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DISTRIBUTION OF MAJOR ELEMENTS (Na, K, Ca, Mg) IN THE VARIOUS ANATOMICAL PARTS OF FADAMA CROPS IN EKITI STATE, NIGERIA

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ABSTRACT. Levels of sodium, potassium, calcium and magnesium were determined in plant organs (bud, flowers, fruit, seed, leaves, stems, roots, cobs, styles, shaft, grains and efflorescences) of three Fadama farms located in Ifaki-Ekiti, Ado-Ekiti and Ikere-Ekiti of Ekiti State, Nigeria. The highest levels of Mg, K, Na and Ca were obtained in the bud of *Hibiscus esculentus* with respective values (ppm dry weight, ppm DW) of 4397, 2983, 3928 and 1622; this was closely followed by their levels in *Lycopersicon esculentum* root: Mg (2734), K (1079), Na (2111) and Ca (678). The levels of all the elements were highly varied in the anatomical parts of each plant and between the various plants. The index of bioaccumulation (ratio in plants/soil) was recorded for all the elements with all values falling within 1-10 showing that the degree of accumulation was intensive. The overall levels of the elements were Mg > Na > K > Ca.

KEY WORDS: Fadama crop parts, Major elements, Concentration ranking, Intensive bioaccumulation

INTRODUCTION

Soil analyses can sometimes be usefully supplemented by the analysis of leaves and other plant parts provided that they are carefully sampled and enough is known about what levels of the various nutrient elements can be considered to be normal or deficient [1]. Analysis of oil palm and coffee leaves in Cote d'Ivoire and elsewhere is claimed to be useful in detecting low nutrient levels in the plant early enough for deficiencies to be corrected before they become harmful [1].

Certain elements are considered as especially desirable for successful crop growth. If they are lacking or improperly balanced, normal development does not occur. Of the eleven essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, boron, copper and zinc) obtained from the soil by plants, six are used in relatively large quantities and consequently are receiving major attention [2]. They are magnesium, phosphorus, potassium, calcium, nitrogen and sulphur. Because they are used by plants in relatively large amounts they are sometimes designated for convenience as the primary elements [2]. Plant growth may be retarded because these elements are actually lacking in the soil, because they become available too slowly, or because they are not adequately balanced by other nutrients. Sometimes all three of these limitations are operative particularly with respect to nitrogen [2]. The list of elements essential to animals is slightly different and includes sodium, although it is not essential to the plant, clearly it is desirable that grasses and other plants eaten by grazing animals should contain sufficient quantities of it [1].

Crops provide nutritional needs of both man and animals. Man in turn also consumes the animals. The major elements essential for man are also essential for animals. This work therefore provides correlated information on the levels of four elements (Mg, K, Na and Ca) in the plant organs or parts (buds, flowers, fruits, seeds, leaves, stems, root, cobs, styles, shaft, grains and efflorescences), in a total of fifty-nine (59) samples and 236 parameters in three different Fadama farms in Ekiti State, Nigeria.

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EXPERIMENTAL

Sampling

Samples were taken from three Fadama farms located in Ifaki-Ekiti (Northern Division), Ado-Ekiti (Central Division) and Ikere-Ekiti (Southern Division) of Ekiti State, Nigeria [3]. Plant samples were collected at the various sites where soil samples were taken [3]. The plants collected at the sites were *Celosia argentea* (L.), *Hibiscus esculentus* (L.), *Zea mays* (L.), *Corchorus olitorius* (L.) and *Lycopersicon esculentum* (Mill.). The plants were separated into buds, flowers, fruits, seeds, leaves, stems, roots, cobs, styles, shaft, grains and efflorescences as the case may be and put in different acid – leached polyethylene bags and transferred into the laboratory. The characteristics of the sampling sites and samples had earlier been given [3].

Sample treatment

All the plant parts were transferred to the laboratory where they were spread on polyethylene sheets until dried. After air-drying, roots were rinsed with deionized water, re-dried and homogenised, the plant samples were sieved using 200 mm mesh. After sieving the plant tissues, they were prepared for analyses by the method of wet digestion using a combination of nitric acid and perchloric acid (70% solution). 1.0 g ground tissue plus 5 mL HNO_3 and 2 mL $HClO_4$, digested in fume cupboard, heating to a volume of 3 to 5 mL, 10 mL distilled de-ionized water added and filtered into 50 mL standard flask. The filtered solutions were made up to volume with deionized water [4]. Between 10-15 plant buds were used for analysis where applicable, they were of different ages.

Magnesium, potassium, sodium and calcium were analysed in the samples using a Perkin Elmer Model 306 Atomic Absorption Spectrophotometer for magnesium and calcium while potassium and sodium were determined by flame photometer (Corning, Halstead, Essex, UK, Model 405) using NaCl and KCl to prepare standards. Analyses were made in duplicate. The detection limits of all the elements were determined before the sample solutions were analysed [5]. The detection limits were Mg (0.002), Ca (0.04), Na (0.001) and K (0.005) ppm (all for aqueous solutions). The optimum analytical range was 0.5-10 absorbance units with coefficient of variation of 0.05-0.40%. Determinations were made on dry weight (DW) basis for all the samples.

Names of towns (as appropriate) were used in the various Tables whereas alphabets (A, B, C, D) were used to represent zones in the Tables.

Statistical analysis

All data generated were analysed statistically [6]. From the zones for each town, the variation ranges of the elements in the crops were calculated. From the average values obtained for elements in the plants and soils (not reported here), index of bioaccumulation were calculated and the results gave the degree of accumulation [7]. The overall ranking (%) of element concentrations in the samples according to positions were also reported.

RESULTS AND DISCUSSION

Table 1 shows the major elements in Ifaki-Ekiti Fadama farm crops (DW). Zone A contains *Celosia argentea.* Although fruit has the highest value for Mg, the leaves generally have the highest levels of Mg and Na. Ca is consistently the least value in the four anatomical parts of *C.*

argentia. Zone B contains *Hibiscus esculentus.* In all the plant parts here, the bud has the highest levels for all the four elements with values ranging from 4397 ppm (DW) for Mg and 1622 ppm (DW) for Ca. The CV% here is high for all the elements with values ranging from 131 in Ca to 142 in K. Only the root and leaves are available for analyses in *Zea mays* in zone C. In these two samples the trend of element concentration is Mg > Na > K > Ca. Zone D contains *Corchorus olitorius.* It appears here that the flower has a luxury accumulation for Mg where its value is 1040 ppm (DW). The spread of the elements here among the *C. olitorius* parts appears to compare favourably with *C. argentea* because the CV% ranges from 41 down to 25 with Mg recording the highest spread.

Table 1. Major elements (ppm) in the Ifaki-Ekiti Fadama farm crops (DW).

Zone	Plant	Plant part	Element			
			Mg	K	Na	Ca
A	*Celosia argentea*	Root	479	421	475	204
		Leaves	566	255	578	254
		Stem	332	247	345	144
		Fruit	604	257	453	189
		Mean	495	295	462	197
		SD	121	84	95	45
		CV%	22	29	21	23
B	*Hibiscus esculentus*	Root	512	414	392	180
		Leaves	402	391	485	304
		Bud	4397	2983	3928	1622
		Fruit	632	198	363	171
		Stem	522	237	397	156
		Mean	1293	845	1113	487
		SD	1737	1199	1574	638
		CV%	134	142	142	131
C	*Zea mays*	Root	347	285	472	187
		Leaves	534	268	531	169
		Mean	441	276	502	179
		SD	132	12	42	13
		CV%	30	4	8	7
D	*Corchorus olitorius*	Root	492	280	299	229
		Leaves	600	268	444	185
		Bud	382	259	303	162
		Flower	1040	444	653	397
		Stem	575	313	424	185
		Mean	618	313	425	240
		SD	251	77	144	92
		CV%	41	25	34	38

Table 2 shows the major elements in Ado-Ekiti Fadama farm crops (DW). Zone A contains *Hibiscus esculentus.* On comparative basis, the stem and the leaves have the least values of all the elements while the flower and the bud have higher concentrations of all the elements while fruit and root are in the middle class. The element distribution in *H. esculentus* here is close with the CV% ranging between 24 and 27. This is in sharp contrast to what occurs in the *H. esculentus* in Ifaki-Ekiti zone B where CV% ranged between 131 and 142. This may be due to the difference in their ages because the Ifaki-Ekiti sample is in the fruiting stage (more mature) while the Ado-Ekiti sample is just maturing [3]. Zone B contains *Celosia argentea. Zea mays* is in zone C. The values of the elements in the various parts are very close with CV% ranging between 10 and 18. Zone D contains *Lycopersicon esculentum.* Here the stem has the overall highest value with Mg (528 ppm DW) followed by the root in K (486 ppm DW) but the lowest values in root, fruit and stem are reported for Ca but Ca occupied the third position in the leaves.

Table 2. Major elements (ppm) in the Ado-Ekiti Fadama farm crops (DW).

Zone	Plant	Plant part	Element			
			Mg	K	Na	Ca
A	*Hibiscus esculentus*	Root	486	465	424	301
		Leaves	493	473	372	192
		Bud	463	733	359	232
		Flower	673	421	655	399
		Fruit	399	471	453	266
		Stem	329	386	414	235
		Mean	474	491	446	271
		SD	116	123	108	73
		CV%	24	25	24	27
B	*Celosia argentea*	Root	512	373	390	253
		Leaves	523	398	450	234
		Seeds	425	454	493	205
		Stem	341	485	452	229
		Mean	450	427	446	230
		SD	85	51	42	20
		CV%	19	12	10	9
C	*Zea mays*	Root	638	370	391	234
		Style	599	473	360	250
		Leaves	486	375	396	306
		Stem	447	425	486	270
		Efflorescence	356	480	521	277
		Cob	520	452	370	330
		Grain	441	417	516	252
		Mean	494	422	432	278
		SD	90	44	66	33
		CV%	18	10	15	12
D	*Lycopersicon esculentum*	Root	421	486	438	224
		Leaves	390	381	301	363
		Fruit	427	474	454	278
		Stem	528	468	348	174
		Mean	441	452	385	260
		SD	60	48	73	81
		CV%	14	11	19	31

Table 3 shows the major elements in Ikere-Ekiti Fadama farm crops (DW). Zone A contains *Zea mays.* On general comparison, leaves are consistently highest in the concentration for Mg, K, Na and Ca whereas the style is lowest in Mg and Na. Zone B contains *Hibiscus esculentus.* Areas of hot spot accumulation of the elements are observed for root in Mg (510 ppm DW), leaves in Mg (612 ppm DW), bud in Mg (413 ppm DW), flower in Mg (456 ppm DW), fruit in Mg (697 ppm DW) and stem in Mg (573 ppm DW). Zone C contains *Celosia argentea.* The trend of accumulation in the plant parts are: root, Mg > Na > Ca > K; leaves, Mg > Na > K > Ca; fruit, Na > Mg > K > Ca and stem, Mg > Na > Ca > K. Zone D contains *Lycopersicon* *esculentum.* The root has the highest levels of concentration in Mg (2734 ppm DW), K (1079 ppm DW), Na (2111 ppm DW) and Ca (677 ppm DW). This is the only plant part here that has such a pride of place. The elements here are heterogeneously distributed in the plant parts with the element CV% range of 62 to 97. These are the highest variation reported in all the crops in Ikere-Ekiti.

Table 3. Major elements (ppm) in the Ikere-Ekiti Fadama farm crops (DW).

Zone	Plant	Plant part	Element			
			Mg	K	Na	Ca
A	*Zea mays*	Leaves	656	556	731	385
		Cob	471	322	363	225
		Grain	603	219	576	288
		Shaft	426	440	510	289
		Stem	495	310	369	343
		Efflorescence	448	262	335	325
		Style	387	248	305	284
		Mean	498	336	456	306
		SD	97	121	156	51
		CV%	20	36	34	17
B	*Hibiscus esculentus*	Root	510	362	445	274
		Leaves	612	369	481	292
		Bud	413	225	312	294
		Flower	456	285	412	276
		Fruit	697	324	446	195
		Stem	573	370	450	212
		Mean	543	322	424	257
		SD	105	58	59	43
		CV%	19	18	14	17
C	*Celosia argentea*	Root	667	273	420	300
		Leaves	689	424	489	330
		Fruit	473	445	543	361
		Stem	520	258	369	271
		Mean	587	350	455	316
		SD	107	98	76	39
		CV%	18	28	17	12
D	*Lycopersicon esculentum*	Root	2734	1079	2111	677
		Leaves	744	296	426	311
		Fruit	604	388	369	177
		Stem	723	451	541	264
		Mean	1201	553	861	357
		SD	1024	356	836	220
		CV%	85	64	97	62

Table 4 contains the variation range of the elements in the crops in the different zones in the three towns. In Ifaki-Ekiti, the lowest variation range is observed in *Z. mays,* zone C in Ca with a value of 19 ppm DW whereas the highest variation is observed in Mg with a value of 3995 ppm DW in *H. esculentus.* In Ado-Ekiti crops, the lowest variation range is in *C. argentea* (zone B) with a value of 48 ppm DW whereas the highest variation is in *H. esculentus* with a value of

347 ppm DW in K. In Ikere-Ekiti, the hot spots in variation range is observed in the zone D plant, *L. esculentum* whose variation range is 500 ppm DW in Ca to 2130 ppm DW in Mg. Lowest variation range is observed for zone C plant, *C. argentea* in Ca with a value of 90 ppm DW. The CV% for the variation range in Ikere-Ekiti is high with a range of 81 to 129; these values are comparable to the values reported for Ifaki-Ekiti crops. On comparative basis the variation range CV% in the elements of the crops in the three towns are Ifaki-Ekiti > Ikere-Ekiti > Ado-Ekiti.

Table 4. The variation range (ppm) of the elements in the crops in the different zones in the three towns.

Town	Zone	Plant	Element			
			Mg	K	Na	Ca
Ifaki – Ekiti	A	*C. argentea*	273	174	232	110
	B	*H. esculentus*	3995	2786	3565	1466
	C	*Z. mays*	187	165	59	19
	D	*C. olitorius*	658	186	354	235
		Mean	1278	828	1053	457
		SD	1823	1306	1679	679
		CV%	143	158	160	148
Ado-Ekiti	A	*H. esculentus*	344	347	295	208
	B	*C. argentea*	182	113	103	48
	C	*Z.mays*	282	110	161	960
	D	*L. esculentum*	138	105	153	190
		Mean	236	169	178	135
		SD	94	119	82	76
		CV%	40	71	46	56
Ikere-Ekiti	A	*Z. mays*	269	337	427	160
	B	*H. esculentus*	285	144	169	99
	C	*C. argentea*	215	187	174	90
	D	*L. esculentum*	2130	783	1742	500
		Mean	725	363	628	212
		SD	938	292	753	194
		CV%	129	81	120	92

The overall ranking percent of element concentrations in the samples according to their positions are shown in Table 5. In summary we can conveniently say that the trend of element concentration in the crop samples is Mg > Na > K > Ca.

Table 5. Overall ranking (%) of element concentrations in the samples according to positions.

Metal	Position[a]				
	1st	2nd	3rd	4th	Total
Magnesium	42 (71)	9 (15)	8(14)	-[b]	59
Potassium	5 (9)	14 (24)	32(54)	8(14)	59
Sodium	12(20)	36(61)	10(17)	1(2)	59
Calcium	--	--	7(12)	52(88)	59
Mean	20	20	14	20	n.a.[c]
SD	20	14	12	28	n.a.
CV%	100	73	83	136	n.a.

[a]Percentage values are within the brackets. [b]No figures in that position. [c]Not applicable.

The range of concentration of a particular element varies widely between different plants and is also affected by the conditions under which the plants are grown, but all plant ash is similar in certain respects. The main constituent is usually potassium, which often comprises nearly 50% of the total weight of ash. Animal tissues, in general, are much less rich in potassium, but on the other hand, they usually contain more sodium [8]. It is possibly related to the preferential accumulation of potassium in the large vacuoles which are a prominent feature of many plant cells, but meristematic cells, which only have small vacoles, show an even greater preference for potassium over sodium [9]. After potassium, calcium is often the most abundant element in plant ash, although its concentration ranges widely from trace amounts in maize *(Zea mays)* grains to over 7% of the dry weight in mature sunflower *(Helianthus annuus)* leaves. In contrast to potassium, calcium occurs mainly in combined forms either associated with cell walls or as crystalline deposits of insoluble calcium salts, such as calcium oxalate, in the cytoplasm [8]. Plant ash is also rich in magnesium, which is a constituent of some organic molecules, including chlorophyll, and also occurs as free ions in the cell sap. Individual plant species and varieties differ markedly in their salt content even when they are grown under the same conditions. Sometimes these differences can be traced to differences in the size and form of the root system which enables the plants to exploit different regions of the soil, but in other areas they appear to be attributable to differing characteristics of absorption [10]. Grasses tend to have lower amounts of calcium than leguminous plants, both in the field and when grown in solution culture [10].

Sodium is not said to be universally essential in plant growth but its soluble compounds may increase crop growth [2]. It has been known for many years that this element will in part replace potassium and that common salt will at times increase crop yield [2]. Such seems to be the situation with respect to mangels, sugar beets, Swiss chard, table beets, celery and turnips grown on peat soils [2]. That sodium is essential with certain crops under certain conditions is highly probable [11-13]. Sodium is an activator of transport ATP-ases in animals and possibly also in plants. There is evidence that sodium can replace potassium partly in some of its functions. Na effects are particularly evident when K is deficient. There is now good evidence that Na is an essential micro-nutrient for *Atriplex vesicara* and some other plants notably those showing the C_4 photosynthetic pathway [14]. Na is most concentrated in the leaves of *C. argentea, H. esculentus* and *Z. mays* (Table 1). Na does not enjoy this pride of place in the results given in Table 2 but Na is most concentrated in *Z. mays* and *H. esculentus* leaves (Table 3). It is evident that during evolution animals have maintained an internal environment more similar to that of the sea than have most plants. One consequence of this is that the diet of domesticated herbivorous animals such as cattle must be supplemented with common salt [8], hence, the requirement of high sodium in fodders as seen in these results. Calcium is an essential element for all higher plants and is found in relatively large quantities in plant leaves (Tables 1-3) but plants differ widely in the amounts of calcium they need. Calcium, in the form of calcium pectate, is an important component of plant cell walls. Calcium salts of phosphatidic acid occur in membranes and are essential to the maintenance of their structure and properties. Amylase is activated specifically by calcium [8]. Calcium deficiency results in early death of meristematic regions of stem and root; malformation of the young leaves, causing the tips to be hooked back. Once it is deposited in leaves, calcium like sulphur is immobilized [8]. It is observed in the current report that the bulk of Ca is present in the leaves (Tables 1-3). In the absence of Ca roots do not grow well and often appear brown in colour and stunted. Degeneration at the apex of young fruits ('blossom end rot') is a common symptom of Ca deficiency in tomatoes.

Magnesium is a constituent of every chlorophyll molecule, and therefore essential for photosynthesis, green plants cannot do without it. Magnesium is also found in plant seeds. It is also associated with many plant proteins [8]. It appears to be connected with phosphorus metabolism in the plant, with the activation of enzymes affecting carbohydrate metabolism, and also (in association with sulphur) in the synthesis of plant oils [1]. It is mobile in the plant, being transferred from old leaves to young ones if necessary, and deficiency symptoms, usually a chlorosis or whitening of the tissue between the veins appear first on the older leaves. Leafy crops such as tobacco are particularly sensitive to Mg deficiency, and deficiencies have been observed in West Africa in oil palms where they have been thought to be responsible for orange frond disease [1]. Other symptoms of Mg deficiencies are: interveinal chlorosis followed by accumulation of anthocyanin pigment and necrosis, reduction of growth, marked shortening of internodes, premature death of leaves and inhibition of flowering [8]. The current report shows the dominant level of Mg in virtually all the samples analysed.

Table 6. Bioaccumulation of elements in the crops from the various zones and towns.

Town	Zone	Mg	K	Na	Ca
Ifaki-Ekiti	A	2	2	3	3
	B	5	5	6	5
	C	2	2	3	2
	D	-[a]	-	-	-
	Mean	3	3	4	3
	SD	2	2	2	2
	CV%	69	59	50	55
Ado-Ekiti	A	4	4	3	4
	B	4	4	3	3
	C	3	4	3	3
	D	3	3	2	3
	Mean	4	4	3	3
	SD	0.8	0.4	0.1	0.5
	CV%	22	11	4	16
Ikere-Ekiti	A	2	2	2	3
	B	2	3	2	3
	C	2	3	3	4
	D	6	3	6	3
	Mean	3	3	3	3
	SD	2	0.3	2	0.4
	CV%	68	12	53	13

[a]Soil values not available here for bioaccumulation calculation.

Potassium is lower in very many respects to Mg in the samples because it is possible that the K is concentrated solely in the cytoplasm where K requirement of plants would presumably be much lower. K, the third of the so-called primary or major nutrients in plants is essential for the formation and transfer of carbohydrates in plants, and for photosynthesis and protein synthesis. K occurs particularly in the growing points, fruits, and seeds of plants. This information is particularly true for fruits, buds, flowers, seeds, efflorescence and roots (Tables 1-3) in the present report. Plants such as cassava which synthesize and store relatively large amounts of starch usually have particularly high potassium needs [15]. By increasing crop resistance to certain diseases and by encouraging strong root systems, K tends to prevent the undesirable "lodging" of plants and to counteract the damaging effects of excessive nitrogen. In delaying maturity, K works against undue ripening influences of phosphorus. In a general way, K exerts a balancing effect on both N_2 and P, and consequently is especially important in a mixed fertilizer. This element is important to cereals in grain formation, as it aids in the development of plump and heavy kernels [16]. Abundant available K is also absolutely necessary for tuber development. Therefore, the percentage of K usually is comparatively high in mixed fertilizers recommended for potatoes [16]. All root crops respond to liberal applications of K. The leaves of crops suffering from a K deficiency [17] appear dry and scorched at the edges, and the surfaces are irregularly chlorotic. As a result of deterioration, photosynthesis is much impaired and the synthesis of starch is practically brought to a standstill [17]. These symptoms were not observed in any of the samples.

The bioaccumulation of major elements by plants from soil is depicted in Table 6 (major elements in soils not shown here). The degree of accumulation is intensive for all the values recorded in the plants. The ability of different plants to absorb major elements varies greatly. Marked differences in the element uptake between both plant species and varieties open up new aspects for plant breeding programmes for the biodepletion in element transport to the food chain.

CONCLUSION

The Fadama farms contain crops of short gestation periods and no tuber crop is involved, hence crops analysed contain low level of K than in tubers. Most of the plant parts analysed can act as fodder for ruminants but such analyses are normally not bothered about. This work therefore will serve as a baseline information for future work.

REFERENCES

1. Ahn, P.M. *West African Soils,* Oxford University Press: Oxford; **1970**; pp. 20-100.
2. Lyon, T.L.; Buckman, H. O.; Brady, N.C. *The Nature and Properties of Soils*, 5th ed., The Macmillan Company: New York; **1952**; pp. 20-44.
3. Adeyeye, E.I. *Bull. Chem. Soc. Ethiop.* **2005**, 19, 1.
4. Walsh, L.M. (Ed.) *Instrumental Methods for Analysis of Soils and Plant Tissue*, Soil Society of America: Madison, Wisconsin, U.S.A.; **1971**; pp. 27-32.
5. Varian Techtron, *Basic Atomic Absorption Spectroscopy – A Modern Introduction,* Varian Techtron: Springvale, Australia; **1975**; pp. 104 - 106.
6. Steel, R.G.D.; Torrie, J.H. *Principles of Procedures of Statistics*, McGraw-Hill: London; **1960**; pp. 1- 360.
7. Kabata – Pendias, A.; Pendias, H. *Trace Elements in Soils and Plants*, 2nd ed., CRC Press: Boca Raton, Florida; **1992**; pp. 1-200.
8. Sutcliffe, J.F.; Baker, D.A. *Studies in Biology No. 48 – Plants and Mineral Salts,* Edward Arnold Publishers Ltd.: London; **1974**; pp. 1-25.
9. Sutcliffe, J.F.; Counter, E.R. *Nature* **1962**, 183, 1513.
10. Collander, R. *Plant Physiology* **1941**, 16, 691.
11. Lehr, J.J. *Soil Sci.***1941**, 52, 373.
12. Harmer, P.M.; Erwin, J.B. *Soil Sci.***1945**, 60, 137.
13. *Bibliography of References to the Literature on the Minor Elements and Their Relation to the Science of Plant Nutrition*, Vol. 1, 4th ed., Chilean Nitrate Educational Bureau, Inc.: New York; **1948**.
14. Brownell, P.F.; Crossland, C.J. *Plant Physiology* **1972**, 49, 794.
15. Adeyeye, E.I.; Ayejuyo, O.O. *Pak. J. Sci. Res.* **2002**, 45, 10.
16. Brady, N.C. *The Nature and Properties of Soils*, 8th ed., MacMillan: New York; **1974**; p 639.
17. American Society of Agronomy and the National Fertilizer Association (ASA/NFA) *Hunger Signs in Crops*, David Mckay: New York; **1964**.