Influence of Organic Fertiliser Management on Growth, Yield Performance, and Quercetin Content of Four Onion (Allium cepa L.) Cultivars under Highland Agroecological Conditions of Cameroon

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ABSTRACT

The productivity and nutritional quality of onion (Allium cepa L.) are influenced by cultivar characteristics and nutrient management practices. However, limited information exists on the interaction between onion cultivars and organic fertiliser sources in determining yield performance and quercetin accumulation under highland agroecological conditions of Cameroon. This study evaluated the influence of organic fertiliser management on growth, yield and quercetin content of four onion cultivars grown in Bambili, North-West Region of Cameroon. The experiment was conducted using a 4 × 3 factorial arrangement in a Randomised Complete Block Design (RCBD) with three replications. Four cultivars (Red Bombay, Red Creole, Texas Grano and Pusa White Flat) were evaluated under three fertiliser treatments: cow dung, fowl droppings and an unfertilised control. Data on stem diameter, plant height, number of leaves, bulb yield and quercetin content were analysed using analysis of variance (ANOVA), and treatment means were separated using Tukey's HSD test at 5% probability. Cultivar, fertiliser treatment and their interaction significantly influenced growth, yield and quercetin content. Organic fertiliser application improved vegetative growth and bulb yield compared with the control, with fowl droppings producing the best overall response. Red Bombay showed superior performance, recording the highest stem diameter (10.79 mm), plant height (58.32 cm), bulb yield (129.96 g plant^{-1}) and quercetin content (31.30 mg plant^{-1}). The highest yield (158.63 g plant^{-1}) and quercetin concentration (33.37 mg plant^{-1}) were obtained from Red Bombay treated with fowl droppings. The study demonstrates that integrating suitable cultivar selection with organic fertiliser management can improve onion productivity and nutritional quality under highland conditions of Cameroon.

Keywords: Allium cepa L., bulb yield, Cameroon, fowl droppings, onion cultivars, organic fertiliser, quercetin, sustainable agriculture

INTRODUCTION

Onion (Allium cepa L.) is one of the most important vegetable crops cultivated worldwide and belongs to the family Amaryllidaceae (formerly Liliaceae). It ranks among the most widely cultivated and consumed vegetables because of its culinary, nutritional and economic importance (Griffiths et al., 2002; Brewster, 2018). Onion is an annual cool-season crop that has been cultivated for thousands of years and is produced across Asia, Europe, North and South America, and Africa (Brewster, 2018; FAOSTAT, 2020).

Globally, onion production has increased steadily due to growing consumer demand. According to FAOSTAT (2020), onions are cultivated in more than 170 countries, with China and India accounting for a substantial proportion of global production. In Africa, Niger and Nigeria are among the leading producers, whereas in Cameroon, onion cultivation is concentrated mainly in the Far North Region around Maroua and Kousseri. Despite favourable agroecological conditions in several parts of the country, including the Western Highlands, onion productivity remains below its potential due to constraints related to cultivar selection, soil fertility management and production practices (Brewster, 2018; Shock et al., 2019).

Onion is valued not only as a culinary vegetable but also as a rich source of nutrients and health-promoting phytochemicals. It contains vitamin C, potassium, calcium, phosphorus, thiamine, riboflavin, niacin and dietary fibre. More importantly, onion bulbs are among the richest dietary sources of flavonoids, particularly quercetin, a naturally occurring flavonol with antioxidant, anti-inflammatory, antimicrobial and cardioprotective properties (Slimestad et al., 2007; Lanzotti, 2006; Nile et al., 2020). Regular consumption of quercetin-rich foods has been associated with reduced risks of oxidative stress-related disorders and chronic diseases (Griffiths et al., 2002; Upadhyay, 2016). The concentration of quercetin in onion is influenced by several factors, including genotype, environmental conditions, maturity stage and crop management practices (Griffiths et al., 2002; Mogren et al., 2007). Similarly, onion growth and bulb yield depend on varietal characteristics, soil fertility, climate and nutrient availability (Brewster, 2018; Shock et al., 2019). Because onions possess a shallow root system and high nutrient demand, adequate soil fertility management is essential for optimum growth and bulb development (Sullivan & Nair, 2011).

Although inorganic fertilisers are widely used to improve onion productivity, their prolonged and excessive application has raised concerns regarding declining soil health, environmental pollution and production sustainability. Organic fertilisers such as cow dung, fowl droppings and pig manure improve soil physical, chemical and biological properties while enhancing nutrient availability, soil organic matter, water-holding capacity and microbial activity (Agegnehu et al., 2017; Gong et al., 2020; Roldán et al., 2018). Poultry manure is considered a nutrient-rich organic fertiliser because of its relatively high nitrogen and phosphorus content and rapid mineralisation rate, whereas cattle manure contributes significantly to long-term soil fertility improvement (Agegnehu et al., 2017; Yoldas et al., 2011). Consequently, organic nutrient management has become an important strategy for promoting sustainable vegetable production (Khan et al., 2019).

Despite the increasing importance of onion production in Cameroon, particularly in the Western Highlands, productivity remains below its potential because of declining soil fertility, limited use of appropriate organic nutrient sources, and inadequate information on cultivar-specific nutrient requirements. Although organic fertilisers such as cow dung and poultry manure are commonly used by smallholder farmers, their comparative effects on the growth, yield and nutritional quality of different onion cultivars under the highland agroecological conditions of Cameroon have not been adequately investigated. Most previous studies have either focused on the effects of fertilisers on crop growth and yield or evaluated onion varieties independently, with little attention given to the interaction between cultivar and organic fertiliser source. Furthermore, information on the influence of organic fertiliser management on quercetin accumulation in onion bulbs under Cameroonian conditions is scarce. This lack of locally generated scientific evidence limits the development of site-specific recommendations that can simultaneously improve onion productivity, soil fertility and bulb nutritional quality for farmers in the Western Highlands.

Therefore, this study was conducted to evaluate the influence of organic fertiliser management on the growth, yield performance and quercetin content of four onion (Allium cepa L.) cultivars grown under the highland agroecological conditions of Bambili, Cameroon. Specifically, the study aimed to:

1. Assess the effects of different organic fertilisers on the growth performance of four onion cultivars.
2. Determine the most suitable organic fertiliser for enhancing onion productivity.
3. Evaluate the effects of organic fertilisers on bulb yield.
4. Determine the quercetin content of onion cultivars grown under different organic fertiliser treatments.

LITERATURE REVIEW

Origin, Botanical Background and Importance of Onion

Onion (Allium cepa L.) is one of the oldest cultivated vegetable crops and is believed to have originated in Central Asia before spreading to other parts of the world through trade and human migration (Brewster, 2018). It belongs to the family Amaryllidaceae, subfamily Allioideae, and is cultivated as an annual for its edible bulb.

Bulb development is influenced by genotype, photoperiod, temperature and nutrient availability (Brewster, 2018; Kumar et al., 2022).

Onion is among the world's most important vegetable crops because of its culinary, economic and nutritional value. It provides essential vitamins, minerals and bioactive compounds, particularly flavonoids, which contribute to human health (Griffiths et al., 2002; Slimestad et al., 2007). Considerable variation exists among onion cultivars in bulb colour, maturity, yield potential and phytochemical composition. Red onion cultivars generally contain higher concentrations of quercetin and other phenolic compounds than white or yellow cultivars because of genetic differences in flavonoid biosynthesis (Griffiths et al., 2002; Rodríguez Galdón et al., 2008; Nile et al., 2020). The four cultivars evaluated in this study (Red Bombay, Red Creole, Texas Grano and Pusa White Flat) were selected because they are commonly grown under tropical conditions, differ in agronomic characteristics (bulb colour, maturity and yield potential), and represent both red and white types that are relevant to local markets and consumer preferences in Cameroon. Successful onion production requires moderate temperatures (15–25 °C), well-drained fertile soils with a pH of 6.0–7.0, and balanced nutrient management to support vegetative growth and bulb development (Brewster, 2018; Shock et al., 2019).

Organic Fertilisers and Quercetin in Onion

Organic fertilisers improve soil fertility by increasing organic matter, enhancing soil structure, stimulating microbial activity and promoting nutrient cycling (Diacono & Montemurro, 2010; Agegnehu et al., 2017). Poultry manure is recognised as a nutrient-rich organic fertiliser because of its relatively high nitrogen and phosphorus contents and rapid mineralisation rate, whereas cattle manure contributes substantially to long-term soil organic matter accumulation and sustained soil fertility (Agegnehu et al., 2017; Gong et al., 2020).

In addition to improving crop growth and yield, organic fertilisers may influence the synthesis of secondary metabolites such as flavonoids by modifying nutrient availability and plant metabolism (Nile et al., 2020; Kumar et al., 2022). However, the magnitude of this response depends on cultivar, environmental conditions and the nutrient release characteristics of the organic amendment.

Quercetin is the principal flavonol in onion bulbs and is largely responsible for their antioxidant, anti-inflammatory and health-promoting properties. Its concentration varies with genotype, environmental conditions, maturity stage and nutrient management (Griffiths *et al.,* 2002; Slimestad *et al.,* 2007; Nile *et al.,* 2020). In the present study, quercetin content was determined using the aluminium chloride ($AlCl_3$) colourimetric assay, a widely accepted spectrophotometric method based on the formation of stable aluminium–flavonoid complexes (Woisky & Salatino, 1998; Zhishen *et al.,* 1999).

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at the research farm of the Agricultural School, College of Technology (COLTECH), University of Bamenda, Bambili Campus, Tubah Subdivision, Mezam Division, North-West Region of Cameroon. Bambili is situated within the Western Highlands Agro-Ecological Zone of Cameroon, between latitudes 5° and 6°N and longitude 10°E, at an altitude ranging from 1600 to 2000 m above sea level. The area has an average annual rainfall of approximately 1713–2359 mm and a mean temperature of about 19.6–21 °C. These climatic conditions are favourable for vegetable production. The soils of Tubah Subdivision are predominantly volcanic soils derived from basaltic and igneous parent materials; they are generally deep, fertile, well-drained and rich in organic carbon. These volcanic soils typically exhibit moderate to high cation-exchange capacity and a pH range suitable for onion production (approximately 5.5–6.5), although continuous cultivation without adequate nutrient replenishment often lead to progressive fertility decline with many Farmers depending on organic fertilisers for soil nutrients. The combination of cool temperatures, adequate rainfall and fertile volcanic soils makes Bambili a representative highland site for evaluating onion performance under highland agroecological conditions (Mbanga., *et al,* 2021).

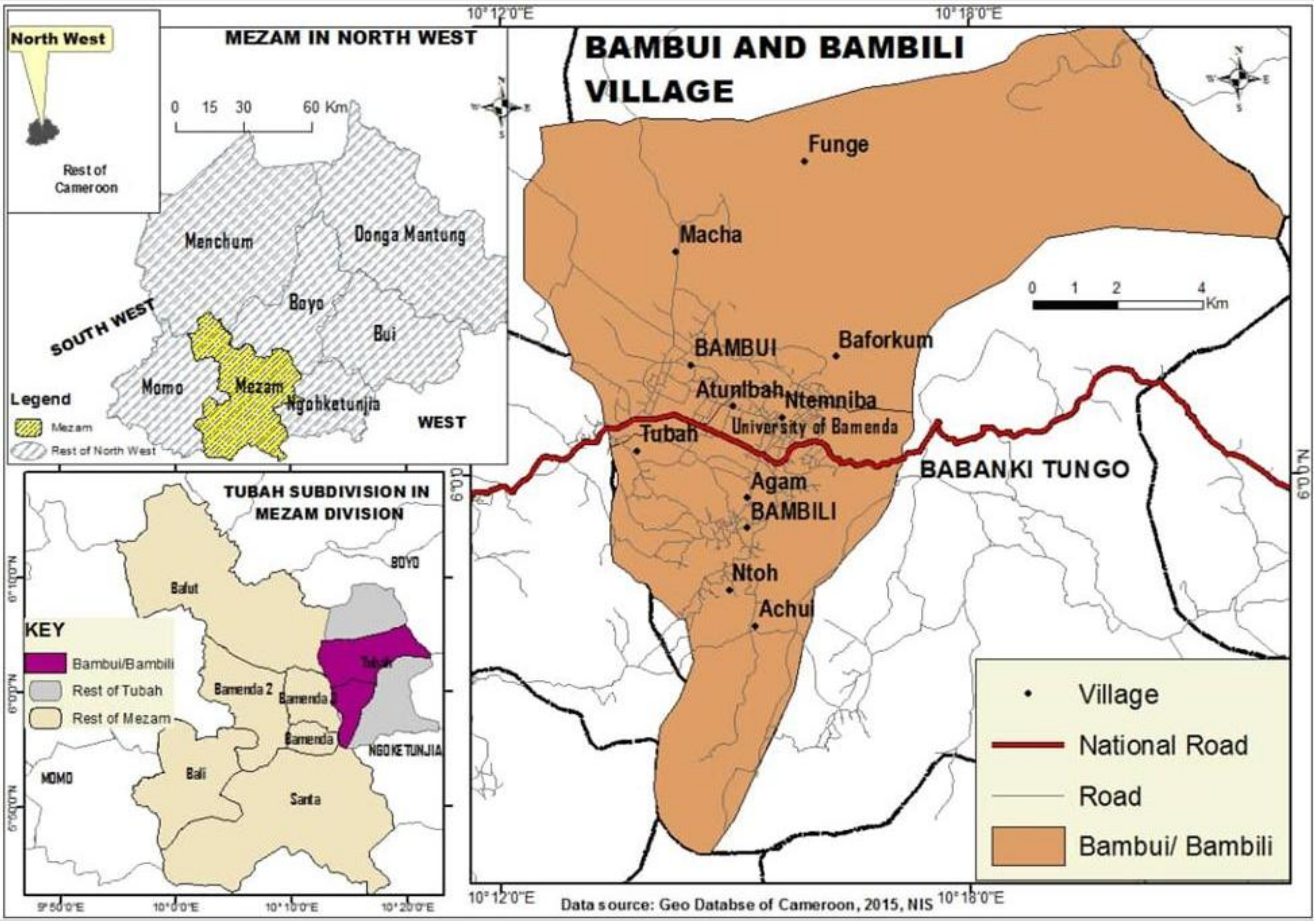

Figure 1: Location Map of Bambili in Mezam, North-West Region (Mbanga., et al, 2021).

Experimental Period, Design and Treatments

The study was conducted from 15 March to 15 August 2022, covering the main cropping season under rainy-season conditions. The experiment involved two factors: onion variety (four levels) and organic fertiliser treatment (three levels), arranged in a 4 × 3 factorial combination.

Four onion cultivars were used: Red Bombay (RB), Texas Grano (TG), Pusa White Flat (PWF) and Red Creole (RC). These cultivars were selected because they are widely available to farmers in Cameroon, differ in bulb pigmentation (red versus white/yellow) and maturity characteristics, and have shown variable performance under tropical conditions. Seeds of all cultivars were purchased from a local agricultural input shop to reflect the planting material typically accessible to smallholder farmers.

The fertiliser treatments consisted of cow dung (CD), fowl droppings (FD) and an unfertilised control (C_0). Both organic fertilisers were air-dried under shade to a moisture content suitable for handling and application. Five kilograms of each air-dried organic fertiliser were applied uniformly to individual plots measuring 3 m² (equivalent to approximately 16.7 t ha^{-1}) one day before transplanting. The fertilisers were incorporated into the top 10–15 cm of soil by light forking to ensure good contact with the root zone and to minimise nutrient losses. No inorganic fertiliser or additional organic amendments were applied during the cropping cycle. The control plots received neither organic nor inorganic fertiliser.

Seedlings were raised in a nursery for 21 days and then transplanted into the experimental plots. Each plot contained 12 plants. Maize plants were established around the borders of the experimental field to minimise edge effects and reduce soil erosion. One healthy plant was randomly selected and permanently tagged in each plot for repeated non-destructive measurements throughout the experimental period.

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The twelve treatment combinations were arranged in a Randomised Complete Block Design (RCBD) with three replications, resulting in a total of 36 experimental plots. Each plot measured 2 m × 1.5 m (3 m²). A spacing of 1 m was maintained between blocks and 50 cm between adjacent plots. The total experimental field area was 216 m² (18 m × 12 m). The treatment combinations were as follows:

T_1 = Red Bombay + Cow dung; T_2 = Red Bombay + Fowl droppings; T_3 = Red Bombay + Control;

T_4 = Texas Grano + Cow dung; T_5 = Texas Grano + Fowl droppings; T_6 = Texas Grano + Control;

T_7 = Pusa White Flat + Cow dung; T_8 = Pusa White Flat + Fowl droppings; T_9 = Pusa White Flat + Control;

T_{10} = Red Creole + Cow dung; T_{11} = Red Creole + Fowl droppings; T_{12} = Red Creole + Control.

Table 1: Randomised Complete Block Design (RCBD) Layout

Replicate I (R_1).	Replicate II (R_2)	Replicate III (R_3)
T_5.	T_{11}.	T_3
T_1.	T_4	T_9
T_9.	T_7	T_{12}
T_{12}.	T_2	T_6
T_8.	T_{10}	T_1
T_3.	T_5	T_8
T_{10}.	T_1	T_{10}
T_6.	T_{12}.	T_4
T_2.	T_8.	T_{11}
T_{11}.	T_6.	T_7
T_4.	T_3.	T_2
T_7.	T_9.	T_5

Figure 2: Field layout with onion seedlings immediately after transplanting (Author, 2022).

Crop Management and Data Collection

Standard agronomic practices were followed throughout the cropping period, including land preparation, transplanting, manure application, weeding and other necessary field management practices. Growth parameters measured were plant height (cm), number of leaves per plant and stem diameter (mm). Yield parameters included bulb weight (g) and yield per sample plant. Measurements were taken on the tagged plant in each plot at appropriate growth stages.

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Determination of Quercetin Content

Quercetin concentration in onion bulbs was determined using the aluminium chloride ($AlCl_3$) colorimetric assay method described by Woisky and Salatino (1998) and Zhishen et al. (1999) with slight modifications to ensure reproducibility under local laboratory conditions.

Harvested onion bulbs were thoroughly washed with distilled water to remove adhering soil particles and other contaminants. The outer dry scales were removed, and the edible bulb tissues were chopped into small pieces and homogenised. The homogenised samples were oven-dried at 50 °C until a constant weight was attained and then ground into a fine powder using a blender. The powdered samples were stored in airtight polyethylene containers at room temperature until analysis.

Two grams (2.0 g) of the powdered onion sample were weighed into a 100 mL conical flask, and 20 mL of 80% methanol was added as the extraction solvent. The mixture was shaken on an orbital shaker for 2 hours at room temperature (approximately 25 °C) and subsequently filtered through filter paper to obtain a clear extract.

For colour development, 1.0 mL of the methanolic extract was transferred into a test tube and mixed with 1.0 mL of 2% aluminium chloride ($AlCl_3$) solution prepared in methanol. The reaction mixture was incubated in the dark for 30 minutes at room temperature to allow the formation of a stable flavonoid–aluminium complex. The absorbance of the resulting solution was measured at 415 nm using a UV–Visible spectrophotometer, with the reagent blank used for instrument calibration.

A standard calibration curve was prepared using quercetin standard solutions (0, 20, 40, 60, 80 and 100 $\mu g\ mL^{-1}$). Quercetin content in each sample was calculated using regression analysis and expressed as milligrams of quercetin equivalent per plant (mg $plant^{-1}$). Bulbs collected from each field replicate were analysed independently, and each laboratory analysis was performed in triplicate. Mean values were used for statistical analysis.

Figure 3: Preparation and extraction of samples from onion bulbs for quercetin analysis (Author, 2022).

Statistical Analysis

Data collected were subjected to two-way analysis of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS version 26.0) to evaluate the main effects of cultivar and fertiliser treatment as well as their interaction. Significant differences among treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at the 5% level of probability ($P \leq 0.05$). Means are presented with standard deviations (SD) where appropriate. The coefficient of variation (CV) was calculated for key parameters to assess experimental precision.

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RESULTS

Stem Diameter

Stem diameter of onion plants was significantly influenced by onion variety ($P < 0.001$) and organic fertiliser application ($P < 0.001$). The interaction between variety and fertiliser treatment was not significant ($P = 0.057$). Among varieties, Red Bombay recorded the highest mean stem diameter (10.79 mm), followed by Red Creole (10.12 mm), Texas Grano (8.39 mm) and Pusa White Flat (6.13 mm). Fowl droppings produced the highest mean stem diameter (10.72 mm), followed by cow dung (8.91 mm), while the control recorded the lowest value (6.95 mm). The highest stem diameter was observed in Red Bombay supplied with fowl droppings (13.50 mm).

Table 2. Effect of onion variety and organic fertiliser on stem diameter (mm)

Variety	Cow dung	Fowl droppings	Control	Variety mean
Red Bombay	10.87 bc	13.50 a	8.00 cde	**10.79**
Texas Grano	8.40 cde	10.10 bcd	6.67 ef	**8.39**
Pusa White Flat	5.90 f	7.23 de	5.27 f	**6.13**
Red Creole	10.47 bc	12.03 ab	7.87 cde	**10.12**
Treatment mean	**8.91**	**10.72**	**6.95**	—

Means followed by the same letter(s) are not significantly different according to Tukey's HSD test at $P \leq 0.05$. ANOVA: Variety $P < 0.001$; Fertiliser $P < 0.001$; Variety × Fertiliser $P = 0.057$ (ns).

Plant Height

Plant height was significantly affected by onion variety ($P < 0.001$), organic manure treatment ($P < 0.001$) and their interaction ($P < 0.001$). Red Bombay supplied with fowl droppings produced the tallest plants (64.57 cm), followed by Red Creole with fowl droppings (62.07 cm). The shortest plants were recorded in Pusa White Flat under the control treatment (18.97 cm). Across varieties, Red Bombay had the highest average plant height (58.32 cm) and Pusa White Flat the lowest (25.13 cm). Fowl droppings and cow dung produced significantly taller plants than the control.

Table 3. Effect of onion variety and organic fertiliser on plant height (cm)

Variety	Cow dung	Fowl droppings	Control	Variety mean
Red Bombay	58.23 ± 0.75 c	64.57 ± 0.40 a	52.17 ± 0.60 e	**58.32 a**
Red Creole	55.60 ± 0.87 d	62.07 ± 0.31 b	49.90 ± 1.00 f	**55.86 a**
Texas Grano	55.07 ± 0.31 d	50.83 ± 0.35 ef	50.50 ± 1.51 f	**52.13 b**
Pusa White Flat	31.43 ± 1.96 g	25.00 ± 1.58 h	18.97 ± 1.50 i	**25.13 c**
Treatment mean	**50.08 a**	**50.62 a**	**42.88 b**	—

Values are mean ± SD ($n = 3$). Means followed by different letters are significantly different at $P \leq 0.05$ (Tukey HSD). ANOVA: Variety $P < 0.001$; Fertiliser $P < 0.001$; Variety × Fertiliser $P < 0.001$. CV = 3.38%.

Number of Leaves

Organic manure application significantly affected the number of leaves ($P = 0.001$), whereas variety ($P = 0.066$) and the variety × manure interaction ($P = 0.435$) were not significant. Plants treated with fowl droppings recorded the highest mean number of leaves (9.83), followed by cow dung (9.17); the control recorded the lowest value (7.50). Although varietal differences were not statistically significant, Red Creole and Red Bombay tended to produce more leaves than Texas Grano and Pusa White Flat.

Table 4. Effect of onion variety and organic fertiliser on number of leaves per plant

Variety	Cow dung	Fowl droppings	Control	Variety mean
Red Bombay	10.33 ± 0.58 a	10.33 ± 1.53 a	7.33 ± 1.15 b	**9.33 a**
Texas Grano	8.33 ± 1.15 ab	10.00 ± 1.00 a	7.33 ± 1.53 b	**8.56 a**
Pusa White Flat	7.67 ± 1.53 b	8.33 ± 1.15 ab	7.67 ± 1.53 b	**7.89 a**
Red Creole	10.00 ± 1.00 a	10.67 ± 1.15 a	7.67 ± 1.53 b	**9.44 a**
Treatment mean	**9.17 a**	**9.83 a**	**7.50 b**	—

Values are mean ± SD (n = 3). Means followed by different letters are significantly different at $P \leq 0.05$ (Tukey HSD). ANOVA: Variety $P = 0.066$ (ns); Fertiliser $P = 0.001$; Variety × Fertiliser $P = 0.435$ (ns).

Bulb Yield per Sample Plant

Yield per sample plant was significantly influenced by onion variety ($P < 0.001$), organic manure treatment ($P < 0.001$) and their interaction ($P < 0.001$). Red Bombay recorded the highest mean yield (129.96 g), followed by Red Creole (94.03 g); Texas Grano (45.43 g) and Pusa White Flat (35.18 g) produced significantly lower yields. Fowl droppings resulted in the highest average yield (94.94 g), followed by cow dung (81.05 g); the control recorded the lowest yield (52.46 g). The highest individual treatment mean was obtained from Red Bombay treated with fowl droppings (158.63 g).

Table 5. Effect of onion variety and organic fertiliser on bulb yield per sample plant (g)

Variety	Cow dung	Fowl droppings	Control	Variety mean
Red Bombay	147.03 ± 6.65 b	158.63 ± 5.10 a	84.20 ± 11.57 e	**129.96 a**
Red Creole	94.50 ± 5.77 d	127.20 ± 8.82 c	60.40 ± 7.09 f	**94.03 b**
Texas Grano	45.77 ± 5.15 h	54.70 ± 0.91 g	35.83 ± 1.55 j	**45.43 c**
Pusa White Flat	36.90 ± 3.28 ij	39.23 ± 2.68 i	29.40 ± 2.65 k	**35.18 d**
Treatment mean	**81.05 b**	**94.94 a**	**52.46 c**	—

Values are mean ± SD (n = 3). Means followed by different letters differ significantly according to Tukey's HSD at $P \leq 0.05$. ANOVA: Variety $P < 0.001$; Fertiliser $P < 0.001$; Variety × Fertiliser $P < 0.001$. LSD ($P = 0.05$) = 9.65 g; CV = 6.02%.

Quercetin Content

Quercetin content of onion bulbs was significantly affected by variety ($P < 0.001$), organic manure treatment ($P < 0.001$) and their interaction ($P < 0.001$). Red Bombay recorded the highest mean quercetin content (31.30 mg plant^{-1}), followed by Red Creole (25.11 mg plant^{-1}) and Texas Grano (21.34 mg plant^{-1}); Pusa White Flat recorded the lowest value (12.50 mg plant^{-1}). Fowl droppings (24.77 mg plant^{-1}) and cow dung (24.76 mg plant^{-1}) produced similar and significantly higher quercetin levels than the control (18.17 mg plant^{-1}). The highest concentration was recorded in Red Bombay supplied with fowl droppings (33.37 mg plant^{-1}).

Table 6. Effect of onion variety and organic fertiliser on quercetin content (mg plant^{-1})

Variety	Cow dung	Fowl droppings	Control	Variety mean
Red Bombay	32.80 ± 2.10 a	33.37 ± 8.59 a	27.73 ± 2.51 b	**31.30 a**
Red Creole	28.27 ± 1.86 b	30.93 ± 1.81 ab	16.13 ± 2.00 e	**25.11 b**

Texas Grano	22.70 ± 1.64 c	22.57 ± 1.54 c	18.77 ± 1.42 d	**21.34 b**
Pusa White Flat	15.27 ± 1.17 e	12.20 ± 1.29 f	10.03 ± 1.40 g	**12.50 c**
Treatment mean	**24.76 a**	**24.77 a**	**18.17 b**	—

Values are mean ± SD (n = 3). Means followed by different superscript letters are significantly different according to Tukey's HSD at $P \leq 0.05$. ANOVA: Variety $P < 0.001$; Fertiliser $P < 0.001$; Variety × Fertiliser $P < 0.001$.

DISCUSSION

Growth Performance

The significant effects of onion variety and organic fertiliser treatments on growth parameters indicate that both genetic characteristics and nutrient availability play important roles in determining onion performance under the agro-ecological conditions of Bambili. Red Bombay consistently exhibited superior vegetative growth compared with the other cultivars, suggesting better adaptation to the prevailing environmental conditions and more efficient utilisation of available nutrients. Similar differences in vegetative growth among onion cultivars have been reported by Brewster (2018), who highlighted the importance of genotype, photoperiod, temperature and nutrient availability in regulating onion growth and development. The observed variation among cultivars may therefore be attributed to genetic differences in nutrient uptake efficiency, biomass accumulation and adaptation to local growing conditions.

Organic fertiliser application significantly enhanced vegetative growth, with fowl droppings producing the highest growth response. This improvement may be related to the relatively high nitrogen and phosphorus content of poultry manure, rapid nutrient mineralisation and its ability to stimulate microbial activity in the soil. Agegnehu et al. (2017) reported that organic amendments improve soil fertility by increasing nutrient availability, soil organic matter and biological activity, thereby enhancing crop growth. Similarly, Diacono and Montemurro (2010) demonstrated that long-term application of organic fertilisers improves soil quality and nutrient cycling, resulting in better crop performance. The superior response obtained with fowl droppings compared with cow dung may be associated with the faster release of essential nutrients from poultry manure, as reported by Yoldas et al. (2011). The reduced growth observed under the control treatment further confirms the importance of adequate nutrient supply for onion production, since onions possess a shallow root system and require continuous nutrient availability throughout the growing period (Sullivan & Nair, 2011).

Bulb Yield

The significant differences in bulb yield among onion varieties and organic fertiliser treatments demonstrate the importance of combining suitable cultivar selection with effective nutrient management. Red Bombay supplied with fowl droppings produced the highest yield, indicating its superior ability to exploit improved nutrient conditions and adapt to the highland environment of Bambili. Similar findings have been reported by Brewster (2018), who indicated that yield differences among onion cultivars are largely determined by genetic potential, environmental adaptation and nutrient availability.

The improvement in bulb yield following organic fertiliser application may be attributed to enhanced nutrient supply, improved soil structure and increased vegetative growth, which provide greater photosynthetic capacity for bulb formation. Agegnehu et al. (2017) and Gong et al. (2020) reported that organic amendments enhance soil physical, chemical and biological properties, resulting in improved crop productivity. Furthermore, Palm et al. (2001) emphasised that organic inputs contribute significantly to sustainable soil fertility management, particularly in smallholder production systems where soil nutrient depletion is common. The lower yield recorded in unfertilised plots agrees with previous observations that inadequate nutrient availability limits leaf development, photosynthate production and final bulb enlargement in onion (Shock et al., 2019). Because onion has a shallow root system and a high nutrient requirement during bulb initiation and development, maintaining adequate nutrient availability is essential for achieving optimum yield (Sullivan & Nair, 2011).

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Quercetin Concentration

The variation in quercetin concentration among onion varieties indicates that phytochemical accumulation is strongly influenced by genotype. Red Bombay recorded the highest quercetin concentration, whereas Pusa White Flat had the lowest concentration, demonstrating the influence of bulb pigmentation and genetic background on flavonoid accumulation. These results agree with Griffiths et al. (2002), who reported considerable differences in flavonoid content among onion cultivars, with red onions generally containing higher concentrations of quercetin derivatives than yellow and white varieties. Similarly, Slimestad et al. (2007) and Rodríguez Galdón et al. (2008) reported that red onion cultivars accumulate greater amounts of phenolic compounds due to enhanced flavonoid biosynthesis pathways associated with anthocyanin and flavonol production.

Organic fertiliser application also influenced quercetin accumulation, with higher concentrations observed under fowl droppings and cow dung treatments compared with the control. Improved nutrient availability may enhance plant metabolic activity and influence pathways involved in phenolic and flavonoid synthesis. Nile et al. (2020) reported that nutrient management practices can modify the accumulation of bioactive compounds in onion by affecting secondary metabolism. However, the response of quercetin concentration to fertiliser application may depend on cultivar characteristics, environmental conditions and nutrient release patterns of the applied organic materials (Mogren et al., 2007).

The significant interaction between variety and organic fertiliser treatment observed in this study indicates that the effect of nutrient management on phytochemical accumulation is cultivar-dependent. This finding supports previous reports that genotype and environmental factors interact strongly to determine flavonoid concentration in onion bulbs (Griffiths et al., 2002; Mogren et al., 2007). The combination of high bulb yield and elevated quercetin concentration observed in Red Bombay supplied with fowl droppings suggests that this cultivar–fertiliser combination has potential for sustainable onion production while improving the nutritional and functional quality of onion bulbs.

Practical Implications for Farmers

From a practical standpoint, the findings indicate that smallholder farmers in the Western Highlands of Cameroon can improve both onion productivity and nutritional quality by selecting the Red Bombay cultivar and applying fowl droppings at approximately 16.7 t ha^{-1} (5 kg per 3 m^2 plot) one day before transplanting. Fowl droppings are widely available in mixed crop–livestock systems and mineralise relatively quickly, making them a feasible and relatively low-cost organic nutrient source. Promoting the use of poultry manure within integrated soil fertility management strategies can help reduce reliance on costly inorganic fertilisers, improve soil health over time, and enhance the market value of onions through higher bulb size and quercetin content. Adoption of these practices is therefore consistent with sustainable intensification goals under highland agroecological conditions.

CONCLUSION

This study demonstrated that onion variety and organic fertiliser management significantly influenced growth, yield performance and quercetin concentration under the highland agro-ecological conditions of Bambili, Cameroon. Red Bombay exhibited the best overall performance, recording superior vegetative growth, higher bulb yield and greater quercetin accumulation compared with the other evaluated cultivars. This superior performance may be attributed to its greater genetic vigour, higher nutrient uptake efficiency, improved photosynthetic capacity and better adaptation to highland conditions. Among the organic fertiliser treatments, fowl droppings consistently enhanced plant growth, yield performance and bulb nutritional quality.

The combination of Red Bombay and fowl droppings represents a promising production strategy for improving onion productivity and nutritional value under similar agro-ecological conditions. Therefore, Red Bombay showed strong potential for cultivation in Bambili and other comparable highland environments due to its superior agronomic performance and high quercetin content. The use of fowl droppings as an organic nutrient source should be promoted among farmers as a sustainable approach for improving onion production and bulb quality. Further studies should investigate additional onion genotypes, organic amendment sources and integrated nutrient management practices across multiple locations and seasons to determine the consistency and wider applicability of these findings. Future work should also include chemical characterisation of organic amendments to establish precise nutrient–yield relationships.

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