depth of 15 cm, 10-15 cm from plant base in order to avoid plant burns. Regarding EM, a foliar spray of 500 l/ha at weekly intervals was performed from transplanting to the beginning of harvest. In total, eleven (11) sprayings were performed each year. 14.8 liters of liquid EM were sufficient to treat all plots over the trial duration.

The NPK was spread 15 days after transplanting (DAP) at a rate of 300 kg/ha, and supplemented with urea (46% N) at 150 kg/ha at 30 DAP and 50 kg/ha at 45 DAP. Supplementary watering was needed during dry periods in the month following transplanting. Finally, three weeding operations were carried out at 15, 30 and 45 DAP, followed by ridging and staking at the beginning of flowering.

For phytosanitary protection, two bio-pesticides, Neem oil (H-N) and Piol, were applied alternately at 5 l ha⁻¹. Spraying was done once every 14 days, from flowering until the beginning of harvest.

Data collected

Agronomic parameters

We assessed yield by weighing tomatoes harvested from the useful plot (PU), which has 09 plants. We harvested three times in 2020 between 69 and 79 DAP, five times in 2022 between 65 and 88 DAP. For each treatment, the different successive harvests were summed for both weights and numbers of fruits. We then calculated the average

number of fruits per plant (NFP) as the ratio between the number of fruits harvested and the number of tomato plants (09) in the PU. Finally, we deduced the average weight of a fruit (AWF) as the ratio between the weight of the harvests and the total number of fruits harvested.

Laboratory analysis

Soil samples were taken at 0-20 cm soil depth before the trials and after final harvest. To analyse soil chemistry, we took composite samples from each individual plot. Three (03) fraction granulometry were separated using the Robinson densimetric method. Total Carbon was determined using the WALKLEY-BLACK method and total Nitrogen using the KJEDHAL method. Available phosphorus Bray 1 was quantified by photocolourimetry. Available potassium was also determined by flame photometer. The sum of exchangeable bases (SEB) and of cation exchange capacity (CEC) were measured by atomic absorption spectrophotometry for Ca^{2+} and Mg^{2+} and by flame photometry for Na^{2+} and K^{+} , respectively. CEC was determined according to AFNOR NF X 31-130 standards [32]. The pH-water was read directly with an electrode pH-meter in a solution of soil and water respecting the ratio 1:2.5. Finally, for the chemical analysis of biofertilizers, three samples of each type of biofertilizer were taken to determine pH, C, N, P, K, following the same methods described for soil samples.

Analysis of the data

The collected data were used to descriptive and inferential analysis. The effects of fertilizers type on soil chemical parameters and tomato yield were analysed using General Linear Model (GLM). Variance analyses were performed, after normality distribution assessment. The parametric Newman-Keuls test was used to compare means (when necessary) at 95% confidence interval. All inferential analysis as well as box-plot, were performed using RStudio 4.2.2 [33].

Results:-

Effects of fertilisers on soil chemical indicators

According to soil particles size analysis, the sandy fraction is made up of 77% sand, 15% silt and 8% clay (result not shown). This granulometric composition confers a silty sand type texture to this soil. The indicators of the chemical quality of the soil that were analyzed before and after the trials are shown in Table 3. The degraded status of soil is confirmed by the chemical characteristics of the initial soil which was very depleted in C, N and P (Table 3). The CEC is also very low in relation to the low C and clay content of the soil. In a nearby plot which has the same cropping history as the experimental plot, we found a total porosity of 40%, an average bulk density of 1.58, while the highest level of structural stability is only 55%. This plot has a low soil water capacity ranging from 13 to 15 mm in the topsoil (100 mm).

Table 3:- Chemical characteristics of the soil (0-20 cm) at the beginning and the end of the trial.

Fertilizers [Unit]	pH_water [--]	C (%)	Total N (%)	P Bray I (mg/kg)	SBE (cmol+/kg)	CEC (cmol+/kg)	SR (%)	
Initial Soil	6.01	0.31	0.035	18.71	-	3.81	-	
Final Soil status	Compost	6.17 ± 0.09 ^a	0.47 ± 0.07 ^a	0.037 ± 0.005 ^a	38.38 ± 8.77 ^b	2.36 ± 0.44 ^{ab}	4.10 ± 0.65 ^a	56.52 ± 2.57 ^{ab}
	Bokashi	6.04 ± 0.09 ^a	0.40 ± 0.08 ^a	0.031 ± 0.006 ^a	61.04 ± 10.74 ^a	2.20 ± 0.31 ^{ab}	3.63 ± 0.97 ^a	63.63 ± 9.86 ^{ab}
	EM	6.15 ± 0.24 ^a	0.36 ± 0.07 ^a	0.027 ± 0.004 ^a	35.92 ± 7.81 ^b	1.65 ± 0.10 ^b	3.10 ± 0.75 ^a	55.73 ± 7.20 ^{ab}
	Compost + EM	6.18 ± 0.12 ^a	0.44 ± 0.07 ^a	0.035 ± 0.004 ^a	29.81 ± 8.08 ^b	2.71 ± 0.71 ^a	3.90 ± 0.58 ^a	71.13 ± 8.13 ^a
	Bokashi + EM	6.20 ± 0.10 ^a	0.44 ± 0.07 ^a	0.034 ± 0.004 ^a	46.95 ± 1.60 ^{ab}	2.25 ± 0.36 ^{ab}	3.74 ± 0.72 ^a	61.83 ± 9.96 ^{ab}
	NPK + Urea	5.94 ± 0.16 ^a	0.37 ± 0.06 ^a	0.028 ± 0.004 ^a	34.74 ± 8.67 ^b	1.65 ± 0.31 ^b	3.16 ± 0.36 ^a	52.35 ± 9.53 ^b
	p_value	0.128	0.278	0.052	< 0.001	0.013	0.264	0.049

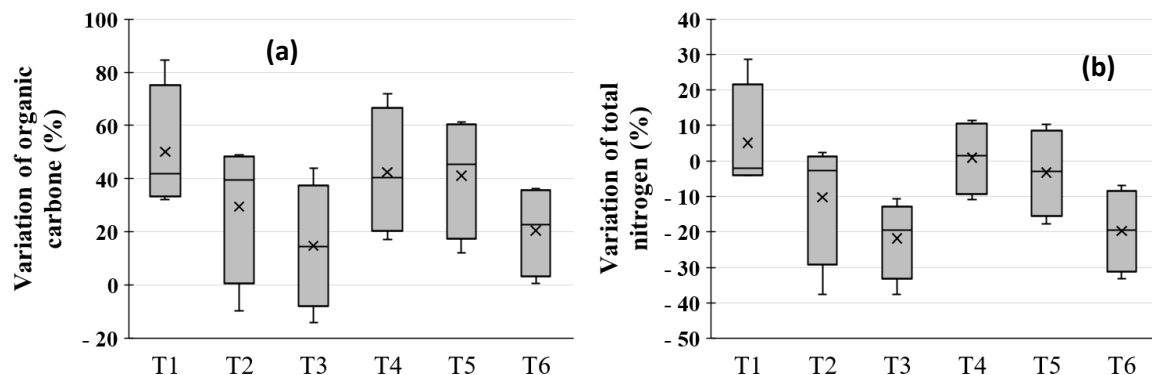
Values followed by the same letter in the same column do not differ significantly at the 5% level. $p > 0.05$ = not significant; $p < 0.05$ = significant; $p < 0.01$ = highly significant; $p < 0.001$ = very highly significant. C: carbon. N: nitrogen. P: phosphorus. SBE: sum of exchangeable bases. CEC: cation exchange capacity. SR: saturation rate

The pH, C, N and CEC values after the trials do not seem to be significantly affected by the different types of fertilizers used. However, only mineral fertilization plots showed a downward trend in pH, N and CEC, compared to the initial state of the soil. Carbon trend is generally upward, regardless of the treatment. The changes in soil indicators between the two periods are detailed in section 3.2. The P Bray I content increased significantly from 29.81 mg/kg with the EM enriched compost to 61.01 mg/kg with the Bokashi. It should be noted that the two fertilizers containing Bokashi provided the highest P Bray I content. The other biofertilizers had P Bray I contents equivalent to those obtained under mineral fertilization. SEB was significantly influenced by fertilizer type. The least efficient were mineral fertilizer and EM alone. The highest values were achieved in treatments with ordinary compost or compost enriched with EM. The other two Bokashi-based fertilizers had intermediate values and were also similar to compost and mineral fertilizer. As with SEB, the EM-enriched compost stands out with the best saturation rate (71%) of the clay-humus complex. This rate was significantly higher than that obtained with mineral fertilization. Similarly, the other fertilizer formulations improved the saturation rate of the complex compared to mineral fertilization, although the differences were not significant. In summary, Bokashi and compost, whether or not enriched with EM, tended to improve P Bray I, SEB and soil saturation rate.

Changes in soil chemical quality indicators as a result of fertilizers

Some soil chemical parameters exhibited significant variations between the beginning and the end of the trial. The trends of these parameters are depicted in figure 2. The variations were heterogeneous depending on indicators and applied fertilizers. The smallest variations were observed for pH (-4 to +6%). Under mineral fertilization, the amplitude of change was also insignificant. These changes were positive for compost, as well as for the combination of compost and Bokashi, both enriched with EM. On the other hand, variations were more moderate for simple Bokashi and EM alone, even if the median and average values of these variations were positive. It can be noted that the widest magnitude was recorded with EM treatments. Regarding carbon, trends were relatively more homogeneous. Indeed, average variations were positive. Compost, Bokashi and EM-enriched Bokashi induced the highest average increases, while the lowest were associated with application of EM alone or mineral fertilization. When considering Nitrogen content, treatments followed the same patterns as carbon. However, the average variation in soil nitrogen content was positive only for compost (5.17%) and, to a lesser extent, for compost enriched with EM (0.88%). For the other treatments, the variation was negative ranging from -3.26% to -21.84% for Bokashi + EM and EM alone, respectively. The decrease in nitrogen content was also significant under mineral fertilization (-19.71%).

Variation in available phosphorus was the most sensitive, with the highest values recorded. For all treatments, the variations were positive, ranging from +68% to +245% for compost + EM and Bokashi respectively. The lowest median value of variation was associated with mineral fertilization. In addition, the amplitude of the variations was lower under Bokashi + EM in contrast to those observed with compost and mineral fertilization. In general, all fertilizers improved the availability of phosphorus (P Bray I values). The same applies to available potassium content, with the highest increases under compost and Bokashi fertilizers. Indeed, this increase reaches 112% with EM enriched compost and 102% with compost alone. It is reduced to 89% and 79% respectively with Bokashi alone, and EM enriched Bokashi. Although the average variations were also positive, they remained low with EM alone (2.5%) and even lower under mineral fertilization (0.63%). Finally, the CEC was improved by ordinary compost (9.33%) and to a lesser extent with compost + EM (2.27%). It became poorer with Bokashi (-2 to 5%) and even poorer with mineral fertilization (-17%) and EM alone (-19%).



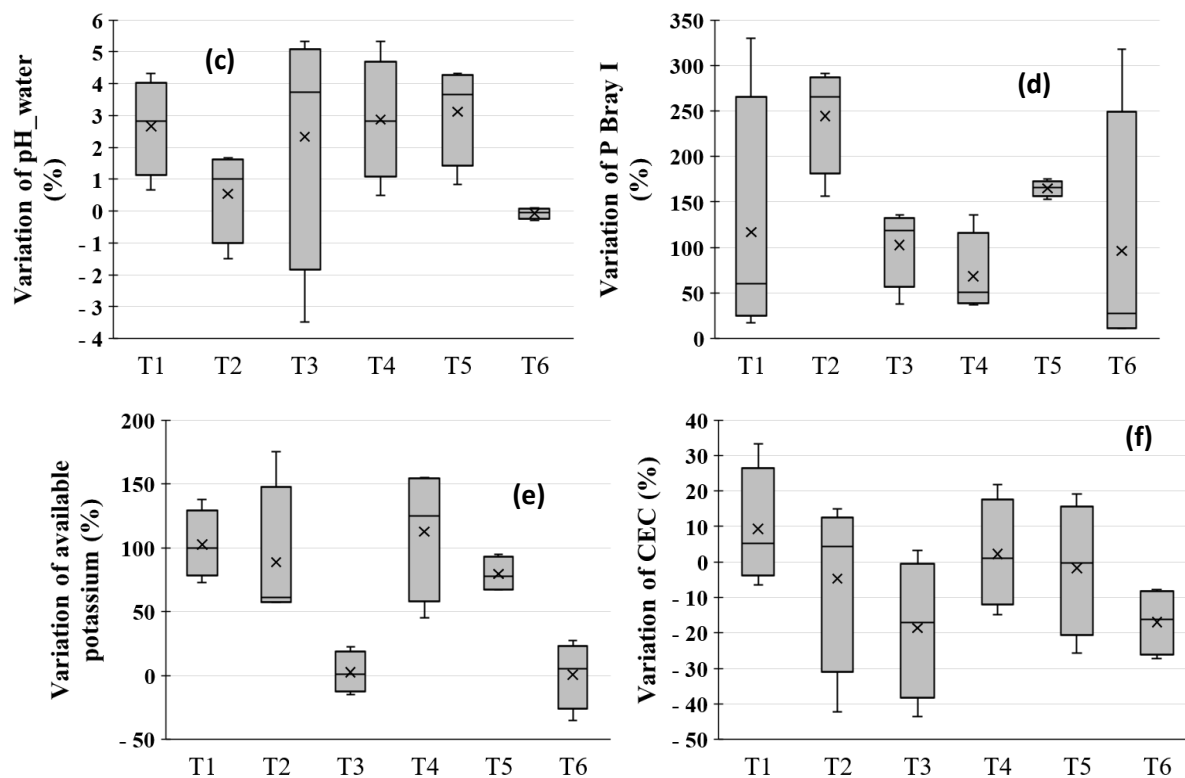


Figure 2:- Variations (%) in the level of soil chemical characteristics between the end and the beginning of the trial: organic carbon (a), total nitrogen (b), pH water (c), P Bray I (d), available potassium (e) and CEC (f). The horizontal line and the cross in the boxes indicate the median and mean values, respectively.

Effect of fertilizer types on tomato yield

Total yields, number of fruits per plant (NFP) and average fruit weight (AFW) varied significantly between treatments in 2020. This was also the case in 2022, except for AFW (Table 4). Regardless of the year, EM alone appeared to perform less efficiently in terms of yield obtained. In fact, the plants under EM produced fewer fruits than under other treatments. Moreover, the fruits in this treatment had lower mass compared to other treatments, especially in 2020. In contrast, in 2022, all fertilizers produced fruits of equivalent average mass. When considering yields data in year 1, biofertilizers, except for EM alone, performed relatively better than mineral fertilizer, with yield increases of 23% and 57% for compost and Bokashi + EM, respectively. In year 2, EM treatments are still less performing than mineral fertilizer, but with a smaller gap (-41%) than in year 2020 (-79%). Simple Bokashi (+30%) and Bokashi enriched with EM (+23%) still performed better, with lower surpluses than in year 1.

Table 4:- Average yield, average number of fruits and average fruit weight.

Fertilizer type	2020			2022		
	Yield	NFP	AFW	Yield	NFP	AFW
[Unit]	[t/ha]	[--]	[g]	[t/ha]	[--]	[g]
Compost	14,75 ± 3,5 ^a	15 ± 3 ^a	35 ± 4 ^a	9,65 ± 1,18 ^b	7 ± 2 ^{ab}	41 ± 4 ^a
Bokashi	15,69 ± 2,84 ^a	16 ± 2 ^a	40 ± 5 ^a	18,18 ± 1,39 ^a	13 ± 3 ^a	43 ± 4 ^a
EM	2,42 ± 0,96 ^b	5 ± 1 ^b	25 ± 9 ^b	8,29 ± 1,21 ^b	6 ± 1 ^b	44 ± 7 ^a
Compost + EM	15,18 ± 3,22 ^a	9 ± 4 ^{ab}	37 ± 2 ^a	12,42 ± 3,05 ^{ab}	8 ± 3 ^{ab}	47 ± 3 ^a
Bokashi + EM	18,90 ± 2,47 ^a	17 ± 3 ^a	41 ± 5 ^a	17,14 ± 1,94 ^a	12 ± 2 ^a	45 ± 5 ^a
NPK + Urea	12,01 ± 3,89 ^a	16 ± 4 ^a	32 ± 6 ^{ab}	13,98 ± 1,67 ^{ab}	9 ± 4 ^{ab}	48 ± 7 ^a
p-value	0,002	0,009	0,011	< 0,001	0,012	0,529

Values followed by the same letter in the same column do not differ significantly at the 5% level. $p > 0.05$ = not significant; $p < 0.05$ = significant; $p < 0.01$ = highly significant; $p < 0.001$ = very highly significant. NFP: number of fruits per plant. AFW: average fruit weight.

Early ripening of fruit in relation to fertilizer type

Results indicate that the tomato harvest started later in 2020 than in 2022 (Figure 3). On the other hand, the harvest period was shorter in 2020 (10 days) than in 2022 (23 days). Three (03) successive harvests were required in 2020 compared to five (05) in 2022.

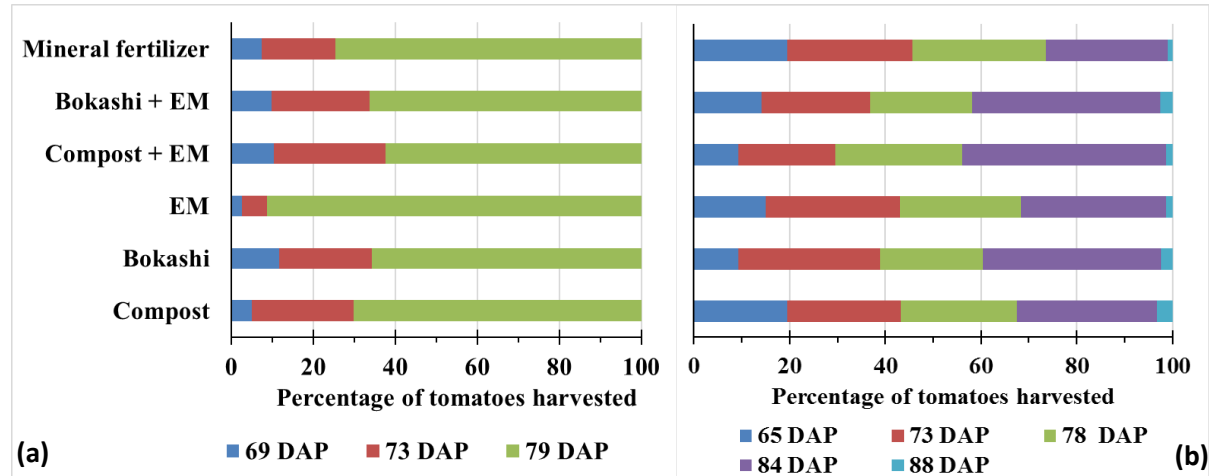


Figure 3:- Histogram depicting the early ripening of tomato fruit and harvests as a function of fertilizers applied.

Except for EM alone and ordinary compost, all other treatments showed equivalent percentages at the first harvest in 2020. At the second harvest, the cumulative harvests percentages for biofertilizers, except for EM alone, were higher than those obtained under mineral fertilization.

In 2022, the percentage obtained at the first harvest was equivalent for compost and mineral fertilizer. These two treatments differed slightly after the second harvest. The total of these two first harvests was slightly higher under mineral fertilization. At the same date, compost + EM gave the lowest harvest rate. It should be noted that even if mineral fertilization sometimes tends to accelerate the earliness of tomato harvesting, as in year 2, the differences remain negligible compared to ordinary compost. Harvest rate always appeared lower for Bokashi and EM than for the mineral fertilizer.

Discussion:-

Improvement of soil chemical indicators as affected by biofertilizers

The use of compost and Bokashi, whether enriched with EM or not, favorably changed some chemical characteristics of the soil, particularly available P and exchangeable bases. This resulted in a relatively high saturation of exchangeable bases and a tendency (albeit small) toward a reduction of soil acidity. Carbon content and CEC also tended to be improved. Results (Table 2) indicate that compost and Bokashi were significant sources of carbon, major nutrients (NPK) and alkaline minerals (Ca and Mg). Compost provided more carbon, which explains why CEC values and carbon content were relatively better in the compost-amended plots. The Bokashi is enriched with a diversity of materials and microorganisms, which contribute to Burkina Phosphate solubilization and thus to the improvement of phosphorus availability (P Bray I) and exchangeable bases [34]. Indeed, organic fertilizers release organic acids and hormones that contribute to the solubilization and availability of phosphorus as it is strongly bound in tropical soils [35]. In addition, EMs were less efficient, while the solid form had higher carbon, phosphorus and potassium contents (Table 2). This suggests that the application of EM in liquid form had a diluted effect on the initially determined dose. The low organic matter content of the soil could also be a limiting factor as EM need organic substrates to grow ([36]; [30]).

Composts and Bokashi abilities to improve the chemical quality of vegetable cropping soils corroborate several previous results in Burkina ([37]; [38]; [39]) and elsewhere ([40]; [41]). Generally, these references report improvements in chemical indicators, because soils used from the start were richer, in contrast to our study based on a degraded and highly depleted soil. The limited period of the study (and therefore of the amendments applied) explains why increases were sometimes very small, as for pH. For nitrogen, the changes in soil content were negative with the highest deficit observed under mineral fertilization. However, the studies of [38] and [39] found a

positive balance for nitrogen when mineral fertilizer was combined with compost or Bokashi. Thus, the use of compost and Bokashi is doubly justified (in degraded soils) by the restoration of soil quality on the one hand, and by the increase in the efficiency of nitrogenous mineral manure on the other. Indeed, these substrates (compost, Bokashi and EM) provide organic matter whose role in fixating acidifying elements such as iron and aluminium, is widely known. In addition, they were sources of bases (Ca^{2+} and Mg^{2+}) provided by various inputs including crushed bones that have been incorporated into their manufacture. Mineral fertilizers had an acidifying effect linked to the NH_4^+ ions released by urea into the soil [42]. Furthermore, the study of [43] found that the use of mineral fertilizers does not significantly improve the sum of exchangeable bases (SEB). Also, biofertilizers have an overall beneficial effect on the residual contents (upward trend) of mineral elements (P, K) compared to mineral fertilizer. Even if the overall nitrogen content decreased, the rate of decrease was more significant under mineral fertilization. This nitrogen depletion can be attributed to an insufficient supply and poor stabilization of nitrogen ions, given the low organic matter content of soil, which is the essential component of the clay-humus complex in tropical soils. And also, the low capacity of the soil complex probably constrained the improvement of all chemical elements. This confirms the key role of organic matter in maintaining tropical soil fertility ([44]; [45]).

Effects of fertilizers on yields and earliness of harvest

Firstly, it should be noted that the yields obtained were low compared to the potential yield of the tomato variety Cobra 26 (more than 25 t ha^{-1}). This low overall yield was probably related to the initial soil poverty, which was not sufficiently compensated by nutrients input through the different fertilizer sources. In any case, Bokashi, alone or enriched with EM, performs better than mineral fertilizer alone in terms of yield, with yield increases of +31% to +57% in year 1 and +30% to +23% in year 2. Bokashi performance seems to reflect not only its good fertilizing quality, but also its greater stability from one year to the next. This could be ascribed to the fact that inputs used for the manufacturing of Bokashi are usually the same. In contrast, the crop residues used for manufacturing compost can vary according to their availability and origin. This probably explains why compost is less effective in year 2 (-11 to +31% compared to mineral fertilizer) as opposed to year 1 (+23% to +30% compared to mineral fertilizer).

Numerous authors have confirmed the efficacy of Bokashi, especially when combined with EM, on various vegetable crops growth and yield ([46]; [30]). The latter report even higher yield surpluses on cabbage (+167%) and potato (+129%). Unlike to our results, [47] reports a better performance of EM applied alone on groundnut (+175%) and carrot (+112%) yields compared to mineral fertilizers. The right performance of biofertilizers, in particular compost and Bokashi, on tomato growth and yield confirms the fertilizing value of organic sources compared to mineral fertilizers, as noted by several authors ([48]; [18]; [49]). In addition, organic fertilizers raised soil pH (6.01 to 6.20) close to the level where soil nutrient assimilability by plants is enhanced [50]. Therefore, mineral fertilization does not clearly imply early harvesting. Yet this is often used as a pretext for farmers to use mineral fertilizers with the intention of accelerating the cropping cycle.

In general, it is widely recognized that organic resources are beneficial to degraded tropical soils as a source of nutrients and a factor in the physical structuring of the soil. Bokashi, which can be made in a short time (15 days) with available materials, can be an alternative to mineral fertilizers and ordinary compost to improve the productivity of degraded soils. These preliminary results suggest that further investigation is needed. Among other things, it is necessary to characterize the microorganisms contained in Bokashi and in EMs, to analyze the overall nutrient balance, and to optimize the doses of biofertilizers as well as the combinations of fertilizers in order to minimize their costs.

Conclusion And Perspectives:-

With a view to sustainable improvement of vegetable crop productivity through practices that respect human and environmental health, this study tested the effectiveness of biofertilizers on tomato yield and soil chemical properties. Biofertilizer inputs tended to improve pH, P Bray I levels, the sum of exchangeable bases, and cation exchange capacity of the soil compared to their initial levels in the soil. These inputs mitigate the nitrogen deficit more than mineral fertilizer. As a result, tomato yields increased by 23-58% with Bokashi compared to mineral fertilizer. With compost, changes were unstable (gain or loss), probably due to an insufficient fertilizing quality in relation to the materials used in the manufacture. Inoculated EMs alone were found to be less effective, suggesting that they should be combined with organic substrates, especially in soils poor in organic matter. The results obtained suggest that Bokashi can be an effective alternative to mineral fertilizers and compost. Further investigations are needed in order to consolidate the results. It will involve to characterize the microorganisms in Bokashi and in the

manufactured EMs, to analyze the overall nutrient balance in soils, to optimize the dose of biofertilizer use, and to assess the associated economic benefits in the different cropping systems.

References:-

- [1] Drechsel P., Gyiele L., Kunze D. et Cofie O., 2001. Population density, soil nutrient depletion, and economic growth in sub-Saharan Africa. *Ecological Economics*, 38, 251–258
- [2] Lal R., 2004. Soil Carbon Sequestration Impacts on Global Climate Change and food security. *Science* 304, 1623-1627p. DOI: 10.1126/science.1097396
- [3] Lal R., 2009. Soil degradation as a reason for inadequate human nutrition. *Food Security*, 1, p.45–57.
- [4] ELD Initiative & UNEP. 2015. L'économie de la dégradation des terres en Afrique: les bénéfices de l'action l'emportent sur ses frais. www.eld-initiative.org.
- [5] UNCCD., 2016. La grande muraille verte l'espoir pour le Sahara et le sahel. https://www.unccd.int/sites/default/files/documents/26042016_GGW_FR.pdf. Consulté le 18.06.2021
- [6] Economic Commission for Africa (ECA)., 2007. Africa Review Report on drought and desertification. United Nations, 71 p.
- [7] Ray D.K., Ramankutty N., Mueller N.D., West P.C., Foley J.A., 2012. Recent patterns of crop yield growth and stagnation. *Nature communications*, 3, 1293, 7 p.
- [8] Ministère de l'Agriculture et des Aménagements Hydro-agricoles (MAAH)., 2018. Situation de référence des terres dégradées et de la CES au Burkina Faso. GIZ, Burkina Faso, 154p
- [9] Alexandratos N., Bruinsma J., 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper, 12-03, Rome, FAO, 146 p.
- [10] Guèdègbè T. Sinsin T. et Rachid M.D., 2018. La neutralité en termes de dégradation des terres en Afrique est-elle envisageable ? Policy Brief - 18/31
- [11] Ministère de l'Agriculture et des Aménagements Hydro-agricoles (MAAH), 2019. Rapport bilan annuel des activités de l'année. Ouagadougou, Burkina Faso. 64 p
- [12] Kaboré M., Ouédraogo F. & Tapsoba K.P., 2018. Revenu maraîcher et sécurité alimentaire du ménage du producteur dans les villes de Bobo-Dioulasso, Ouagadougou et Ouahigouya au Burkina Faso. *Revue Echanges*, Vol. 3 (010) : 723-736
- [13] Ouédraogo R. A., Kambiré F.C., Kestemont M-P., Biolders C., 2019. Caractériser la diversité des exploitations maraîchères de la région de Bobo-Dioulasso (Burkina Faso) pour faciliter leur transition agro-écologique. *Cah. Agri.* 28 :20
- [14] Ouédraogo A.R, Kambiré F.C., Isola R.A., Nebié R.H-C., Somda I., 2020. Pratiques de fertilisation maraîchère et pourriture post-récolte des bulbes d'oignon (*Allium cepa* L.) au Burkina Faso. *Revue burkinabè de la recherche Sciences naturelles et appliquées*. Vol. 39,n° 2 (2) : 27-41
- [15] Lompo D. J. P., 2012. Matter flows and balances in urban vegetable gardens of Bobo Dioulasso, Burkina Faso. Thèse de doctorat. University of Kassel, Allemagne, 64p.
- [16] Sangaré, S. K., Compaoré, E., Buerkert, A., Vanclooster, M., Sedogo, P. M., Biolders, L. C., 2012. Field-scale analysis of water and nutrient use efficiency for vegetable production in a West African urban agricultural system. *NutrCyclAgro-ecosyst*, 92(2), 207-224
- [17] Kiba, D. I., Zongo, N. A, Lompo, F., Jansa, J., Compaore, E., Sedogo, P. M., & Frossard, E., 2012. The diversity of fertilization practices affects soil and crop quality in urban vegetable sites of Burkina Faso. *European Journal of Agronomy*, 38 : 12-21.
- [18] Kitabala M. A., Tshala U. J., Kalenda M. A., Tshijika I. M., Mufind K. M., 2016. Effets de différentes doses de compost sur la production et la rentabilité de la tomate (*Lycopersicon esculentum* Mill) dans la ville de Kolwezi, Province du Lualaba (RD Congo), *Journal of Applied Biosciences*, 102: 9669 – 9679.
- [19] Stassart P. M., Baret Ph., Grégoire J-Cl., Hance Th., Mormont M., Reheul D., Stilmant D., Vanloqueren G., Visser M., 2012. L'agroécologie : trajectoire et potentiel pour une transition vers des systèmes alimentaires durables. In « Agroécologie entre pratiques et sciences sociales », Educagri éditions, Supérieure Agronomique, 21p.
- [20] Faessel L., Tostivint C., Schaller N., 2015. Produits de stimulation en agriculture visant à améliorer les fonctionnalités biologiques des sols et des plantes : état des lieux et perspectives. Rapport final d'une étude commanditée par le Centre d'Etude et de Prospective du Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt. 2015. 8 p.
- [21] Inckel M., Smet P., Tersmette T., Veldkamp T., 2005. *Agrodok 8 : La fabrication et l'utilisation du compost*, sixième édition, ISBN Agromisa: 90-8573-007-4, 73p.
- [22] Motta I., 2010. Production de semis de laitue avec différentes concentrations de Bokashi. *Cadernos de Agroecologia*, v. 5, n.1, p.1-5.

- [23] Kyan, T., Shintani, M., Kanda, S., Sakurai, M., Ohashi, H., Fujisawa, A., 1999. Kyusei Nature Farming and the Technology of Effective Microorganisms. (R. Sangakkara, Ed.) Bangkok, Thailand: Asia Pacific Natural Agriculture Network. p. 49.
- [24] Higa, T., Parr, J. F., 1994. Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Research Center, Atami, Japon, p. 16.
- [25] Higa T., 1993. Effect of lactic acid fermentation bacteria on plant growth and soil humus formation. In: Parr, J.F., Hornic, S.B., Whitman, C.E., (Eds.), Proceedings of the 1st International Conference on Kysuei Nature Farming, 17–21 October 1989, Khan Kaen, Thailand, pp. 140–147.
- [26] Siqueira A. P., Siqueira M.F.B., 2013. Bokashi : engrais organique fermenté. Niterói, 16p
- [27] Piotrowska A., Boruszko D., 2022. The Effect of Using Effective Microorganisms on the Changes in the Chemical Composition of Spring Wheat. Journal of Ecological Engineering, 23(6), 50–57. <https://doi.org/10.12911/22998993/147874>
- [28] Younas, T., Umer, M., HusnainGondal, A., Aziz, H., Khan, M. S., Jabbar, A., Shahzad, H., Panduro-Tenazoa, N., Jamil, M., Ore Areche, F., 2022. A Comprehensive Review on Impact of Microorganisms on Soil and Plant, Journal of Bioresource Management, 9 (2).
- [29] Roque A., 2001. Nutricion vegetal organica en Cuba. Asociacion nacional de agricultores Pequenos, Cuba.
- [30] Dorian F., 2015. Microorganismes Efficaces '(EM)'. Compilation de documents et témoignages cubains sur le fonctionnement, la production artisanale et l'usage des microorganismes efficaces en milieu paysan, 42p.
- [31] Polmans A., 2018. Étude comparative en vue de l'optimisation des propriétés physicochimiques du bokashi produit par la coopérative « UdomSorya » à Takéo, mémoire de master en gestion de la fertilité des sols, 133p.
- [32] AFNOR., 1981. Détermination du pH. (Association Française de Normalisation) NF ISO 10390. AFNOR qualité des sols, Paris, 339-348.
- [33] R Development Core Team, 2019. A Language and Environment for Statistical Computing. R Development Core Team: Vienna, Austria
- [34] Gashua, A.G.; Sulaiman Z., Yusoff, M.M.; Samad, M.Y.A.; Ramlan, M.F.; Salisu, M.A., 2022. Assessment of Fertilizer Quality in HorseWaste-Based Bokashi Fertilizer Formulations. Agronomy, 12, 937. <https://doi.org/10.3390/agronomy12040937>
- [35] Ahmed S., Khan M., Raza T., Ahmad R., Iqbal J., Eash N.S., 2022. Integrated use of bio-organic and chemical fertilizer to enhance yield and nutrients content of tomato Eurasian Journal of Soil Science, 11(2):126-132
- [36] Raman, J.; Kim, J.-S.; Choi, K.R.; Eun, H.; Yang, D.; Ko, Y.-J.; Kim, S.-J., 2022. Application of Lactic Acid Bacteria (LAB) in Sustainable Agriculture: Advantages and Limitations. Int. J. Mol. Sci., 23, 7784. <https://doi.org/10.3390/ijms23147784>
- [37] Ouédraogo R. A., Chartin C., Kambiré F.C., van Wesemael B., Delvaux B., Milogo H., Bielders, C.L., 2020. Short and long-term impact of urban gardening on soil organic carbon fractions in Lixisols (Burkina Faso). Geoderma, 362, 114110
- [38]. Coulibaly P.J.A, Sawadogo J., Bambara Y.A.I, Ouédraogo W.B.M., Legma J.B., Compaoré E., 2021. Effect of Bio-Fertilizers on Tomato (*Solanum Lycopersicum*) Production and on soil physico-chemical properties in sudan area of Burkina Faso. Current Agriculture Research Journal, Vol. 9, N°(1): 43-53
- [39] Sawadogo J., Coulibaly P.J., Beogo M., Savadogo C.A, Legma J.B., 2022. Effects of biological fertilizers on the yields of onion (*Allium Cepa L.*) and on soil physico-chemical, microbiological properties in the Centre-west of Burkina Faso. International Journal of Innovation and Applied Studies, Vol. 35 (2) : 249-259
- [40] Lasmini S.A., Nasir B., Hayati N., Edy N., 2018. Improvement of soil quality using bokashi composting and NPK fertilizer to increase shallot yield on dry land. AJCS, 12 (11):1743-1749
- [41] Fajeriana N., Ali A., Sangadji Z., Setyawati A., 2022. Application of cow manure Bokashi fertilizer to nutrients of top soil oxisol planting media with the and yield of red spinach (*Amaranthus tricolor L.*). JASAE, Vol. 18 (3) : 909-915
- [42] Soltner D., 2003. Les bases de la production végétale, tome1 : Le sol et son alimentation, 102p.
- [43] Akanza P. K., Yoro G., 2003. Effets synergiques des engrais minéraux et de la fumure de volaille dans l'amélioration de la fertilité d'un sol ferrallitique de l'ouest de la Côte d'Ivoire. Agronomie Africaine 15 (3): 135-144.
- [44] Feller C., 1995. La matière organique du sol : un indicateur de la fertilité : application aux zones sahélienne et soudanienne. Agric. Dev., 8, p.35-41
- [45] Bationo A., Kihara J., Vanlauwe B., Waswa B., Kimetu J., 2006. Soil organic carbon dynamics, functions and management in West African agro-ecosystems. Agric. Syst., 94, p.13-25.
- [47] Milagrosa S.P., Balaki E.T., 1999. Influence of Bokashi organic fertilizer and Effective Microorganisms (EM) on growth and yield of field grown vegetables. Proceedings of the conference on Kyusei nature farming and

Effective Microorganisms for agricultural and environmental sustainability held at Bangkok, Thailand; Japan: International Conference on Kyusei Nature Farming, 82p.

[48] Arakawa, Y., 1998. Kyusei nature farming in Japan. 8p.

[48] Btissam M., Amina O-T., Allal D., 2013. Effet du compost de *Trichoderma harzianum* sur la suppression de la verticilliose de la tomate, 17p.

[49] Biaou O. D. B., Saidou A., Bachabi F-X., Padonou G. E., Balogoun I., 2017. Effet de l'apport de différents types d'engrais organiques sur la fertilité du sol et la production de la carotte (*Daucus carota* L.) sur sol ferrallitique au sud Bénin, *Int. J. Biol. Chem. Sci.* 11(5): 2315-2326.

[50] Ognalaga M., Odjogui P. I. O., Lekambou J. M., Poligui R. N., 2015. Effet des écumes à cannes à sucre, de la poudre et du compost de à base de *Chromolaena odorata*(L.) King R.M. et H.E. Rob sur la croissance de l'oseille de Guinée (*Hibiscus sabdariffa* L.). *Int. J. Biol. Chem. Sci.*, 9(5): 2507-2519.