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Influence of Poultry Manure and NPK Fertilization on Growth, Yield and Storability of Onion (*Allium cepa* L.) Grown Under Rain-fed Conditions

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Authors' contributions

This work was carried out in collaboration between all authors. Author HKD designed the study, wrote the protocol, analyzed data and edited manuscript. Author JGAK was involved in the design of the study, carried out the field work, collected and compiled data; author KD helped in compilation of data and wrote the first draft. Author EBBL critically reviewed the first draft. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: To evaluate the growth, yield and storability response of two onion varieties to different levels of poultry manure and NPK fertilizer application.
Study Design: The design used was a 2 x 5 factorial arranged in a Randomized Complete Block Design (RCBD) with four replications.
Place and Duration of Study: Field experiments were conducted at the University of Education, Winneba, Mampong-Ashanti campus research fields from October 2009 to February 2010 and March to July 2010.
Methodology: Two onion varieties (Bawku Red and Texas Grano) and five soil amendments (10 t ha^{-1} poultry manure (PM); 15 t ha^{-1} PM; 20 t ha^{-1}PM; 450 kg/ha NPK fertilizer and no fertilizer) were studied.
Results: The results showed that, on the average, Texas Grano produced higher number of leaves per plant, plant height, total dry biomass, bulb dry biomass, mean bulb weight, bulb diameter and 40-72% greater fresh bulb yield than Bawku Red in both seasons. The

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soil amendments also had higher number of leaves per plant, 43-83%, 38-90%, 40%, 42-63% and 13-73% greater total dry biomass, dry bulb biomass, mean bulb weight, bulb diameter and fresh bulb yield, respectively, than the control. On the average, the PM treatments produced 7-60% higher fresh bulb yield than the NPK treatment. The Bawku Red variety had lower percentage sprouted and rotten bulbs than Texas Grano, while the control unfertilized check onions stored better than the soil amended treatments. There was no difference between storing onions on the bare concreted floor and in a cane basket.

Conclusion: Growing Bawku Red with application of 10 t ha^{-1}PM or 450 kg ha^{-1} NPK and Texas Grano with application of 15-20 t ha^{-1}PM are recommended for possible adoption by farmers or further testing on-farm in the transition agro-ecological zone or similar environments.

Keywords: Allium cepa; fresh bulb yield; poultry manure; dry matter; NPK fertilizer; rotten and sprouted bulbs.

1. INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important commercial vegetables cultivated in Ghana. It is a high value and high income generating vegetable crop for most farmers or producers. In Ghana, the cultivation of the crop has been concentrated in the Guinea savannah and coastal savanna agro-ecological zones. However, the transition zone has very conducive soil and climatic conditions for its production. In addition, very limited research work has been carried out on the crop in the country. The most popular onion cultivars grown in Ghana include Bawku Red (a local variety) and Early Texas Grano and Red Creole, both exotic varieties.

Farmers have increased onion production, over the last decade, to meet the high demand for the crop in Ghana and the sub-region. However, applying sufficient plant nutrients is needed to sustain the increased production in the face of depleting soil fertility status, continuous cropping and reduced arable land area. Other constraints to sustained increased production include inadequate information and insufficient knowledge on the use of different sources and the application rates of various soil amendments.

Compared with most crops, onions are usually quite susceptible to nutrient uptake because of their shallow and unbranched root system. Thus, they require and often respond well to addition of fertilizers. Hence the use of soil amendments has become indispensable to sustain the high yields required [1,2]. In addition, onions have relatively high demand for soil nutrients, especially nitrogen and potassium [3,4]. This has necessitated the application of inorganic fertilizers for maximum growth and yield. However, inappropriate application of inorganic fertilizers may lead to soil acidity or alkalinity. The cost of inorganic fertilizers has also increased over the past years, such that most farmers who have traditionally used them can no longer afford their use or apply adequate quantities of recommended rates [5,6]. Under sub-optimal supply of nutrients, especially N, the growth of onions and shallots can be severely stunted, with bulb size and marketable yields reduced [1,7].

Organic fertilizer sources (such as animal manures), which are locally available and may constitute cheaper sources of maintaining soil fertility, offer good alternatives to the use of inorganic fertilizers [8]. Furthermore, added organic sources may improve soil texture and water holding capacity; enhance microbial activity and eventually promote improved plant growth and yield. An integrated strategy or approach in applying soil amendments may complement the advantages of the inorganic and organic fertilizers.

Most farmers also have the perception that the application of inorganic and/or organic fertilizers cause high levels of rotten and sprout onion bulbs in storage than when fertilizers are not applied. Different varieties of onions are likely to respond differently to soil amendment factors and different storage systems. Farmers therefore, need to know these soil amendment factors and storage systems and the method of their application as well as the varieties that respond favourably to these factors and systems in order to increase yield and storage of bulbs.

The objectives of the study were to: (i) evaluate the responses of two popular onion cultivars to different rates of poultry manure and inorganic fertilizer; and (ii) determine the effects of these soil amendments and storage media on the storability of these onion cultivars.

2. MATERIALS AND METHODS

Field experiments were carried out at the Multipurpose crop nursery research site of the College of Agriculture Education, University of Education, Winneba, Mampong-Ashanti from October, 2009 to February, 2010 and March to July, 2010. Mampong-Ashanti (7°45'N, 1°24'W) lies at an altitude of 402 m above sea level and is located in the forest-savannah transition agro-ecological zone. The area has a bimodal rainfall pattern with the major rainy season in March to July and the minor rainy season from mid-August to November. There is a long dry harmattan season from December to March. The soils belong to the Bediese series (which are sandy loam, well-drained with a thin layer of organic matter, deep yellowish red, friable and free from stones [9] and are classified as Chromic Luvisol according to the FAO/UNESCO soil classification [10].

Two onion cultivars (Bawku Red and Texas Grano) were combined with five soil amendments [(i) 10 t ha^{-1} poultry manure (PM), (ii) 15 t ha^{-1} PM, (iii) 20 t ha^{-1} PM, (iv) 450 kg ha^{-1} NPK (15-15-15) and (v) Control (no fertilizer)] in a 2 x 5 factorial arranged in a randomized complete block design (RCBD) with four replications.

Seeds were sown in drills on a well prepared nursery seed bed. The seedlings were transplanted from the nursery to the field after one month onto well prepared ridges/beds at a plant spacing of 30 cm between rows x 15 cm within-row. Each plot size measured 3 m wide (consisting of 10 rows) by 1.5 m long. Poultry manure was applied 2 weeks before transplanting of seedlings, while the NPK (15-15-15) was applied at transplanting. The poultry manure used in each season was 6-month old dry manure from layers in a deep litter system. The manure was collected and stored under a shed to protect it from the vagaries of the weather and for further decomposition processes. The crop received 150 l and 60 l per plot of supplementary irrigation during the 2009 and 2010 growing seasons, respectively. Three hand weedings using a hoe were done to control weeds. Topsin-M, 70% CM fungicide (a.i. Methythiophanate) at the rate of 30g per 15 litre of water in a knapsack sprayer was applied to control purple blotch disease at 40 days after transplanting.

Bulked soil samples randomly taken from different parts across the experimental field at 0-30cm depth before transplanting and samples of manure used each season were analyzed for their chemical properties. Data collected included number of leaves per plant, plant height, total dry biomass, bulb dry biomass, mean bulb weight, bulb diameter and bulb yield.

The number of leaves per plant (i.e. total count of leaves per plant) and plant height were measured at maturity from five randomly selected plants from the two middle rows. Plant height was measured using a ruler from the soil surface to the top of the longest mature leaf. Total dry biomass and bulb biomass at final harvest were estimated from ten selected plants after drying in an oven at 75℃ to constant weight. The fresh bulb yield was recorded from plants harvested from the four middle rows.

The storability study involved a factorial combination of two storage media (bare concrete floor and cane basket) and the combined treatments of variety and soil amendments as used in the field experiment, arranged in a completely randomized design (CRD) with four replications. The bulbs harvested from the same treatments in all the four replicates from the field trial were bulked together. Eighty bulbs of similar sizes (0.3-0.5 cm diameter; measured using vernier calipers) were randomly selected from each treatment. Twenty bulbs were randomly selected as a replicate and stored in a room at ambient temperature using a cane basket and on the concrete bare floor as practiced by some farmers and market traders of onion [11]. Data on percentage rotten and sprouted bulbs is cumulative. The bulbs were observed weekly and the rotten and sprouted bulbs picked, counted and recorded for a period of three (3) months. The rotten and sprouted bulbs were discarded after each count to avoid double counting.

All data collected were analyzed using standard analysis of variance techniques for a factorial experiment arranged in a RCBD using the SAS statistical package [12].

3. RESULTS AND DISCUSSION

3.1 Climatic Conditions

The rainfall during the 2009 growing season totaled 284.6 mm (Table 1). The mean minimum monthly temperature ranged from 22℃ and 23℃, while the mean maximum monthly temperature ranged from 31℃ in October to 35℃ in February. The mean monthly relative humidity of the area ranged from 94- 98% at 6 h and 47-67% at 15 h (Table 4.1).

The total rainfall for the 2010 cropping season was 547.5 mm, about two times the total rainfall for the 2009 growing season (Table 1). It was well distributed within the growing season with June as the peak month of receipt. The temperatures were similar to the 2009 season, with mean minimum monthly temperature ranging from 21.7℃ to 23.4℃, while the mean maximum monthly temperature ranged from 29.6℃ to 34.3℃ (Table 1). The mean monthly relative humidity during the growing season ranged from 94-97% at 6 h and 54-69% at 15 h, similar to the 2009 growing season (Table 1).

3.2 Soil and Poultry Manure Characteristics

The chemical properties of the top 0-30 cm soils at the experimental sites and the characteristics of poultry manure used in the study are presented in Table 2. The pH of the soil was 7.4 and 6.1 for both seasons, respectively, indicating the soils were slightly acidic and neutral. Organic matter content was moderate for 2009 and high for 2010 according to the ratings of Soil Research Institute [13]. The total N levels were moderate for both seasons. Exchangeable Ca, Mg and K levels were high for 2009 and moderate for 2010. Available P was high for both 2009 and 2010, while Bray extractable K was high for 2009 and moderate for 2010 cropping seasons (Table 2).

Table 1. Weather conditions at the experimental site during the 2009 and 2010 growing seasons

Month	Total monthly rainfall (mm)	Mean monthly relative humidity (%)		Mean monthly temperature (^oC)	
		6h	15h	Min	Max
		2009 growing season			
Oct 2009	138.6	98	67	22.0	31.0
Nov	45.2	98	60	22.0	32.0
Dec	33.4	97	56	23.0	33.0
Jan 2010	14.7	95	50	22.9	33.6
Feb	52.7	94	47	23.3	35.2
Total	284.6				
		2010 growing season			
Mar 2010	52.6	94	54	23.3	34.3
Apr	77.3	94	56	23.4	33.8
May	108.8	96	63	23.3	32.4
Jun	225.8	97	68	22.3	30.9
Jul	83.0	97	69	21.7	29.6
Total	547.5				

The pH level of the 6-month old poultry manure from a deep litter system in 2009 and 2010 cropping seasons was slightly alkaline and slightly acidic, respectively Table 2). The organic C and organic matter contents were relatively high for both cropping seasons. Total N and the exchangeable cations, especially Ca, Mg, K and available P were moderate for the 2009 season and high for the 2010 season (Table 2).

Table 2. Soil chemical properties (0-30 cm depth) of the experimental site and characteristics of poultry manure used in 2009 and 2010

Soil chemical properties	2009	2010
pH (1:1 H_2O)	7.4	6.1
Organic matter (%)	1.32	3.72
Total nitrogen (%)	0.10	0.17
Available P (pCM)	220.5	293.4
Available K (pCM)	101.7	83.7
Exchangeable cations:		
Ca (me/100g)	10.55	3.74
Mg (me/100g)	3.85	1.87
K (me/100g)	0.80	0.42
Na (me/100g)	0.12	0.38
Poultry manure characteristics		
pH (1:1 H_2O)	7.9	6.4
Organic carbon (%)	24.4	22.9
Organic matter (%)	48.7	39.5
Total nitrogen (%)	1.23	3.0
Available P (pCM)	300..45	776.54
Exchangeable cations:		
Ca (me/100g)	3.04	42.7
Mg (me/100g)	0.29	21.4
K (me/100g)	0.78	157.9
Na (me/100g)	2.30	20.1

3.3 Percentage Crop Establishment

The percentage crop establishment was high and similar for both seasons and ranged from about 87-92% and 88-97% for the 2009 and 2010 growing seasons, respectively (data not shown). There were no significant differences between the cultivars or among the soil amendment levels studied. The high crop establishment indicated possible attainment of optimum plant population density. Good land preparation coupled with judicious application of both organic and inorganic fertilizers in addition to good quality seeds result in a higher percentage crop establishment [14]. The regular watering and rainfall received during the first two weeks after transplanting the onion seedlings might have also contributed significantly to the high percentage crop establishment in both seasons.

3.4 Number of Leaves per Plant and Plant Height

The number of leaves per plant and plant height differed significantly among the varieties and the soil amendments. On the average, Texas Grano produced similar number of leaves per plant in 2009, but 28% higher number of leaves per plant in 2010 than Bawku Red (Table 3). However, in both seasons Texas Grano produced 26-39% higher plant height than Bawku Red (Table 3). The addition of soil amendments to Bawku Red resulted in about 30-42% and 9-21% higher number of leaves per plant and plant height, respectively, than the control unfertilized check. Similarly, under Texas Grano, the amended treatments produced 18-45% greater number of leaves per plant and 63% greater plant height in 2009, than the control check (Table 3). Generally, the poultry manure and NPK had similar plant height in both seasons. However, the 15 t $ha^{-1}$and 20 t ha^{-1}PM treatments produced about 8-21% higher number of leaves per plant than NPK for both onion varieties (Table 3). The higher number of leaves per plant and plant height in the amended treatments over the control check could be attributed to increase in vegetative growth resulting from the significant roles or effects of available essential plant nutrients in the synthesis of the different components of protein required for leaf development, photosynthesis and metabolic processes required for plant growth, thus enhancing rapid growth [15]. The size of the onion bulb is dependent upon the number and size of the green leaves or tops at the time of bulb maturity. For each leaf there will be a ring of onion, the larger the leaf, the larger the ring will be. Organic manures and inorganic fertilizers support a lot of vegetative growth as a result of high supply of nutrients, especially nitrogen [16,17]. The results of this study are similar to those observed by [18], who reported that N fertilization (92 kg N ha^{-1}) significantly increased the number of leaves per plant and plant height of onion by 8% and 10%, respectively, over the control. [19] and [20] also found that application of 120-150 kg N ha^{-1} significantly increased the number of leaves per plant of onion. The high percentage crop establishment might have also contributed generally to enhanced crop growth and hence the high leaf number per plant and plant height [21].

3.5 Total Dry Biomass and Dry Bulb Biomass

The total dry biomass and dry bulb biomass generally did not differ significantly between the two onion varieties in both seasons (Table 4). However, the application of poultry manure and NPK fertilizer significantly affected total dry biomass and dry biomass of onion over the control unfertilized check. On the average, the amended treatments increased total dry biomass of Bawku Red and Texas Grano varieties by 43% and 83%, respectively, over the control (Table 4). Among the amended treatments, the poultry manure on the average increased total dry biomass over the NPK by 17.1% and 3.4% for Bawku Red and Texas Grano, respectively (Table 4).

Table 3. Effects of variety and soil amendments on the number of leaves per plant and plant height of onion at harvest in 2009 and 2010

Treatments		Number of leaves per plant		Plant height (cm)	
		2009	2010	2009	2010
Bawku Red	10 t ha^{-1}PM	6.6	4.4	34.0	31.7
	15 t ha^{-1}PM	7.1	6.1	34.5	30.3
	20 t ha^{-1}PM	7.6	7.0	29.7	35.5
	450 kg ha^{-1} NPK	6.1	5.5	32.4	31.3
	Control	4.8	4.4	26.9	29.7
Texas Grano	10 t ha^{-1}PM	6.1	7.2	43.6	44.7
	15 t ha^{-1}PM	7.0	6.7	44.3	42.1
	20 t ha^{-1}PM	7.3	7.8	39.2	45.7
	450 kg ha^{-1} NPK	6.2	7.2	44.7	43.9
	Control	4.6	6.1	26.4	43.7
SED (Variety)		0.25	0.48	1.10	2.97
SED (Soil amendment)		0.39	0.76	1.74	4.69
SED (V x SA interaction)‡		0.38	0.75	1.74	3.84

‡ V = Variety, SA = Soil amendment

Similarly, the amended treatments on the average increased the dry bulb biomass of onion over the control check by 38% and 90% for Bawku Red and Texas Grano, respectively (Table 4). Poultry manure on the average, also increased dry bulb biomass over the NPK by 19.4% and 27.6% for Bawku Red and Texas Grano. The total dry biomass and dry bulb biomass for Bawku Red were similar for 10 t ha^{-1} and 20 t ha^{-1} PM, but higher than that produced by 15 t ha^{-1} PM, whereas both variables for Texas Grano showed a tendency to increase up to 15 t ha^{-1}PM and declined (Table 4).

The observed increases in total dry biomass and dry bulb biomass in response to the amendments could be attributed to the increased number of leaves per plant culminating in increased photosynthetic area and improved solar radiation interception that enhanced assimilate production and partitioning to the bulbs. The addition of both organic and inorganic fertilizers to the soil contributed significant amounts of essential soil nutrients needed for healthy vegetative and reproductive growth, as reported by [22]. Similar results were reported for onion by [23,24,18]. The slight increases in total dry biomass and dry bulb biomass of onions with poultry manure application over the NPK could be attributed to the slow and effective release of plant nutrients from the manure for effective plant growth compared with the readily available plant nutrients in the NPK. Perhaps some possible leaching of available nutrient might have occurred in the NPK. [25] noted that organic fertilizers improve both the physical and biological properties of the soil and also serve as a source of mineral nutrients to support plant growth. Similar results were obtained by [24], who reported that application of chicken manure increased onion dry matter and enhanced yield and quality of onion. [26] also found that the application of organic fertilizer increased the biomass yield of main crops.

Table 4. Effects of variety and soil amendments on total dry matter and bulb dry matter of onion at harvest in 2010

Treatments		Total dry biomass(g m^{-2})	Dry bulb biomass (g m^{-2})
Bawku Red	10 t ha^{-1}PM	167.9	143.8
	15 t ha^{-1}PM	125.7	103.4
	20 t ha^{-1}PM	204.9	148.8
	450 kg ha^{-1} NPK	141.9	110.6
	Control	111.7	91.6
Texas Grano	10 t ha^{-1}PM	150.6	81.8
	15 t ha^{-1}PM	214.2	144.4
	20 t ha^{-1}PM	167.8	102.3
	450 kg ha^{-1} NPK	171.6	85.8
	Control	96.0	54.5
SED (Variety)		0.98	12.41
SED (Soil amendment)		1.55	19.63
SED (V x SA interaction)‡		5.02	27.76

‡ V = Variety, SA = Soil amendment

3.6 Mean Bulb Weight and Bulb Diameter

The mean bulb weight and bulb diameter differed among the varieties as well as the soil amendments. Averaged over both seasons, Texas Grano produced about 44-116% greater mean bulb weight, but only about 8-13% greater bulb diameter than Bawku Red (Table 5). With the addition of PM and NPK to the two onion varieties, the mean bulb weight increased by 23-76% over the control check. Similarly, the bulb diameter with soil amendments increased by 7-22% over the control unfertilized check (Table 5). The PM on the average, had 11-15%greater mean bulb weight than the NPK treatment especially in 2010. However, the bulb diameter was similar among the soil amendment treatments.

The higher growth rate of Texas Grano resulting from the greater number of leaves per plant, plant height, total dry biomass accumulation and dry bulb biomass contributed significantly to the greater mean bulb weight and bulb diameter than Bawku Red. Similarly, the higher mean bulb weight and bulb diameter in response to PM and NPK application over the control check could be attributed to the increases in number of leaves per plant, plant height, total dry biomass accumulation and dry bulb biomass resulting from increased assimilate production and partitioning to the bulbs. Mean bulb weight was significantly and positively correlated with the number of leaves per plant, plant height, total dry biomass accumulation (data not shown), similar to observations made by [18]. Similar results were reported by [23,27,28,18], where fertilizer application enhanced significantly mean bulb weight and bulb diameter.

3.7 Fresh Bulb Yield

Fresh bulb yield for Bawku Red ranged from 588-938 and 1276-2213 kg ha^{-1}, while that for Texas Grano ranged from 964-1187 and 2325-3800 kg ha^{-1} in 2009 and 2010, respectively (Table 5). On the average, Texas Grano produced about 27-64% and 71-82% higher fresh bulb yield than Bawku Red in 2009 and 2010, respectively, (Table 5). The greater number of leaves per plant, plant height, total dry biomass accumulation, dry bulb biomass, mean bulb weight and bulb diameter produced by Texas Grano might have contributed significantly to the greater fresh bulb yield than Bawku Red. In general, the fresh bulb yields produced in 2010 by the two onion varieties were about three times higher than the yields produced in 2009. This could be attributed to the well-distributed rainfall and more favourable moisture conditions (about two times higher total rainfall) in the 2010 growing season compared to the 2009 growing season. Although the crop is currently produced in both minor (2009) and major (2010) seasons by farmers, the growing season or time of planting could have significant implications for yield produced, with the major season having the advantage of producing higher yields. However, farmers may have to invest slightly more time and expenses in curing the onions after harvest in the major (wetter) season than the slightly drier minor season before storage.

Averaged over both seasons, the application of PM and NPK resulted in 23-63% and 18-50% higher fresh bulb yields of Bawku Red and Texas Grano, respectively, than the control unfertilized check. The soil amended onion plants also had greater number of leaves per plant, plant height, total dry biomass accumulation, dry bulb biomass, mean bulb weight and bulb diameter than the control check, thus influenced significantly the greater fresh bulb yield.

Table 5. Mean bulb weight, bulb diameter and fresh bulb yield of two onion varieties as affected by soil amendments in 2009 and 2010

Treatments		**Mean bulb weight (g)**		**Mean bulb diameter(cm)**		**Fresh bulb yield (kg ha^{-1})**	
		2009	**2010**	**2009**	**2010**	**2009**	**2010**
Bawku Red	10 t ha^{-1}PM	34.90	48.32	4.08	3.45	938	1363
	15 t ha^{-1}PM	29.60	53.32	3.75	3.74	813	1875
	20 t ha^{-1}PM	24.93	45.87	3.63	4.18	628	1550
	450 kg ha^{-1} NPK	30.45	42.85	3.63	3.65	831	2213
	Control	23.03	26.74	3.38	3.26	588	1276
Texas Grano	10 t ha^{-1}PM	46.78	124.65	4.05	5.02	1130	3800
	15 t ha^{-1}PM	43.58	90.92	4.13	4.43	1187	2788
	20 t ha^{-1}PM	40.70	89.27	4.08	3.90	1059	2500
	450 kg ha^{-1} NPK	40.00	91.58	3.90	3.90	970	2850
	Control	34.88	72.68	3.78	3.53	964	2325
SED (Variety)		2.49	8.40	0.11	0.39	64.46	189.03
SED (Soil amendment)		3.93	13.29	0.18	0.61	101.99	298.88
SED (V x SA interaction)‡		5.56	18.79	0.25	0.87	144.25	422.69

‡ V = Variety, SA = Soil amendment

These results suggest that an increase in photosynthetic area (i.e. number of leaves per plant and plant height) in response to addition of PM and NPK, resulted in the production and partitioning of more assimilates to bulbs (i.e. total dry biomass accumulation, dry bulb biomass, mean bulb weight and diameter) contributed substantially to increased fresh bulb yields. The average fresh bulb yields over both seasons under PM were 1339 kg ha^{-1} and 2136 kg ha^{-1} for Bawku Red and Texas Grano, respectively, which were 23% higher than the fresh bulb yields produced under NPK application (Table 5). Averaged over both seasons, applying 15 t ha^{-1}PM or 20 t ha^{-1}PM to Bawku Red gave the highest fresh bulb yields, while 10 t ha^{-1}PM or 15 t ha^{-1}PM applied to Texas Grano produced the highest fresh bulb yields. In both seasons, fresh bulb yield was positively and highly significantly correlated with mean weight per bulb (r=0.93, P< 0.001) and mean bulb diameter (r=0.86, P< 0.001) (data not shown).

Working on shallots, [17] reported that poultry manure promoted plant growth and bulb yield. Similarly, [24] indicated that the addition of chicken manure increased onion yield, weight of individual bulbs and bulb diameter. High soil organic status improve soil stability, lower bulk density and balance fine and course pores leading to better root penetration, good soil moisture properties, improved cation exchange capacity and better retention of nutrients [29]. Several other authors have also reported improved plant growth characters (number of leaves per plant, plant height, total dry biomass accumulation and dry bulb biomass) in response to added soil amendments that have resulted in increased yield of onion [30,19,20,31,15].

3.8 Storability - Rotten and Sprouted Bulbs

The percentage rotten and sprouted bulbs of the two onion varieties as affected by storage medium and soil amendments are shown in Table 6. There were significant varietal differences in the percentage rotten bulbs with Bawku Red having 9-11% compared with 28-50% for Texas Grano, over both seasons (Table 6). However, the percentage sprouted bulbs were similar for both varieties at 2-6% and 3-8% for Bawku Red and Texas Grano, respectively. The larger bulb sizes of Texas Grano, coupled with possible higher moisture content and inadequate curing of the bulbs in the field after harvest before storage could have accounted for the higher levels of rot than Bawku Red [32].

There were no differences in the percentage rotten and sprouted bulbs between the two storage media. The percentage rotten bulbs were 18-30% and 21-29% for bare concrete floor and cane basket, respectively, while the percentage sprouted bulbs were 3-6% and 3-8%, respectively (Table 6). In a storage study in the Bawku East and West districts of Ghana, [11] observed that percentage rotten bulbs were 44% for bare non-concreted floor compared with 33% for bare concreted floor.

Table 6. Percentage rotten and sprouted bulbs of two onion varieties as affected by storage medium and soil amendments in 2009 and 2010

Treatment	Rotten bulbs (%)		Sprouted bulbs (%)	
	2009	2010	2009	2010
Variety (V)				
Bawku Red	10.8	9.2	5.6	2.4
Texas Grano	27.9	49.6	8.4	3.3
SED	8.5	20.2	1.4	0.5
Storage medium (SM)				
Bare concrete floor	18.2	30.1	5.5	2.8
Canned basket	20.5	28.7	8.2	2.9
SED	1.2	0.7	1.4	0.1
Soil amendment (SA)				
10 t ha^{-1}PM	25.9	30.3	9.8	3.8
15 t ha^{-1}PM	19.8	33.5	3.8	2.3
20 t ha^{-1}PM	16.8	29.8	8.3	1.5
450 kg ha^{-1} NPK	20.5	29.3	3.8	2.5
Control	14.0	24.3	3.3	1.0
SED	1.9	1.5	1.4	0.5
V x SM interaction	NS	NS	NS	NS
V x SA interaction	NS	NS	NS	NS
SM x SA interaction	NS	NS	NS	NS
V x SM x SM interaction	NS	NS	NS	NS

The soil amendments had slightly higher percentage rotten and sprouted bulbs (17-34% and 2-10%, respectively) compared with the control unfertilized check (14-24% and 1-3%, respectively) (Table 6). The slightly higher levels of rotten and sprouted bulbs in response to application of PM or NPK could be attributed to the production of larger soft succulent tissue bulbs and higher moisture content predisposing the bulbs more to attack by disease causing micro-organisms; and increases in the concentration of growth promoters than inhibitors [33,34]. These results agree with the findings of [33,34,35], who observed increasing rotting and sprouting of onions in response to increasing N levels and over the control. On the contrary, while [36] observed decreases in rotting and sprouting of onions with increasing P levels, [37] observed no effects on storage life of onions with addition of P and K. There were no differences in the percentage rotten and sprouted bulbs among the soil amended treatments over both seasons.

4. CONCLUSION

In conclusion, both organic and inorganic fertilization are essential for increased onion yield. Farmers could substitute or integrate NPK fertilizers with poultry manure. . Texas Grano is recommended for the fresh market since it had the better vegetative performance, high yield and bigger bulbs which are the most preferred on the local market. However, for distant markets where dry, cured bulbs are in demand, Bawku Red is recommended since it has a longer shelf life and can store better. The treatment combinations of Bawku Red + 15 t ha^{-1}PM or 450 kg ha^{-1} NPK and Texas Grano + 10 t ha^{-1}PM or 15 t ha^{-1}PM are recommended for optimum crop performance and to maximize yield productivity per unit area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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