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ORIGINAL RESEARCH

Response of cauliflower (*Brassica oleracea* var. botrytis) grown in the field to organic waste fortification and cropping seasons

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Abstract

Purpose: To evaluate cauliflower (*Brassica oleracea* var *botrytis*) field performance in response to season, organic waste types, and rates; a cultivar (ATRIA 153F1) was grown for two years (2019 and 2020) under two different seasons (Rainy and Dry). This is to ascertain the effective season, type, and rate of organic waste for the promotion of sustainable agriculture and organic farming practices for cauliflower.

Method: The experiment was 2 × 4 factorial in a randomized complete block design with four replications. Factor A was the two different organic wastes (poultry and pig slurry) while factor B was the four rates (0, 10, 20, and 30t ha^{-1}) of the organic wastes. The growth and yield parameters monitored were plant height, number of leaves, curd diameter, and curd fresh weight. Data on nutrient assessment of the fortified plots were also collected.

Results: The study reveals that Season played a significant role in the growth and yield of cauliflower on average for the two years studied. Dry seasons produced taller plants (30.40 cm), and a higher number of leaves (15.90), while rainy seasons produced larger curd diameter (10.28 cm) and higher curd weights (71.39 t ha^{-1}). Soil fertility significantly improved with the application of the organic wastes. Plant height and number of leaves showed responses to manure type (MT) and manure rates (MR) suggesting that both assist in the growth and development of cauliflower in the field.

Conclusion: The responses of yield components tended towards the positive side and the parameters responded to MT and varying MR. This study recommends the use of organic waste and emphasizes the need to consider cropping seasons in optimizing benefits. Optimization of organic waste management practices for cauliflower farming could lead to a significant increase in yield and sustainability in large-scale commercial agriculture.

Keywords: Brassicas; Rainy season; Poultry manure; Pig slurry; Curd weight

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is among the most popular cruciferous vegetable crops cultivated for their succulent curds as edible parts. Other crucifers include cabbage, kale, Brussels sprouts, collards, kohlrabi, mustard, and broccoli. Crucifers have been ranked by the Food and Agriculture Organization among the top twenty vegetable crops grown worldwide, establishing them as an important food source globally (Avato and Argentieri 2015). It is a good source of vitamins, minerals, and chemoprotective phytochemicals (Manchali et al., 2012; Satheesh et al., 2020; Raiola et al., 2018; Favela-González et al., 2020). Cauliflower is a productive vegetable based on biomass per area of cultivation. They are grown all through the year for their tender curds and vegetables but thrive best in a cool, moist climate and do not withstand extreme temperatures (Din et al., 2007). Cropping season plays a vital role in vegetable production as rainfed production reduces evapotranspiration during the rainy season which leads to adequate water use efficiency (Tesfaye and Walker 2004; Li and Troy 2018). It is known to promote soil improvements and agricultural productivity. Poultry and pig slurry are good sources of N, P, K, and S which is responsible for the higher yield of cauliflower. An increase in the application of this manure sometimes leads to an increase in yield but sometimes becomes toxic to the plants and also saturates the soil, therefore adequate rate of manure should be considered in this vegetable production. Information on the influence of cropping season, organic manure type, and rates on the growth and yield of cauliflower is lacking in the study area. Therefore, it is necessary to identify suitable growing seasons, manure types, and rates that will increase yield and income for resource-poor farmers this study aimed to evaluate the response of cauliflower grown in the field to cropping season, organic manure type, and rates.

Materials and methods

Collection of climatic data

The meteorological data on temperature, rainfall distribution, and relative humidity were collected from the Department of Crop Science Meteorological unit, University of Nigeria, Nsukka during the period of the experiments.

Soil sample collection

Soil samples were collected (using a soil auger at 15cm depth) and taken to the Department of Soil Science laboratory for routine analysis including particle sizes, textural classes, soil pH and the Cation exchange capacity, organic matter component, total Nitrogen, phosphorus and potassium. The nutrient content of the organic waste utilized was also determined.

Field experiment

ATRIA 153F1 cauliflower seeds were sourced from East-west seeds in Kaduna State, Nigeria and seedlings were raised in the nursery for six weeks and were transplanted to an already made bed measuring 1m x1m, 0.5m between beds and 1m between blocks. This study was laid out as a 2 × 4 factorial experiment in a randomized complete block design replicated three times. The main factor is the manure type (MT) while the manure rates MR (0 tonnes, 10 tonnes, 20 tonnes, and 30 tonnes per hectare) is the sub-factor. Beds were prepared 2 weeks before transplanting and well-cured manure was applied on the already-made bed. Seedlings were transplanted with a spacing of 25cm in between plants. These experiments were performed in rainy and dry seasons (May to August 2019 and November 2019 to February 2020). It was repeated in (May to August 2020 and November 2020 to February 2021. The following parameters were collected: Plant height, number of leaves, number of days to curd formation, curd diameter, and total curd weight.

Results and discussion

Meteorological data for the 2019 and 2020 planting seasons

The meteorological data from the experimental sites shows that there is a marked variation in the weather elements being considered (Table 1). The rainfall distribution shows that during the rainy season, it ranges between 220.73-264.38 mm, whereas the dry season ranges between 4.57-10.67 mm of rainfalls in the 2019 season. During the 2020 rainy season, rainfall ranged between 198.63-219.18 mm while in the 2020 dry season, the distribution ranged between (15.75-41.91mm). Moreover, the temperature ranged between 20.29-38.00 ºC for both seasons in 2019 and 19.39-35 ºC. The data also revealed that the mean relative humidity for rainy and dry seasons ranged between 56.06-76.15 % and 24- 77 % respectively.

Physicochemical properties of soil of the experimental site and organic wastes used for the study

The physicochemical properties of the soil from the experimental sites before planting revealed that the soil was not fertile (Table 2). The percentage of Nitrogen (2.44 %), Phosphorus (30.28 %), and Potassium (2.00 %) was low. Cation exchange capacity (13.60 meq/100g) and base saturation (19.93) were relatively low. Organic matter (2.44 %) and organic carbon (1.42 %) depict the low fertility of the soil of the study area. The pH was slightly acidic. The soil was classified as Sandy loam.

Poultry and pig manure utilized during the experiments were relatively high in percentage organic matter content (77.98 and 52.69 %) and organic carbon (22.70 and 18.96 %). Percentages of Nitrogen (2.17 and 1.68 %), Potassium (0.13 and 1.09 %), and Phosphorus (0.41 and 0.36 %) were low.

Effect of season, manure type, and rates on the growth of cauliflower

Season significantly ($p \leq 0.05$) influenced the plant height at 2, 4, 6, and 8 weeks after transplanting (WAT) (Table 3). The dry season produced taller cauliflower (31.66 cm) at 8 WAT while the rainy season had shorter plants (26.61 cm) in 2019. It followed the same trend in 2020 where the dry season had taller plants (29.14 cm) and the rainy season gave shorter plants (23.32cm). The season also had a significant effect ($p \leq 0.05$) on the number of leaves at 2, 4, and 6 WAT in 2019 and 2020. The dry season recorded more leaves (15.92) while the rainy season had fewer leaves (13.48) in 2019. The trend was the same in 2020 where the dry season recorded 15.92 numbers of leaves whereas the rainy season recorded fewer leaves (9.79).

MT significantly ($p \leq 0.05$) influenced the plant height at 2, 4, 6, and 8 WAT (Table 3). Poultry manure produced taller plants (29.82 cm) at 8 WAT while pig manure had shorter plants (28.45) in 2019. It followed the same trend in 2020 where poultry manure had taller plants (28.41cm) and dry season had shorter plants (25.99cm). MT significantly ($p \leq 0.05$) influenced the number of leaves at 2, 4, and 6 WAT. Poultry manure had a higher number of leaves (15.56) at 10 WAT while pig manure had lesser leaf numbers (13.83) in 2019. During the 2020 planting, poultry manure had 14.22 while in the dry season; it recorded 13.53 numbers of leaves.

MR significantly ($p \leq 0.05$) influenced the plant height at 2, 4, 6, and 8 WAT (Table 3). 20 t ha^{-1} produced taller kales (30.60cm) at 8 WAT while 0 t ha^{-1} had shorter plants (18.80 cm) in 2019. It followed the same trend in 2020 where 20 t ha^{-1} had taller plants (34.72cm) and 0 t ha^{-1} had shorter plants (15.81cm). MR significantly ($p \leq 0.05$) influenced the number of leaves at 2, 4, and 6 WAT. The number of leaves recorded for 0, 10, 20, and 30 t ha^{-1} in 2019 was 11.25, 14.38, 17.04 and 16.02 respectively. In 2020, it followed the same trend and recorded 10.39, 12.29, 16.50, and 15.67 numbers of leaves for 0, 10, 20, and 30 t ha^{-1} respectively. 20 t ha^{-1} had more leaves while 0 t ha^{-1} had the least number of leaves.

The interaction between season and MT (Table 4) was significant ($p \leq 0.05$) at 4, 6, and 8WAT in 2019. At 8WAT, the interaction between dry season and pig manure had taller plants (31.58 cm) while rainy season and poultry manure had shorter cauliflower (22.40 cm). The interaction between season and manure was not significant in 2020. The interaction between season and manure type did not significantly ($p > 0.05$) influence the number of leaves at 2, 4, and 6 WAT in both 2019 and 2020.

The interaction of season and MR was statistically significant ($p \leq 0.05$) at 4, 6, 8, and 10 WAT. The dry season with 20 t ha^{-1} recorded taller plants (39.47cm) whereas the dry season and 0 t ha^{-1} gave the least height of 19.38cm in 2019. It was not significant in 2020. The interaction of season and manure rates did vary across different weeks after transplanting for the number of leaves during the two-year studies.

The interaction of MT and MR was not statistically significant ($p \leq 0.05$) at 8 WAT in both 2019 and 2020 for plant height. The interaction significantly ($p \leq 0.05$) influenced the number of leaves at 6 WAT. In 2019, poultry manure in combination with 0, 10, 20, and 30 t ha^{-1} recorded 9.52, 13.27, 15.98, and 15.48 numbers of leaves respectively while that of pig manure and 0, 10, 20, and 30 t ha^{-1} recorded 9.75, 11.17, 12.42 and 11.67 numbers of leaves respectively. It was not significant in 2020.

Effect of season, manure type, and rates on the yield of cauliflower

Season significantly ($p \leq 0.05$) influenced the curd diameter and weight at 8 and 10 WAT (Table 5). The rainy season produced bigger curds (12.94cm) and an average curd weight of 134.84 t ha^{-1} at 10WAT while the dry season had smaller curds (6.58 cm) and curd weight of 58.95 t ha^{-1} in 2019. It followed the same trend in 2020 where the rainy season had bigger curds (7.61cm) and curd weight of 7.93 t ha^{-1}, while the dry season had smaller curds (5.25cm) and curd weight of 4.27 t ha^{-1} significantly ($p \leq 0.05$) influenced the curd diameter and curd weight at 10 WAT (Table 5). Poultry manure produced bigger curds (10.08cm) and curd weight of 9.97 t ha^{-1} while pig manure had smaller curd diameter and lesser curd weight of 9.44cm and 9.40 t ha^{-1} at 10 WAT in 2019. It did not follow the same trend in 2020, pig manure outperformed poultry manure by producing bigger curds with bigger curd weights (6.29cm and 5.69 t ha^{-1}) respectively while poultry manure had smaller curd diameter and lesser curd weights of 5.78cm and 5.29 t ha^{-1} at 10 WAT.

MR significantly ($p \leq 0.05$) influenced the curd diameter but did not influence the curd weight at 10WAT (Table 40). 30 t ha^{-1} produced cauliflower with a bigger curd diameter (10.54cm). The head weight was not significant in 2019. In 2020, the curd diameter and weight were statistically ($p \leq 0.05$) significant. 30 t ha^{-1} produced cauliflower with bigger curd diameter and weight (6.58cm and 5.88 t ha^{-1}) respectively

The interaction between season and MT (Table 6) was significant ($p \leq 0.05$) at 8WAT but not significant at 10WAT for the curd diameter. At 10 WAT, in 2019, planting in the rainy season and using pig manure produced a bigger cauliflower curd weight (138.49 t ha^{-1}) while the interaction between the dry season and pig manure had a smaller curd (44.10 cm) with a curd weight of 15.10 t ha^{-1}. In 2020, planting in dry season and utilizing poultry manure had a smaller curd weight of 56.96 t ha^{-1} while dry season with pig manure curd weight of 60.93 t ha^{-1})

The interaction between season and MR (Table 6) was not statistically significant ($p>0.05$) at 10 WAT for curd diameter but highly significant for the curd weight. The rainy season with 30 t ha^{-1} recorded 145.87 t ha^{-1} curd weight while interaction between the dry season and 0 t ha^{-1} had a smaller weight of 53.33 t ha^{-1} in 2019. In 2020, both curd diameter and curd weight were not significant.

The interaction between MT and MR (Table 6) was significant ($p \leq 0.05$) at 10WAT in 2019 and 2020. In 2019 combination of pig manure at 30 t ha^{-1} produced cauliflowers with bigger curd diameter and weight (11.33cm and 111.14 t ha^{-1}) while the control (0 t ha^{-1}) had a smaller curd diameter and weight (8.68cm and 53.53 t ha^{-1}). In 2020 combination of pig manure at 30t ha^{-1} produced cauliflower with a bigger curd diameter and weight (7.17cm and 63.84 t ha^{-1}) while the control (0 t ha^{-1}) had a smaller head diameter and weight (5.24cm and 48.47 t ha^{-1}).

The results from the study showed significant variations in the two growing seasons considered. Cauliflower produced taller plants at 8WAT during the dry season. The yield of cauliflower was significantly higher during the rainy season (134.84 ton ha^{-1}). This may be probably due to a reduction in evapotranspiration during the rainy season that led to adequate water use efficiency. This affected all aspects of the production of the cauliflower. This observation aligns with the findings of Li and Troy (2018), where he linked the high yield of maize to rainfall other than irrigated maize. Previous findings of Tesfaye and Walker (2004) established the relationships between crops and the environment.

The study revealed that variability existed among the two organic manures utilized in this study on the growth and yield, of the cauliflower. Growth attributes were highest with poultry manure where the pig manure supported the yield components. These results may be attributed to the release of nutrients from the early decomposition of poultry-based manure whereas pig-based organic manure tends to release nutrients slower than poultry. The variability observed may also be attributed to increased organic matter component in poultry manure as opined by Øvsthus et al. (2015) and Hameed et al. (2019). From the physicochemical properties of the field, poultry, and pig manure utilized during this study, showed that their organic matter content is 47.98% and 32.69% respectively. Total N, available K and P, exchangeable Ca, and Mg also varied. Poultry manure contains high N, P, and K.

Organic matter content is high in poultry-based manure compared with the pig slurry. Organic matter as opined by Ayinlai et al. (2018) is the major determinant of soil fertility in most tropical soils which accounts for its use to raise seedlings in tropical areas. Singh et al. (2020) also observed that the addition of organic manure can sustain soil fertility. Poultry manure as suggested by Ani and Baiyeri (2008) is a valuable source of nutrients, organic matter, and available N and K. Manure is an excellent source of Nitrogen, Phosphorus, and Potassium as opined by Al-Jebarii (2017). Growth and yield of cabbage as stated by Reza et al. (2016) are greatly influenced by organic and inorganic nutrients where he established that the use of inorganic manure on crops is not good for health due to residual effects but does not occur with the use of organic manure. He further stated that organic manure increases the productivity of soil as well as crop quality and yield. Organic soil amendment sustains crop production systems since it forms an integral source of N and Carbon (Liang et al., 2012; Rinaldi et al., 2014). It is also an important part of soil pH moderation (Abubakari et al. (2015). Manure provides secondary nutrients and amino acids that are required by plants for photosynthetic activities, cell division cell enlargement, and accumulation of dry matter content (Hameed et al., 2019). Thapa et al. (2021) and El-Monem and Hamed. (2017) stated that nutrient from chicken sources slowly releases nutrients that anchor root development leading to higher yield and better-quality soil and broccoli. The findings are also in consonance with the findings of Laczi et al. (2016) who observed that organic manure (Horse effluents) in comparison with cow dung and inorganic fertilizer in Chinese cabbage production gave more yield than that of cow dung.

Higher fertilization rates are common in crucifer production. From the results of these studies, different rates of manure (0, 10, 20, and 30 t ha^{-1}) had variations in plant height, number of leaves, and yield. 20 and 30 t^{-}ha^{-1} gave the highest plant height, number of leaves, and yield of cauliflower. The higher value of morphological and yield attributes of this crucifer with the application of different rates of manure suggests that they are highly responsive to manure application. Islam et al. (2017) studied the effects of the rate of organic fertilizers on broccoli and found that the use of different rates of poultry manure increases vegetative development and yield. The observations were also in tandem with the findings of Agbede (2010); Adekiya (2020); Hover et al. (2019); Adeleye et al. (2010) and Yaldiz et al. (2019)

Conclusion

Rainy season supported the best growth and yield parameters in cauliflower production. Application of poultry manure improved growth, while pig manure supports higher yield in the production of Cauliflower. Since yield is the major concern for the farmers, pig manure is recommended in the production of cauliflower in Southeastern Nigeria. Among the four rates of poultry and pig manure (0, 10, 20, and 30 t ha^{-1}) utilized, 30 t ha^{-1} of poultry and pig manure enhanced growth and yield parameters, and this could be recommended in the study area.

Authors contributions: The authors confirm the study conception and design: Ugwuoke K. I. Baiyeri K.P and Ishieze P.U.; data collection: Ishieze P.U.; analysis and interpretation of results: Ishieze P.U. and Olajide K.; draft manuscript preparation: Ishieze P. U. The results were evaluated by all authors, and the final version of the manuscript was approved.

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