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Dry Matter Accumulation and Uptake of Cations in Roselle (*Hibiscus sabdariffa* L.) as influenced by Nitrogen, Phosphorus and Farmyard manure rates in the Northern Guinea Savanna zone of Nigeria

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ABSTRACT

An investigation was conducted during 2005, 2006 and 2007 wet seasons at the experimental farm of the Institute of Agricultural Research, Samaru (11° 11'N, 07° 38'E, 686m above sea level) to study the effect of nitrogen, phosphorus and farmyard manure rates on dry matter accumulation and uptake of cations by roselle in the Northern Guinea Savanna zone of Nigeria. The experiment consisted of three levels nitrogen in the form of urea (0, 60 and 120 kg N ha^{-1}), three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}) and three levels of farmyard manure (0, 5 and 10 t ha^{-1}). The twenty seven treatments were laid out in a split plot design with three replications. The factorial combinations of nitrogen and phosphorus were assigned to the main plot while, farmyard manure was allocated to the sub-plot. The results obtained showed that application of 60 kg N and 5t FYM ha^{-1} recorded significant increase in dry matter accumulation in Roselle, while applied P had no significant effect on dry matter production. Combined application of 120 kg N ha^{-1} with 5 t FYM ha^{-1} was optimum for dry matter production in Roselle. Nitrogen application reduced K and Mg content but increased the uptake of the nutrients. Similarly, FYM reduced K and Ca content of shoots, while the uptake of the nutrients was increased by manure application. Phosphorus application increased K and Mg but reduced Ca contents of shoots. Application of P had no significant effect on the K and Mg uptake but reduced Ca uptake of Roselle.

Key words: *Dry matter accumulation, Farmyard manure, nutrients, multiproduct, roselle, and "Zoborodo"*

Introduction

Roselle (Hibiscus sabdariffa L.) which originated in Tropical, Central or West Africa (Murdock, 1995) is a multi product and multipurpose annual plant belonging to the family *Malvaceae* cultivated in the tropical and sub tropical regions for its leaves, edible calyces, seeds and fibre (Adamson and O'bryan, 1981). In Nigeria and elsewhere, the leaves are used as a vegetable while the calyces are major raw materials in local and commercial beverages in the production of vitamin C rich soft drinks popularly known as "*zoborodo"* or "*zobo"* and "Roselle apple" (Fasoyiro *et al.,*2005). Extracts from the calyces are widely used in the treatment of many diseases like: treatment of high blood pressure (Faraji and Tarkhani, 1999), cardiac, cancer and nerve diseases (Anon, 2008), and in the buildup of body immune system against diseases (CTA, 2001). It is an important source of natural colouring and flavoring agent in food and fruit processing industries. The seeds which contain 17-20% oil is a valuable source of edible oil (Abu Tarboush *et al.,* 1997), and also a good source of protein (23%) with high tryptophan level. It is also roasted and used as a local substitute for coffee (Aliyu and Morufu, 2006). Roselle is also an important source of fibre in India, Java and Philippines. The fibre content of fresh stem is 5-6% and 18-22% of dry weight.

Currently, apart from the diverse uses of Roselle, the increased use of the calyces and the leaves in local and commercial beverages has led to an upsurge in demand for the crop in Nigeria. However, since its production is still predominantly at subsistent level and mostly in mixture with other crops, where its specific nutrient needs and spacing are not considered, yields are generally low. As a result, the increased demand cannot be met unless appropriate production practices, especially the use of optimum rates of nutrients are adopted. Effective and efficient fertilizer use, however, emanates from the understanding of the crop's nutritional needs and its responses to nutrient supply.

Although there is a paucity of information on the nutritional needs of Roselle in Nigeria (Kumar *et al.,* 1985 and Aliyu, 1998), studies by Adamson *et al.,* (1979) and Bhangoo *et al.,* (1989) on Kenaf indicated that N application reduced K contents of whole plants, while the application of N and P increased K content and Ca uptake of pepper. This study was, therefore, undertaken to investigate the effect of N, P and farmyard manure on dry matter accumulation and the uptake of cations by Roselle plant.

Materials and Methods

Field experiment was conducted during the rainy seasons of 2005, 2006 and 2007 at the research farm of the Institute for Agricultural Research, Samaru (11^o 11′N, 07^o 38′E 686m above sea level) in the Northern Guinea Savanna agro ecological zone of Nigeria. This was to determine the effect of various combinations of three levels of nitrogen in the form of urea (0, 60 and 120 kg N ha^{-1}), three levels of phosphorus in the single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}) and three levels of farmyard manure (0, 5 and 10 t ha^{-1}) on the growth and nutrient uptake of Roselle (*Hibiscus sabdariffa* L.). The farmyard manure (FYM) used was cow dung mixed with bedding materials. Before application, samples of the FYM were taken and analyzed to determine its chemical contents. The twenty seven treatments combinations were laid out in a split plot design with factorial combinations of nitrogen and phosphorus allocated to the main plot while, farmyard manure was assigned to the sub plot. Treatments were replicated three times. The gross plot size was $13.5m^2$ (4.5 x $3m^2$) while the net plot size was $9m^2$ (3 x 3m). Composite samples of soils at depths of 0- 15 and 15 -30cm were taken from the experimental sites prior to crop establishment and application of fertilizer treatments and analyzed for the chemical and physical properties using standard procedure (Black, 1965). The soils of the experimental sites were: clay loam in 2005, loam in 2006 and sandy loam in 2007; with moderate acidity in 2005 and 2007, while it was strongly acidic in 2006 (Table 1). During the three seasons, the soils had low organic carbon, N and medium exchangeable K, while available P was low in 2005 but medium in 2006 and 2007 seasons. Details of the physico-chemical properties of the soils of the experimental sites used are presented in Tables I.

Planting was done on ridges 75 cm apart and 3 m long at intra-row spacing of 60cm. the rates of phosphorus and FYM as well as the base dose of 30 kg K ha^{-1} were side banded and incorporated 2 weeks before seeds were planted. Two-hoe-weedings at 3 and 7 WAS and ridge moulding at 11 WAS were done to control weeds. Karate (Lambdacyhalothrin) at the rate of 0.8 litre ha^{-1} along with Benlate (benomyl) at the rate of 1Kgai ha^{-1} were applied three times fortnightly using knapsack sprayer starting from 3 WAS each season as a routine preventive measure against pest and disease incidences.

At 10 WAS, two plants were sampled randomly from each plot and thoroughly cleaned and oven dried at 70^oC to a constant weight for the determination of TDM after which it was ground with a Wiley mill and passed through a 2mm sieve. Total nitrogen in plant tissues was determined by micro-Kjeldahl procedure (IITA, 1975). The percent concentration of P was determined by the vanodomolybdate yellow colour of Bray and Kurtz (1945) modified by Riley (1962). The concentration of K, Ca, and Mg were determined by atomic absorption spectrophotometry using Perking Elmer model 290B. The data collected were subjected to statistical analysis of variance as described by Senedecor and Cochran (1967). The differences between treatment means were determined using DMRT (Duncan, 1955).

Results and Discussion

Dry matter accumulation as influenced by N, P and FYM rates is presented in Table 2. Application of both rates of N resulted in similar but significantly higher DM production over the control in 2005 and combined data, while in 2006 and 2007, each increase in N rate led to a significant increase in dry matter accumulation. The positive influence of N on TDM could be due to its role in promoting rapid vegetative growth and its direct effect on cell division, expansion, synthesis of enzymes and chlorophyll (Brady and Weil, 2004). The application of both rates of FYM resulted in comparable but significantly more dry matter accumulation over plots with no manure treatments (Table 2). The positive influence of FYM on TDM could be attributed to the ability of manure to improve soil physical condition and supply essential nutrients (particularly

N) required for vegetative growth (Eghball 2002; anon, 2007 and Bationo *et al.,* 2007). Phosphorus application had no significant effect on dry matter production in all the years of study and even their combined effect (Table 2), probably because unlike N, it doesn't promote aerial vegetative growth of most crops. It could also be linked to the presence of appreciable amount of P in the experimental soils especially in 2007 season (Table I).

Applied N reduced K and Mg, and only increased Ca concentration in 2007, while the uptake of all the cations by roselle was increased following N application (Tables 5, 6 and 7). The reduction of K and Mg probably resulted from the increased demand for them with N application which enhanced the growth of the crop. Similarly, because of increased demand for these nutrients more growth stimulated nutrient uptake. According to Brady and Weil (2004) provision of sufficient quantities of N encouraged rapid vegetative growth and regulates the uptake of K and other nutrients from the soil. Phosphorus application increased K and Mg but reduced Ca concentration in shoots (Tables 4, 5 and 6). The increase in K and Mg contents of

Table 1 Physio-chemical properties of soils of the experimental sites during 2005, 2006 and 2007 wet seasons

	2005		2006		2007	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-15	15-30	0-15	15-30	0-15	15-30
Particle size distribution (%)						
Clay	18	42	24	24	10	26
Silt	52	22	34	34	32	34
Sand	30	36	42	46	58	40
Textural class	Silt loam	Clay	loam	loam	Sandy loam	Clay loam
Textural characteristics						
pH in water	6.0	6.56	5.40	5.30	6.20	6.30
pH in 0.01M $CaCl_2$	5.2	4.90	4.84	4.84	5.10	4.80
Organic carbon (gkg^{-1})	12.40	4.00	9.60	4.00	6.00	4.28
Total nitrogen (gkg^{-1})	0.35	0.54	1.10	0.52	1.33	1.24
Available phosphorus ($mgkg^{-1}$)	7.13	1.78	6.20	8.40	17.50	7.00
Exchangeable bases ($Cmolkg^{-1}$)						
Ca	0.56	0.98	1.08	0.42	0.37	0.93
Mg	0.45	1.15	0.63	0.41	1.17	2.36
K	0.23	0.26	0.18	0.27	0.17	0.19
Na	0.47	0.22	0.54	0.43	0/33	0.37
Exchangeable acidity (H+Al)	0.20	0.20	0.20	0.20	0.18	0.18
CEC	6.80	13.00	8.60	7.20	8.40	12.50

Provision of sufficient quantities of N encouraged rapid vegetative growth and regulates the uptake of K and other nutrient from the soil. Phosphorus application increased K and Mg but reduced Ca concentration in shoots (Tables 4, 5 and 6). The increase in K and Mg contents of shoots could be due to increased development of root system by P which encouraged the utilization of more nutrients and moisture from the soil (Brady and Weil, 2004; Douglas and Philips, 2008). The decrease in Ca content as Mg content increased in shoots probably corroborates the mutual antagonisms reported between Ca and Mg in plant tissues by Jones (2003) in plant tissues. The uptake of K and Mg by Roselle were, however, not influenced by P application. The effect of applied P on potassium and magnesium indicated that there were adequate amounts of these nutrients in the plants while the increased Ca uptake may be ascribed

Table 2: Total dry matter of Roselle as influenced by N, P and FYM rates at in various seasons

	Seasons			
Treatments	2005	2006	2007	Mean
Nitrogen (KgNha^{-1})				
0	56.7	82.5c	50.9c	61.3b
60	67.0	106.7b	75.8b	80.6a
120	75.6	119.4a	86.2a	90.3a
SE±	5.34	4.65	2.97	4.32
Phosphorus (Kg P ha^{-1})				
0	76.7	110.4	73.1	86.7
13.2	75.5	121.0	72.3	89.6
26.4	74.1	119.4	67.6	87.0
SE±	5.34	4.65	2.97	4.32
FYM (t ha^{-1})				
0	56.2b	98.0b	63.3b	70.3
5	82.1a	129.3a	73.2a	94.9a
10	88.0a	123.5a	76.4a	96.0a
SE±	4.48	3.61	2.14	3.41
Interaction				
N x P	NS	NS	NS	NS
N x M	NS	NS	**	NS
P x M	NS	NS	NS	NS
N x P x M	NS	NS	NS	NS

Means followed by unlike letter(s) within atreatment group column differ significantly using DMRTf (P=0.05). NS=Not significant **=Significant at P=0.01

Table 3: TDM of roselle as influenced by a highly significant interaction between nitrogen and farmyard manure in 2007

	FYM (t ha^{-1})		
	0	5	10
Nitrogen (KgNha^{-1})			
0	48.1c	51.0c	53.5c
60	73.5b	76.5b	77.5b
120	68.4b	92.2a	98.1a
SE±		4.24	

Means followed by different letter(s) within a set of interaction differ significantly using DMRT (P=0.05)

to increased demand for it especially for subsequent reproductive phase of the crop. The effect of FYM treatments on the contents and uptake of K, Ca and Mg are shown in Tables 4, 5 and 6). The decreased K and Ca contents of Roselle shoots could be attributed to increased respiratory process and dilution effect resulting from increased growth activities following the application of FYM. On the other hand, the uptake of K, Ca and Mg were enhanced by manure application (Tables 4, 5 and 6). It could also be attributed to the favourable soil physical conditions and increased availability of nutrients through the process of manure mineralization (Egball, 2002 and Bationo, 2007). The influence of N and FYM interaction on Dry matter accumulation is shown in Table 3. The application of 120 kg N ha^{-1} with either rates of FYM maximized dry matter production in Roselle. The significant and positive effect of an interaction between N and FYM on dry matter production further affirmed the critical roles of N and FYM in promoting growth and drymatter accumulation, and the complementarities of using both on crops.

Table 4: Potassium content (%) and uptake (g $plant^{-1}$) as influenced by N, P and FYM rates at Samaru during 2005, 2006 and 2007 wet seasons.

	Potassium (%)				Potassium (g plant-1)			
Treatments	2005	2006	2007	mean	2005	2006	2007	mean
Nitrogen ($KgNha^{-1}$)								
0	0.64	1.14a	0.89a	0.89a	0.38	0.62b	0.42b	0.61c
60	0.67	1.02	0.85b	0.85b	0.47ab	1.25b	0.63a	0.78b
120	0.65	1.14a	0.84b	0.88	0.58a	1.62a	0.70a	0.97a
SE±	0.027	0.041	0.028	0.012	0.040	0.081	0.040	0.033
Phosphorus ($KgPha^{-1}$)								
0	0.65	1.07	0.85b	0.86b	0.46	1.19	0.57	0.74
13.2	0.63	1.08	0.84b	0.85b	0.47	1.35	0.59	0.80
26.4	0.67	1.15	0.89a	0.90a	0.51	1.34	0.9	0.81
SE±	0.027	0.041	0.028	0.012	0.040	0.081	0.040	0.033
FYM (t ha^{-1})								
0	0.66a	1.18a	0.87	0.91a	0.37b	1.19	0.52b	0.69b
5	0.63b	1.06b	0.86	0.85b	0.45b	1.33	0.62a	0.80a
10	0.66a	1.07b	0.85	0.86b	0.61a	1.37	0.62a	0.87a
SE±	0.027	0.039	0.028	0.011	0.023	0.047	0.023	0.019
Interaction								
N x P	NS	NS	NS	NS	NS	NS	NS	NS
N x M	NS	NS	NS	NS	NS	NS	NS	NS
P x M	NS	NS	NS	NS	NS	NS	NS	NS
N x P x M	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by unlike letter(s) within a treatment group and column differ significantly using DMRT (P=0.05). NS= Not significant

Table 5:Shoot calcium content (%) and its uptake as influenced by N, P and FYM rates in 2005, 2006 and 2007 wet seasons

	calcium (%)				calcium (g plant^{-1})			
Treatments	2005	2006	2007	mean	2005	2006	2007	mean
Nitrogen (KgNha^{-1})								
0	1.42	1.46	1.37b	1.42	0.81b	1.21c	0.69c	0.87c
60	1.44	1.45	1.40a	1.43	0.97a	1.55b	1.06b	1.15b
120	1.42	1.42	1.41a	1.42	0.81b	1.69a	1.22a	1.28a
SE±	0.012	0.023	0.006	0.015	0.007	0.027	0.005	0.013
Phosphorus (KgP ha^{-1})								
0	1.45a	1.48a	1.43a	1.46a	1.11a	1.63b	1.04a	1.27a
13.2	1.39b	1.43ab	1.41b	1.42a	1.05b	1.73a	1.02b	1.27a
26.4	1.40b	1.42b	1.34c	1.38b	1.04b	1.69a	0.91c	1.20b
SE±	0.012	0.023	0.006	0.015	0.007	0.027	0.005	0.013
FYM (t ha^{-1})								
0	1.44b	1.41b	1.45a	1.43a	0.81b	1.38b	0.91b	1.01b
5	1.48b	1.41b	1.37b	1.39b	1.22a	1.82a	1.02a	1.32a
10	1.50a	1.51b	1.36b	1.44a	1.32a	1.86a	1.04a	1.38a
SE±	0.006	0.008	0.002	0.005	0.004	0.011	0.002	0.004
Interaction								
N x P	NS	NS	NS	NS	NS	NS	NS	NS
N x M	NS	NS	NS	NS	NS	NS	NS	NS
P x M	NS	NS	NS	NS	NS	NS	NS	NS
N x P x M	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by unlike letter(s) within a treatment group and column differ significantly using DMRT (P=0.05). NS= Not significant

Table 6:Shoot Mg content (%) and uptake (g plant^{-1}) as influenced by N, P and FYM rates in 2005, 2006 and 2007 wet seasons

	Magnesium (%)				Magnesium (g plant^{-1})			
Treatments	2005	2006	2007	mean	2005	2006	2007	Mean
Nitrogen (KgNha^{-1})								
0	0.82	0.92	0.85	0.87a	0.47c	0.76c	0.43c	0.53c
60	0.79	0.92	0.80	0.84b	0.53b	0.98b	0.61b	0.68b
120	0.84	0.97	0.85	0.89a	0.64a	1.16a	0.73a	0.80a
SE±	0.026	0.031	0.026	0.010	0.019	0.036	0.022	0.008
Phosphorus (Kg P ha^{-1})								
0	0.81	0.93	0.83	0.86b	0.62	1.03	0.61	0.75
13.2	0.79	0.92	0.81	0.84b	0.60	1.11	0.59	0.75
26.4	0.84	0.96	0.86	0.89a	0.62	1.15	0.58	0.77
SE±	0.026	0.031	0.026	0.010	0.019	0.036	0.022	0.008
FYM (t ha^{-1})								
0	0.81	0.95	0.82	0.86	0.46c	0.93c	0.52b	0.61b
5	0.82	0.93	0.85	0.86	0.67b	1.20a	0.62a	0.82a
10	0.82	0.93	0.84	0.86	0.72a	1.15b	0.64a	0.83a
SE±	0.009	0.010	0.009	0.003	0.007	0.013	0.007	0.003
Interaction								
N x P	NS	NS	NS	NS	NS	NS	NS	NS
N x M	NS	NS	NS	NS	NS	NS	NS	NS
P x M	NS	NS	NS	NS	NS	NS	NS	NS
N x P x M	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by unlike letter(s) within a treatment group and column differ significantly using DMRT (P=0.05). NS= Not significant

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