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Integrated Nutrient Management for Sustainable Cultivation of Okro (*Abelmoschus esculentus* L.) and Its Effects on Growth, Yield, and Economic Analysis of Two Okro Varieties

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Abstract

Elevated soil fertility is essential for augmenting agricultural production and achieving substantial yields in okro. Field studies were performed during 2021 and 2022 cropping seasons to evaluate the yield, yield components and partial analysis of okro to different fertilizer combinations. The experiments were conducted at the multipurpose nursery research site at the College of Agricultural Education, AAMUSTED, Mampong-Ashanti, Ghana. The experimental design was a 2 × 6 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with four (4) replications. The treatments were made up of two factors: Factor (A): Two okro varieties [(i) Asontem and (ii) Clemson spineless] and Factor (B): Soil Amendments (i) 650 kg/ha NPK (full NPK), (ii) 20 t/ha Poultry Manure (full PM), (iii) 487.5 kg/ha NPK + 5 t/ha PM (3/4 NPK + 1/4 PM), (iv) 325 kg/ha NPK +10 t/ha PM (1/2 NPK + 1/2 PM), (v) 162.5 kg/ha NPK + 15 t/ha PM (1/4 NPK + 3/4 PM), and (vi) Control. The integrated application of NPK 15:15:15 and poultry manure at 325 kg/ha NPK + 10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM generally increased plant height, number of leaves per plant, stem diameter, canopy spread, number of branches per plant, chlorophyll content and dry matter accumulation over sole applications and control (no fertilizer) application. Asontem variety had slightly higher growth parameters than Clemson spineless. The integrated combination of NPK 15:15:15 and poultry manure at 325 kg/ha NPK + 10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM also showed an increased number of fruits per plant, fruit length and diameter as well as total fresh fruit yield. The partial budget analysis indicated that 162.5 kg/ha NPK + 15 t/ha PM had the highest net benefit and BCR under both varieties.

Keywords

Integrated Nutrient Management, Okro Fruits, Nutritional Quality, Economic Analysis

1. Introduction

Okro (*Abelmoschus esculentus* L. Moench) is a seasonal herb classified within the Malvaceae family. It is considered an important vegetable crop grown in the tropical and subtropical parts of the world. Despite its great adaptability and heat resilience, okro productivity frequently encounters obstacles stemming from soil infertility, nutritional imbalances, and environmental pressures, particularly intensified in tropical and subtropical regions [1]. Okro is cultivated across Ghana in all regions, both as rain-fed and irrigated crops, with the major producers being males [2]. It grows as a warm-season crop cultivated primarily for its edible pods. The high nutritional content of okro includes rich bioactive components such as dietary fibre, protein, carbohydrate, calcium, magnesium, potassium, and vitamins (A & C) [3]-[6]. Okro also lowers the risk of chronic disease, enhances digestion, and controls glucose levels [7]. Okro's diverse use for its young leaves, buds, flowers, pods, stems, and seeds renders it a multifaceted crop [8]. Beyond its culinary applications, okro and its derivatives serve multiple industrial functions, encompassing food, pharmaceuticals, and cosmetics, attributable to its beneficial characteristics, including viscosity agents, dietary fibre, and bioactive substances [9] [10].

The fertility and health of soil are essential for crop development and yield output [11]. Tropical and subtropical lands have difficulties, including insufficient organic matter and restricted capacity for water and nutrient retention [12] [13] as well as excessive dependence on chemical fertilisers, leading to soil deterioration and diminished production [14]. Prolonged use of chemical fertilizers has been shown to reduce soil organic matter and microbial activity, negatively impacting long-term soil health and crop performance [15]. Tackling these challenges is essential for sustainable vegetable production, as preserving soil health plays a key role in improving both yield and crop quality including okro [16].

The availability of soil nutrients is frequently constrained by inadequate application of inorganic and organic fertilisers, together with nutrient losses resulting from erosion and leaching. A lot of smallholder farmers cannot obtain synthetic fertilisers due to elevated costs, insufficient finance, inadequate distribution networks, and various socio-economic limitations. Consequently, crop yields persist at low levels or are dropping in certain regions endangering the sustainability of existing agricultural methods. The persistent application of elevated quantities of chemical fertilisers, without the integration of organic manures or biofertilizers, has led to the degradation of soil health. This encompasses detrimental impacts on the soil's physical and chemical characteristics, a decrease in microbial activity, a decrease in the organic matter in the soil, and heightened pollution of soil, water, and air [17]-[19]. Contemporary nutrition management systems have progressively prioritised sustainability and ecological responsibility. The combined application of several soil fertility amendments aims to rectify nutrient shortages and improve the accessibility of vital nutrients while saving farmers some money. Multiple studies have demonstrated that inorganic fertilisers, organic sources, and biofertilizers, when used independently, cannot maintain long-term agricultural productivity [20]. Furthermore, the escalating expense of inorganic fertilisers has rendered them progressively unsustainable for micro and disadvantaged farms.

The optimal strategy for soil fertility maintenance is the integrated application of chemical and organic fertilisers. This study tackles the major topic of okro by investigating and assessing various nutrition management strategies. This research addresses the inadequate utilisation of nutrients in okro cultivation, which restricts yield potential and presents considerable environmental hazards [21] [22]. Conventional blanket fertiliser recommendations frequently neglect particular site conditions of the soil and crop requirements, resulting in nutrient imbalances that impede growth and diminish crop quality. The primary objectives are to analyse the effects of diverse nutrient management strategies on the growth and yield of okro; to determine the best and most effective combination of both organic and inorganic fertilisers for maximal productivity; and to examine the economic feasibility of these techniques. This strategy is anticipated to promote nutrient utilisation efficiency while also enhancing soil health, ultimately resulting in an increasingly resilient and productive agricultural system, as well as increasing the net profit of okro producers.

2. Materials and Methods

2.1. Description of Experimental Site

The study was carried out at the Multipurpose Crop Nursery research field of University of Skills Training and Entrepreneurial Development (USTED), Mampong-Campus. The study was conducted from August to November 2021 during the minor cropping season, and from March to June 2022 in the major cropping season. Mampong-Ashanti (07081N, 0102411W) has an altitude of 475.5m above sea level and is located within the transitional agro-ecological zone of Ghana. The soils are classified as Chromic Luvisols under the FAO/UNESCO (1988) system.

2.2. Planting Materials, Experimental Design, and Treatments

The planting materials were two okro varieties namely: Asontem (local) and Clemson spineless (exotic) sourced from Agri-seed Company Limited, Kumasi Ghana. The experimental design was a 2 x 6 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with four (4) replications. The treatments were made up of two factors: Factor (A): Two okro varieties [(i) Asontem and (ii) Clemson spineless] and Factor (B): Soil Amendments (i) 650 kg/ha NPK (full NPK), (ii) 20 t/ha Poultry Manure (full PM), (iii) 487.5 kg/ha NPK + 5 t/ha PM (3/4 NPK + 1/4 PM), (iv) 325 kg/ha NPK + 10 t/ha PM (1/2 NPK + 1/2 PM), (v) 162.5 kg/ha NPK + 15 t/ha PM (1/4 NPK + 3/4 PM), and (vi) No Fertilizer (control). The rationale for the "Full NPK" rate (650 kg/ha of 15:15:15) is based on the okro nutrient demand, balanced fertilization principle, and the initial soil fertility status of the experiment site.

2.3. Management of Field Activities and Plant Protection

2.3.1. Land Preparation

The land was prepared by ploughing with a disc plough followed by harrowing to obtain the desired tilth that supports okro seed germination and establishment.

2.3.2. Poultry Manure Preparation, Its Application and That of Inorganic Fertilizer

The fresh poultry manure without litter (at least two weeks old) was collected from USTED's poultry production farm at Mampong-Ashanti using empty sacks and transported to the experimental site. The manure was kept under a tree covered with a black polythene bag for three weeks to enable further decomposition before application. The decomposed farm poultry manure was incorporated into the prepared land for plots that received poultry manure and worked into the soil at a depth of 15 cm, two (2) weeks before sowing okro seeds. Inorganic fertilizer NPK (15:15:15) was applied two weeks after seedling emergence to enhance the establishment of the okro seedlings using side application method.

2.3.3. Sowing of Okro

Sowing was done with a cutlass to a depth of about 3-5 cm. Three seeds were sown per hill and thinned to one seedling at two Weeks After Planting (WAP). Each plot size measured 3.6 m wide by 5 m long. The planting distances were 60 cm between rows and 50 cm within rows. Each plot was made up of 6 rows.

2.3.4. Weed Control, Irrigation, and Control of Pests and Diseases

Weeds were controlled manually using a hoe at three and six WAP. Watering was done using water hose two times a day in the morning before 9:00 am and in the evening after 4:00 pm especially during the minor rain season in 2021. Insects were controlled using Golan SL. at the rate of 12 ml per 15 liters of knapsack full of water. The spraying was done during plant phase starting at three WAP at five-day intervals until the okro plant started fruiting.

2.4. Data Collection

2.4.1. Soil and Poultry Manure Chemical and Physical Properties

Soil samples were randomly taken from the experimental site before the sowing of okro for their physical and chemical analysis. Composite sampling was done along a Z plan across the four blocks using a soil core sampler at a layer of 0 - 30 cm depth and were bulked together, air-dried, and sieved using a 2-mm mesh. Representative samples of the well-decomposed poultry manure used for both the 2021 minor and 2022 major cropping seasons were taken and analyzed for their chemical properties at the Department of Renewable Natural Resources' Soil Laboratory at Kwame Nkrumah University of Science and Technology (KNUST) Kumasi. The poultry manure was analyzed for the following parameters: pH, percentage (%) organic carbon (Total C), % total N, % available phosphorus (P), % Ca, % Mg, Na, Fe, Cu, Zn, and arsenic (As). Also, percentage (%) total potassium (K), % organic matter (OM), and % moisture content were determined.

The soil chemical properties were analysed for their pH, organic matter, organic carbon (%), available N, P, and K (kg/ha), Na (mmol/kg), Ca (Cmol/kg), Mg (Cmol/kg), Al (Cmol/kg) and H (Cmol/kg). Determination of pH was done as outlined by Thomas [23]. Also, determination of Organic Carbon (OC) and Total N was done according to Walkley and Black [24] and Sparks *et al.* [25] respectively. Determination of Available P by the use of the Bray or Olsen method. For acidic soils, Bray No. 1 method (HCl + NH_4F extractant) was used and for neutral to alkaline soils Olsen method was employed [26]. Determination of exchangeable K, Ca, and Mg by following the protocol outlined by Thomas [23] and that of moisture content and total P, K, Ca, and Mg in the manure were done according to protocol described by Haby *et al.* [27]. The procedure outlined by Ross and Ketterings [28] was followed to estimate the Cation Exchange Capacity (CEC). The analysis of the soil samples was also carried out at the Department of Renewable Natural Resources' Soil Laboratory at Kwame Nkrumah University of Science and Technology (KNUST) Kumasi.

2.4.2. Plant Phenology Data

Data on days to 50% emergence, 50% flowering, and 50% podding were taken. The number of days to 50% emergence was estimated from the day of planting to when 50% of the plants in the two harvestable rows in the middle had emerged. Also, the number of days to 50% flowering was taken from the day of planting to when 50% of the plants in the two middle/central harvestable rows produced a flower each. For number of days to 50% podding, five plants were randomly selected and tagged within the harvestable plot area. To calculate 50% podding, plants were monitored daily and the number of plants that had developed pods. The number of days to 50% podding is the total number of days from the date of sowing to the day when half of the tagged plants have formed pods.

2.4.3. Plant Vegetative Growth

1) Plant height and stem diameter

Plant height and stem diameter were measured from five randomly sampled plants using measuring tape and vernier calliper respectively at 4, 6, 8, 10, and 12 WAP and their averages were used.

2) Number of branches and leaves per plant

This was determined by counting all the developed primary lateral branches on each of the five tagged plants. The number of leaves per plant was counted after 4, 6, 8, 10, and 12 WAP by counting all leaves of the five randomly tagged plants. The mean number of branches and the leaves per plant for each treatment was recorded for each of the treatments.

3) Canopy spread, chlorophyll content of leaf, and dry matter accumulation

The maximum canopy spread of the plant in north-south and east-west directions on the five randomly sampled plants was measured with measuring rule and the mean values were computed. The leaf chlorophyll content was determined using the chlorophyll meter at 6 and 10 WAP using the three leaves located at the middle of the growing plant and their averages were used. To estimate the dry matter accumulation, five plants were randomly sampled from each plot at 4, 6, 8, 10, and 12 WAP and were cut into smaller pieces. After that, the fresh weight was taken using the electronic balance and the samples were oven-dried at 70˚C for 48 hours. Samples were then weighed using an electronic balance and the dry matter yield of plants per treatment was subsequently estimated.

2.4.4. Yield and Yield Components

For yield and yield component analysis the harvest maturity standards were taken into consideration. For instance, the fruit size ranged from 5 - 10 cm, the texture was bright green, soft, and non-fibrous and the pods were tender, crisp, and snapped easily. Picking Frequency and Number of Pickings. Harvesting commenced 45 - 55 Days After Planting (DAP), depending on treatment and growth rate. Okro fruits were harvested at 3-day intervals to prevent over-maturity. A total of 10 - 15 pickings were carried out over the productive period (approximately 4 - 6 weeks).

1) Number of fruits per plant

The number of fresh fruits per plant was obtained by harvesting all fruits from the five randomly selected (tagged) plants at physiological maturity. The number of fruits in each one of the tagged plants was counted and then computed to obtain the mean number of fruits per plant for all treatments. The number of fruits per plant was recorded cumulatively across all harvests. The final value for each plant was computed as: Total fruits per plant = Σ (fruits harvested per picking).

2) Fruit length and diameter

The length of five randomly selected fruits was measured in centimetres from the base level of the fruit to the apex using a meter rule at the 1st, 2nd, 3rd, 4th, and 5th picks and their mean values were calculated. The fruit diameter was measured by taking the mid-part of the fruit using a vernier calliper at the 1st to 5th harvest and the mean values were computed.

3) Total fruit yield

The fruit yield per hectare was determined at harvest from the harvested fruits of the two middle/ harvestable rows. The total weight per plot was expressed in kilograms per hectare and the mean was recorded.

2.4.5. Economic Analysis

Economic analysis was carried out to determine the profitability and economic viability of okro production under the different treatment combinations. The analysis involved the computation of Total Gross Benefits (TGB), Total Variable Cost (TVC), Net Benefits (NB), Benefit-Cost Ratio (BCR), and marginal rate of return (MRR).

The TGB was obtained by multiplying the total yield (kg/ha) by the prevailing market price of okro (Gh₵/kg). The TVC included all expenses that varied with production, such as the cost of seed, fertilizers, manure, labor, and other field operations. The NB was calculated as:

$$\text{NB} = \text{TGB} - \text{TVC}$$

The BCR was determined as the ratio of Net Benefit to Total Variable Cost, which indicates the profitability of each treatment. A BCR greater than one implies that the enterprise is profitable.

$$\text{BCR} = \frac{\text{TVC}}{\text{NB}}$$

Also, the MRR was determined as:

$$\text{MRR} = \frac{\Delta\text{NB}}{\Delta\text{TVC}} \times 100$$

3. Result and Discussion

3.1. Climatic Conditions, Initial Soil, and Poultry Manure Analysis

Table 1 indicates the climatic data of the study area in 2021 and 2022. The average humidity was about 77 % in the 2021 cropping season and that of 2022 cropping season was about 82 % Table 1. The minimum rainfall and maximum rainfall recorded were 34.4 mm in January and 225.1 mm in September in the 2022 cropping season Table 1.

Table 1. Climatic data of the study area in the 2021 and 2022 cropping seasons.

Month	2021 Cropping Season				2022 Cropping Season			
	Total rainfall (mm)	Temp Max (˚C)	Temp Min (˚C)	Relative humidity (%)	Total rainfall (mm)	Temp Max (˚C)	Temp Min (˚C)	Relative humidity (%)
JAN.	34.4	33.3	23.2	66	0.0	34.8	21.5	46
FEB.	63.1	35	24.3	62	72.5	35.2	24.4	60
MAR.	62.8	33.5	23.2	68	109.2	34	23.9	67

Continued

APR.	48.9	33.8	24.2	67	79.6	33.1	23.5	66
MAY	176.0	33.4	24.2	68	147.8	32.7	23.8	71
JUN	101.7	31.5	23.1	73	149.0	31	23.3	74
JUL	144.2	30.1	22.9	75	203.6	30	22.7	74
AUG	169.5	29.7	22.7	77	100.8	29.7	22	78
SEPT	225.1	30.3	23.2	77	190.1	29.1	21.9	82
OCT	208.7	32.1	22.3	72	108.4	31.9	22.5	74
NOV	73.4	33.1	23.4	68	0	0	0	0
DEC	0.0	34.3	23.7	58	0	0	0	0

Source: Ghana Meteorological Agency 2022 Mampong-Ashanti.

The preliminary physical and chemical properties of the soils at the research sites are presented in **Table 2**. **Table 3** indicates the nutrient composition of poultry manure used in the experimental sites in 2021 and 2022 cropping seasons. The physical analysis showed that the soil was sandy loam for both seasons and shows they are moderately acidic soils (**Table 1**), which is typical of many tropical cultivated soils and can influence nutrient availability, especially Phosphorus (P) which confirms the works of Mabagala [29]. The medium N status obtained in both seasons suggests enhanced soil fertility due to the previously applied amendments on the sites. This trend aligns with findings by previous researchers, who reported that organic amendments such as poultry manure significantly improve soil N status over time [30] [31]. Available P was generally low in both seasons, although slightly higher in 2022. The below-critical P levels confirm the well-known fixation effect in moderately acidic soils [32]. However, the K levels slightly above the critical threshold suggest that the soil can support crop growth, but may require supplementation to prevent depletion, consistent with the assertions of Habib *et al.* [33]. The magnesium (Mg) and calcium (Ca) levels were moderate, with the latter slightly exceeding critical thresholds (**Table 2**). The initial soil was expected to supply substantial quantities of exchangeable bases for crop growth [34].

The poultry manure characteristics showed slightly alkaline pH values of 7.22 in 2021 and 7.7 in 2022, which can help neutralize soil acidity, improve nutrient availability and be suitable for the cultivation of okro as noted by Espeland and Kettenring [35]. The manure was rich in N, P, K, Ca, Mg, and micronutrients, confirming its value as a balanced organic amendment. In support of this, previous researchers reported that poultry manure increases soil pH, macronutrients, phosphorus, and cation exchange capacity, which could improve okro production [31] [36]. These rich components in the poultry manure used enable the poultry manure to supply substantial quantities of exchangeable bases. The significantly higher P content in the poultry manure aligns with the observations by Rasool *et al.*, who noted seasonal and management-driven variation in manure nutrient composition [36]. High Na levels observed in both seasons warrant cautious use, as excessive Na can affect soil structure; however, organic carbon and moisture content indicate good decomposition dynamics and nutrient release patterns [37] [38].

Table 2. Initial soil characteristics of the experimental sites in 2021 and 2022 cropping seasons.

Soil Characteristics	2021 Cropping Season	2022 Cropping Season
Soil Chemical Properties		
Soil pH	5.5	5.5
Organic carbon (%)	0.2	1.1
Organic matter (%)	0.34	1.9
Available N mg/kg (ppm)	0.14	0.2
Available P mg/kg (ppm)	0.5	0.7
Available K cmol (+)/kg	0.16	0.2
Na (mmol/Kg)	0.05	0.1
Ca (Cmol/Kg)	1.0	3.7
Mg (Cmol/Kg)	0.2	1.0
Al (Cmol/Kg)	1.002	0.9
H (Cmol/Kg)	0.17	1.6
Physical Properties		
Sand (%)	87.44	86.4
Clay (%)	9.36	8.5
Silt (%)	3.2	5.0
Soil texture	Sandy Loam	Sandy Loam

Table 3. Characteristics of poultry manure used in the experimental sites in 2021 and 2022 cropping seasons.

Poultry Manure Characteristics	2021 Cropping Season	2022 Cropping Season
pH	7.22	7.7
N (%)	2.66	2.4
P (%)	0.09	1.42
K (%)	15.67	12.3
Na (%)	8.33	8.1
O.C (%)	18.34	21.2

Continued

O.M (%)	31.64	36.5
Ca (%)	1.16	3.2
Mg (%)	1.08	0.4
Moisture (%)	15.8	14.2

3.2. Soil Analysis after Harvest in 2021 and 2022 Cropping Seasons

Soil analyses conducted after harvesting in the study area for 2021 and 2022 cropping seasons are shown in **Table 4**. The N content observed in both seasons was 1.42% and 0.27%, and the OM content was lower in 2021 (1.84%) compared to 2022 (2.76%) (**Table 4**). The OM content of the soil was moderate in both cropping seasons (**Table 4**). These findings are similar to the research findings [39] [40]. They observed that nutrients seemed more available to okro plants in an integrated form than when organic or inorganic fertilizer was applied alone. The moderate OM content reflects the cumulative effect of manure application, consistent with findings by Manna *et al.* [41], who were of the view that repeated organic inputs enhance soil OM and buffer capacity.

Table 4. Soil analysis after harvest in 2021 and 2022 cropping seasons.

Soil parameter	2021 Cropping season	2022 Cropping season
pH	5.8	6.4
N (%)	1.42	0.27
P (mg/Kg)	1.5	5.75
K (Cmol/Kg)	1.52	1.53
Na (Cmol/Kg)	0.65	0.68
O.C (%)	0.87	2.50
O.M (%)	1.84	2.76
Ca (Cmol/Kg)	1.76	4.50
Mg (Cmol/Kg)	0.69	2.30
Al (Cmol/Kg)	1.72	1.80
H (Cmol/Kg)	0.97	2.47
SandD (%)	85.74	82.3
Clay (%)	8.56	7.62
Silt (%)	3.85	4.84
Soil texture	Loamy Soil	

3.3. Phenology of Okro

Number of days to 50% emergence

Table 5 shows result of days to 50% emergence as influenced by variety and Integrated Nutrient Management (INM) in the 2021 and 2022 cropping seasons. Days to 50% emergence were generally similar between 2021 and 2022, ranging between 6 and 9 days. There were, however, significant differences between the varieties and among the fertilizer rates in both seasons. The slight earlier in emergence time during the 2022 season may be attributed to seasonal environmental variability such as rainfall patterns and soil temperature, factors known to affect germination dynamics [42]. On average, Asontem took slightly longer days to emerge (7 - 9 days) than Clemson spineless (6 - 8 days) (**Table 5**). The application of 20 t/ha poultry manure (full PM) and NPK + PM combinations emerged slightly earlier than the control and 650 kg/ha NPK (full NPK). This might be due to the increased moisture content or retention from the poultry manure which was applied two weeks earlier before planting in the sole PM or integrated nutrient treatments. Recent studies in West Africa showed that poultry manure improves soil structure, moisture retention, and microbial activity, leading to enhanced germination and early seedling growth [43]-[45]. None of the interactions between year, variety and fertilizer were significant for days to 50% emergence.

Table 5. Number of days to 50% emergence of okro as affected by variety and integrated nutrient management.

Fertilizer combination	Days to 50% emergence					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	9	7	8	8	8	8
20 t/ha Poultry Manure	7	6	7	8	7	8
487.5 kg /ha NPK + 5t/ ha PM	7	6	7	7	7	7
325 kg/ ha NPK + 10 t/ha PM	7	6	7	7	7	7
162.5 kg/ ha NPK + 15t/ha PM	7	7	7	7	7	7
Control	8	8	8	8	8	8
Mean	8	7		8	7	
CV (%)		7.08			7.08	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.21**			0.21**	
Fertilizer (LSD = 0.05)		0.32**			0.32**	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	

Continued

Year × Fertilizer (LSD = 0.05)	NS	NS
Variety × Fert. (LSD = 0.05)	NS	NS
Year × Var. × Fert. (LSD = 0.05)	NS	NS

* = $p < 0.05$; NS = Not significant; ** = $p < 0.01$.

Number of days to 50% flowering

The effects of INM on the number of days to 50% flowering of okro varieties, are shown in Table 6. Significant differences ($p < 0.05$) were observed in both the varieties and fertilizer treatment in both seasons (Table 6). On average, the 650 kg/ha NPK flowered slightly earlier (66 days) than the other fertilizer treatments (67 - 68 days). 487.5 kg/ha NPK + 5 t/ha PM, 325 kg/ha NPK + 10 t/ha PM and 20 t/ha PM fertilizer application recorded 76 - 77 days 50% flowering. Similar to days to 50% emergence, there were no significant ($p > 0.05$) interaction effects between the variety × Fertilizer, year × Variety, year × Fertilizer or variety × Fertilizer x year. The Asontem variety exhibited delayed flowering (up to 77 days) under treatments involving 20 t/ha Poultry Manure (PM), 487.5 kg/ha NPK + 5 t/ha PM, 325 kg/ha NPK + 10 t/ha PM, and the control. In contrast, the Clemson Spineless variety, known for its early maturity, reached 50% flowering in fewer days (56 days), regardless of nutrient application treatment, demonstrating its genetic predisposition to early flowering. Similar findings have been reported that varietal differences and balanced nutrient supply significantly influence phenological traits such as days to flowering [46] [47]. The delayed flowering in Asontem could be attributed to its late-maturing nature and the possible nitrogen-induced vegetative growth resulting from higher NPK and organic manure applications [48]. Conversely, Clemson spineless recorded shorter flowering period which aligns with previous studies identifying it as an early-maturing cultivar [49]. Clemson is an early maturing okro variety hence early flowering and fewer days to 50% flowering. This finding is in support of earlier researchers [50] [51].

Table 6. Effect of integrated nutrient management on days to 50% flowering.

Fertilizer combination	Days to 50% flowering					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	76	56	66	75	56	66
20 t/ha Poultry Manure	77	57	67	76	58	67
487.5 kg /ha NPK + 5t/ ha PM	77	58	68	77	57	67
325 kg/ ha NPK + 10 t/ha PM	77	57	67	77	57	67
162.5 kg/ ha NPK + 15t/ha PM	75	56	66	77	56	67

Continued

Control	77	58	68	76	58	67
Mean	77	57		76	57	
CV (%)		2.49			2.49	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.67**			0.67**	
Fertilizer (LSD = 0.05)		1.17**			1.17**	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	
Year × Fertilizer (LSD = 0.05)		NS			NS	
Variety × Fert. (LSD = 0.05)		NS			NS	
Year × Var. × Fert. (LSD = 0.05)		NS			NS	

* = $p < 0.05$; NS = Not significant; ** = $p < 0.01$.

Number of days to 50% podding

There were significant differences between varieties and among the fertilizer treatments for days to 50% podding (**Table 7**). For instance, Clemson spineless podded earlier (57 - 61 days) than Asontem (76 - 79 days). Previous researchers observed similar varietal differences that significantly influence phenological traits such as days to podding [46]. The delayed podding in Asontem could be attributed to its late-maturing nature [48] and Clemson spineless's shorter flowering period resulting in earlier podding, which aligns with previous studies identifying it as an early-maturing cultivar [52]. However, none of the interaction effects were significant. On average, Asontem podded within 78 - 79 days, while Clemson podded 58 - 60 days across both seasons. The 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and the control treatments, on average, podded in 67 - 68 days, 69 days and 70 days, respectively **Table 7**). The treatment combinations of NPK and PM podded in 67 - 68 days similar to the full NPK (**Table 7**). The results showed that although PM and NPK combinations improved soil nutrient availability, these changes did not substantially alter the inherent phenology of the okro varieties evaluated. This observation aligns with earlier researchers who noted that INM and organic manure applications mainly enhance soil fertility, nutrient uptake and biomass accumulation, but exert limited influence on genetically predetermined reproductive timing [14] [53]. Some studies on vegetable and field crops report that genotype explains much of the variation in days to flowering/podding, while nutrient management more commonly affects vegetative vigour and final yield than the calendar date of reproductive onset. These studies have indicated that poultry manure and manure + NPK combinations often improve growth traits more than they modify phenological traits [54] [55]. Under such conditions, high organic inputs may delay reproductive development slightly due to greater early vegetative vigour and slower nutrient mineralization. Organic amendments typically release nutrients gradually, which can promote vigorous vegetative growth and sometimes extend the vegetative phase before flowering or podding [54]. In conclusion, varietal differences remained the most significant determinant of podding date in this experiment. The findings confirm that phenology in okro is largely genotype-controlled, with nutrient management exerting only minor modifications under typical field conditions in Ghana's forest savannah transition zone.

Table 7. Effect of integrated nutrient management on the number of days to 50% podding.

Fertilizer combination	Number of Days to 50% podding					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	77	57	67	78	58	68
20 t/ha Poultry Manure	79	58	69	78	59	69
487.5 kg /ha NPK + 5t/ ha PM	78	58	68	79	60	70
325 kg/ ha NPK + 10 t/ha PM	79	59	69	78	60	69
162.5 kg/ ha NPK + 15t/ha PM	76	58	67	78	59	69
Control	80	60	70	79	61	70
Mean	78	58		79	60	
CV (%)		2.26			2.26	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.54**			0.54**	
Fertilizer (LSD = 0.05)		1.27*			1.27*	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	
Year × Fertilizer (LSD = 0.05)		NS			NS	
Variety × Fert. (LSD = 0.05)		NS			NS	
Year × Var. × Fert. (LSD = 0.05)		NS			NS	

* = $p < 0.05$; NS = Not significant; ** = $p < 0.01$.

3.4. Vegetative Growth Parameters

Plant height

Figure 1 and Figure 2 show the effects of different fertilizer combinations on plant height of two okro varieties (Asontem and Clemson) during the 2021 and 2022 cropping seasons.

In both years, fertilizer application significantly ($p < 0.05$) increased plant height of both varieties compared to the control across all sampling periods from 4 to 12 Weeks After Planting (WAP). For instance, in the 2021 cropping season, the combination of 487.5 kg/ha NPK + 5 t/ha PM, 325 kg/ha + 10 t/ha PM and 20 t/ha PM generally produced the tallest plants for both Asontem and Clemson spineless across the sampling period, while 650 kg/ha NPK and 162.5 kg/ha NPK + 15 t/ha PM produced intermediate plant height (**Figure 1**). The control treatment produced the least or shortest plants for both Asontem and Clemson spineless (**Figure 1**). Similar results were obtained for the 2022 cropping season for both varieties where 487.5 kg/ha NPK + 5 t/ha PM, 325 kg/ha + 10 t/ha PM and 20 t/ha PM generally produced the tallest plants and the control the shortest plants (**Figure 2**). The 650 kg/ha NPK and 162.5 kg/ha NPK + 15 t/ha PM treatments produced intermediate plant height (**Figure 2**).

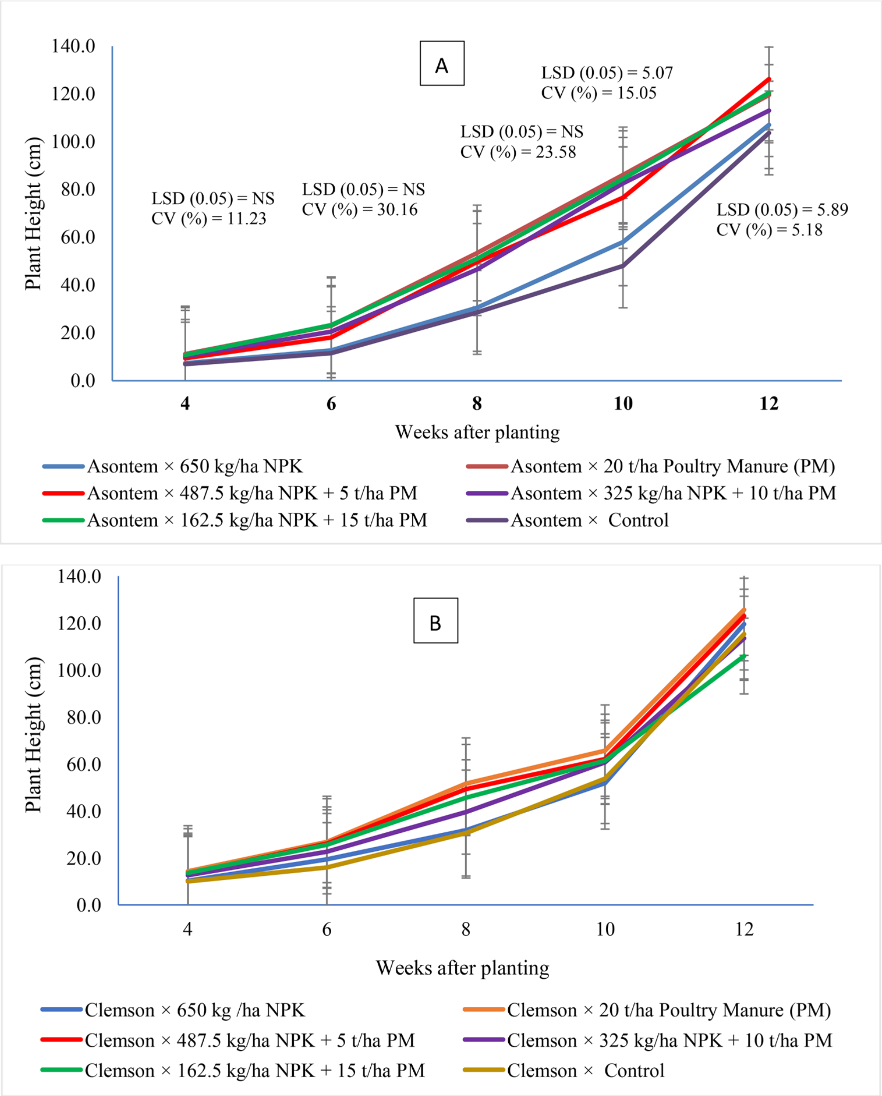


Figure 1. (A) Effect of integrated nutrient management on plant height of Asontem okro in 2021 cropping seasons; (B) Effect of integrated nutrient management on plant height of Clemson okro in 2021 cropping seasons.

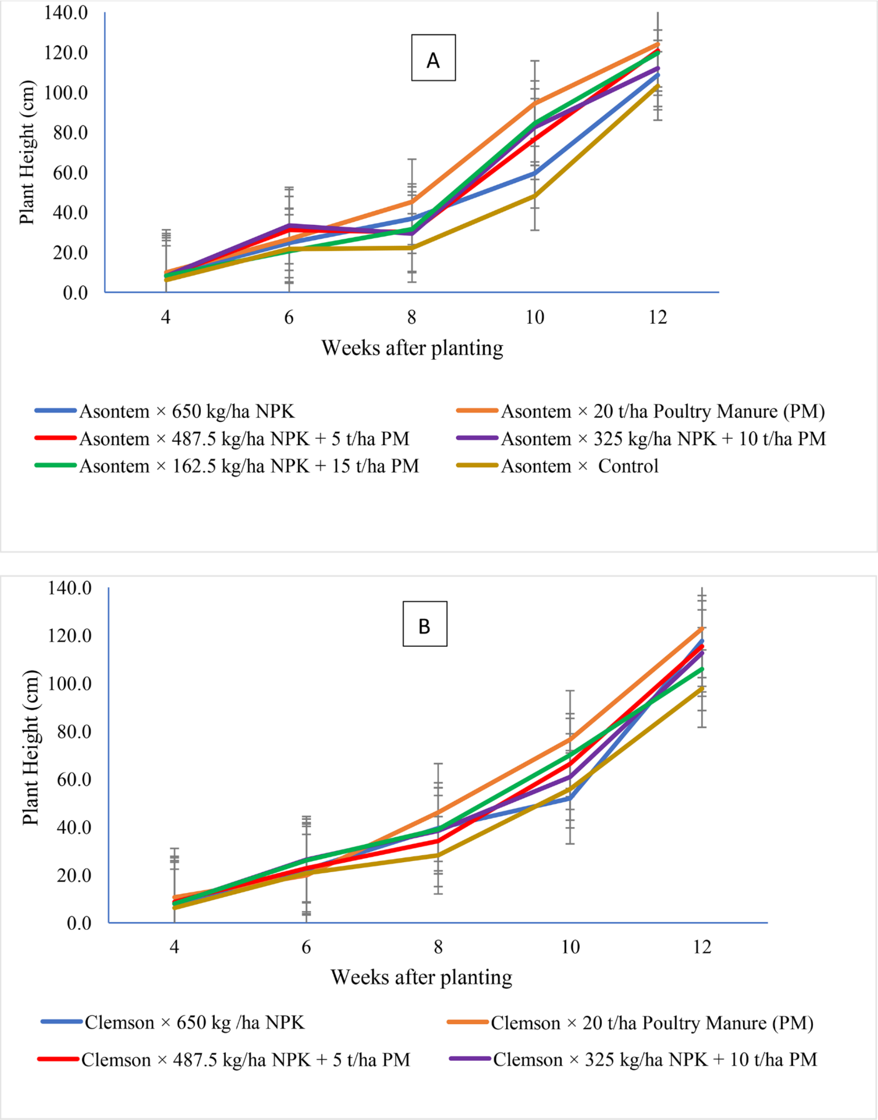


Figure 2. Effect of integrated nutrient management on plant height of okro in 2022 cropping season. (A) Asontem; (B) Clemson.

We conclude that the plant height of both Asontem and Clemson spineless varieties increased with the application of soil amendments over the control. These differences could be attributed to the INM strategy, suggesting that integrated use of poultry manure and NPK fertilizer enhances nutrient availability and promotes vegetative growth more effectively than single applications. The combined application of poultry manure and NPK fertilizer proved to be the most influential in producing good growth performance in okro [56]. Generally, the maximum plant height of okro is influenced by the presence and availability of adequate plant nutrients. Poultry manure increases soil pH, macronutrients, phosphorus, and cation exchange capacity, improving okro production [57]. Also, potassium and phosphorus are also important for maintaining proper plant growth and development [58].

Number of leaves per plant and stem diameter

Figure 3 and Figure 4 show the effect of Poultry Manure (PM) and NPK fertilizer treatments on the number of leaves per okro plant during the 2021 and 2022 cropping seasons and significant effects were observed, possibly due to the different nutrient sources and their combinations. For example, in 2021 cropping season, the number of leaves per plant for Asontem were generally higher for 325 kg/ha NPK + 10 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM, intermediate for 650 kg/ha NPK and 162.5 NPK + 15 t/ha PM and lowest for control and 20 t/ha PM over the sampling periods (Figure 3). For Clemson, 20 t/ha PM and 650 kg/ha NPK had the highest number of leaves per plant, with control (no fertilizer producing the lowest number of leaves per plant). The 325 kg/ha NPK + 10 t/ha PM,

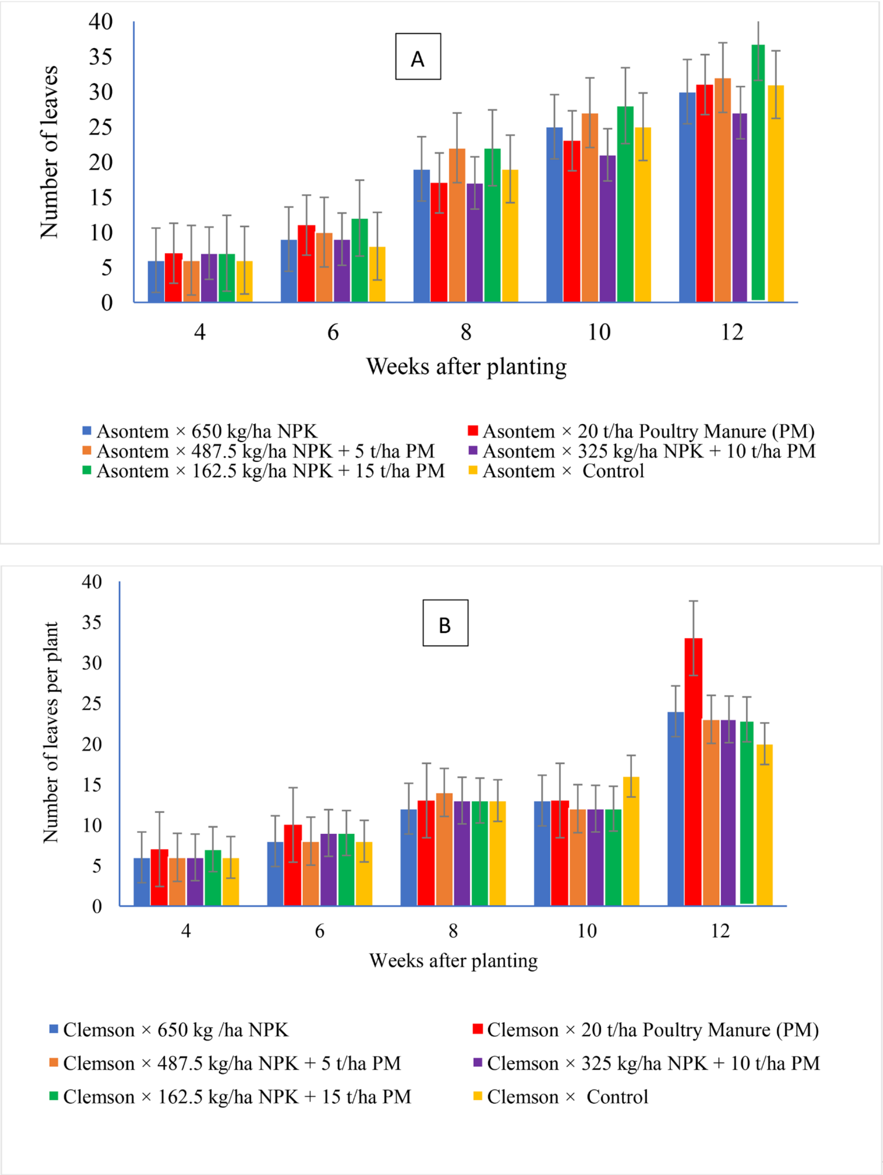


Figure 3. Effect of integrated nutrient management on number of leaves of okro in 2021 cropping seasons. (A) Asontem; (B) Clemson.

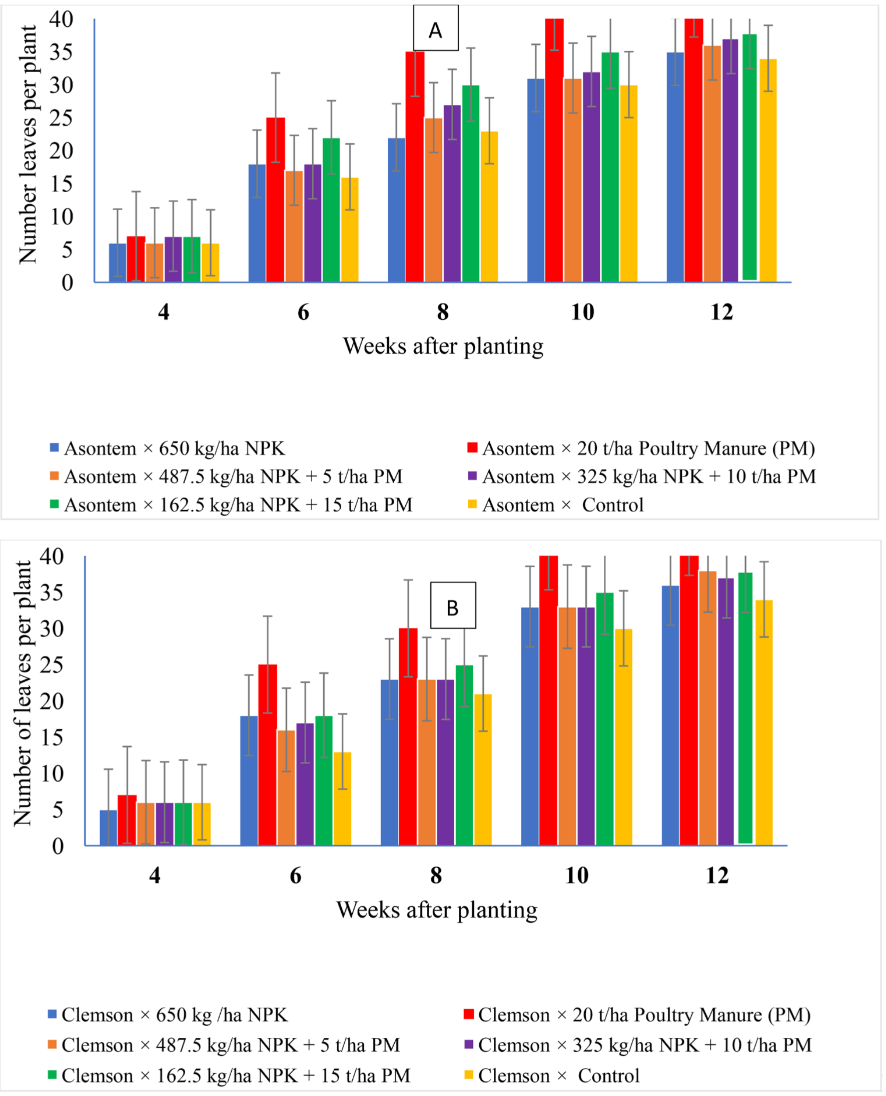


Figure 4. Effect of integrated nutrient management on number of leaves of okro in 2022 cropping season. (A) Asontem; (B) Clemson.

487.5 kg/ha NPK + 5 t/ha PM and 162.5 NPK + 15 t/ha PM had intermediate number of leaves per plant (Figure 3). In 2022, for both Asontem and Clemson spinless, 20 t/ha PM and 162.5 NPK + 15 t/ha PM generally produced the highest number of leaves per plant, followed by 650 kg/ha NPK, 325 kg/ha NPK + 10 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM, while the control (no fertilizer) had the least number of leaves per plant over the sampling periods (Figure 4).

The results in Figure 5 and Figure 6 show the effect of INM on the stem diameter of Asontem and Clemson spineless okro varieties during the 2021 and 2022 cropping seasons. Generally, the stem diameter did not differ significantly over the sampling in 2021. However, 325 kg/ha NPK + 10 t/ha PM and 20 t/ha PM had slightly bigger stem diameters for Asontem and the control (no fertilizer) with the least stem diameter (Figure 5). The Clemson variety had larger stem diameter under 162.5 kg/ha + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM over the sampling periods, with the control having the least stem diameter (**Figure 5**). Similarly, in 2022 cropping season, the stem diameter did not differ significantly over the sampling periods for both Asontem and Clemson spineless. However, generally, 20 t/ha PM, 325 kg/ha NPK + 10 t/ha PM, 162.5 kg/ha + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM had slightly bigger stems for the two varieties, while the control had the lowest stem diameter (**Figure 6**).

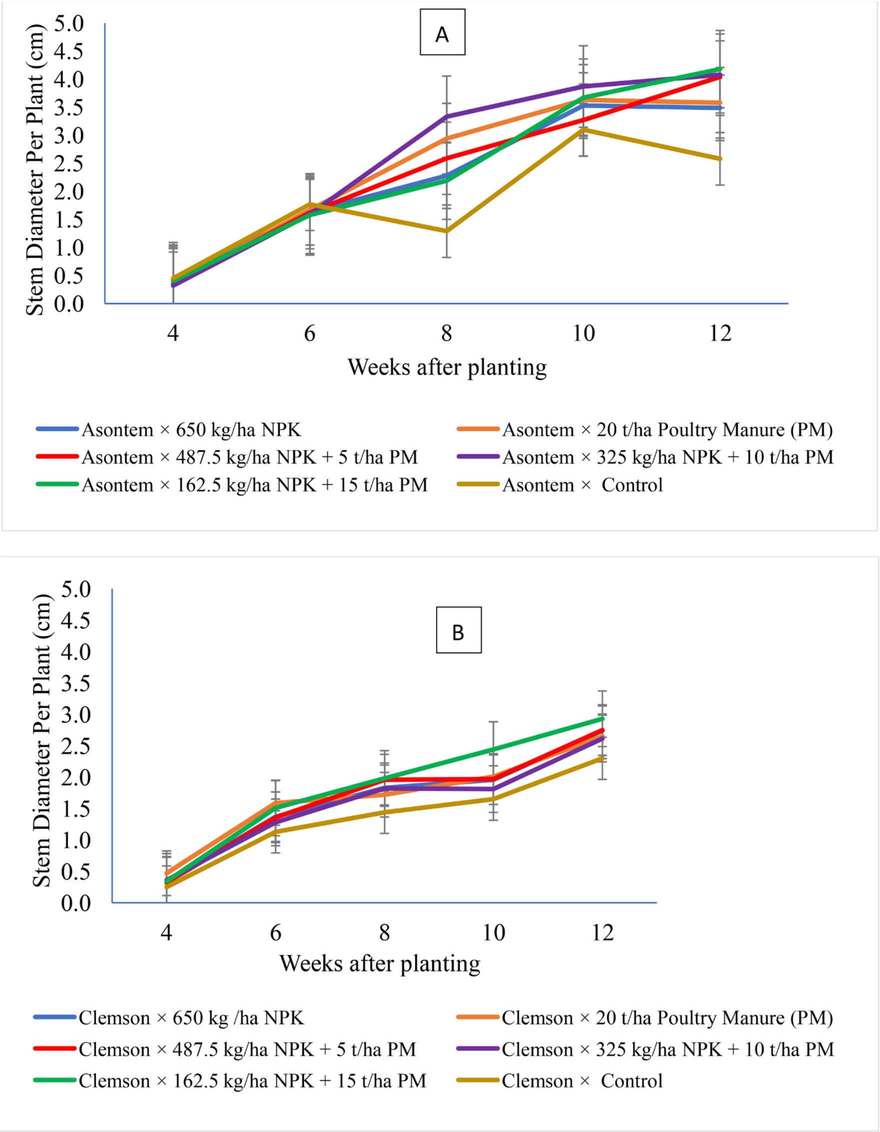


Figure 5. Effect of integrated nutrient management on stem diameter of okro in 2021 cropping season. (A) Asontem; (B) Clemson.

Treatments combining moderate levels of NPK and poultry manure produced higher leaf numbers and stem diameter, indicating that a balanced nutrient supply enhances vegetative growth and leaf and stem development. These findings are also consistent with earlier studies that reported that combining organic and inorganic fertilizers promotes leaf formation and plant growth by improving soil fertility, nutrient uptake, and chlorophyll synthesis [59] [60]. The lower leaf numbers per plant and stem diameter in control treatment and low-nutrient treatments suggest nutrient deficiencies, particularly nitrogen, which is essential for leaf growth and photosynthetic activity [61] [62]. Fewer leaf numbers and stem diameter have been observed in the control treatment which could be partly attributed to nutrient imbalances, thereby limiting leaf expansion and photosynthetic efficiency [63]; and low organic carbon limiting plant growth and stem expansion [64]. The varietal differences observed with Clemson Spineless producing fewer leaves than Asontem, can be attributed to genetic variation, as early maturing varieties typically invest more in reproductive growth than in vegetative expansion, and their genetic potential for greater biomass accumulation and stem robustness [65].

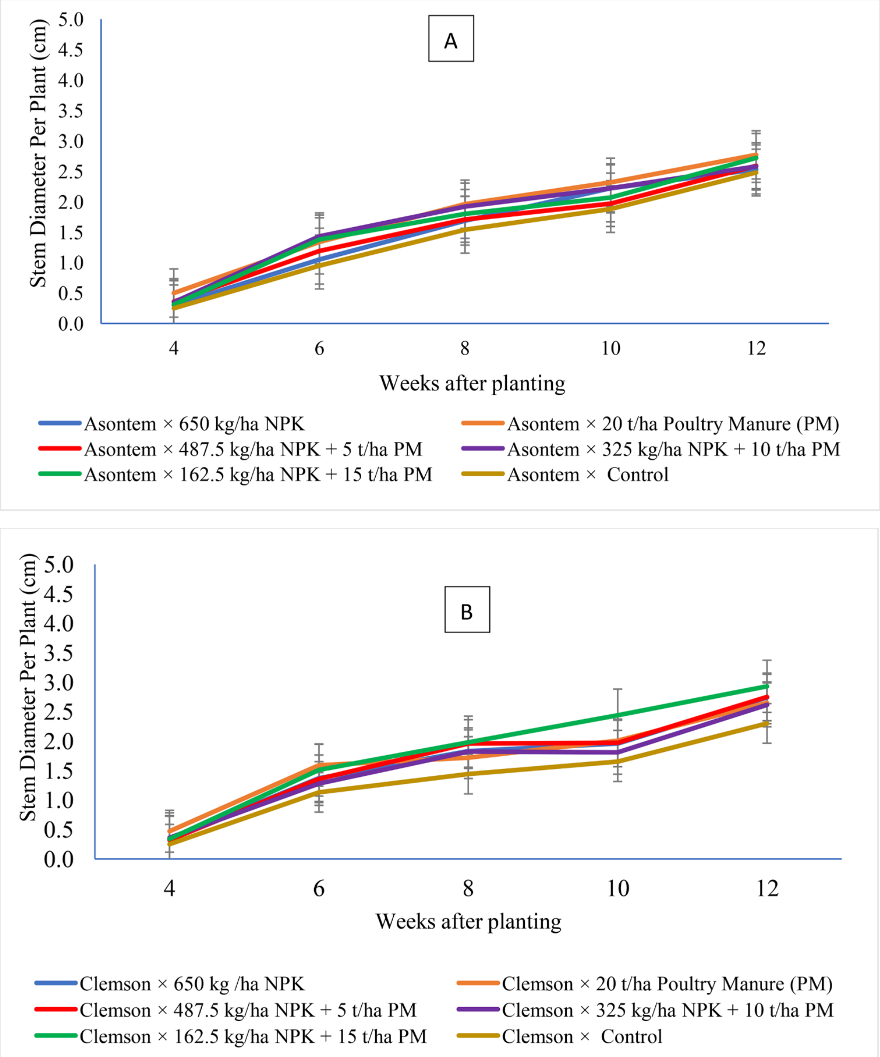


Figure 6. Effect of integrated nutrient management on stem diameter of okro in 2022 cropping season. (A) Asontem; (B) Clemson.

Number of branches per plant

Results in **Figure 7** and **Figure 8** show the number of branches per okro plant as influenced by integrated nutrient management. Generally, there were no significant differences in the number of branches produced per plant among the fertilizer treatments for both Asontem and Clemson spineless varieties for both cropping seasons (**Figure 7** and **Figure 8**). The integrated nutrient combinations of NPK and PM had similar number of branches per plant as the sole NPK, sole PM and the control. The Clemson variety recorded a higher number of branches compared to Asontem indicating genetic variability in branching potential. Varietal differences in branching have been widely reported in crops such as okro, where genotype influences vegetative growth and response to nutrient availability [66] [67]. Generally, poultry manure or its combinations with NPK had higher number of branches compared to the control and sole NPK application. Previous studies reported that the production of okro with poultry manure could increase plant height and number of branches, thus indicating the importance of poultry manure

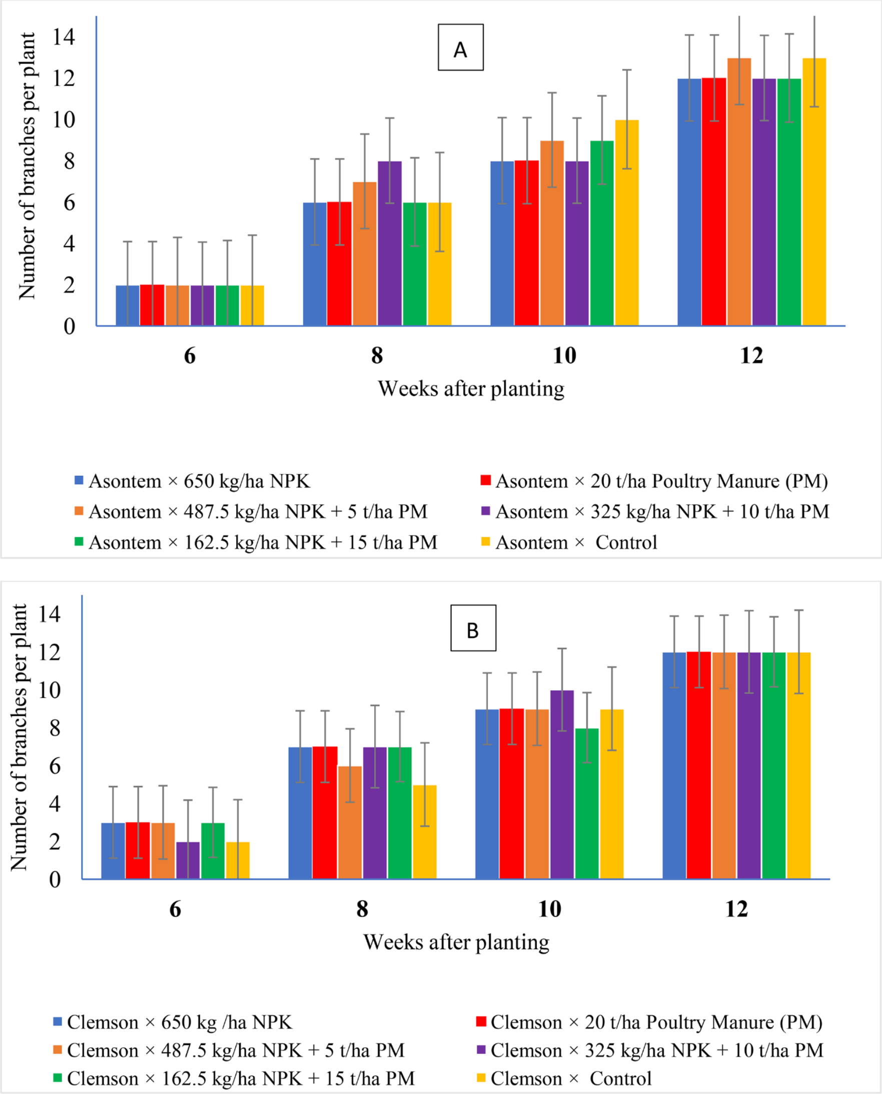


Figure 7. Effect of integrated nutrient management on number of branches of okro in 2021 cropping seasons. (A) Asontem; (B) Clemson.

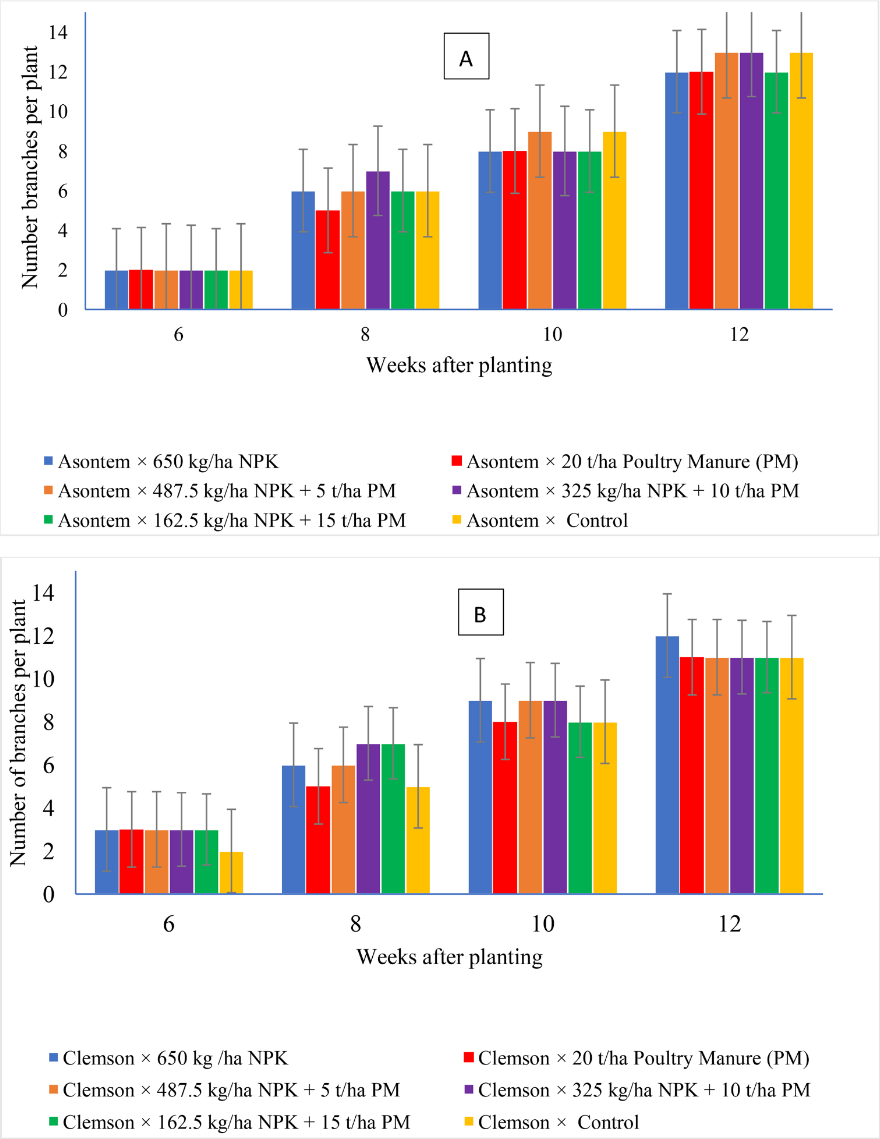
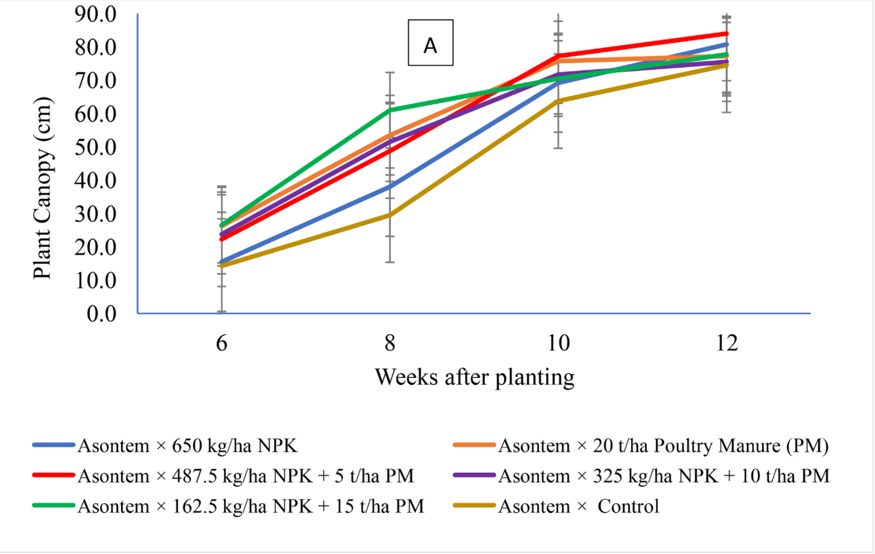


Figure 8. Effect of integrated nutrient management on number of branches of okro in 2022 cropping season. (A) Asontem; (B) Clemson.

on the vegetative growth of okro [68]. This is also in conformity with the previous report that poultry manure contains essential nutrients which are associated with high photosynthetic activities that promote root and vegetative growth [69]. Similar results were reported that nutrient applications significantly enhanced vegetative growth attributes due to improved nutrient uptake and photosynthetic activity [70]. The significant year × variety interaction suggests that environmental conditions across seasons also influenced varietal expression, aligning with earlier studies [71]. They found that genotype × environment interactions significantly affect plant morphological traits under Integrated Nutrient Management (INM). Similarly, the environmental conditions modulated the fertilizer response an outcome consistent with studies emphasizing the influence of seasonal variability on INM performance [72].

Plant canopy spread

Figure 9 and Figure 10 show the effects of INM on plant canopy spread of Asontem and Clemson spineless varieties in the 2021 and 2022 cropping seasons. In 2021 cropping, the canopy spread for Asontem was widest for the 20 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.2 kg/ha NPK + 5 t/ha PM treatments, intermediate for 650 kg/ha NPK and 325 kg/ha + 10 t/ha PM and least canopy spread for control (no fertilizer treatment (Figure 9). The canopy spread for Clemson was widest for 20 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM, intermediate for 487.2 kg/ha NPK + 5 t/ha PM and 487.2 kg/ha NPK + 5 t/ha PM and least for control and 650 kg/ha NPK (Figure 9). Similar results for both varieties were obtained in 2022 cropping season as in 2021 cropping season. For Asontem, the 20 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.2 kg/ha NPK + 5 t/ha PM treatments had the widest canopy spread, intermediate canopy spread for 650 kg/ha NPK and 325 kg/ha + 10 t/ha PM and the least canopy spread for control (no fertilizer treatment (Figure 10). For Clemson, the 20 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM had the widest canopy spread, while 487.2 kg/ha NPK + 5 t/ha PM and 487.2 kg/ha NPK + 5 t/ha PM had the intermediate canopy spread and the least spread was obtained for control and 650 kg/ha NPK (Figure 10). The results indicate that Poultry Manure (PM) significantly enhanced plant canopy spread, with Asontem plants treated with 20 t/ha PM showing larger canopy sizes than those receiving 650 kg/ha NPK or control treatments. This aligns with previous studies reporting that organic amendments, such as poultry manure, improve vegetative growth in okro by enhancing nutrient availability and soil structure [44] [73]. Integrated Nutrient Management (INM), combining NPK and PM fertilizers resulted in the most pronounced canopy development compared to both single-fertilizer treatments. This confirms findings that INM synergistically enhances growth and yield in okro by balancing macro- and micro-nutrients while improving soil fertility [74]. Control plots without fertilizer consistently exhibited the smallest canopy sizes, reinforcing the critical role of fertilization in promoting okro canopy development.



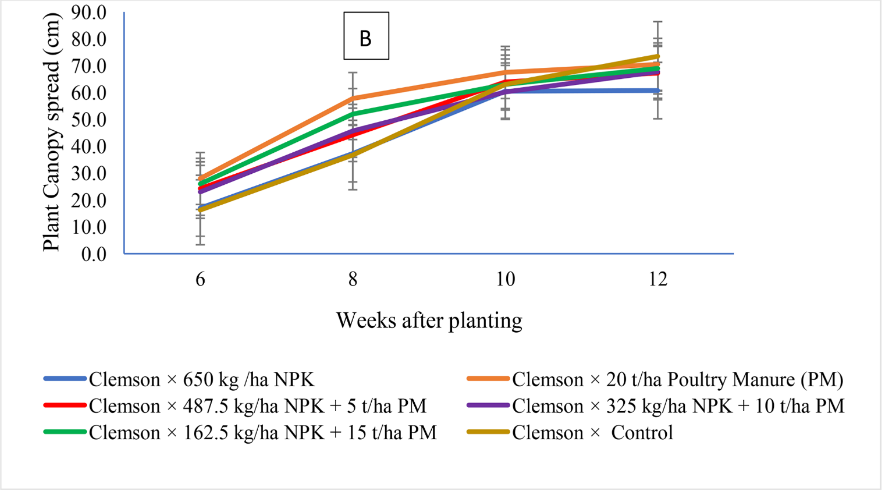


Figure 9. Effect of integrated nutrient management on plant canopy spread per plant in 2021 cropping season. (A) Asontem; (B) Clemson.

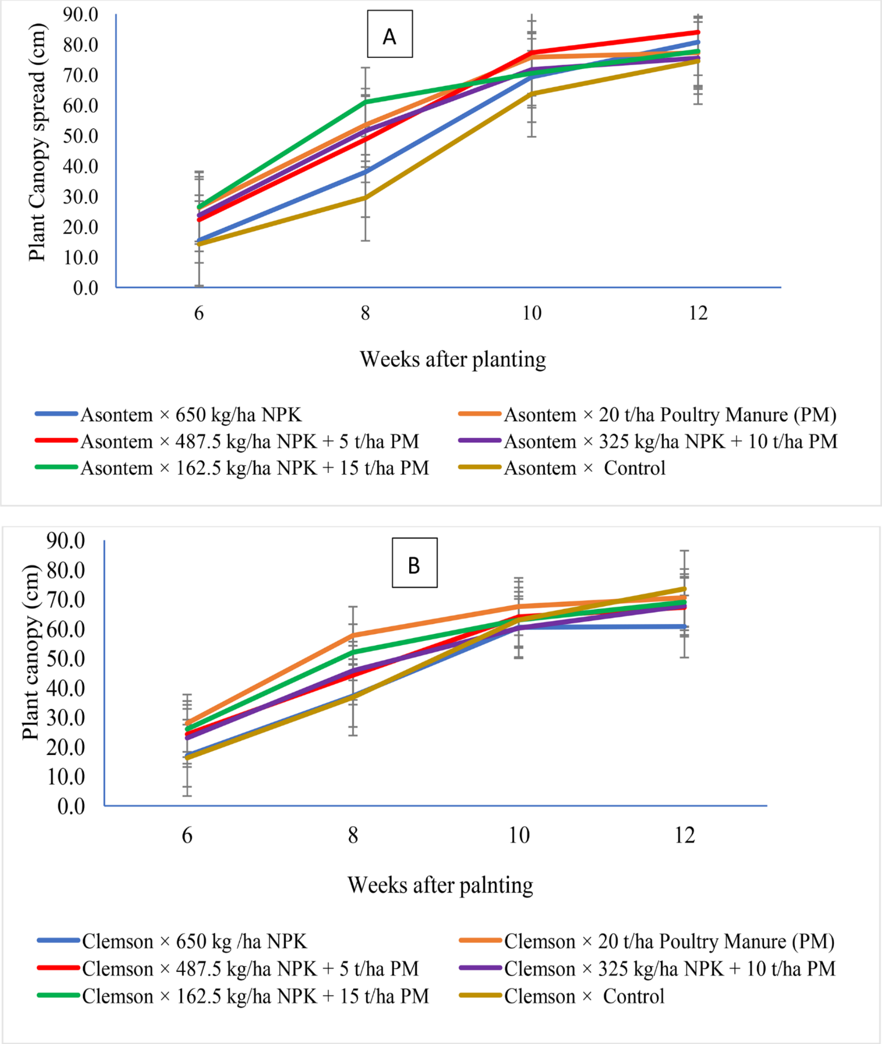


Figure 10. Effect of integrated nutrient management on plant canopy spread per plant in 2022 cropping season. (A) Asontem; (B) Clemson.

Chlorophyll content of leaf

Figure 11 and Figure 12 show the results of chlorophyll content of leaf as influenced by the combined effect of Poultry Manure (PM) and NPK (15:15:15) fertilizer in both 2021 and 2022 cropping seasons. In both cropping seasons, the Asontem variety consistently showed higher chlorophyll content than the Clemson variety under all fertilizer treatments. This indicates that Asontem has a greater physiological efficiency and better response to fertilizer application, possibly due to genetic differences in nutrient use efficiency or leaf pigment concentration. These results are also consistent with the findings of Olowe *et al.* [75], who reported that okra varieties differ in their ability to assimilate and utilize nutrients, influencing leaf greenness and chlorophyll concentration. Generally, the chlorophyll content did not differ significantly at each sampling period for both seasons. In 2021, the 325 kg/ha

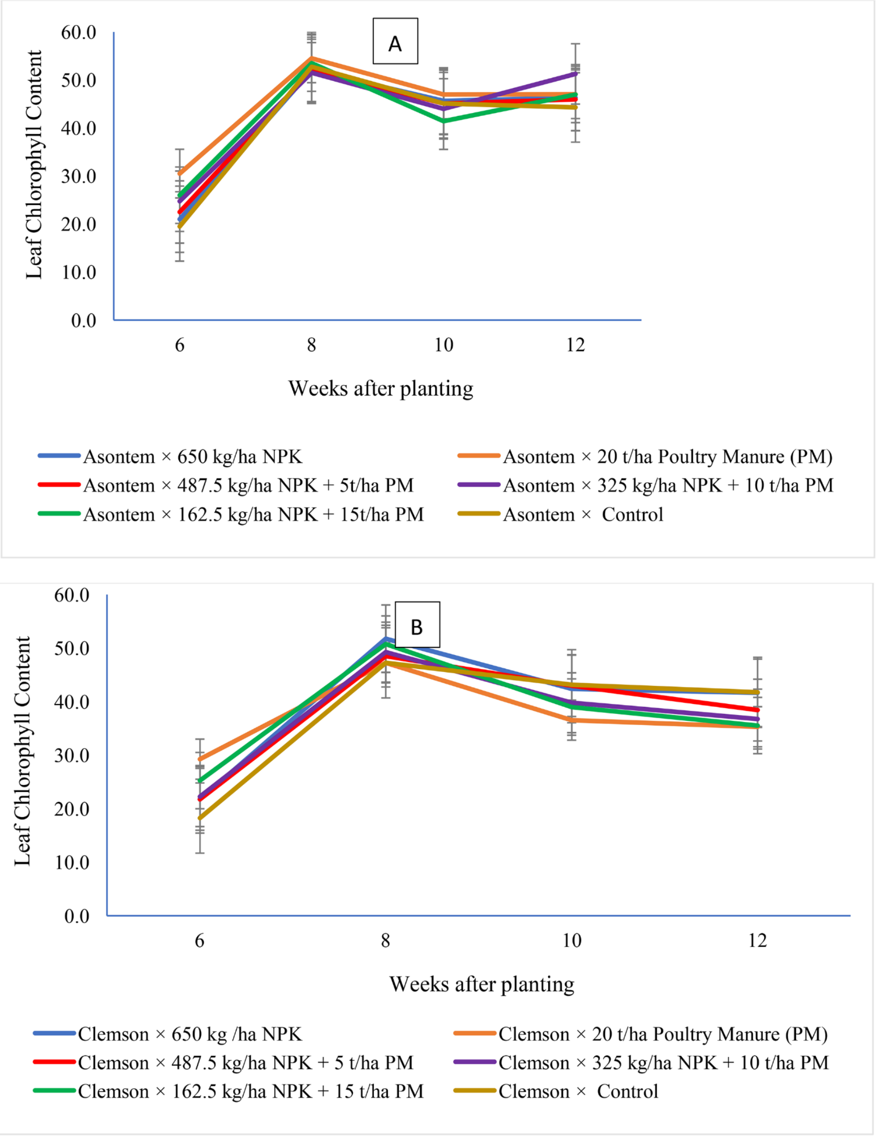


Figure 11. Effect of integrated nutrient management on leaf chlorophyll content for 2021 cropping season. (A) Asontem; (B) Clemson.

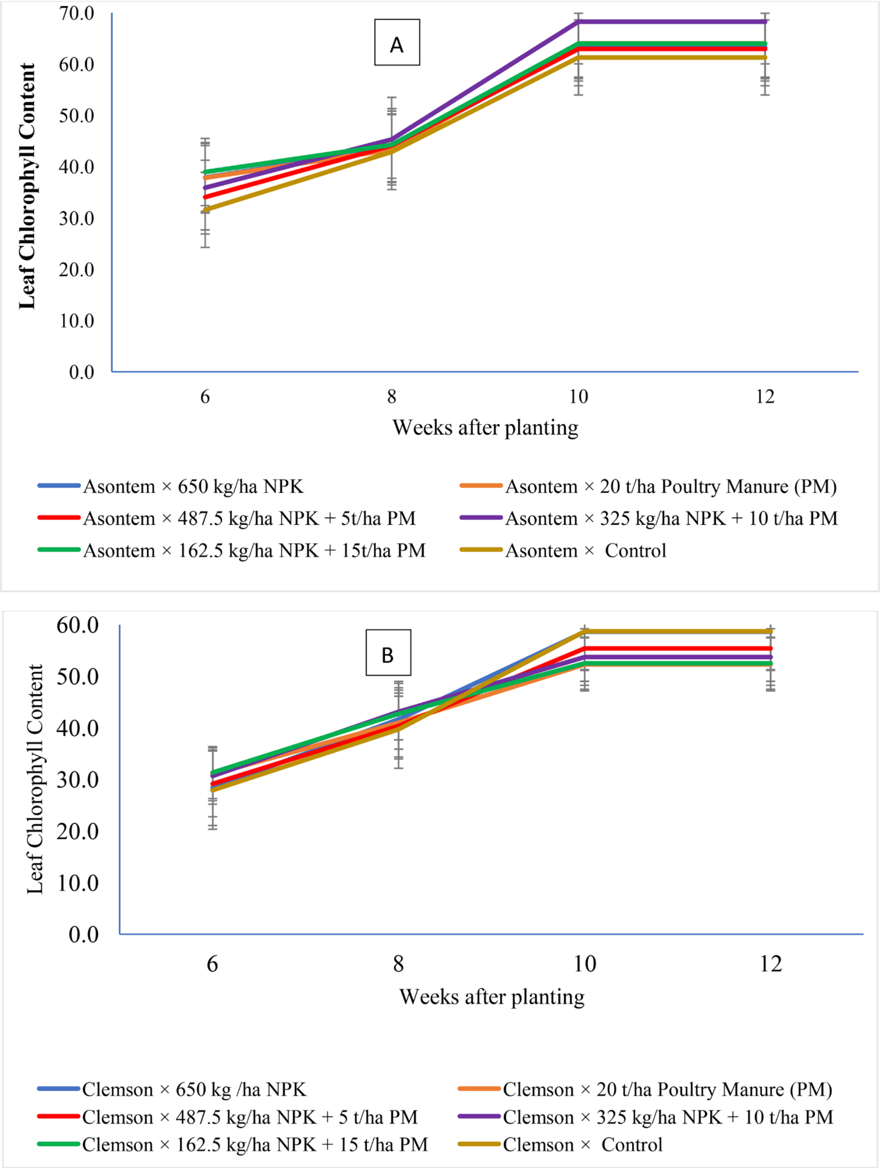


Figure 12. Effect of integrated nutrient management on leaf chlorophyll content for 2022 cropping season. (A) Asontem; (B) Clemson.

NPK + 10 t/ha poultry manure as well as the 20 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM treatments applied to Asontem produced slightly higher chlorophyll content, while the control had the least chlorophyll content (Figure 11). For Clemson spineless the control and 487.2 kg/ha NPK + 5 t/ha PM had slightly higher chlorophyll content, while 20 t/ha PM had the least chlorophyll content (Figure 11). In 2022 cropping season, similar results were obtained for both Asontem and Clemson spineless as in 2021. The 20 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM treatments applied to Asontem produced slightly higher chlorophyll content, while the control had the least chlorophyll content (Figure 12). The 487.2 kg/ha NPK + 5 t/ha PM had slightly higher chlorophyll content applied to the Clemson spineless variety, while 20 t/ha PM had the least chlorophyll content (Figure 12). The results on leaf chlorophyll content revealed significant variation among treatments due to differences in Integrated Nutrient Management (INM) and okro variety. This indicates that the integration of organic and inorganic nutrients improved chlorophyll synthesis by ensuring a steady and balanced supply of essential nutrients, particularly nitrogen, which is a key component of chlorophyll molecules [76] [77]. Moreover, the combined application of NPK and poultry manure has been shown to enhance soil fertility, microbial activity, and nutrient availability, leading to higher chlorophyll content and improved plant vigor [78] [79].

Dry matter accumulation

Figure 13 shows the results of dry matter yield accumulation of Asontem and Clemson spineless varieties as affected by INM for the 2021 and 2022 cropping seasons combined. The trends in dry matter accumulation were similar for both varieties. Generally, the combination of 325 kg/ha NPK + 10 t/ha PM and 20 t/ha PM applied to both varieties had the highest dry matter accumulation over the sampling periods (**Figure 13**). The combination of 162.5 kg/ha NPK + 15 t/ha PM

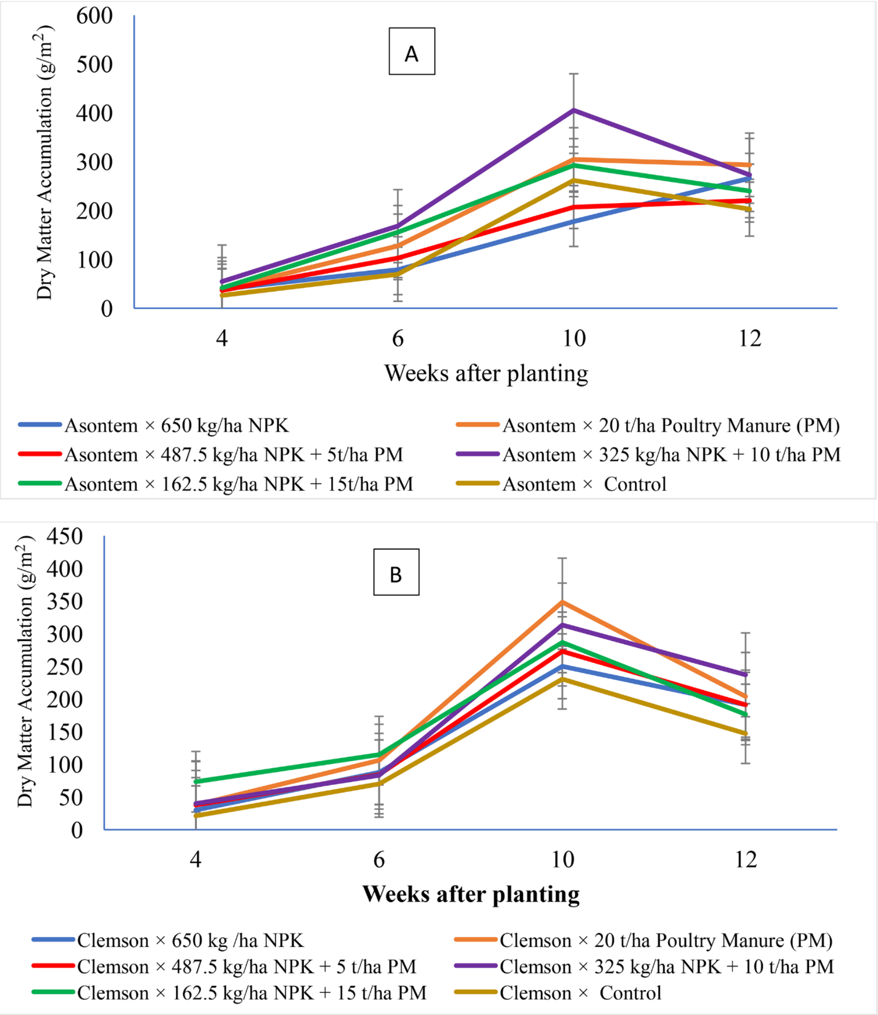


Figure 13. Effect of integrated nutrient management on dry matter accumulation of okro 2021 and 2022.

and 487.5 kg/ha NPK + 5 t/ha PM produced intermediate dry accumulation over the sampling periods, while the 650 kg/ha NPK and no fertilizer (Control), on average, had the least dry matter accumulation over the sampling periods (**Figure 13**). These results indicate that combining organic and inorganic nutrient sources enhances biomass accumulation through improved nutrient availability and soil fertility, and supplying both immediate and slow-release nutrients [59] [79]. The superior performance of treatments that integrated poultry manure with NPK fertilizer could also be attributed to the synergistic effects of the organic and inorganic nutrient sources. While poultry manure improves soil organic matter, microbial activity, and nutrient retention, the NPK provides readily available nutrients essential for rapid vegetative growth [78]. Furthermore, poultry manure combined with NPK fertilizer increases soil pH, macronutrients, phosphorus and cation exchange capacity of the soil which improves dry matter yield of okro (57). Earlier researchers have observed that integrated nutrient management significantly increased dry matter production in okro and other vegetable crops by enhancing photosynthetic efficiency and nutrient uptake [79] [80]. The consistently low dry matter in the control treatment suggests nutrient limitations that restricted plant growth and biomass accumulation [81]. Differences between varieties can be attributed to genetic variations in nutrient use efficiency and growth potential [81]. The relatively lower DMA in Clemson Spineless compared to Asontem reflects its early-maturing nature, which typically results in less vegetative biomass production.

Yield and Yield Components

Number of fruits per plant

Table 8 results show the effects of the INM treatments on the number of fruits per plant (**Table 8**). There were significant differences in the number of fruits per plant between the varieties and among the fertilizer combinations for both seasons. On average, Clemson spineless produced slightly higher number of fruits per plant (19 - 22) than Asontem (17 - 20) in both seasons (**Table 8**). Across the two seasons, the (no fertilizer) treatment had the least number of fruits per plant (15 - 19) compared with the fertilizer treatments (19 - 22). Although, the number of fruits per plant was similar among the fertilizer treatments, the 325 kg/ha NPK + 10 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM produced slightly higher fruits per plant (21 - 22) compared with the others, which ranged from 19 - 21 fruits per plant (**Table 8**).

Combined application of NPK fertilizer and Poultry Manure (PM) only significantly increased the number of fruits per plant for both Asontem and Clemson varieties (**Table 8**). These findings suggest that integrated nutrient management (i.e., combining inorganic and organic fertilizers) enhances fruit production (59) through its capacity to improve soil structure, water retention, and nutrient availability due to a lower C/N ratio, which facilitates faster mineralization (19). Several researchers have reported that the combinations of organic and inorganic fertilizers perform better on crop yield than when each of them is used alone [82]. The control group has the lowest number of fruits per plant in both years. This confirms the earlier research that the organic and inorganic fertilizers affect okro yield and quality, and can significantly increase fruit yield, suggesting a synergistic effect [83].

Table 8. Influence of integrated nutrient management on number of fruits per plant.

Fertilizer	Number of fruits per plant					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	20	21	21	16	18	17
20 t/ha Poultry Manure	20	22	21	18	20	19
487.5 kg /ha NPK + 5 t/ ha PM	20	22	21	18	20	19
325 kg/ ha NPK + 10 t/ha PM	21	23	22	18	21	20
162.5 kg/ ha NPK + 15 t/ha PM	20	23	22	18	21	20
Control	18	20	19	14	16	15
Mean	20	22		17	19	
CV (%)		10.91			10.91	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.86**			0.86**	
Fertilizer (LSD = 0.05)		1.49*			1.49*	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	
Year × Fertilizer (LSD = 0.05)		NS			NS	
Variety × Fert. (LSD = 0.05)		NS			NS	
Year × Var. × Fert. (LSD = 0.05)		NS			NS	

NS = Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Fruit length and diameter

Table 9 shows the fresh fruit length of Asontem and Clemson spineless okro varieties as affected by INM during the 2021 and 2022 cropping seasons. Generally, the fruit length differed significantly among the varieties in 2021 and the 2022 cropping seasons. The year × Fertilizer interaction was also significant for the fruit length. However, there were no significant differences among the fertilizer treatments nor the year × Variety, variety × Fertilizer and Year × Variety × Fertilizer interactions. In both 2021 and 2022 cropping seasons, the Clemson spineless variety had longer fruit length (9.22 cm and 12.99 cm, respectively) than Asontem variety (6.79 cm and 10.19 cm, respectively) (Table 9). For the year × Fertilizer interaction, 325 kg/ha NPK + 10 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM treatments had the longest mean fruit length in the 2021 cropping season (8.28 - 8.60 cm), while the 650 kg/ha NPK and 487.5 kg/ha + 5 t/ha PM had the longest mean fruit length in the 2022 cropping season (12.05 -13.20 cm). The 650 kg/ha NPK had the least mean fruit length in 2021 cropping season, while the control (no fertilizer) had the least fruit length in 2022 cropping season (Table 9).

Table 9. Effect of integrated nutrient management on fruit length of okro varieties.

Fertilizer	Fruit length (cm)					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	8.2 0	7.18	7.69	11.57	14.83	13.20
20 t/ha Poultry Manure	6.15	10.10	8.13	10.87	12.35	11.61
487.5 kg /ha NPK + 5 t/ ha PM	5.53	9.10	7.32	9.45	14.65	12.05
325 kg/ ha NPK + 10 t/ha PM	6.93	10.27	8.60	9.88	13.5	11.69
162.5 kg/ ha NPK + 15 t/ha PM	7.28	9.28	8.28	10.49	13.28	11.89
Control	6.68	9.40	8.04	8.87	9.36	9.12
Mean	6.79	9.22		10.19	12.99	
CV (%)		21.07			21.07	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.84**			0.84**	
Fertilizer (LSD = 0.05)		NS			NS	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	
Year × Fertilizer (LSD = 0.05)		2.06*			2.06*	
Variety × Fert. (LSD = 0.05)		NS			NS	
Year × Var. × Fert. (LSD = 0.05)		NS			NS	

NS = Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Table 10 shows the effects of different fertilizer combinations on fruit diameter of two okro varieties (Asontem and Clemson) during the 2021 and 2022 cropping seasons. Generally, the fruit diameter differed significantly between the varieties and among the fertilizer treatments in both cropping seasons. On average in the 2021 and 2022 cropping seasons, Asontem had greater fruit diameter (2.30 cm and 2.69 cm, respectively) compared with the Clemson spineless variety (2.01 cm and 2.41 cm, respectively) (Table 10). For the fertilizer treatments, the 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and 325 kg/ha NPK + 10 t/ha PM ((1/2 NPK + 1/2 PM) had the highest fruit diameter in 2021 cropping season, while the control (no fertilizer) treatment had the least fruit diameter. Similar results were obtained in the 2022 cropping season, where the 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and 325 kg/ha NPK + 10 t/ha PM ((1/2 NPK + 1/2 PM) treatments had the highest fruit diameter, while the control treatment had the least fruit diameter (Table 10).

The variety × Fertilizer interaction was significant for both years. However, all the other interactions were not significant (Table 10). In 2021 and 2022 cropping seasons, 20 t/ha PM applied to Asontem had the highest fruit diameter, whereas with Clemson spinless, 650 kg/ha NPK and 162.5 kg/ha NPK + 15 t/ha PM had the highest fruit diameter for the 2021 and 2022 cropping seasons, respectively. The least fruit diameter for Asontem was obtained for 162.5 kg/ha NPK + 15 t/ha PM in both seasons, while for Clemson spineless, it was the control (no fertilizer) in 2021 and control (no fertilizer) and 487.5 kg/ha NPK + 5 t/ha PM in 2022 cropping season (Table 10).

Table 10. Effect of integrated nutrient management on fruit diameter of okro varieties in 2021 and 2022 cropping season.

Fertilizer combination	Fruit diameter (cm)					
	2021 cropping season			2022 cropping season		
	Asontem	Clemson	Mean	Asontem	Clemson	Mean
650 kg /ha NPK	2.33	2.16	2.25	2.78	2.54	2.66
20 t/ha Poultry Manure	2.54	2.01	2.28	2.88	2.32	2.60
487.5 kg /ha NPK + 5t/ ha	2.27	1.93	2.10	2.70	2.29	2.49
325 kg/ ha NPK + 10 t/ha PM	2.27	2.08	2.18	2.81	2.42	2.62
162.5 kg/ ha NPK + 15t/ha PM	2.16	1.97	2.07	2.48	2.60	2.54
Control	2.25	1.89	2.07	2.53	2.29	2.41
Mean	2.30	2.01		2.69	2.41	
CV (%)		10.28			10.28	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.10**			0.10**	
Fertilizer (LSD = 0.05)		0.16*			0.16*	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	
Year × Fertilizer (LSD = 0.05)		NS			NS	
Variety × Fert. (LSD = 0.05)		0.23*			0.23*	
Year × Var. × Fert. (LSD = 0.05)		NS			NS	

NS = Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

The results demonstrated that Integrated Nutrient Management (INM) significantly influenced fruit length and fruit diameter in both Asontem and Clemson okro varieties (**Table 9** and **Table 10**). This trend suggests that a balanced integration of organic and inorganic fertilizers enhances vegetative and reproductive growth of okro, possibly due to improved nutrient availability and soil structure thereby promoting better fruit formation [57] [84] [85]. Previous reports confirm that moderate to high NPK and poultry manure combinations improved okro growth parameters and yield components in okro [83]. The synergistic effect of organic and inorganic fertilizers supports sustainable nutrient supply, ensuring steady plant growth and optimal fruit development [86].

Total fruit yield

Table 11 shows the effects of different fertilizer combinations on the total fruit yield of the two okro varieties (Asontem and Clemson) during the 2021 and 2022 cropping seasons. Generally, the total fruit yield differed significantly between the varieties and among the fertilizers over the 2021 and 2022 cropping seasons. There were no significant interaction effects on fruit yield. In the 2021 cropping season, Asontem produced higher fruit yield (9.39 t/ha, about 19% higher) than that produced by Clemson spineless (7.90 t/ha). Similarly, in the 2022 cropping season, Asontem produced (4.17 t/ha) about 53.3% higher than the fruit yield produced by Clemson spineless (2.72 t/ha). On average (across) in 2021, the 162.5 kg/ha NPK + 15 t/ha PM treatment significantly produced the highest total fruit yield, while the 487.5 kg/ha NPK + 5 t/ha PM and 325 kg/ha NPK + 10 t/ha PM treatments produced intermediate fruit yields. The 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and control (no fertilizer) treatments produced the least but similar total fruit yields (**Table 11**). Across the 2022 cropping season however, the 162.5 kg/ha NPK + 15 t/ha PM, 487.5 kg/ha NPK + 5 t/ha PM and 325 kg/ha NPK + 10 t/ha PM treatments produced similar but significantly higher fruit yields than the 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and control (no fertilizer) treatments.

Generally, the average total fruit yields of both Asontem and Clemson spineless varieties were influenced by integrated nutrient management, which supports previous findings [82] [85] [87]. They reported that the combinations of organic and inorganic fertilizers performed better on crop yield than when each of them is used solely. These findings also align with previous research showing that the combined application of organic and inorganic fertilizers improves soil fertility, nutrient availability, and ultimately crop yield [59] [88]. Nutrient use efficiency of crops tends to be better with a mixture of organic manure and inorganic fertilizer. Also, nutrients were more available to okro plants with the combination compared to only one type of manure [89]. The control treatments recorded the lowest total fruit yields in both years. Overall, Asontem performed better than Clemson in terms of fresh yield of okro in both 2021 and 2022 cropping seasons. The differences in the yield could be reasonably attributed to variations in weather conditions and management practices. For instance, the weather variability likely played a major role. Higher yields in 2021 may reflect more consistent rainfall or better moisture distribution, which supports continuous flowering and pod set in okro. Moderate temperatures favor vegetative growth and reduce flower abortion. In contrast, the lower yields in 2022 could be linked to erratic rainfall or short dry spells, leading to intermittent water stress and higher temperatures, which can accelerate senescence and reduce fruit retention.

Table 11. Influence of integrated nutrient management on total fruit yield (t/ha) and number of fruits per plant.

Fertilizer combination	Total Fruit Yield (t/ha)					
	2021 cropping season			2022 cropping season		
	Asontem	Clemson	Mean	Asontem	Clemson	Mean
650 kg /ha NPK	8.99	7.89	8.44	3.83	2.39	3.11
20 t/ha Poultry Manure	8.94	7.96	8.45	3.79	2.95	3.37
487.5 kg /ha NPK + 5t/ ha	9.87	8.04	8.96	4.49	2.78	3.64
325 kg/ ha NPK + 10 t/ha PM	9.75	8.18	8.97	4.49	2.95	3.72
162.5 kg/ ha NPK + 15t/ha PM	10.03	7.84	9.94	4.73	2.98	3.86
Control	8.76	7.51	8.14	3.68	2.29	2.99
Mean	9.39	7.90		4.17	2.72	
CV (%)		9.72			9.72	
Year (LSD = 0.05)		NS			NS	
Variety (LSD = 0.05)		0.24**			0.24**	
Fertilizer (LSD = 0.05)		0.41**			0.41**	
Interaction						
Year × Variety (LSD = 0.05)		NS			NS	
Year × Fertilizer (LSD = 0.05)		NS			NS	
Variety × Fert. (LSD = 0.05)		NS			NS	
Year × Var. × Fert. (LSD = 0.05)		NS			NS	

NS = Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Partial budget analysis for 2021

The partial budget analyses were done considering only fertilizer cost and its application as the total variable cost. All other production costs such as cost of land preparation, planting, weeding, etc, that did not vary among the treatments were not considered. The partial budget analysis for the 2021 cropping season is shown in Table 12 and Table 13. In general, all the treatments were economically attractive or profitable as they had positive net benefits. Furthermore, all the Benefit: Cost Ratio (BCR) for all the fertilizer treatments under the two varieties were greater than 5.0, ranging from 10.01 - 12.13 for Asontem and 7.45 - 8.44 for Clemson spineless (Table 12 and Table 13). The results indicate that the Asontem variety with 162.5 kg/ha NPK + 15 t/ha PM application gave the highest net benefit and BCR among the treatments in 2021, while the Clemson spineless 650 kg/ha NPK gave the least net benefit and BCR. The 325 kg/ha NPK + 10 t/ha and 20 t/ha PM treatments under both Asontem and Clemson spineless gave intermediate BCR (Table 12 and Table 13).

The Dominance Analysis (DA) for the 2021 cropping season shows that Asontem no fertilizer control treatment has dominated both Clemson spineless and Asontem at 20 t/ha PM and then Clemson at 162.5 kg/ha NPK + 15 t/ha PM because these treatments had higher TVC and lower net benefit compared to the Asontem control (no fertilizer) treatment (Table 12 and Table 13). The MRR results was 66.21% for Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem control (no fertilizer treatment), indicating that adopting Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem control (no fertilizer treatment) would give an additional gain of 65.21 Ghana cedis for every extra cedi invested. Asontem at 162.5 kg/ha NPK + 15 t/ha PM has dominated all other treatments because it has a higher net benefit, but a lower TVC than all the other treatments (Table 12 and Table 13).

Table 12. Partial budget analysis of Asontem during 2021 cropping season.

	Asontem Full NPK	Asontem Full PM	Asontem 3/4 NPK + 1/4 PM	Asontem 1/2 NPK + 1/2 PM	Asontem 1/4 NPK + 3/4 PM	Asontem Control
Gross Benefits (GB)						
Total fruit yield	8.99	8.94	9.87	9.75	10.03	8.76
Farm gate price (GH¢/ton)	8000	8000	8000	8000	8000	8000
Total Gross Benefits (GH¢)	71,920	71,520	78,960	78,000	80,240	70,080
Variable Cost (VC)						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
NB (GH¢)	65,390	65,620	72422.5	71,675	74127.5	70,080
Benefit: Cost Ratio (BCR)	10.014	11.122	11.078	11.332	12.127	0.000
MRR						
	Clemson Control	Asontem Control	Clemson Full PM	Asontem Full PM	Clemson 1/4 NPK + 3/4 PM	Asontem 1/4 NPK + 3/4 PM

Continued

TVC (GH¢)	0	0	5900	5900	6112.5	6112.5
NB (GH¢)	52,570	70,080	49,820	65,620	48767.5	74127.5
			D*	D*	D*	66.217
MRR = (ΔNB/ΔTVC) × 100				221.187		

TVC = Total Variable Cost (GH¢); NB = Net Benefit (GH¢); MRR = Marginal Rate of Returns; D* = Dominated.

Table 13. Partial budget analysis of Clemson Spineless during 2021 cropping season.

	Clemson Full NPK	Clemson Full PM	Clemson 3/4 NPK + 1/4 PM	Clemson 1/2 NPK + 1/2 PM	Clemson 1/4 NPK + 3/4 PM	Clemson Control
Gross Benefits						
Total fruit yield	7.89	7.96	8.04	8.18	7.84	7.51
Farm gate price (GH¢/ton)	7000	7000	7000	7000	7000	7000
Total Gross Benefits (GH¢)	55,230	55,720	56,280	57,260	54,880	52,570
Variable Cost						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
NB (GH¢)	48,700	49,820	49742.5	50,935	48767.5	52,570
Benefit: Cost Ratio (BCR)	7.458	8.444	7.609	8.053	7.978	0.000
MRR						
	Clemson 1/2 NPK + 1/2 PM	Asontem 1/2 NPK + 1/2 PM	Clemson Full NPK	Asontem Full NPK	Clemson 3/4 NPK + 1/4 PM	Asontem 3/4 NPK + 1/4 PM
TVC (GH¢)	6325	6325	6530	6530	6537.5	6537.5
NB (GH¢)	50,935	71,675	48,700	65,390	49742.5	72422.5
	D*	D*	D*	D*	D*	D*
MRR = (ΔNB/ΔTVC) × 100			D*	D*	D*	351.765

TVC = Total Variable Cost (GH¢); NB = Net Benefit (GH¢); MRR = Marginal Rate of Returns; D* = Dominated.

Patial Budget analysis for 2022

Table 14 and Table 15 show the partial budget analysis for the 2022 cropping season. Similar to the 2021 cropping season, all the treatments were economically attractive or profitable with positive net benefits. In addition, all the Benefit: Cost Ratio (BCR) for all the fertilizer treatments under the two varieties were close to 2.0, ranging from 3.69 - 5.19 for Asontem and 1.56 - 2.50 for Clemson spineless (Table 14 and Table 15). Similarly, in 2022, the Asontem variety with 162.5 kg/ha NPK + 15 t/ha PM fertilizer application gave the highest net benefit and BCR among the, while the Clemson spineless 650 kg/ha NPK gave the least net benefit and BCR (Table 14 and Table 15) The 325 kg/ha NPK + 10 t/ha and 487.5 kg/ha NPK + 5 t/ha PM treatments under Asontem and 325 kg/ha NPK + 10 t/ha and 162.5 kg/ha NPK + 15 t/ha PM under Clemson spineless gave intermediate BCR (Table 14 and Table 15).

Table 14. Partial budget analysis of Asontem during 2022 cropping season.

	Asontem Full NPK	Asontem Full PM	Asontem 3/4 NPK + 1/4 PM	Asontem 1/2 NPK + 1/2 PM	Asontem 1/4 NPK + 3/4 PM	Asontem Control
Gross Benefits (GB)						
Total fruit yield	3.83	3.79	4.49	4.49	4.73	3.68
Farm gate price (GH¢/ton)	8000	8000	8000	8000	8000	8000
Total Gross Benefits (GH¢)	30,640	30,320	35,920	35,920	37,840	29,440
Variable Cost (VC)						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
NB (GH¢)	24,110	24,420	29382.5	29,595	31727.5	29,440
Benefit: Cost Ratio (BCR)	3.692	4.139	4.494	4.679	5.191	0.000
MRR						
	Clemson Control	Asontem Control	Clemson Full PM	Asontem Full PM	Clemson 1/4 NPK + 3/4 PM	Asontem 1/4 NPK + 3/4 PM
TVC (GH¢)	0	0	5900	5900	6112.5	6112.5
NB (GH¢)	16,030	24,110	14,750	24,420	14747.5	31727.5
			D*	5.254	D*	3438.823
MRR = (ΔNB/ΔTVC) × 100				142.203		

TVC = Total Variable Cost (GH¢); NB = Net Benefit (GH¢); MRR = Marginal Rate of Returns; D* = Dominated.

Table 15. Partial budget analysis of Clemson Spineless during 2022 cropping season.

	Clemson Full NPK	Clemson Full PM	Clemson 3/4 NPK + 1/4 PM	Clemson 1/2 NPK + 1/2 PM	Clemson 1/4 NPK + 3/4 PM	Clemson Control
Gross Benefits (GB)						
Total fruit yield	2.39	2.95	2.78	2.95	2.98	2.29
Farm gate price (GH¢/ton)	7000	7000	7000	7000	7000	7000
Total Gross Benefits (GH¢)	16,730	20,650	19,460	20,650	20,860	16,030
Variable Cost (VC)						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
NB (GH¢)	10,200	14,750	12922.5	14,325	14747.5	16,030
Benefit: Cost Ratio (BCR)	1.562	2.500	1.977	2.265	2.413	0.000
MRR						
	Clemson 1/2 NPK + 1/2 PM	Asontem 1/2 NPK + 1/2 PM	Clemson Full NPK	Asontem Full NPK	Clemson 3/4 NPK + 1/4 PM	Asontem 3/4 NPK + 1/4 PM
TVC (GH¢)	6325	6325	6530	6530	6537.5	6537.5
NB (GH¢)	14,325	29,595	10,200	24,110	12922.5	29382.5
	D*	D*	D*	D*	D*	D*
MRR = (ΔNB/ΔTVC) × 100			D*	D*	D*	D*

TVC = Total Variable Cost (GH¢); NB = Net Benefit (GH¢); MRR = Marginal Rate of Returns; D* = Dominated.

The DA for the 2022 cropping season showed that Asontem control (no fertilizer) treatment has dominated both Clemson spineless at 20 t/ha PM. However, Asontem at 20 t/ha PM had an MRR of 5.254% over Asontem no fertilizer control, indicating that adoption of Asontem at 20 t/ha PM over the Asontem no fertilizer control would give an additional 4.524 Ghana cedis for every extra one cedi invested. Asontem 20 t/ha PM also Clemson spineless at 162.5 kg/ha NPK + 15 t/ha PM because this treatment had a higher TVC and lower net benefit compared to the Asontem at 20 t/ha PM (Table 14 and Table 15). The MRR results showed an MRR of 3438.82% for Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem at 20t/ha PM, indicating that adopting Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem at 20 t/ha PM would give an additional gain of 3437.82 Ghana cedis for every extra one cedi invested. Similar to 2021, Asontem at 162.5 kg/ha NPK +

15 t/ha PM has dominated all other treatments in 2022 cropping season, because it has a higher net benefit, but a lower TVC than all the other treatments (**Table 14** and **Table 15**).

Farm-gate prices were obtained from local market surveys and validated with Ministry of Food and Agriculture (MoFA) extension data, reflecting prevailing prices at the time of harvest for each season. Price differences among varieties were based on market preferences for pod quality attributes such as tenderness, size, and shelf life. Poultry manure costs, including transport and application, were calculated on a per-ton basis and scaled according to the rate applied, ensuring that higher manure treatments incurred proportionally higher costs.

The results showed that the Asontem variety with 162.5 kg/ha NPK + 15 t/ha PM application gave the highest net benefit and BCR among the treatments in both years, while the Clemson spineless 650 kg/ha NPK gave the least net benefit and BCR. The 325 kg/ha NPK + 10 t/ha and 20 t/ha PM treatments under both Asontem and Clemson spineless gave intermediate BCR. The high net benefits and BCR observed under integrated nutrient management treatments agree with recent studies that showed that combining organic and inorganic fertilizers improves nutrient availability, enhances soil biological activity, and increases crop productivity more effectively than either source alone, especially the sole NPK [85] [90].

The DA also showed that Asontem at 162.5 kg/ha NPK + 15 t/ha PM had an MRR of 66.21 % over Asontem control (no fertilizer) treatment and also dominated all other treatments. Asontem variety in combination with 162.5 kg/ha NPK + 15 t/ha PM treatment achieved the highest yield, net benefit, and benefit–cost ratio, demonstrating superior profitability and resource use efficiency. These results align with economic evaluations in recent fertilizer integration studies, which report that combining organic and inorganic sources consistently yields MRR values well above the 100% threshold used in smallholder decision-making [91]. The trend generally showed strong crop responsiveness to balanced nutrient supply, consistent with findings that okro varieties with high nutrient demand perform exceptionally well under integrated nutrient management and produce higher productivity and profitability [57].

In contrast, Clemson spineless, though responsive, generally produced lower yields and net benefits, suggesting lower varietal nutrient-use efficiency under the same management regime. The Clemson spineless treatment performances might indicate less efficient use of inputs and lower economic performance a trend reported in comparative variety studies where certain okro varieties fail to translate nutrient supply into proportionate yield gains [92] [93]. Different varieties of okro have been reported to respond differently to various fertilizer treatments [94] [95]. Given the consistently higher performance of Asontem over Clemson spineless, varietal choice alongside balanced fertilizer integration should be prioritized for sustainable and profitable okro production. These findings also support previous reports that indicated that varietal characteristics significantly influence economic performance under fertilizer regimes [96] [97].

4. Conclusion

The results indicate that integrated nutrient management, utilising both organic and inorganic fertilisers, improves soil physical and chemical properties, plant phenology, vegetative growth, which subsequently impact the yield and yield components of okro. The integrated application of NPK 15:15:15 and poultry manure at 325 kg/ha NPK + 10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM generally increased plant height, number of leaves per plant, stem diameter, canopy spread, number of branches per plant, chlorophyll content and dry matter accumulation over sole applications and control (no fertilizer) application. Asontem variety had slightly higher growth parameters than Clemson spineless. The integrated combination of NPK 15:15:15 and poultry manure at 325 kg/ha NPK + 10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM also showed an increased number of fruits per plant, fruit length and diameter as well as total fresh fruit yield. Asontem variety also had higher total fruit yields than Clemson spineless. The partial budget analysis indicated that 162.5 kg/ha NPK + 15 t/ha PM had the highest net benefit and BCR under both varieties. The 325 kg/ha NPK + 10 t/ha PM and 20 t/ha PM had intermediate net benefits and BCR. With the dominant analysis (MRR), the 162.5 kg/ha NPK + 15 t/ha PM had an average of 66.21 % over the control treatments and dominated all other treatments under both varieties.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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