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Research Article

Comparative Effects of Organo-Mineral, Organic and Mineral Fertilizations on the Agronomic Performance of the Cabbage (*Brassica oleracea* L.) in the Sudano-Sahelian Zone of Burkina Faso

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Abstract

Cabbage (*Brassica oleracea* L.) is a vegetable grown for its leaves, apples or flower. Its production ranks third after onions and tomatoes in Burkina Faso. However, the fertilizers used in its production limit its yield performance. With this in mind, the aim of the present study was to compare the effect of different fertilization regimes on the agronomic performance of cabbage. The study was carried out at the Eden II farm in Kougsabla, in the town of Tenkodogo. The experimental set-up was a completely randomized block design with three fertilization regimes repeated four times. Fertilization regimes consisted of Compost+NPK (6 t/ha +50 kg/ha), Compost (12 t/ha) and NPK (100 kg/ha). Cultivation consisted of ploughing, burying fertilizers and transplanting seedlings. Physiological, morphological, phytopathological and agronomic parameters were evaluated. Analysis of variance (ANOVA at 5 % threshold) revealed no significant difference between cabbage morphological, physiological, phytopathological and yield parameters according to the fertilization regimes. The Compost+NPK fertilization improved cabbage morphological performance with increases of 4 % of plant height; 6 % of plant width; 3 % of number of leaves; 9 % of apple circumference; 19 % of apple length; and 14 % in apple width compared with the NPK fertilization regime. Early onset of the first cabbage apple of 2 and 3 days was observed under the Compost+NPK fertilization regime compared with the Compost and NPK fertilization regimes. The Compost reduced the number of rotten apples by 50 % and the number of punctured apples at harvest by 78 % compared with the NPK. The Compost fertilization recorded the highest apple yield at 68 %, followed by the Compost+NPK fertilization regime at 55 % compared with the NPK fertilization. These results show that the compost fertilization performed well in terms of plant health and cabbage apple yield, while the Compost+NPK fertilization regime performed better in terms of cabbage morphological and physiological parameters.

Keywords: Cabbage; Fertilization; Evaluation; Productivity; Sudano-Sahelian; Burkina Faso

Introduction

Market gardening in Burkina Faso is a source of monetary income that helps to improve the living conditions of market gardeners, reduce poverty and solve the challenge of food insecurity [1]. Market gardening plays an important role in Burkina Faso's agricultural sector. It accounts for 16.5 % of agricultural production, 10.5 % of primary sector production and 4.5 % of gross domestic product. Market gardening creates nearly 400,000 jobs

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[2]. More than 22 crops are produced in market gardening, including cabbage, which ranks third in terms of surface area after bulb onions and tomatoes, with production of around 2,438 ha, or 8.8 % of the total market garden area, unevenly distributed across the regions [2]. Cabbage (*Brassica oleracea* L.) is considered a major crop belonging to the Brassiceae family [3]. It is a leaf or flower vegetable for some, generally produced for leaves or flowers. Their edible leaves may or may not form a compact head or "apple". Its cultivation as a vegetable dates back to ancient times, from wild forms originating in Western or Southern Europe. It spread from the Mediterranean basin to the Atlantic coast in the Middle Ages, and its varieties have been known in Europe since the 8th century [4]. This vegetable is rich in dietary fiber, water and vitamins A, B and C, giving it a very high nutritional density. It is used fresh in salads and pickles, and can be boiled, cooked or dehydrated. It neutralizes acidity, improves digestion and appetite [5]. Poverty and declining soil nutrient levels are some of the biggest constraints in cabbage production. It founded that over 40% of soils in the sub-Saharan African region are nutrient-depleted [6,7]. This soil poverty is a function of the overexploitation of plots without a sufficient supply of organic matter characteristic of market gardening [8].

In order to promote sustainable agriculture in a context marked by physical, chemical and biological soil degradation, a number of soil fertility management practices are required [9,10]. Among these practices, organic and mineral fertilization provide plants with the mineral elements essential for better plant growth and maximum yields [11]. Organic fertilizers act on the physico-chemical and biological components of the soil [12]. They are environmentally friendly as they improve soil health, water retention capacity and lead to better soil structure through increased cation exchange capacity [13] and lower bulk density. They also promote a diverse population of beneficial soil microorganisms [14]. Organic fertilizers used in a complementary manner to mineral fertilization promote greater phosphorus (P) availability in the soil [15]. The work of Hafez et al. [16] in Egypt on potatoes revealed better performance with organo-mineral fertilization on growth and yield parameters compared with the application of compost alone and NPK. In addition, the best sesame yield performance was obtained with 1.5 t/ha of organo-mineral fertilizer [17]. Thus, the coupling of organic and mineral fertilizers would be an alternative to improve the agronomic quality of crops in order to efficiently increase yields. The overall aim of this study is to improve cabbage yield performance by comparing several fertilization regimes.

Materials and Methods

Experimental site

The study was conducted in Kougsabla, a village located in the commune of Tenkodogo in the Centre-Est region of Burkina Faso. The study was carried out on the Eden II farm, which has geographical coordinates of 11°49'2.71812" N and 0°22'42.80412" W.

The climate is of the Sudano-Sahelian type, characterized by two seasons [18]. A dry season from November to May and a short rainy season from June to September. Rainfall ranges from 600 to 900 mm. According to the meteorological station of the experimental site, the average monthly temperature observed over certain periods is 33°C, and maximum temperatures can reach 41°C. Rainfall over the past ten years (2014-2023) has been irregular, with poor distribution in time and space. The highest rainfall of 1049.6 mm was recorded in 2016, compared with 659.2 mm in 2017. Rainfall in 2023 ranged from 24 mm in April to 306.7 mm in August, considering only rainy months. The number of rainy days was 1 in April and 13 in August, considering only rainy months.

The vegetation consists of shrubs and tree savannahs [18]. According to the World Reference Base for Soil Resources [19], the following soil groups have been mainly identified in the Centre-Est region. These are Leptic or lithic Leptosols, Epipetric Plinthosols, endopetroplinthic Lixisols, haplic or vertic Cambisols, Fluvisols (epiarenic), and umbric (eutriic) or haplic Gleysols, hypereous or mazic Vertisols. These soils are predominantly poor in the mineral elements Ca, K and P, with low water retention capacity. These soils are relatively suitable for cereal crops and legumes such as millet, sorghum, groundnuts and cowpeas.

Plant material, fertilizers and pesticides

Brassica oleracea (L) var tropica plants were used as planting material. Approximately, 50-day-old plants from a nursery were used.

NPK (14-23-14) and compost were used as fertilizers. Compost was obtained by composting plant residues (rice husks, straw) under a shelter with an effluent. The effluent is derived from the anaerobic degradation of cow dung and pig manure over a 30-day period in a closed system known as a biodigester. Table 1 shows the organic and chemical characteristics of compost.

Table 1: Organic and chemical characteristics of compost.

Parameters	Units	Values
Total organic matter	%	48.14
Total carbon	%	27.92
Total nitrogen	%	1.81
C/N		15
$N\text{-}NH_4^+$	mg/kg	171.91
$N\text{-}NO_3^-$	mg/kg	58.75
N-Mineral ($N\text{-}NH_4^+ + N\text{-}NO_3^-$)	mg/kg	230.67
Total phosphorus	%	2.84
Available phosphorus	g/kg	20.22
Total Potassium	%	2.28
Available potassium	g/kg	21.12

$N\text{-}NH_4^+$ = ammoniacal nitrogen; $N\text{-}NO_3^-$ = nitrate nitrogen.

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Experimental design and fertilization regimes

The experimental design consisted of four completely randomized blocks comprising three fertilization regimes repeated four times, corresponding to a total of 12 elementary plots (1.5 m × 4 m = 6 m^2). The blocks were separated by 0.6 m aisles, and the individual plots within each block by 0.5 m. The following fertilization regimes were applied:

- Compost: 12 t/ha
- Compost+NPK: 6 t/ha + 50 kg/ha NPK (14-23-14)
- NPK: 100 kg/ha NPK (14-23-14)

Crop management

The experiment consisted in setting up the experimental layout. Ploughing was carried out with a rototiller, followed by levelling with rakes. The set-up began with the delimitation of blocks and elementary plots. Next, organic compost was applied and then ploughed in for the plots receiving these fertilization regimes. The cabbage plants were transplanted on July 12, 2023, at a spacing of 40 cm between rows and 40 cm between rows. For each elementary plot, there were four lines and 10 plants per line, for a total of 480 plants for the entire experimental set-up. For crop maintenance, weeding was carried out every two or three weeks, depending on the level of weed cover. The aim of these cultivation operations was to reduce weed proliferation, but also to promote water infiltration.

Phytosanitary treatments were also carried out by spraying. These treatments were applied once and separately. The first phytosanitary treatment (Sultan) was applied one week before the second treatment (Emectin pro). Treatments were carried out at doses of 25 ml for a 16 l sprayer in the evenings. The phytosanitary products used were all approved by the Sahelian Pesticides Committee in 2020.

Agronomic data collection

Data collection consisted in assessing morphological, physiological, phytopathological and yield parameters at cabbage harvest. Growth parameters were recorded every two weeks from the date of transplanting. These growth parameters include plant height (PH), plant width (PW), number of leaves (NL), apple length (AL), apple width (AW) and circumference (AC). PH was measured in cm from the base to the top of the longest leaf on the plant, using a graduated ruler. The PW was measured from the two longest opposing leaves. AL and AW were measured using a caliper. AC was measured by winding a metric tape around the apple. PH, PW and NF were measured on 05 plants per plot, including 04 extreme plants and 01 in the center. A total of 60 plants were examined at each data collection session. The physiological parameters recorded were: recovery rate (RR) of plants assessed 15 days after transplanting, plant maturation rates in percentage (MR), number of days from sowing to appearance of the first apple (NDS); number of days from sowing to appearance of 50 % of fruits (NDS50).

The phytopathological parameters assessed were: number of diseased plants (NDP), number of punctured leaves (NPL), number of rotten apples (NRAH), number of punctured apples (NPAH). The ratios of the number of diseased plants to the number of plants (NDP/NP), the number of rotten apples to the number of apples harvested (NRAH/NAH), the number of the punctured apples at harvest to the number of apples harvested (NPAH/NAH) and the ratio of the number of punctured leaves to the number of leaves (NPL/NL) were also assessed. Harvesting parameters consisted in assessing the number of apples harvested (NAH), the weight of apples harvested (WAH) in kg, the apple yield (CAY) and the ratio of weight of apples harvested to number of apples harvested (WAH/NAH).

Statistical analysis

The EXCEL 2021 software was used to enter and process the data, and to produce the graphs. The Shapiro-Wilk test was used to test the normality of the data. An analysis of variance (ANOVA) and a Tukey HSD test of separation of means at the 5% threshold were performed on the agronomic parameters of cabbage according to the fertilization regimes. A Pearson correlation at the 5% threshold was also performed on all data according to the fertilization regimes. XLSTAT 4.1, version 2023 (ADDINSOFT, 2023) was used for these analyses.

Results

Effects of the fertilization regimes on cabbage morphological performance

Table 2 shows the overall effect of the fertilization regimes on plant heights (HP) and widths (PW), number of leaves (NL), apple widths (AW), apple lengths (AL) and apple circumferences (AC) according to the fertilization regimes. Analysis of variance (ANOVA at 5% threshold) shows that these different morphological parameters were not significantly affected by fertilization regimes.

Plant heights (PH) varied from 16.07 ± 0.60 cm under the Compost fertilization regime to 16.82 ± 0.62 cm under the Compost+NPK fertilization regime. Increases of the order of 4 and 0.27% were obtained under the Compost+NPK and NPK fertilization regimes respectively, compared with the compost fertilization regime.

Plant widths (PW) fluctuated between 23.46 ± 1.08 cm under the NPK fertilization regime and 24.96 ± 1.11 cm under the Compost+NPK fertilization regime. LPs were improved by 6% and 3% under the Compost+NPK and the Compost fertilization regimes respectively, compared with NPK.

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The number of leaves (NL) varied from 67.30 ± 2.20 under the NPK fertilization regime to 69.32 ± 2.26 under the Compost+NPK. Increases of around 3 % and 1 % were recorded respectively under the Compost+NPK and the Compost fertilization regimes compared with the NPK fertilization.

Apple length (AL) varied from 39.34 ± 36.74 mm under the Compost fertilization regime to 79.78 ± 36.74 mm under the Compost+NPK. Increases of 48.7% and 41% were obtained respectively under the Compost+NPK and the NPK fertilization regimes compared with Compost.

Apple widths (AW) ranged from 34.65 ± 29.19 mm under Compost to 61.23 ± 29.19 mm under Compost+NPK. LAPs were improved by 43% and 35% respectively under the Compost+NPK and the NPK fertilization regimes compared with compost.

Apple circumferences (AC) fluctuated between 13.25 ± 12.50 cm under the compost and 25.75 ± 12.50 cm under the Compost+NPK fertilization. Increases of 49% and 44% were recorded under the Compost+NPK and NPK fertilization regimes respectively, compared with the Compost fertilization.

Table 2: Effects of fertilization regimes on cabbage morphological performance.

Fertilization regimes	PH (cm)	PW (cm)	NL	AL (mm)	AW (mm)	AC (cm)
Compost+NPK	16.82±0.62	24.96±1.11	69.32±2.26	79.78±36.74	61.23±29.19	25,75±12,50
Compost	16.07±0.60	24.05±1.08	67.85±2.20	39.34±36.74	34.65±29.19	13,25±12,50
NPK	16.11±0.60	23.46±1.08	67.30±2.20	66.82±42.42	53.72±33.70	23,50±14,44
P Significance	0.63 NS	0.62 NS	0.8 NS	0.74 NS	0.8 NS	0,77 NS

Compost+NPK: 6 t/ha of Compost+50 kg/ha NPK; Compost: 12 t/ha of Compost; NPK: 100 kg/ha; PH: Plant height; PW: Plant width; NL: Number of leaves; AL: Apple length; AW: Apple width; AC = Apple circumference. P = probability according to ANOVA at 5% significance level. P ≥ 0.05: not significant (NS).

Effects of the fertilization regimes on cabbage physiological parameters

Table 3 shows the effects of the fertilization regimes on cabbage physiological parameters. Statistical analysis of variance (ANOVA at 5% threshold) reveals that there was no significant difference between cabbage physiological parameters according to fertilization regimes.

The recovery rate (RR) varied from 98 ± 0.90 under the NPK fertilization regime to 100 ± 0.78 under the Compost+NPK. Increases of 2% in TXR were obtained under the Compost and Compost+NPK fertilization regimes respectively, compared with the NPK.

The number of days from sowing to the appearance of the first apple (NDS) ranged from 40 ± 2.23 days under the compost+NPK to 44 ± 2.23 days under the Compost. The compost+NPK reduced NDS by 4 and 3 days respectively compared with the Compost and NPK fertilization regimes.

The number of days from sowing to 50% apples (NDS50) ranged from 47 ± 0.62 and 47 ± 0.72 days respectively under the compost+NPK and NPK fertilization regimes to 48 ± 0.62 days under the Compost. The compost+NPK and NPK fertilization regimes respectively reduced NDS50 by 1 day compared with the Compost.

Maturation rates (MR) fluctuated between 66 ± 20.46 under the Compost and 76 ± 23.88 under the NPK. Increases of 15% and 3% respectively were obtained under the NPK and compost+NPK fertilization regimes compared with the Compost.

Table 3: Effects of fertilization regimes on cabbage physiological parameters.

Fertilization regimes	RR (%)	NDS (days)	NDS50 (days)	MR (%)
Compost+NPK	100±0.78	40±2.23	47±0.62	68±20.46
Compost	100±0.78	44±2.23	48±0.62	66±20.46
NPK	98±0.90	43±2.58	47±0.72	76±23.88
P	0.42	0.88	0.22	0.93
Significance	NS	NS	NS	NS

Compost+NPK: 6 t/ha of Compost + 50 kg/ha of NPK; Compost: 12 t/ha of Compost; NPK: 100 kg/ha; RR: Plant recovery rate; NDS: number of days from sowing to appearance of first apple; NDS50: number of days from sowing to appearance of 50 % of apple; MR: Plant maturation rate; P = probability according to ANOVA at 5% significance level. P ≥ 0.05: not significant (NS).

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Effects of fertilization regimes on cabbage phytopathological parameters

Table 4 shows the effects of fertilization regimes on cabbage phytopathological parameters. Statistical analysis of variance (ANOVA at 5% threshold) revealed that there was no significant difference between cabbage phytopathological parameters according to the fertilization regimes.

The number of punctured leaves (NPL) ranged from 20.95 ± 2.33 under the NPK fertilization regime to 22.35 ± 2.33 under the compost+NPK. The NPK reduced NPL by 3 and 7% compared with Compost and Compost+NPK fertilization regimes respectively.

The number of diseased plants (NDP) fluctuated between 6.40 ± 1.62 under NPK fertilization regime and 7.20 ± 1.62 under Compost. The NPK fertilization regime reduced NDP by 13% and 10% compared with Compost and compost+NPK fertilization regimes respectively.

The ratio of number of diseased plants to number of plants (NDP/NP) ranged from 0.27 ± 0.06 under the NPK fertilization regime to 0.30 ± 0.06 under the compost+NPK fertilization regime. NPM/NP were reduced by 11 and 7 % under NPK compared with the Compost+NPK and compost fertilization regimes respectively.

The ratio of the number of punctured leaves to number of leaves (NPL/NL) fluctuated from 0.31 ± 0.02 under the NPK and compost fertilization regimes to 0.32 ± 0.02 under the Compost+NPK fertilization regime. The NPK reduced NPL/NL by 3% compared with the Compost+NPK and Compost fertilization regimes respectively.

The number of rotten apples at harvest (NRAH) varied from 0.00 ± 0.39 under the compost fertilization regime to 0.50 ± 0.34 under the NPK fertilization regime. The compost fertilization regime reduced NRAH by 50 % and 100 % respectively, compared with the Compost+NPK and NPK fertilization regimes.

The number of punctured apples at harvest (NPAH) fluctuated between 0.33 ± 0.71 in the Compost and 1.50 ± 0.62 in the NPK. The Compost fertilization regime reduced NPAH by 78 and 73 % compared with the NPK and Compost+NPK fertilization regimes respectively.

The ratio of the number of rotten apples at harvest to the number of apples harvested (NRAH/NAH) varied from 0.00 ± 0.01 under compost to 0.02 ± 0.01 under NPK. The Compost reduced NRAH/NAH by 2 % and 1 % compared with the NPK and Compost+NPK fertilization regimes respectively.

The ratio of number of punctured apples at harvest to number of apples harvested (NPAH/NAH) varied from 0.02 ± 0.04 under the compost fertilization regime to 0.11 ± 0.03 under the NPK fertilization regime. The Compost reduced NPAH/NAH by 81 % and 71 % compared with the NPK and Compost+NPK fertilization regimes respectively.

Effects of the fertilization regimes on cabbage yield attribute and yield at harvest

Table 5 shows the effects of the fertilization regimes on cabbage yield attribute and yield at harvest. Statistical analysis of variance (ANOVA at 5 % threshold) reveals that there was no significant difference between cabbage yield parameters according to the fertilization regimes.

Table 4: Effets des traitements sur les paramètres phytopathologiques du chou.

Fertilization regimes	NPL	NDP	NDP/ NP	NPL/ NL	NRAH	NPAH	NRAH/ NAH	NPAH/ NAH
Compost+NPK	22,35±2,33	7,20±1,62	0,30±0,06	0,32±0,02	0,25±0,34	1,25±0,62	0,01±0,01	0,07±0,03
Compost	21,60±2,70	7,07±1,88	0,29±0,07	0,31±0,02	0,00±0,39	0,33±0,71	0,00±0,01	0,02±0,04
NPK	20,95±2,33	6,40±1,62	0,27±0,06	0,31±0,02	0,50±0,34	1,50±0,62	0,02±0,01	0,11±0,03
P Significance	0,92 NS	0,94 NS	0,94 NS	0,85 NS	0,65 NS	0,48 NS	0,65 NS	0,29 NS

Compost+NPK: 6 t/ha of compost + 50 kg/ha of NPK; Compost: 12 t/ha of compost; NPK: 100 kg/ha; NPL: Number of punctured leaves; NDP: Number of diseased plants; NP: Number of plants; NL: Number of leaves; NRAH: Number of rotten apples at harvest; NPAH: Number of punctured apples at harvest; NAH: Number of apples at harvest. P = probability according to ANOVA at 5% significance level. P ≥ 0.05: not significant (NS).

Table 5: Effects of the fertilization regimes on cabbage yields at harvest.

Fertilization regimes	NAH	WAH (Kg)	WAH /NAH (Kg)	CAY (t/ha)
Compost+NPK	16.25±4.33	4.63±1.41	0.27±0.05	7.71±2.3a
Compost	15.75±4.33	5.00±1.41	0.24±0.05	8.33±2.35
NPK	13.00±5.00	2.98±1.63	0.23±0.05	4.97±2.72
P	0.88	0.64	0.82	0.64
Significance	NS	NS	NS	NS

Compost+NPK: 6 t/ha of Compost + 50 kg/ha of NPK; Compost: 12 t/ha of Compost; NPK: 100 kg/ha; NAH: Number of apples harvested; WAH: Weight of apples harvested; CAY: cabbage apple yields. P = probability according to ANOVA at 5 % significance level. P ≥ 0.05: not significant (NS).

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The number of apples harvested (NAH) varied from 13.00 ± 5.00 under the NPK fertilization regime to 16.25 ± 4.33 under the Compost+NPK the fertilization regime. Increases of around 25 % and 21 % of NAH were obtained under the Compost+NPK and compost fertilization regimes respectively, compared with the NPK fertilization regime.

Weights of apple harvested (WAH) fluctuated between 2.98 ± 1.63 kg under NPK and 5.00 ± 1.41 under compost. The Compost+NPK and compost fertilization regime respectively improved WAH by 55 and 68 % compared with NPK application.

The ratio of the weights of apple Harvested to number of apples harvested (WAH /NAH) ranged from 0.23 ± 0.05 kg under the NPK to 0.27 ± 0.05 under the Compost+NPK. WAH /NAH improved by 4 % and 15 % under Compost and Compost+NPK fertilization regimes respectively, compared with NPK.

Cabbage apple yields (CAY) ranged from 4.97 ± 2.72 t/ha under NPK to 8.33 ± 2.35 t/ha under compost. Increases of around 68 % and 55 % were recorded under the Compost and Compost+NPK fertilization regimes respectively, compared with NPK.

Correlation between agronomic parameters of cabbage according to NPK fertilization regimes

Correlation between cabbage agronomic parameters under compost+NPK

Figure 1 shows a map of Pearson correlation matrices at the 5% threshold between cabbage agronomic parameters as a function of compost+NPK NPK fertilization regime. The number of rotten apples at harvest (NRAH) is positively correlated (r =1 and P < 0.0001) with the number of rotten apples over the number of apples (NRAH/NAH) (Figure 1). The Maturation rate (MR) is strongly positively correlated (r = 1 and P < 0.0001) with the number of harvested apples (NAH). The number of apples harvested (NAH) is positively correlated (r = 0.98 and P = 0.02) with the weight of apples harvested per plot (WAH). Cabbage apple yield (CAY) was positively correlated (r = 0.95; 0.95 and P = 0.04; 0.04) with apple circumference (AC) and apple length (AL). Apple circumference (AC) was strongly and positively correlated (r = 0.99 and P = 0.002) with plant width (PW). The number of diseased plants (NDP) correlated strongly and significantly (r = 1 and P < 0.0001) with the number of diseased plants out of the number of plants (NDP/NP). The ratio of the number of diseased plants to the number of plants (NDP/NP) correlated positively (r = 0.98 and P = 0.03) with the ratio of number of punctured apples to the number of apples harvested (NPAH/NAH).

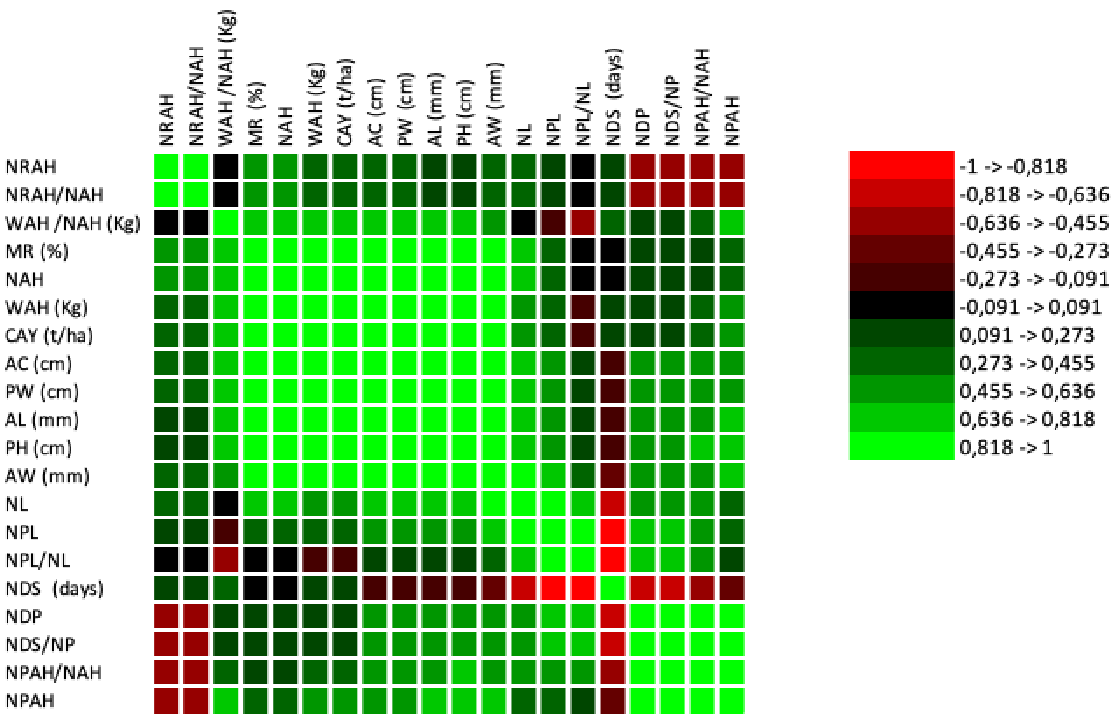

Figure 1: Map of correlation matrix between agronomic parameters of cabbage under Compost+NPK.

Compost+NPK: 6 t/ha of the Compost+50 kg/ha of the NPK ; HP: plant height; PW: plant width; NL: number of leaves; AL : apple length; AW : apple width; AC = apple circumference; RR: recovery rate of plant; NDS: number of days from sowing to appearance of first apple; NDS50: number of days from sowing to appearance of 50 % of apple; MR: maturation rate of plant; NDP : number of diseased plants; NP : number of plants; NPL: number of perforated leaves; NL: number of leaves; NRAH: number of rotten apples harvested; NPAH: number of perforated apples harvested; NAH: number of apples harvested; WAH: weight of apples harvested; CAY: cabbage apple yields.

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Correlation between cabbage agronomic parameters under Compost

Figure 2 shows a map of Pearson correlation matrices at the 5% threshold between cabbage agronomic parameters as a function of Compost NPK fertilization regime. Apple width (AW) is strongly positively correlated (r = 0.99; P = 0.008) with apple circumference (AC). The ratio of the number of perforated apples to the number of apples harvested (NPAH/NAH) is strongly correlated and significant (r = 1; P < 0.0001) with the number of perforated apples (NPAH). The number of punctured apples (NPAH) is strongly negatively correlated (r = -1; P < 0.0001) with the recovery rate (RR). The weight of apples harvested (WAH) is strongly correlated and positive (r = 1; P < 0.0001) with cabbage apple yield (CAY). Cabbage apple yield (CAY) is negatively correlated and significant (r = -1; P = 0.000) with the number of diseased plants (NDP) and the ration number of diseased plants to the number of plants (NDP/NP). The ratio of number of diseased plants to the number of plants (NDP/NP) is strongly negatively correlated (r = -0.99; P = 0.01) with the weight of harvested apples (WAH).

Correlation between cabbage agronomic parameters under NPK

Figure 3 shows a map of Pearson correlation matrices at the 5% threshold between cabbage agronomic parameters as a function of NPK fertilization regime. Number of leaves (NL) is positively and significantly correlated (r = 0.96; P = 0.04) with plant width (PW). Plant height (PH) is negatively correlated (r = -0.973; -0.98 and P=0.03; P = 0.024) with the number of perforated apples (NPAR) and the number of perforated apples over the number of harvested apples (NPAH/NAH). The number of punctured apples at harvest (NPAH) was negatively correlated (r = -0.995 and P = 0.006) with plant width (PW). The number of rotten apples at harvest (NRAH) was positively correlated (r = 1 and P < 0.0001) with the ratio of the number of rotten apples to the number of harvested apples (NRAH/NAH). Apple circumference (AC) was positively correlated (r = 0.999 and P = 0.001) with apple width (AW). Weight of apple harvested (WAH) is positively correlated (r = 1 and P < 0.0001) with cabbage apple yield (CAY).

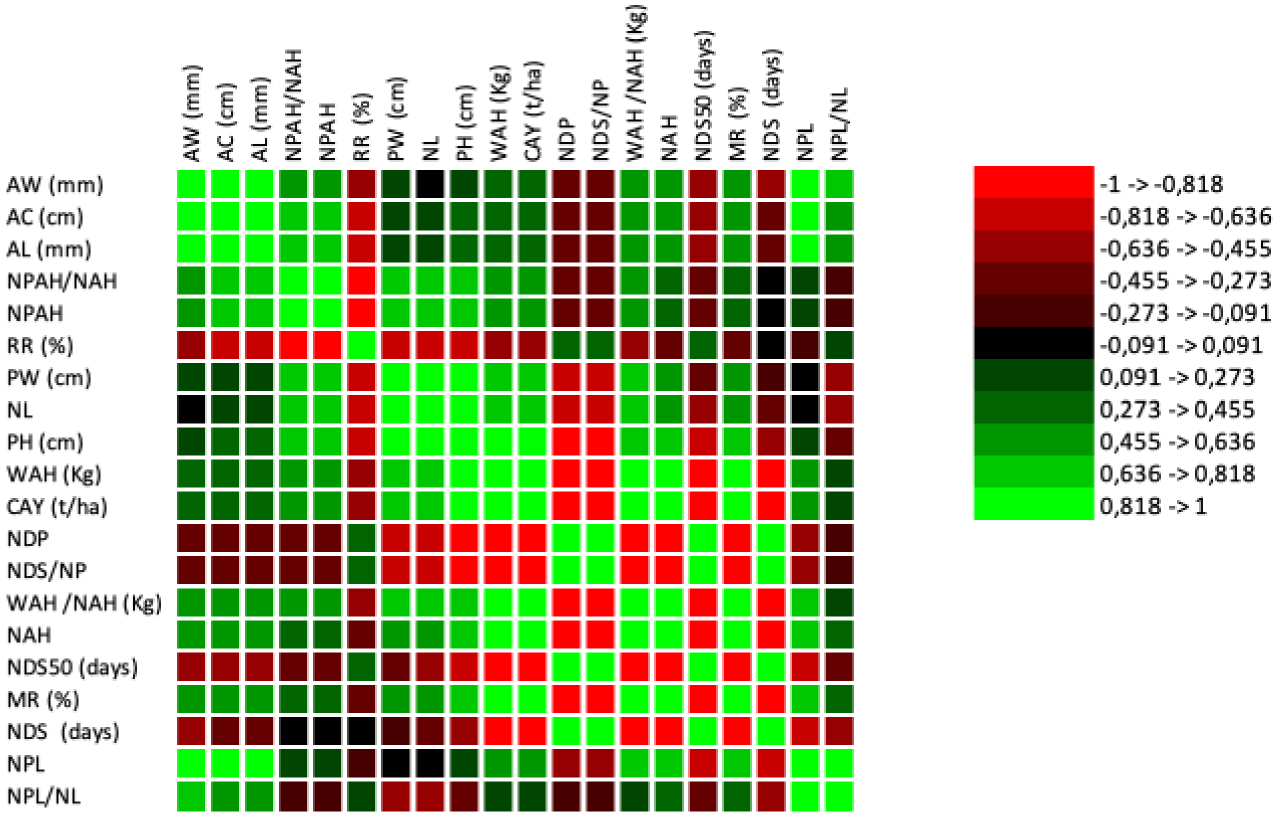

Figure 2: Map of correlation matrix between agronomic parameters of cabbage under Compost.

Compost : 12 t/ha of the Compost; HP: plant height; PW: plant width; NL: number of leaves; AL : apple length; AW : apple width; AC = apple circumference; RR: recovery rate of plant; NDS: number of days from sowing to appearance of first apple; NDS50: number of days from sowing to appearance of 50 % of apple; MR: maturation rate of plant; NDP : number of diseased plants; NP : number of plants; NPL: number of perforated leaves; NL: number of leaves; NRAH: number of rotten apples harvested; NPAH: number of perforated apples harvested; NAH: number of apples harvested; WAH: weight of apples harvested; CAY: cabbage apple yields.

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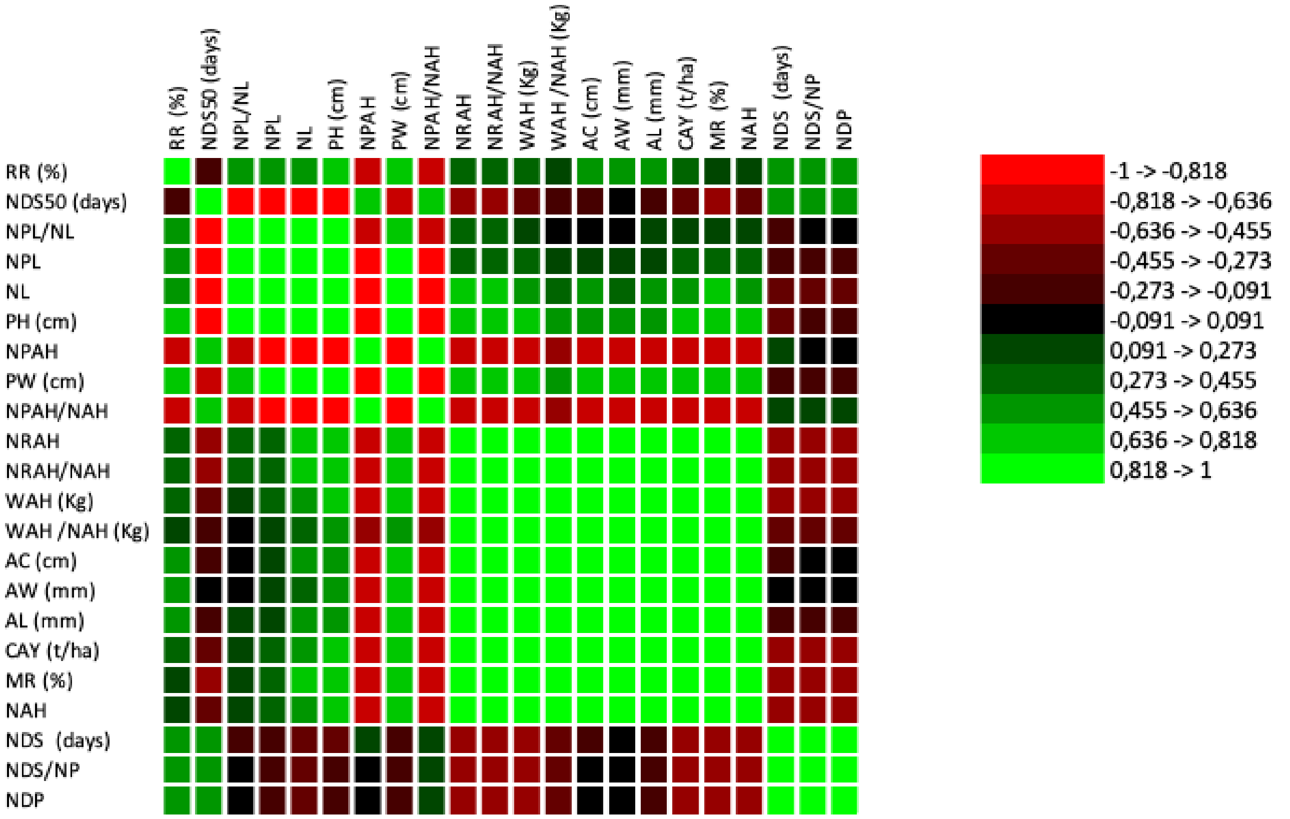

Figure 3: Map of correlation matrix map between agronomic parameters of cabbage under NPK.

NPK: 100 kg/ha ; HP: plant height; PW: plant width; NL: number of leaves; AL : apple length; AW : apple width; AC = apple circumference; RR: recovery rate of plant; NDS: number of days from sowing to appearance of first apple; NDS50: number of days from sowing to appearance of 50 % of apple; MR: maturation rate of plant; NDP : number of diseased plants; NP : number of plants; NPL: number of perforated leaves; NL: number of leaves; NRAH: number of rotten apples harvested; NPAH: number of perforated apples harvested; NAH: number of apples harvested; WAH: weight of apples harvested; CAY: cabbage apple yields.

Discussion

The objective of the present study was to compare the effects of fertilization on the agronomic performance of cabbage. The effects of compost (12 t/ha), compost (6 t/ha) + NPK (50 kg/ha) and NPK (100 t/ha) fertilization regimes on cabbage morphological, physiological, phytopathological and apple yield parameters were evaluated. The results of the analysis of variance show that the different fertilization regimes had no significant effects on any of these evaluated cabbage parameters. However, the different fertilizers did act differently on the traits, although this difference was not statistically significant. In fact, the non-significant difference observed in the recovery rate of transplanted plants can be explained by the selection of vigorous plants prior to transplanting. Plant vigor, unlike fertilization, influences recovery. Numerous studies, including those by Bhardwaj et al. [20], Olaniyi and Akanbi [21], Olaniyi et al. [22], Ojetayo et al. [23] and Musas [24] have shown that the recovery rate of cabbage, tomato, spinach and onion was similar on unfertilized soil, fertilized with NPK 15-15-15 and various manures. Compost+NPK fertilization regime reduced the time to appearance of the first fruit of cabbage by 3 and 4 days respectively, compared with compost and NPK applications. The presence of the high available potassium content (21.12 g/kg) of compost applied could explain the earlier appearance of fruit. In addition, NPK provides compost the supplementary phosphorus for better expression of cabbage. This would also explain the early appearance of fruit. Jones et al. [25] demonstrated in their study that phosphorus and potassium play a crucial role in flower and fruit formation. In addition, Smith et al. [26] also confirmed that fertilizer potassium enhances early fruit set by promoting optimal cell growth.

The Compost+NPK fertilization regime induced better performance on morphological parameters. Maximum plant height and width, maximum apple length and width, greater girth and higher number of leaves were observed compared with Compost alone and NPK. This vegetative growth induced by the Compost+NPK could be explained by the balanced supply of essential nutrients, mineral nitrogen (230.67 mg/kg),

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available phosphorus (20.22 g/kg) and available potassium (21.12 g/kg) provided by the compost, which are crucial for plant growth and development. These results are in line with those of Yéboua et al. [27], who showed that organo-mineral fertilization increased eggplant height growth. Hafez et al. [16] had found that compost+NPK significantly increased potato growth parameters. Similar results had also been observed by Ouédraogo [28], on transgenic cotton.

The application of 100 kg/ha NPK led to the appearance of large numbers of rotten and perforated apples. This could be explained by a deficiency in phosphorus, which is responsible for fruit set. This deficiency would have led to stunted growth and disrupted sugar metabolism during production. Indeed, phosphorus deficiencies are often associated with other nutritional disorders such as iron toxicity at acidic pH, zinc (Zn) deficiency, and iron (Fe) deficiency at basic pH [29]. Coupling compost (6 t/ha) +NPK (50 kg/ha) induced a significant appearance in the number of diseased apples. Indeed, the lack of interaction between the organic amendment and the mineral fertilizer in the first year of application could partly explain the appearance of the number of diseased apples [30].

The Compost and Compost+NPK fertilization regimes fared better than the NPK fertilization regime in terms of cabbage yield parameters at harvest. The quality of the compost used could explain these results. Indeed, analysis of the compost indicates a good content of organic matter (48.14 % for 1 kg of compost), carbon, nitrogen, phosphorus and potassium, as well as a balanced C/N ratio [15], suggesting a quality compost favorable to plant growth. The input would have been some organic source rich in mineral elements, which led to increases in apple cabbage yields compared with the NPK fertilization regime alone. These observations are in line with those of Liu et al. [31], who demonstrated that the addition of organic matter, such as compost, promotes better availability of essential mineral elements in the soil, thereby stimulating the growth and yield of apple cabbage crops. Similar results were observed by Zeba [32] who attests that the addition of organic manure illustrated by Compost in our case, improves the organic status of the soil by promoting good hydromineral nutrition of nutsedge.

The results of Person's correlation test revealed a significant relationship between the different morphological, physiological, phytopathological, yield attribute and yield of cabbage according to fertilization regimes. The positive correlation between apple yield and girth, as well as apple length under the 6 t/ha compost+50 kg/ha NPK (compost+NPK) fertilization regimes, highlights the importance of fruit morphological characteristics in determining yield. It also reveals that apple circumference is related to plant width. This positive correlation shows that the different parameters vary in the same direction. Similar results were observed in Kenya by Kariithi [33] on amaranth, revealing increased yields with growth parameters. Furthermore, a study carried out on voandzou by Touré et al. [34] revealed that yield is positively related to all vegetative development parameters.

The strong positive correlation between apple circumference and width under applications of 12 t/ha of compost (i.e. an application of 217.2 kg N/ha) indicates that this fertilization regime favors overall apple development. The negative correlation between the number of perforated apples and the recovery rate shows that perforated apples are more likely to fail to develop fully. In addition, the negative correlation between cabbage apple yield and the number of diseased plants indicates that plant health is a crucial factor in ensuring optimum apple yield. This negative correlation reveals that the various parameters evolve inversely. These results are not in agreement with those obtained by Asnor [35], who revealed that the higher the dose of nitrogen fertilization, the greater the incidence of lepidopteran attacks in cabbage crops.

Under 100 kg/ha of NPK inputs, the negative correlation between plant height and the number of punctured apples, as well as the number of rotten apples, highlights the relationship between morphological and phytopathological parameters in cabbage. This correlation reveals that taller plants may be more vulnerable to disease or other environmental stresses. Taller plants tend to develop tender, succulent tissues, which may make them more susceptible to pathogens such as bacteria and fungi according to the conclusion of a study conducted in Colombia by Bejarano-Herrera et al. [36], which is not the case in the present study. In addition, the positive correlation between apple circumference and apple width, and the positive correlation between harvested apple weight and apple yield, highlight the importance of fruit characteristics in determining overall crop yield under 100 kg/ha NPK fertilizer.

Conclusion

This experiment compared the effects of fertilization on the agronomic performance of cabbage. There were no significant differences between the fertilization regimes in terms of physiological, morphological, phytopathological or apple yield parameters. Nevertheless, the Compost+NPK and compost-only the fertilization regimes had positive effects on the agronomic performance of cabbage. The Compost and Compost+NPK the fertilization regimes outperformed the NPK in terms of cabbage apple yield gains. The Compost+NPK performed better on cabbage physiological parameters than the compost the fertilization regimes. The Compost+NPK the fertilization regimes also performed better on morphological parameters. In terms of phytopathological parameters, the Compost performed better than the other the fertilization regimes, Compost+NPK and NPK, in terms of rotten apples at harvest. Looking ahead, it would be advisable to: i) conduct these investigations in other agro-ecological zones in order to confirm or invalidate the results obtained; ii) characterize the soil at the trial site before and after sowing to ensure efficient use of the fertilization regimes.

Declaration of interest statement

The authors declare no competing interest.

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