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Effects of Natural Organic and Mineral Fertilizers on the Growth and Productivity of Cabbage (*Brassica oleracea*) in Daloa Commune, West-central Côte d'ivoire

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ABSTRACT

The aim of the study was to evaluate the effect of natural organic fertilizers (*Azolla caroliniana* and compost) and mineral fertilizers (NPK 15-15-15) on growth and production parameters of cabbage, variety Fortune F1. The experiment was conducted at the University of Daloa, on a 210m^2 plot in a three-block Fisher design with four treatments (Control, NPK, aqueous extract of *Azolla* and compost). Growth and production parameters were measured every 10 days after transplanting and analyzed using STATISTICA7.1 software. Results showed improved cabbage growth, with good evolution of leaf area, number of leaves, span, height and collar diameter of seedlings transplanted with *Azolla caroliniana* aqueous extract. Yield (14.7t/ha) and cabbage head diameter (44.13+5.86cm) were obtained with NPK, while *Azolla caroliniana* liquid indicated (17.33t/ha) and (46.69+8.68cm), respectively, compared with the other treatments (control and compost). In conclusion, the aqueous extract of *Azolla* was found to be the best performer for improving cabbage productivity in the study area. It can be recommended as a natural organic fertilizer.

Keywords: Biofertilizers, Cabbage, NPK fertilizer, Production, Côte d'Ivoire.

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INTRODUCTION

Agriculture is one of the sectors of activity that contributes to the socio-economic development of populations (FAO, 2012). It employs more than 40% of the working population worldwide, including more than 52% in Africa (Ainika et al*.,* 2012). Within this sector, vegetable crops play an important role in human nutrition (FAO, 2012). They play a key role in most nutrition programs and contribute significantly to family incomes (Batamoussi et al*.,* 2016). Among these vegetable crops, cabbage (*Brassica oleracea*) is one of the most important (Arvanitakis, 2013). Its global production was estimated at 152 million tonnes in 2011 (FAO, 2012). Cabbage is an important vegetable in the human diet (Pamplona, 2014). Indeed, cabbage is one of the most widely consumed vegetables in Africa (Talekar and Shelton 1993). Its nutritional virtues are highly appreciated by consumers (Pamplona, 2014; Depezay, 2006). Cabbage contains vitamins (A, B, C, E and K) and is rich in potassium, iron, calcium, sulfur, sodium and beta-carotene etc (Alalade and Iyayi, 2006; Pamplona, 2014).

Because of its nutritional importance, demand for cabbage in Côte d'Ivoire is becoming increasingly strong, making its price more attractive, especially between November and September. On Ivorian markets, the unit price of cabbage varies between 100 and 400 FCFA/Kg in the southern region and between 400 and 1000FCFA/kg in the northern region (Dao et al*.,* 2003; CNLVC, 2018). To satisfy this growing demand for cabbage, growers make excessive use of mineral and organic fertilizers to double their production (Dao et al*.,* 2003). However, the use of chemical fertilizers, with their immediate beneficial effect on food crop productivity, is one solution (Tougma, 2006). However, these chemical fertilizers disturb the soil balance and contaminate groundwater (Cissé, 2000). In order to minimize the risks of environmental pollution, market gardeners must turn to organic fertilizers such as *Azolla sp*., droppings and compost. These biofertilizers enrich the soil without leaving toxic residues in the produce. This study will evaluate the effect of different forms of organic fertilizer (*Azolla caroliniana* and compost) and mineral fertilizer on the growth and production parameters of cabbage.

MATERIALS & METHODS

Study Environment Presentation

The study was carried out in the urban area of the town of Daloa (Fig. 1). This city is located in the Haut-Sassandra region situated between 6° and 7°N latitude and between 7° and 8°W longitude (Koffie-Bikpo and Kra, 2013). This region has a humid tropical climate, with rainfall ranging from 1,200 to 1,600mm/year (Sangaré et al*.,* 2009). The region's soil is ferralitic of medium to slightly denatured granitic origin.

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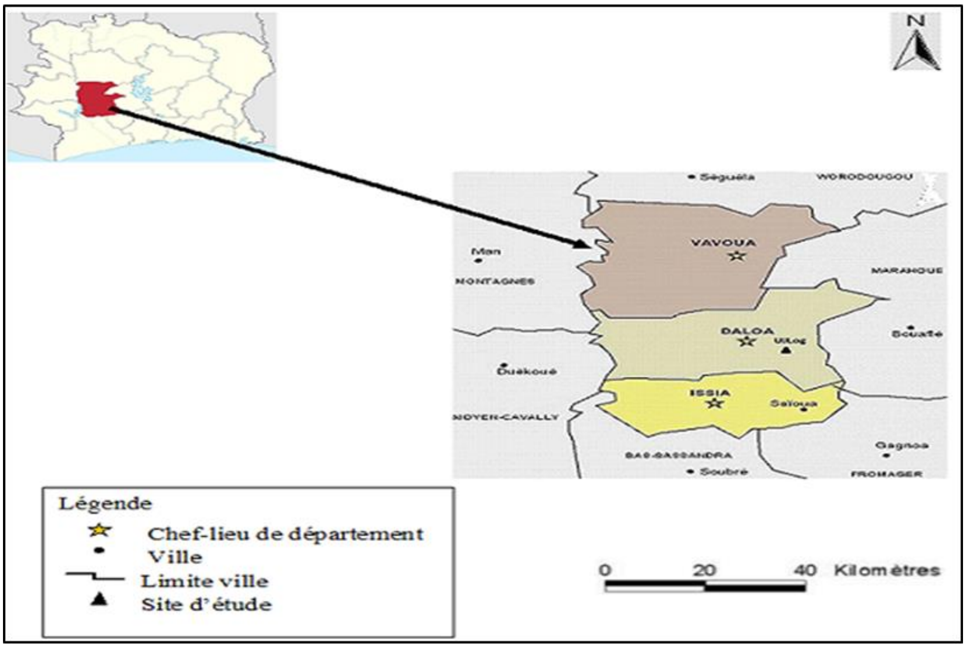

Fig. 1: Study area location (Koffie-Bikpo and Kra 2013).

Plant Material

For this study, we chose to use the hybrid cabbage variety Fortune F1 (Fig. 2). The choice of this variety was guided firstly by the personal experiences of the market gardeners with the aptitudes of the varieties grown in the study area, secondly by the availability of seeds locally, and thirdly by agronomic performance in all seasons. In fact, Fortune F1 cabbage is a short-cycle variety (75-80 days), much appreciated for its freshness, semi-flattened shape, bluish-green color, savory taste and good tolerance to shattering. When properly planted and maintained, it guarantees good yields.

Fig. 2: Fortune F1 hybrid cabbage

Natural Organic Fertilizers

The organic fertilizers used were aqueous extract of Azolla caroliniana and compost of organic waste.

Compost Production

The compost was produced by combining organic waste of animal and vegetable origin (rice husk-based chicken droppings, sawdust, coffee pulp and charcoal). Each natural waste was taken at a rate of 100kg of rice husk-based chicken droppings, 50kg of white sawdust, 35kg of coffee pulp and 100kg of charcoal, and the heap composting technique was applied. This involved first lightly ploughing the composting site and then piling the organic fertilizers directly onto the bare soil in a shady spot. The pile was 80cm high with a base of 1m. After the heap was made, wood ash was added to accelerate the biological activity of the microorganisms and covered with perforated black plastic film (closed fermentation system) to regulate heat. Every two weeks, the pile was turned for complete oxygenation and more homogeneous fermentation, then lightly watered to prevent the compost from becoming too dry or too wet, until it reached maturity after eight months. Compost maturity was monitored by measuring the internal temperature of the compost heap using a REOTEMP precision digital thermocompost, graduated from 0°F (-17.77°C) to 200°F (93.33°C). To take the internal temperature of the pile, push the thermocompost into the pile to a depth of about 35cm and read the temperature on the dial. Compost reaches maturity when the temperature drops below 40°C until it stabilizes. At the end of the composting process, the mature compost obtained is dried, sieved to remove impurities and then packed in a bag in an ambient environment before being used as an organic fertilizer.

Azolla Caroliniana Production

Azolla caroliniana was produced in a pit or trough measuring 300x100x50cm, open and exposed to daylight. The bottom and edges of the tray were covered with waterproof black plastic. A quantity (6L) of liquid organic fertilizer, in particular chicken droppings previously collected from a poultry farm and prepared for this purpose, was poured into the bottom of the tray. The liquid chicken manure was prepared by taking 20kg of chicken manure in a 10L bucket, adding water and mixing. The bucket was closed and kept for a period of 1 month in an ambient environment before taking the quantity required for its use. The bucket was then filled with water (845L). The prepared medium was inoculated with 125g of *Azolla caroliniana* for propagation. Three weeks after inoculation, a quantity (5kg) of *Azolla caroliniana* produced by matting on the tank's water surface was harvested fresh by hand, ground, filtered and its aqueous extracted liquid was preserved for use as a biofertilizer for cabbage cultivation.

Mineral Fertilizers

The mineral fertilizer used is NPK 15-15-15. This synthetic fertilizer is often used for its immediate beneficial effect on the productivity of vegetable crops.

Experimental Set-up for Cabbage Cultivation

A 210 m^2 plot was used to grow cabbage. This area was used to set up a system of three complete Fisher blocks, held together by a 2m walkway. Each block comprises four elementary plots of 15m^2 (5×3m), spaced 1.5m apart. Treatments are: control, NPK15-15-15, liquid *Azolla. caroliniana* and compost. In each elementary plot, 10 pots were planted with a regular spacing of 0.5m between pots and rows, into which vigorous 10-day-old cabbage seedlings were transplanted. At transplanting, bio-fertilizers were applied as a basal fertilizer at a rate of 2kg of compost; 0.5L of *Azolla. caroliniana* and the mineral fertilizer 2g of NPK around the base of the cabbage and during the development stages of the plant.

Collecting Cabbage Growth and Production Parameters

Cabbage growth parameters were measured every ten days from day 10 (T1) to day 50 (T5) after transplanting of the seedlings:
- seedling recovery rate. This was calculated as the ratio between the number of seedlings transplanted and the number of seedlings surviving one week after transplanting.
- plant height. This was determined by measuring the main stem in cm from the soil surface to the apex.
- plant span. This was measured between the tips of the terminal leaflets of the two outermost leaves of the cabbage plant.
- stem collar diameter. measured with a caliper at ground level, at the base of the cabbage plant stem.
- average number of leaves per plant. This was determined by counting from the first leaf to the last true leaf at the apex.
- Cabbage leaf area (LS). This was determined on the first five cabbage leaves using the equation of Spagnoletti and Qualset (1990): SF (cm^2) = L x l x 0.607; where, SF: leaf area expressed in cm^2; L (cm): leaf length; l (cm): leaf width and 0.607: area regression coefficient.

As for the production parameters at harvest, they concerned:
- the number of cabbage heads obtained on each plant at harvest;
- the diameter of each head on each plant at harvest;
- the yield (t/ha) was evaluated after 90 days of sowing by calculating the ratio between the total mass of harvested apples in tons and the cultivated area in hectares.

Data Statistical Analysis

The data collected were subjected to a normality test (Shapiro et al., 1968) and a variance homogeneity test (Brown and Forsythe, 1974). The data were subjected to a one-factor analysis of variance (ANOVA) using STATISTICA 7.1 software. The hypothesis tested by the ANOVA is that of zero difference between treatments, H0: T1=T2=......Tn. The analysis of variance is significant when the probability level is lower than the theoretical probability level at risk (α = 5%). When a significant difference was observed between treatments (P<0.05), the ANOVA was completed by Tukey's test. This test identified the treatment(s) whose effect differed significantly at the 5% level.

RESULTS

Evolution of Cabbage Growth Parameters

Recovery rate

The recovery rate of cabbage seedlings from the different treatments ranged from 96.96 to 88.88% (Fig. 3). Seedling survival on beds fertilized with NPK and liquid Azolla was 96.96%. The compost and control treatments had survival rates of 88.88 and 89.89%, respectively.

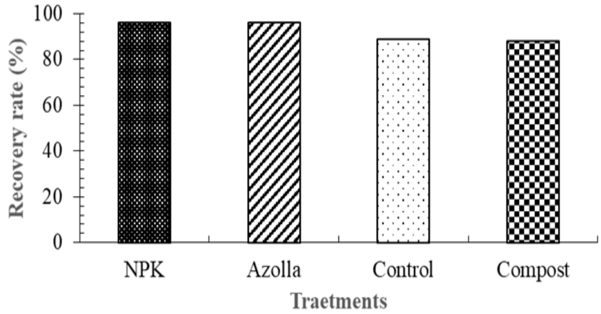

Fig. 3: Recovery rate of cabbage seedlings.

Evolution of the Number of Cabbage Leaves

The average number of cabbage leaves is shown in Table 1. This table shows that the number of leaves on cabbage plants in beds treated with *Azolla* caroliniana liquid was higher than in the other treatments. Twenty days after transplanting (T2), the leaf numbers of cabbage plants in beds fertilized with *Azolla caroliniana* liquid (11.66 leaves) and NPK (11.23 leaves) were higher than those in beds amended with compost (10.64) and the control (10.56). At this stage of the cycle, a significant treatment effect was observed on the number of cabbage leaves (ANOVA, P=0.04). At T4 (day 40), the effect of fertilization showed that *Azolla* caroliniana liquid and compost induced a substantially identical leaf emission (18.86 and 18.83 leaves, respectively). These leaf numbers were significantly higher than those from NPK and the control (ANOVA, P=0.00).

Height Growth of Cabbage Plants

The growth in height of cabbage plants from the different treatments presented in Table 2 shows that cabbage plants from beds fertilized with compost and *Azolla caroliniana* liquid grew taller than those from the other beds (control and NPK), with values ranging respectively from 6.92±1.01 (T1) to 12.05±0.95cm (T5) and from 6.8±1.31 (T1) to 13.43±1.81cm (T5). This growth in height was only significant at day 50 after transplanting (T5) (ANOVA, P<0.05).

Table 1: Average number of leaves of cabbage seedlings in different treatments

	Average number of cabbage leaves per treatment				
Measurement time Control	Control	Compost	*Azolla*	*NPK*	*P value*
T1	7.06±0.54a	6.66±0.38a	7.36±0.88a	6.76±0.77a	0.10
T2	10.56±0.87a	10.64±0.78a	11.66±0.96b	11.23±1.22ab	0.04
T3	14.33±1.32a	14.42±1.72a	14.72±1.78a	14.33±1.50a	0.93
T4	16.53±1.53a	18.83±2.06b	18.86±1.37b	17.59±1.4a	0.00*
T5	27.73±4.71a	27.66±3.6a	28.33±2.38a	27.96±2.13a	0.97

For each mean, values bearing the same letters (a, b, c) on the same row are statistically identical at the 5% threshold. T=measurement time every 10 days; 0.00* = highly significant.

Table 2: Evolution of average height (cm) of cabbage plants

Measurement time Control	Average cabbage plant height by treatment				
	Control	Compost	*Azolla*	*NPK*	*P value*
T1	6.09±0.6a	6.92±1.01a	6.8±1.31a	6.35±0.77a	022
T2	8.02±0.83a	8.63±0.87a	8.95±1.1a	8.87±0.93a	0.13
T3	9.10±0.76a	9.51±1.04a	9.88±1.35a	9.39±1.22a	0.48
T4	10.38±0.89a	11.04±1.01a	11.10±1.09a	11.00±0.97a	0.34
T5	11.59±1.12a	12.05±0.95ab	13.43±1.81b	11.86±1.48a	0.01

For each mean, values bearing the same letters (a, b, c) on the same row are statistically identical at the 5% threshold. T=measurement time every 10 days.

Table 3: Evolution of span (cm) of cabbage plants.

Measurement time Control	Evolution of average span of cabbage plants per treatment				
	Control	Compost	*Azolla*	*NPK*	*P value*
T1	19.00±3.42a	19.16±3.13a	22.25±1.99b	21.35±2.65ab	0.03
T2	27.04±2.63a	28.91±3.13a	31.74±2.66b	29.21±2.25b	0.00*
T3	36.15±4.36a	37.98±4.28ab	42.9±2.41c	38.47±5.64ab	0.01
T4	43.95±4.27a	45.85±3.24ab	59.15±1.5c	48.51±3.1b	0.00*
T5	50.00±5.49a	51.92±4.65a	59.92±2.92b	53.91±4.1a	0.00*

For each mean, values bearing the same letters (a, b, c) on the same row are statistically identical at the 5% threshold. T=measurement time every 10 days; 0.00* = highly significant.

Table 4: Evolution of cabbage plant diameter (cm).

Measurement time Control	Neck diameter of cabbage plants by treatment				
	Control	Compost	Azolla	NPK	P value
T1	0.4±0.05a	0.42±0.05a	0.43±0.05a	0.42±0.03a	0.65
T2	0.53±0.04a	0.57±0.13a	0.6±0.08a	0.58±0.06a	0.30
T3	0.70±0.08a	0.71±0.08ab	0.81±0.08c	0.78±0.18ab	0.01
T4	0.75±0.12a	0.78±0.07a	0.90±0.04bc	0.86±0.1ab	0.00*
T5	1.08±0.08a	1.09±0.08a	1.4±0.18b	1.14±0.15a	0.00*

For each mean, values bearing the same letters (a, b, c) on the same row are statistically identical at the 5% threshold. T=measurement time every 10 days; 0.00* = highly significant.

Evolution of Cabbage Plant Span

The span of cabbage plants from the different treatments is shown in Table 3. Analysis of variance of soil coverage by cabbage plants revealed significant effects from day 10 after transplanting (T1) to day 50 after transplanting (T5) at the 5% threshold. Throughout the vegetative cycle, the wingspan of cabbage plants in beds fertilized with *Azolla caroliniana* liquid was better, with values ranging from 22.25±1.99 (T1) to 59.92±2.92cm (T5). The wingspan of these cabbage plants was significantly greater than that of plants from compost- and NPK-treated beds and control plants (Tukey test, P<0.05).

Changes in Collar Diameter of Cabbage Plants

Data on changes in collar diameter of cabbage plants are shown in Table 4. This table shows that the values for the collar diameter of cabbage plants are significantly different only from day 30 after transplanting (T3) (ANOVA test, P<0.5). From this period onwards, the increase in collar diameter of cabbage plants treated with *Azolla caroliniana* liquid was significantly greater (from 0.81 to 1.4cm) than that of plants from other beds (Tukey test, P<0.05).

Leaf Area of Cabbage Plants

Table 5 shows the increase in average leaf area of cabbage plants from the different treatments. The average leaf area of cabbage plants from beds treated with *Azolla caroliniana* liquid was higher than that of plants from the other treatments. *Azolla caroliniana* induced a mean leaf area ranging from 45.60±11.00 at (T1) to 372.08±73.25cm^2 (T5). On the other hand, the leaf areas of plants in beds amended with NPK and compost, which were 39.91±7.27 and 38.25±9.95cm^2, respectively at T1, increased to 294.36±76.93 and 264.22 ± 64.88cm^2, respectively at T5. Analysis of variance of changes in cabbage leaf area revealed significant differences throughout the vegetative cycle (T1 to T5) between all treatments at the 5% threshold.

Cabbage Production Parameters

Number of Heads

The number of cabbage heads harvested on plots amended with *Azolla caroliniana* was higher, accounting for 40% of the total harvest (Fig. 4). On the other hand, those harvested on plots treated with NPK and compost represented 22 and 18%, respectively of the total number of apples harvested.

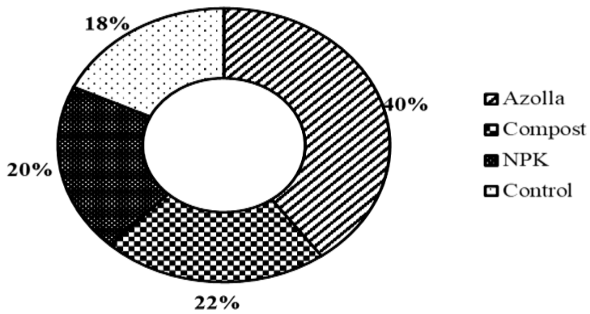

Fig. 4: Diagram of number of apples per fertilization.

Apple Diameter

Table 6 shows the diameter of cabbage apples. The table shows that cabbage plants in beds fertilized with *Azolla caroliniana* liquid and NPK produced apples with a larger diameter, averaging 46.69±8.68 and 44.13±5.86cm, respectively. These averages differed significantly from those of apples from the other treatments (Tukey test, P<0.05). The diameter of harvested cabbage apples differed significantly between treatments (ANOVA, P=0.00).

Table 5: Evolution of leaf area (cm^2) as a function of fertilization time.

Measurement time Control	Leaf area of cabbage plants by treatment				
	Control	Compost	Azolla	NPK	P value
T1	40.67±10.42a	38.25±9.95ab	45.60±11.00b	39.91±7.27ab	0.00*
T2	63.76±17.12a	67.73±11.31a	68.71±22.11a	68.40±11.96a	0.00*
T3	158.93±36.15a	171.45±26.5ab	207.81±20.58c	172.29±48.7ab	0.00*
T4	193.32±20.58a	203±32.88a	355.84±48.15c	269.62±31.29b	0.00*
T5	255.91±46.28a	264.22±64.88a	372.08±73.25b	294.36±76.93ab	0.00*

For each mean, values bearing the same letters (a, b, c) on the same row are statistically identical at the 5% threshold. T=measurement time every 10 days. 0.00* = highly significant.

Table 6: Average diameter (cm) of cabbage apples.

	Average diameter of cabbage apples per treatment				
	Control	Compost	Azolla	NPK	P value
Diameter (cm)	38.17±8.98a	39.55±7.21a	46.69±8.68bc	44.13±5.86b	0.00*

For each mean, values bearing the same letters (a, b, c) on the same row are statistically identical at the 5% threshold: 0.00* = highly significant.

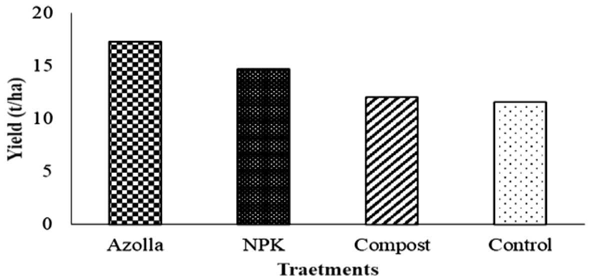

Fig. 5: Histogram of cabbage harvest yields.

Yield

Fig. 5 shows cabbage yields for the different treatments. Cabbage yield was higher in the beds fertilized with *Azolla caroliniana* liquid (17.33t/ha) and NPK (14.7t/ha) than in the other treatments.

DISCUSSION

The various treatments resulted in good survival of transplanted seedlings, with rates ranging from 96.96 to 88.88%. This good survival of cabbage seedlings could be explained by the choice of vigorous seedlings for transplanting, as well as good soil moistening at the time of transplanting. Indeed, the vigour of seedlings in the nursery influences their survival after transplanting. This result is in line with those of Muhammad et al*.* (2007) and Olaniyi et al*.* (2010), who showed that recovery rates of cabbage, Chinese cabbage, tomato, spinach and onion were similar on unfertilized soil, NPK 15-15-15 and compost.

The evolution of leaf area, number of leaves, span, height and collar diameter of cabbage plants in beds treated with *Azolla caroliniana* extract was better than that of plants in control beds fertilized with NPK and compost. Similar results were obtained in Nigeria on okra after application of biofertilizers and NPK 15-15-15 mineral fertilizers (Olaniyi et al., 2010). The higher number of cabbage leaves obtained with *Azolla* concurs with the results of Bikela (2007); Djogbede et al. (2012) and Kouadio (2015). These authors recorded significantly more baselle (*Basella alba var alba*) and rice leaves on plots treated with *Azolla caroliniana* compared with the control respectively. The significant change in height and collar diameter of plants treated with *Azolla* is in line with the results of Groga et al*.* (2018), who recorded better increases in height and collar diameter of tomato plants treated with *Azolla caroliniana*. This very good evolution of these growth parameters would be attributable to *Azolla*'s ability to supply sufficient nitrogen during the vegetative phase of cabbage plants. Indeed, Bruno's work (2009) has shown that nitrogen is the main nutrient responsible for quantitative plant growth. *Azolla* is a fern capable of releasing large quantities of plant-absorbable nitrogen in the form of nitrate NO_3^- and ammonium NH_4^+ when it dies (Layzell, 1990). This fern fixes atmospheric nitrogen through its symbiosis with the *cyanobacterium Anabaena azollae* (Brasset and Couturier, 2005). In addition, *Azolla* releases phosphorus minerals gradually, which could ensure their availability at the time of actual need by the plant (Ojetayo et al*.,* 2011). Mineral nitrogen is volatile in the form of NH_3 or N_2 in the atmosphere, which would also justify the inferior vegetative growth of cabbage plants that received NPK compared with those that received *Azolla* extract.

The apple diameter and cabbage yield obtained from beds fertilized with *Azolla caroliniana* liquid and NPK were significantly higher than those from beds treated with compost. These high yields could be explained by the gradual release of primary, secondary and trace nutrients from *Azolla* and compost into the growing medium. According to Betrand and Gigou (2002); Thomas et al*.* (2004) and Kitabala et al*.* (2016), nitrogen fertilization with biofertilizers affects all parameters contributing to good yields. These results are in line with those of Fondio et al. (2013); Groga et al*.* (2018) and Djekinnou (2018), who showed that the use of *Azolla* as a biofertilizer on tomato and chilli, respectively, results in a higher number of fruits.

Conclusion

Ecological production of cabbage can be achieved using compost and aqueous extract of *Azolla caroliniana*. The use of these biofertilizers gradually improves soil fertility and ensures rapid cabbage growth. The aqueous extract of *Azolla caroliniana* also ensures good cabbage yields with large-diameter apples. *Azolla* can therefore replace NPK in cabbage cultivation.

Competing Interests

Authors declare no competing interests exist.

Authors' Contributions

This work was carried out in collaboration between all the authors. Authors N'GANZOUA Kouamé René and GROGA Noel designed the study and drafted the experimental protocol. Authors ABOBI Akré H.D. and BAKAYOKO Sidiky performed the statistical treatments and interpreted the study results. All authors read and approved the final manuscript.

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