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Full Length Research Paper

Diversity of common bean (*Phaseolus vulgaris* L.) genotypes in iron and zinc contents under screenhouse conditions

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Deficiencies in iron and zinc have health consequences for humans, such as anaemia, poor growth and development in children and low productivity in adults. To guarantee sufficient supply of iron and zinc through diet mainly consisting of staple foods, such as common bean (*Phaseolus vulgaris L.*), specific interventions in plant breeding are needed. However, seed mineral content has not been a selection criterion for plant breeding, although genetic variation for this trait is present in available germplasm collections. The aim of this study was to evaluate variability of iron and zinc concentrations among common bean genotypes grown in four major bean growing areas in Tanzania for breeding work. Ninety genotypes collected were evaluated under screen house at Sokoine University of Agriculture. A completely randomized design with three replications was used. Seeds and leaves were collected, dried, ground and the powder was used for iron and zinc determination using atomic absorption spectrophotometer. Variation in iron and zinc contents was observed among genotypes both in seeds and leaves and best genotypes identified. Results have shown a positive and significant correlation(r=o.416;P<0.001) between iron and zinc, suggesting that genetic factors for increasing iron and zinc are co-segregating with genetic factors for increasing zinc. Leaves of the studied varieties have moderate level of zinc (28.0 ppm) and high level of iron (310.0 ppm) forming good source of micronutrients in combating micronutrient malnutrition. Genotypes with high level of iron and zinc should be used as a gene source in future breeding work.

Key words: Common bean, iron and zinc.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a crop of considerable importance in the world as a grain legume and as a vegetable (Singh, 1999). It is one of the principal food and cash crop legumes grown in the tropics. Most of the production takes place in developing countries (Hillocks et al., 2006). It is a primary and least expensive source of calories, proteins, dietary fibres, minerals and vitamins for the population in these countries although its intake does not satisfy their mineral requirements (Welch and Graham, 1999; Guzman-Maldonado et al., 2000; Hillocks et al., 2006). It complements cereals and other carbohydrate rich foods in providing near perfect nutrition to people of all ages and helps to lower cholesterol and cancer risks (Singh, 1999). However, the concentrations will vary in response to both genetic and environmental factors (Grusak, 2002). Recent reports indicate that Fe deficiency is the most prevalent micronutrient problem in the world affecting over 2 billion people, most of who depend on beans as staple food (Welch and Graham, 1999). Other studies have identified Zn deficiencies in children depending on diets high in starchy foods (Ranum, 1999). Forty percent of Fe intake in developing countries is derived from legumes and cereals (Rosado et al., 2007). Food legumes in general contain appreciable quantities

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of iron and other mineral nutrients (Beebe et al., 2000; Grusak, 2002).

An underlying cause of and fundamental constraints to solution of the micronutrient problem is that non-staple foods, particularly those of animal origin, tend to be the ones richest in bio available micronutrients but beyond the reach of most people in the developing countries. Also, selection for yield and other agronomic traits such as resistance to biotic and abiotic stresses, upright plant architecture, growth habits, lodging resistance, and maturity has been extensively utilized by bean breeders to develop cultivars with superior performance or to develop cultivars that are adapted to specific environments and/or cropping systems (Tar`an et al., 2002). To date, seed mineral content is not a specific selection criterion for plant breeding, although genetic variation for this trait is available in germplasm collections (Vreugdenhil et al., 2004). Available literature indicates existence of comparable ranges of mineral concentrations among seeds of most leguminous species (Wang et al., 2003). Thus, identifying cultivars with high amounts of Fe and Zn could contribute significantly to improvements of micronutrient of people depending on the common bean as major component of their diet. The current study, therefore, was conducted to evaluate variability of iron and zinc concentrations among common bean varieties grown in four major bean growing areas in Tanzania for breeding work.

MATERIALS AND METHODS

Bean seeds of different varieties were collected from four major bean growing Regions in Tanzania; namely Mbeya, Kagera, Arusha and Morogoro. In addition, seeds of improved varieties were collected from three research Institutions that were Sokoine University of Agriculture (SUA), Uyole (Mbeya) and Selian (Arusha) (Figure 1). Mbeya region is located in the south-west of the southern highlands of Tanzania. The region lies between latitude 7^0 $00'$ and $9^0$31'S and between 32°00' and 35°00'E. The climate is generally tropical with marked seasonal and altitudinal temperature variations and sharply defined by dry and rainy seasons. The temperature averages range between 16°C in the highlands and 25°C in the lowlands areas. The region has abundant and reliable rainfall. Annual rainfall varies between 650 mm and 2600 mm. Kagera region is located in the north-west of Tanzania. It lies just below the Equator between 1°00` and 2°45`S. Longitudinally it lies between 30°25` and 32°40`E. The region experiences a pleasant climate, with an average temperature of 20 - 30°C throughout the year, although it can drop as low as 10°C at night in the rainy season. Much of the region is hilly terrain with thick tropical vegetation including forests and wide-open grasslands. The region experiences two rain seasons. The heavy rains fall from March to May and short rains from October to December. Kagera receives an average rainfall of 800 to 2,000 mm per annum. It has an ample rainfall, fertile soils and mild temperature which are conducive for the production of various crops including common bean. Arusha region is located on 3° 22' S, 36° 41' E. It is in the high altitudes ranging from 800 to 4,500 m above sea level. Because of the high altitude the region experiences moderate temperature with rainfall varying with the altitude. The average annual temperature is 21°C in the highlands and 24°C in the low lands. The region has two types of rainfall patterns: Monomodal and bimodal. Monomodal rainfall which usually start in November and ends in April. For bimodal, the short rains normally start in October and end in December, while the long rains start in February and end in June every year. Morogoro is characterized by a bimodal rainfall pattern, with unreliable peaks occurring in November/December of some years and reliable ones in February to May. Annual rainfall could be as high as 1500 mm per annum. There is adequate moisture and temperature for crop production. The average annual temperature in the region's highlands is 18°C but reaches 30°C in the lowland. Rainfall varies from 1200 mm in the highland plateaus to 600 m in lowlands.

Generally, the genotypes collected were diverse, representing a range of seed types, ranging from different seed coat colours, size, shape and other morphological characteristics, such as growth habits. A total of 90 genotypes were collected. There were no specific and strict criteria in choosing genotype to collect. Collections were done both from farmers and markets. Amounts collected varied from 0.5 to 1.0 kg depending on availability from the source. Bulk soil samples were taken at a depth of 0 - 20 cm. Composite soil samples constituted twenty sub-samples randomly collected from an area covering 2.0 ha. Sub-samples were thoroughly mixed, air-dried and ground to pass through a 2.0 mm mesh. The 2.0 mm sieved composite soil samples were used for laboratory physical and chemical analyses. All soil samples were analysed for particle size distribution, soil pH, cation exchange capacity (CEC), exchangeable bases (Ca, K, Mg and Na), micronutrients (Fe and Zn), organic carbon (OC) and available phosphorus. Particle size distribution was determined by the hydrometer method after dispersing the soil samples with sodium hexametaphosphate solution (Day, 1965). Soil textural classes were determined using the USDA textural class triangle (USDA, 1975). Soil pH was determined in water at a soil: water ratio of 1:2.5 suspension using pH meter (MacLean, 1982). Available P was extracted using the Bray 1 method (Bray and Kurtz, 1945) and colour was developed by the ascorbic acid of Murphy and Riley (1962). Exchangeable calcium (Ca) and magnesium (Mg) were determined by atomic absorption spectrophotometry whereas K and Na were extracted using ammonium acetate and analysed by flame spectrophotometry. Cation exchange capacity (CEC) was determined with ammonium acetate saturation method at pH 7.0 (Chapman, 1973). Organic car-bon was determined by the Walkley-Black wet combustion method (Tan, 1996) and total N was determined using the Kjeldahl method. The DTPA extractable Cu, Fe, Mn and Zn were determined by atomic absorption spectrophotometry (Lindsay and Norvell, 1978). The soil was mixed thoroughly with basic nutrients (rates in mg/kg soil) nitrogen 40 (as sulphate of ammonia), potassium 10 (as potassium chloride), zinc 10 (zinc sulphate) and molybdenum 1 (ammonium molybdate). Iron was not applied since it was above the critical level in soil required for common bean growth. Zinc is affected by P application so to assure that Zn was available to plants it was applied in excess of the concentration in the soil. After mixing soil with nutrients it was filled in plastic pots. Each pot was filled with 4.0 kg of uniform mixed soil. The pots used were perforated at the bottom to allow drainage of excess water.

The pots were placed in screen-house benches made of meshed steel, one metre high. The treatments (common bean genotypes) were replicated three times and arranged in a completely randomised design (CRD). Before sowing, the potted soil was watered to 90% field capacity (FC), and allowed to stay for one day. Four bean seeds were planted in each pot. The soils in the pots were maintained at approximately field capacity during the entire experimental period through frequent watering. Thinning was done one week after emergence and two seedlings were left per pot. Two weeks after sowing, nitrogenous fertilizer (Urea 46% N) was applied

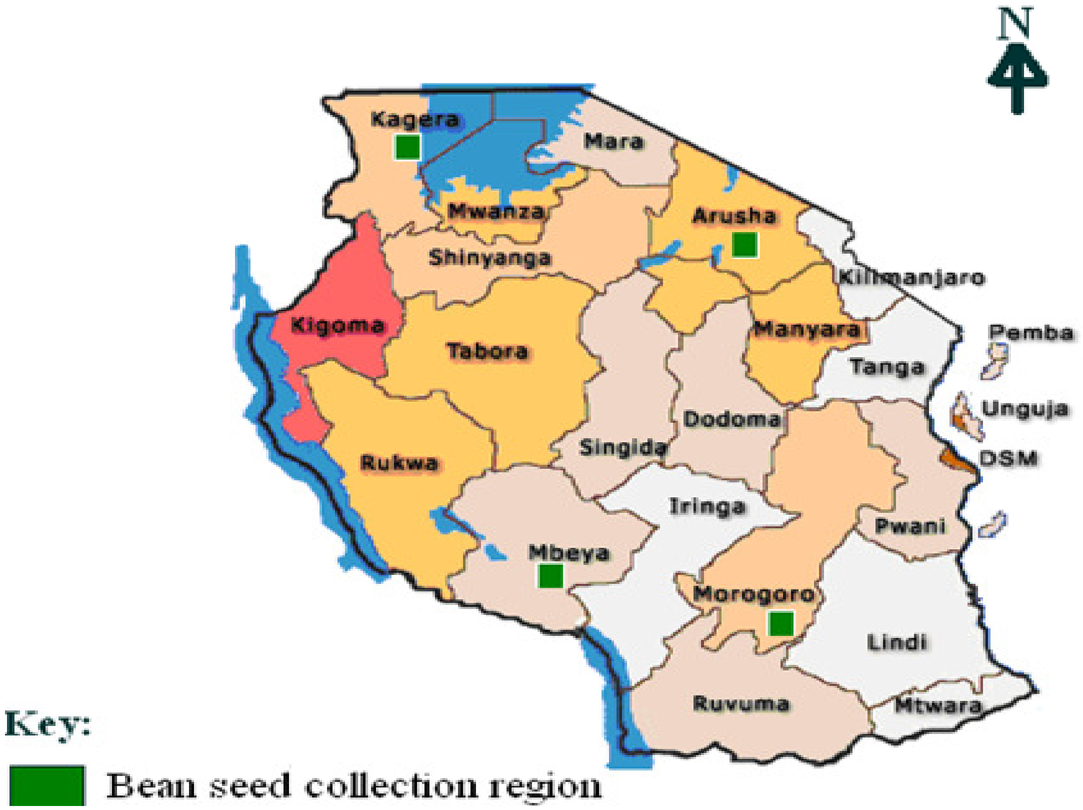

Figure 1. Map of Tanzania showing study area.

in each pot. A trifoliate leaf was sampled from each plant in each pot at early flowering. Leaf samples were put into paper bags, clearly labelled and oven dried and then ground to fine powder using a motor and pestle to pass through a 0.5 mm sieve for Fe and Zn analyses. After physiological maturity, seeds were harvested from each pot, put into paper bags and air dried. Then, seeds were taken to the laboratory and ground using a sample mill. The powder obtained was used for determination of Fe and Zn in the seeds.

The atomic absorption spectrophotometer (AAS) method was used to determine iron and zinc content (AOAC, 1995). A sample of 0.5 g of ground plant leaves were weighed in digestion tubes. Then, 5 ml of 68% nitric acid was added into each tube and the mixture left to stand overnight. The digestion tubes were then placed in the digestion block and the temperature set at 125°C for one hour before being cooled. After cooling, 5 ml of 30% hydrogen peroxide (H_2O_2) was added into each tube and heated at about 70°C on a digestion block until the reaction stopped. After cooling, 5 ml of 30% H_2O_2 was again added and heated at 70°C. The treatment was repeated until the digest was colourless. The temperature was increased to 180°C and continued digesting to almost dryness and then left to cool. Ten ml of 10% nitric acid was added and the dissolved digest was transferred to a 50 ml volumetric flask. The flask was then filled to the mark with distilled water and then mixed. The solution was thus ready for determination of iron and zinc as per AAS method. Analysis of variance (ANOVA) was performed; simple linear correlations were also carried out among the variables. In addition, Duncan's New Multiple Range Test (DNMRT) was used for mean separation. All data analyses were performed using MSTATC statistical package.

RESULTS AND DISCUSSION

Apart from low total N, the experimental soils had medium to high chemical and physical characteristics (Table 1). Thus according to Landon (1991), these soils were suitable for production of field crops, including common beans. The genotypes evaluated differed significantly for days to D50 and D85 ($P \leq 0.001$). D50 varied from 27 days (*Kishoro*) to 45 days (*Rushesheka*) with a mean of 35 days, and D85 ranged from 53 days (*Kihenda ndosho*) to 81 days (*Shona eigunia*), with a mean of 67 days (Tables 2 and 3). This phenological difference among the varieties exists because they are genetically different from each other. Iron concentrations in leaves differed significantly ($P \leq 0.001$) among genotypes, ranging from 163.7 to 485.6 ppm (Tables 3 and 4) with a mean of 310.5 ppm. The leaf iron content among genotypes was divided into sub-groups of low, moderate and high. Hence, genotypes that had a range of 163.7 to 270 ppm were rated as low, 271 to 310 ppm moderate and 311 to 485.6 ppm rated at high (Figure 2). Zinc concentrations in leaves varied significantly ($P \leq 0.001$) among varieties, ranging from 15.7 to 78.3 ppm with a mean of 28.0 ppm. Leaf zinc contents among genotypes was

Table 1. Some physical-chemical characteristics of the experimental soils.

Soil character	Measurements	Rating/remarks
pH in water	7.33	High
Organic carbon (%)	1.55	Medium
Total N (%)	0.13	Low
Bray-1-P (Mg/kg)	40.14	Medium
CEC (cmol(+)/kg)	25.8	High
Exchangeable Ca (cmol(+)/kg)	7.42	Medium
Exchangeable Mg (cmol(+)/kg)	3.55	High
Exchangeable K (cmol(+)/kg)	0.985	Medium
Exchangeable Na (cmol(+)/kg)	0.514	Medium
DTPA Fe (mg/kg)	55.44	very high
DTPA Zn (mg/kg)	1.855	High
Particle size analysis		
%sand	71	
%Silt	11	
%Clay	18	
Textural class	Sand clay	

Table 3. Summary of results of evaluated common bean showing traits, ranges and error mean square (EMS).

Trait	Range	Mean	EMS
Days to 50% flowering	27.00 - 45.00	34.87	11.64***
Days to 85% flowering	53.00 - 81.00	66.70	21.15***
Leaf iron (ppm)	163.70 - 485.60	310.50	5959.29***
Seed iron (ppm)	23.63 - 78.30	55.01	390.31***
Leaf zinc (ppm)	15.70 - 78.30	28.03	55.68***
Seed zinc (ppm)	19.00 - 56.13	31.44	21.47***

*** Level of significance at 0.001.

categorized into sub-groups; 15.7 to 22.9 ppm being low and there were about 37.8% of evaluated genotypes in this group, 23.0 to 29.9 ppm moderate with 33.7% genotypes in this group and 30.1 to 78.3 ppm (28.9%) (High) (Tables 3 and 4). According to Landon (1991) sufficient ranges of micro-nutrients in mature leaves are 50-250 ppm for Fe and 25 -150 ppm for Zn.

Results suggest that leaves contain more than average concentration of Fe (310.5 ppm) and a moderate level of Zn (28.0 ppm). These observations imply that leaves can be consumed as vegetable to supply or supplement Fe and Zn requirements in diets, especially varieties that have high levels of these minerals. A similar opinion was suggested by Hillocks et al. *(*2006).

The genotypes differed significantly (P≤0.001) in iron content in seeds. It varied from 23.63 to 105.50 ppm, with a mean of 55.01 ppm. Seed iron content among genotypes was categorized into subgroups as follows; 23.6 to 42.0 ppm low that accounted for 24.5%, 43.0 to 59.6 ppm (42.2%) (Moderate) and 60.4 to 105.5 ppm (33.3%) (High) (Figure 2).

Iron values obtained in this work are similar to or higher than those reported by other researchers; 61.81- 83.99 ppm (Shimelis and Rakshit, 2005) and 41.0-142.0 ppm (Guzman-Maldonado et al., 2003). The genotypes significantly (P≤0.001) differed in seed zinc contents. Values varied from 19.00 to 56.13 ppm with a mean of 31.44 ppm. Seed zinc contents among bean varieties can be divided into sub-groups; 19.00 to 26.90 ppm (22.2%) (Low), 27.00 to 30.00 ppm (33.3%) (Moderate) and 31.00 to 56.13 ppm (44.5%) (High). (Figure 4) Zinc values obtained are similar to or slightly similar to or slightly greater than concentrations of 15.39 to 28.22 ppm obtained by Shimelis and Rakshit (2005) who screened eight bean varieties; 27 to 67 ppm by Guzman-Maldonado et al. (2003), who screened 120 accessions for Fe and Zn, and of 24 to 57 mg Zn/kg obtained by Hacisalihoglu et al. (2004) who screened 35 accessions

Table 2. Days to flowering and maturity among 90 common bean varieties/lines.

Varieties/Treatments	Days to 50% flowering	Days to 85% maturity	Region of origin
Wanja	31.33 i-q	61.33m-x	Mbeya
Kanunu	38.33 a-i	63.67h-v	Morogoro
Selian 2005	36.33 b-l	71.33b-k	Arusha
Canadian Wonder	31.00 j-q	61.67l-x	Morogoro
Mwaspenjele	29.00 m-q	57.00s-x	Mbeya
Maharage karanga	32.00 g-q	71.67b-j	Arusha
Bilfa-Uyole	34.67 d-o	66.33e-s	Mbeya
Pesa	30.00k-q	56.67t-x	Morogoro
Selian 97	34.00e-p	62.00k-w	Arusha
Uyole 98	33.00f-q	66.00e-t	Mbeya
Kihenda ndosho	29.00m-q	56.00u-x	Kagera
Ngela	34.33e-p	66.33e-s	Kagera
Bugubugu	33.00f-q	53.00wx	Kagera
Maharage soya	34.00e-p	63.67h-v	Morogoro
Rushesheka	45.00a	78.33abc	Kagera
Uyole 90	38.00b-j	67.67d-r	Mbeya
Msafiri	29.67l-q	60.67o-x	Mbeya
Kisapuri	28.00 o-q	60.67o-x	Kagera
Red Wolaita	39.00a-g	70.67b-m	Arusha
Awash melka	42.33a-c	66.67e-r	Arusha
Katunduri	36.33b-l	64.67f-u	Morogoro
Lyamungu 85	38.33a-i	73.00a-h	Arusha
Kishoro	26.67q	54.67vwx	Kagera
Rosekoko	34.00e-p	73.33a-g	Morogoro
Shona eigunia	40.33a-e	81.33a	Kagera
Bangaya akatebe	32.67f-q	64.33f-u	Kagera
Mwamikola	38.00b-j	74.67a-e	Kagera
Kitebe	33.33e-q	70.33b-n	Kagera
Kikobe	34.67d-o	64.00g-v	Kagera
Lyamungu 90	31.67h-q	61.67l-x	Arusha
Canada	34.67d-o	71.00b-l	Kagera
Masai red	39.00a-g	69.33c-p	Arusha
Chipikupiku	27.33pq	56.67t-x	Morogoro
Selian 94	33.00f-q	59.00r-x	Arusha
RWR ii	37.33b-j	70.67b-m	Arusha
Kigoma	27.33pq	55.67u-x	Mbeya
Uyole 84	39.00a-g	79.00ab	Mbeya
Kawanja	36.33b-l	73.67a-f	Kagera
Mwanga Chuchu	35.33c-n	71.00b-l	Kagera
Kyaburundi	37.00b-k	69.33c-p	Kagera
Tibihabwa	34.67d-o	69.67c-o	Kagera
Mjunza	34.67d-o	64.00g-v	Kagera
Kakaritusi	36.33b-l	62.67i-v	Kagera
Tema ekibila	39.67a-f	72.33a-h	Kagera
Kashoro	27.33pq	62.67i-v	Kagera
Kailaguju	38.67a-h	69.00c-p	Kagera
Meru	38.00b-j	75.00a-e	Arusha

Table 2. Contd

Kyakuponza	32.33g-q	62.33j-v	Kagera
Kamoshi	36.00b-m	73.00a-h	Kagera
Bwana shamba	31.67h-q	67.67d-r	Arusha
Rojo	30.00k-q	64.33f-u	Morogoro
Masusu	28.67n-q	60.00p-x	Mbeya
SUA 90	33.33e-q	61.00n-x	Morogoro
Mwanamwana	34.67d-o	52.67x	Kagera
Kyakaragwe	33.00f-q	69.67c-o	Kagera
Mshindi	29.67l-q	59.33q-x	Morogoro
Kinyobwa	31.00j-q	66.67e-r	Kagera
Kachele	33.00f-q	60.00p-x	Kagera
Soya fupi	37.00b-k	66.00e-t	Morogoro
Mayoha	37.67b-j	72.00b-i	Kagera
Jesca	34.67d-o	60.33o-x	Arusha
Roba 1	35.67b-n	69.33c-p	Arusha
Zebra	40.33a-e	67.67d-r	Arusha
White	39.00a-g	75.33a-e	Mbeya
Uyole 94	32.33g-q	71.67b-j	Mbeya
Maini	35.00d-o	62.67i-v	Mbeya
Kablanketi	35.67b-n	66.33e-s	Morogoro
Uyole 96	33.67e-p	61.67l-x	Mbeya
Gofta	35.67b-n	69.33c-p	Arusha
Kirundo	33.33e-q	62.00k-w	Arusha
Kikamba	42.67ab	71.00b-l	Arusha
Matawa	41.67a-d	73.00a-h	Morogoro
Ayenew	34.67d-o	66.33e-s	Arusha
Ranjonomby	33.67e-p	60.33o-x	Arusha
NUA 43	36.33b-l	68.67d-q	Arusha
Ngwakungwaku	36.00b-m	67.33d-r	Arusha
Lingot blanc	35.33c-n	67.67d-r	Arusha
NUA 30	36.33b-l	67.33d-r	Arusha
PVA 8	40.33a-e	76.67a-d	Arusha
Main de Kyondo	38.67a-h	72.00b-i	Arusha
MCM 2001	37.33b-j	75.00a-e	Arusha
NUA35	33.00f-q	64.33f-u	Arusha
OBA 1	37.00b-k	69.33c-p	Arusha
Mwamafutala	37.67b-j	79.33ab	Arusha
K132	37.00b-k	72.00b-i	Arusha
NUA4	35.33c-n	67.00e-r	Arusha
MLB49-89A	33.67e-p	67.67d-r	Arusha
NUA59	36.00b-m	69.33c-p	Arusha
NUA 56	34.00e-p	66.67e-r	Arusha
Kasukanywele	34.33e-p	67.33d-r	Mbeya
Mean	34.67	66.704	
CV (%)	9.79	6.89	
SE±	1.97	2.655	

Table 4. Concentrations of iron (ppm) and zinc (ppm) contents in leaves and seeds of 90 common bean varieties/lines.

Varieties/Treatments	Leaf Fe (ppm)	Leaf Zn (ppm)	Seed Fe (ppm)	Seed Zn (ppm)	Region of origin
Wanja	251.2g-p	21.43i-q	79.87a-e	42.8b-e	Mbeya
Kanunu	485.1a	22.57i-q	76.90a-h	30.63h-r	Morogoro
Selian 2005	361.9a-n	22.60i-q	83.50a-d	27.00j-t	Arusha
Canadian Wonder	352.0a-o	19.77l-q	71.33a-l	25.50m-t	Morogoro
Mwaspenjele	283.0d-p	21.40i-q	36.00h-n	25.30m-t	Mbeya
Maharage karanga	258.3g-p	23.43h-q	25.10mn	29.97i-s	Arusha
Bilfa-Uyole	404.4a-g	27.07g-q	40.80e-n	22.43r-t	Mbeya
Pesa	361.3a-n	25.70g-q	50.00d-n	27.33j-t	Morogoro
Selian 97	232.0j-p	20.50j-q	29.93l-n	28.87i-s	Arusha
Uyole 98	286.2d-p	22.97i-q	37.87f-n	23.13q-t	Mbeya
Kihenda ndosho	381.0a-k	26.33g-q	31.03k-n	26.90j-t	Kagera
Ngela	329.6a-o	20.67j-q	31.33j-n	19.00t	Kagera
Bugubugu	326.0b-o	20.27j-q	40.47e-n	23.10q-t	Kagera
Maharage soya	229.7j-p	22.80i-q	48.30d-n	25.20m-t	Morogoro
Rusheshека	288.0d-p	31.00e-q	23.63n	31.20g-r	Kagera
Uyole 90	470.6ab	35.17c-l	34.47i-n	24.37o-t	Mbeya
Msafiri	202.3nop	18.33o-q	43.60d-n	25.40m-t	Mbeya
Kisapuri	255.4g-p	27.73g-q	54.90c-n	28.97i-s	Kagera
Red Wolaita	395.0a-i	35.33c-l	55.83c-n	47.97b	Arusha
Awash melka	236.1h-p	29.93e-q	60.37b-n	27.07j-t	Arusha
Katunduri	352.0a-o	31.37e-q	36.27g-n	45.93bc	Morogoro
Lyamungu 85	358.2a-n	31.83e-p	55.00c-n	28.97i-s	Arusha
Kishoro	339.7a-o	27.97g-q	76.33a-h	44.53bcd	Kagera
Rosekoko	301.5d-p	22.43i-q	54.70c-n	39.83b-h	Kagera
Shona eigunia	285.7d-p	21.80i-q	74.57a-i	56.13a	Kagera
Bangaya akatebe	278.0d-p	22.70i-q	105.50a	46.43b	Kagera
Mwamikola	287.0d-p	36.97c-i	63.67b-n	35.50e-l	Kagera
Kitebe	297.3d-p	28.40f-q	71.50a-k	34.93e-m	Kagera
Kikobe	207.7m-p	36.73c-i	51.67d-n	41.37b-f	Kagera
Lyamungu 90	264.5g-p	43.20b-f	61.33b-n	32.67f-q	Arusha
Canada	311.0c-p	24.5h-q	68.17a-l	47.57b	Arusha
Masai red	260.0g-p	27.83g-q	66.67a-l	33.47f-o	Arusha
Chipikupiku	290.1d-p	37.03c-i	42.00e-n	26.43k-t	Morogoro
Selian 94	434.8a-e	23.63h-q	40.10e-n	28.83i-s	Arusha
RWR ii	258.50g-p	40.40b-g	41.53e-n	29.67i-s	Arusha
Kigoma	357.1a-o	35.47c-k	44.97d-n	25.30m-t	Mbeya
Uyole 84	375.7a-l	36.67c-i	37.83f-n	24.93o-t	Mbeya
Kawanja	300.6d-p	27.57g-q	33.83i-n	29.40i-s	Kagera
Mwanga Chuchu	256.4g-p	21.93i-q	48.13d-n	35.33e-l	Kagera
Kyaburundi	391.6a-j	33.70d-o	56.17c-n	36.47d-j	Kagera
Tibihabwa	347.0a-o	49.13bc	55.80c-n	28.73i-s	Kagera
Mjunza	376.0a-l	48.03b-d	41.20e-n	35.37e-l	Kagera
Kakaritusi	331.3a-o	31.60e-p	72.70a-j	36.43d-j	Kagera
Tema ekibila	276.1e-p	26.57g-q	77.53a-g	29.47i-s	Kagera
Kashoro	296.2d-p	27.93g-q	40.10e-n	32.90f-p	Kagera
Kailaguju	260.9g-p	35.70c-j	56.20c-n	29.33i-s	Kagera
Meru	271.8g-p	29.90e-q	51.97d-n	36.23d-j	Arusha

Table 4. Contd

Kyakuponza	400.7a-g	34.00d-m	56.63c-n	34.70e-n	Kagera
Kamoshi	303.4d-p	34.70c-m	52.00d-n	33.47f-o	Kagera
Bwana shamba	230.6j-p	26.33g-q	60.90b-n	31.03h-r	Arusha
Rojo	260.0g-p	26.53g-q	75.00a-i	39.40i-s	Morogoro
Masusu	237.4h-p	21.60i-q	72.77a-j	25.57m-t	Mbeya
SUA 90	349.5a-o	43.60b-e	36.60g-n	23.43p-t	Morogoro
Mwanamwana	293.1d-p	25.77g-q	35.53h-n	29.93i-s	Kagera
Kyakaragwe	289.2d-p	22.87i-q	48.27d-n	40.63b-g	Kagera
Mshindi	267.9g-p	23.07i-q	59.57b-n	27.67j-t	Morogoro
Kinyobwa	266.4g-p	21.00j-q	68.43a-l	35.90d-k	Kagera
Kachele	407.3a-g	24.67h-q	98.33ab	28.50i-s	Kagera
Soya fupi	255.9g-p	20.77j-q	43.00d-n	25.17m-t	Morogoro
Mayoha	462.9abc	29.90e-q	50.67d-n	28.50i-s	Kagera
Jesca	210.9m-p	19.13m-q	65.27b-m	29.67i-s	Arusha
Roba 1	262.9g-p	21.77i-q	51.10d-n	24.90o-t	Arusha
Zebra	233.2i-p	20.83j-q	43.47d-n	22.80rst	Arusha
White	365.7a-m	24.03h-q	53.00d-n	29.70i-s	Mbeya
Uyole 94	216.3l-p	19.87k-q	57.47c-n	36.03d-k	Mbeya
Maini	280.2d-p	52.77b	45.73d-n	33.80e-o	Mbeya
Kablanketi	307.2c-p	38.87b-h	56.40c-n	33.67e-o	Morogoro
Uyole 96	358.3a-n	18.43m-q	57.20c-n	21.60g-r	Mbeya
Gofta	362.8a-n	78.27a	76.67a-h	31.53g-r	Arusha
Kirundo	217.0l-p	20.53j-q	81.00a-e	31.77g-r	Arusha
Kikamba	438.6a-d	20.67j-q	44.20d-n	33.40f-o	Arusha
Matawa	396.3a-h	24.33h-q	64.00b-n	33.70e-o	Morogoro
Ayenew	339.1a-o	18.23o-q	58.07b-n	31.47g-r	Arusha
Ranjonomby	301.9d-p	20.93j-q	55.03c-n	31.13h-r	Arusha
NUA 43	289.9d-p	15.73q	54.87c-n	31.17h-r	Arusha
Ngwakungwaku	273.6f-p	23.03i-q	47.63d-n	30.77h-r	Arusha
Lingot blanc	373.6a-l	27.90g-q	64.43b-n	40.13b-h	Arusha
NUA 30	261.0g-p	32.23e-p	94.67abc	29.30i-s	Arusha
PVA 8	381.2a-k	25.90g-q	50.67d-n	20.50st	Arusha
Main de Kyondo	222.4k-p	29.90e-q	45.27d-n	28.00i-t	Arusha
MCM 2001	195.6o-p	20.97j-q	50.33d-n	29.00i-s	Arusha
NUA35	344.7a-o	21.97i-q	65.67b-m	34.80e-n	Arusha
OBA 1	235.5h-p	23.53h-q	61.60b-n	34.83e-n	Arusha
Mwamafutala	485.6a	34.70c-m	79.27a-f	28.03i-t	Arusha
K132	163.7p	17.17p-q	47.50d-n	30.63h-r	Arusha
NUA4	396.7a-h	23.70h-q	50.33d-n	37.60c-i	Arusha
MLB49-89A	302.0d-p	21.90i-q	36.73g-n	27.27j-t	Arusha
NUA59	209.7m-p	44.70b-e	36.23g-n	26.13l-t	Arusha
NUA 56	433.9a-f	28.00g-q	44.40d-n	28.40i-t	Arusha
Kasukanywele	304.0c-p	22.50i-q	74.33a-i	30.07i-s	Mbeya
Mean	310.49	28.03	55.01	31.44	
CV(%)	24.86	26.62	35.91	14.73	
SE±	44.57	4.308	11.41	2.675	

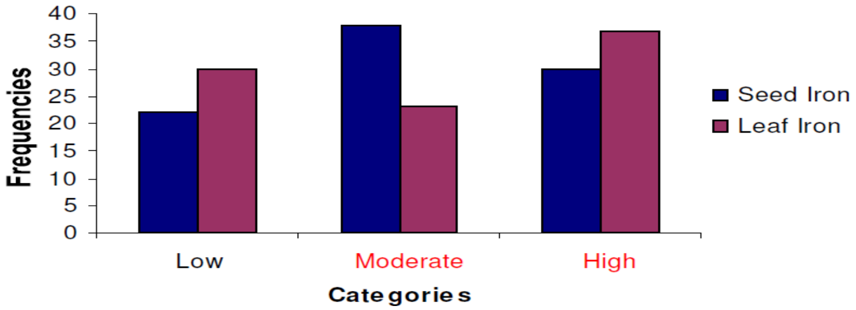

Figure 2. Categories of iron in common bean leaves and seeds.

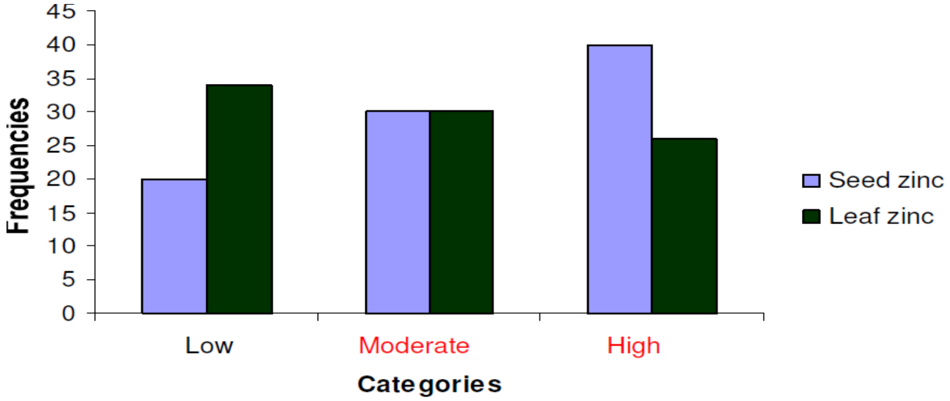

Figure 3. Categories of Zinc in common bean leaves and seeds.

Table 5. Simple correlation coefficients among zinc and iron in common bean leaves and seeds.

	leaf iron	leaf zinc	seed iron
Leaf iron			
Leaf zinc	0.285***		
Seed iron	0.037	0.006	
Seed zinc	-0.025	-0.015	0.416***

*, *** level of significance at 0.05 and 0.001, respectively.

of common bean. There was genetic variability among the tested since the genotypes used were derived from populations with wide genetic base. This finding are in agreement with those reported by Islam et al. (2002) that there is a wide variation in Fe and Zn contents among bean genotypes. However, the large variation in Fe and Zn concentrations observed in this study are similar to those reported by other workers (Islam et al., 2002; White and Broadley, 2005). Furthermore, seed Fe and Zn concentrations are quantitative traits and associated quantitative trait loci (QTL) have been identified in bean (Beebe et al., 2000; Guzman-Maldonado et al., 2000; Cichy et al., 2005; Gelin et al., 2007). Thus, breeding for bio fortification of Fe and Zn in seeds of common bean is feasible.

Relationships of iron and zinc in common beans genotypes

Seed iron was found to be positively correlated with leaf iron although not statistically significant (r = 0.037), implying that the amount in leaves can be reflected in seeds (Table 5). Seed zinc was negatively correlated and not significant with leaf zinc (r = -0.015). The results suggest that plant mineral concentrations vary between plant tissues (e.g. leafy structure versus seeds) thereby demonstrating that genetic differences exist, which can contribute to the plant's ability to acquire and sequester minerals in plant. In leaves, iron was found to have a positive and highly significant ($P \leq 0.001$) correlation with leaf zinc (r = 0.285). Seed iron was found to have a positive and highly significant ($P \leq 0.001$) correlation with seed zinc (r = 0.416). Positive correlation between Fe and Zn in common bean has also been reported by other authors. For example, studies by Gregorio (2002) showed a high and significant positive correlation coefficient of 0.52 between the concentrations of Fe and Zn across common bean genotypes. The positive correlations between each of the two mineral in the leaves and seeds is very important because it indicates that genetic factors for increasing Fe are co-segregating with genetic factors for increasing Zn, therefore selection for one trait will consequently increase levels of another one. This implies that selecting for a higher Fe level in bean seeds will also tend to select for increased Zn levels in the seeds (Graham and Welch, 1996; Gregorio, 2002). The common bean supplies significant amounts of minerals to populations in Latin America and Africa, Tanzania inclusive. It is speculated that increasing Fe and Zn concentrations in the common bean seeds could significantly increase the dietary intake of Fe and Zn in these regions. The trait should be considered in the varieties selection (White and Broadley, 2005). However, to the rural communities, the leaves can be consumed as a vegetable for healthy improvement.

CONCLUSION AND RECOMMENDATION

The findings from this study suggest that there is Fe and Zn variability among common bean genotypes collected in Tanzania. It is concluded that it is possible to identify genetic differences within common bean genotypes for Fe and Zn contents as a pre-requisite for breeding strategy aiming at increasing their concentrations. The genotypes with high levels of leaf iron are *Mwamafutala, Kanunu, Uyole 90, Mayoha* and *Kikamba*; high leaf zinc were *Maini, Tibihabwa, Mjunza, NUA 59.* Genotypes with high seed iron includes *Bangaya akatebe, Kachele, NUA 30, Selian 2005, Kirundo;* seed zinc were *Shona eigunia, Red wolaita, Katunduri, Kishoro and Wanja.* Those genotypes found to have high level of Fe and Zn can be used as gene sources in future breeding work which farmers use those varieties for consumption and production. Selecting genotypes with higher capacity to accumulate Fe and Zn could contribute significantly to the improvement of micronutrient status of people depending on common bean as a major component of their diet. Also, effort should be made to encourage people in bean growing areas to use bean leaves as vegetables.

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