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Variability in cooking time, iron and zinc content in common bean (*Phaseolus Vulgaris* L.) genotypes

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ABSTRACT

Prolonged cooking time leads to structural changes at the grain cellular level, resulting in loss of nutrients such as iron (Fe) and zinc (Zn) which are among the main nutrients important in addressing micronutrient malnutrition. The aim of this study was to evaluate the diversity of cooking time, Fe and Zn content in a total of 152 common bean (*Phaseolus vulgaris*) genotypes from around Eastern Africa, in order to identify short cooking genotypes with high Fe and Zn content. Field trials were conducted at CIAT-Uganda research station over two seasons in 2016. Cooking time was estimated using an automated Mattson cooker at CIAT-Uganda while Fe and Zn content was determined using XRF analysis at Rwanda Agricultural Board (RAB) in Rubona. A wide variability was evident from the test genotypes both for cooking time and mineral concentration. Cooking time exhibited a continuous distribution ranging from 35-100 minutes for the first season and 43–122 minutes for the second season. Seventy-three percent of the test genotypes had Fe levels higher than the low Fe check, CAL 96 (55mg/kg) which is popularly known as 'Nambale' and a popular commercial variety in Uganda. A total of 15 genotypes (Amahunja, Awash melka, Bihogo, CAB 2, ECAPAN021, G858, Icaquimbaya, KK20, NABE12C, NABE4, NABE6, ROBA-1, RWR1873, RWV3006) were consistent in short cooking time for the two seasons and had a Fe content above the low Fe check (CAL96 – 55mg/kg). A high correlation (r = 0.71) was observed between Fe and Zn whereas a low correlation between cooking time and Fe (r = -0.04) and Zn (r = 0.04) was observed. Great variability was evident for both traits indicating possible improvement by breeding and thus the possibility of having short cooking common bean genotypes with high Fe and Zn content.

KEYWORDS: Cooking time, diversity, micro nutrients, genotypes

INTRODUCTION

Cooking time of common bean (*Phaseolus vulgaris* L.) is an important feature in many countries in Africa and Latin America where the dry seeds are a dietary staple and firewood is the main fuel source used for cooking (Carbonell, 2003). The scarcity of firewood due to restrictions on deforestation in Eastern Africa has made the reduction in resources required to prepare beans for eating an important economic consideration . In addition, the rapid rate of urbanization and participation of women into the labor market has led to major changes into the food habits of the population. This has led to a demand for energy efficient and less time in food preparation (Zilio *et al.*, 2014). Cooking times for beans can vary from 1 1/2 to 8 hours, depending on the variety and the cooking method used (Zilio *et al.*, 2014). Fast cooking bean cultivars compared to the cultivars currently grown for consumption may be a means to conserve firewood. In addition, the Eastern Africa countries place a lot of emphasis on attaining food security and adequate nutrition for its citizens. In Uganda, persistent undernutrition in children is a perilous issue given that 33% of children under five years are stunted and 14 % are underweight (USAID, 2016). In addition, undernutrition is a core cause of 60 % of deaths for children under five years. Micronutrient deficiencies, including vitamin A and Fe, are highly prevalent in women and children (USAID, 2016).

Long cooking beans have been shown to have more structural changes at the grain cellular level, resulting in a loss of nutrients such as iron (Fe) and zinc (Zn) compared to short cooking beans (Wiesinger *et al.*, 2015). To combat the micronutrient malnutrition problem, research plays a key role in scaling up the production and marketing of biofortified crops like orange-fleshed sweet potato rich in Vitamin A and beans biofortified with Zn and Fe (USAID, 2016). Breeding progress for improving any trait is proportionate with the amount of genetic variability in the population.

Assessing genetic variability for a trait requires screening or evaluation of large amounts of germplasm. Based on the high

consumption of beans in East Africa, this study was conducted to investigate the genetic variability in cooking time, Fe and Zn in bean seed grown and consumed in Eastern Africa.

MATERIALS AND METHODS

One hundred and fifty-two (152) common bean genotypes were evaluated; 121 bush beans and 31 climbers. This germplasm consisted of released bean (commercial) varieties from seven East African countries (Table 1), Ethiopia, Madagascar, Uganda, Kenya, Tanzania, Rwanda and Burundi (PABRA, 2015). Breeding parents for important traits commonly used by members of the Pan-Africa Bean Research Alliance (PABRA) being maintained in the regional common bean gene bank at International Centre for Tropical Agriculture (CIAT) station based at the National Agricultural Research Laboratories (NARL) at Kawanda in Uganda were also included.

Trial Establishment

Two separate field trials were set up at Kawanda; one for the bush beans and another for the climbers for the ease of management practices and to reduce on inter-plot interference likely to occur if planted in one trial. Kawanda is located in Wakiso district in central Uganda, at Latitude 0° 23' 39" North, Longitude 32° 32' 11" East. It stands at an elevation of 1193 m above sea level, with the mean annual rainfall of 1250 mm, daily temperatures average 15.3°C minimum and 27.3°C maximum, relative humidity of 76.3% and soil that is of a sandy loam type with pH of 5.5-6.0 (Fallingrain, 2015).The trials were set up during the 2015B season (April to July) and 2015D (September-December), using a 6 x 21 alpha lattice design with three replications for bush beans on a plot of five rows each measuring two meters and a spacing of 10cm x 50 cm and a 3 x 9 alpha lattice with three replications for climber beans at 20cm x 50cm. NPK fertilizer(17:17:17) was applied at the rate of 100 kg/ha during planting (PABRA,2015). Weed control was done using selective chemical, Bean Clean (Clethodim 240g/L) a broad spectrum herbicide that is selective on beans only followed by manual weeding. Routine spraying against pest and diseases was done weekly from three weeks after planting to when the beans reach physiological maturity, using Ridomil (Mancozeb, 2g/L) and Rocket insecticide (Cypermethrin 50 g/L).

These genotypes were evaluated alongside six Fe seed content checks, {(Climbers: MIB 456= universal high Fe, RWV1129= regional high Fe (East Africa) and Decelaya = universal low Fe: Bush beans: RWR2154= regional high Fe and DOR 500; universal low Fe and CAL 96; regional low Fe. No established checks exist for cooking time.

Soil Sampling and Analysis

Soil samples were obtained from the trial site by random sampling a week after planting the experiments. Soil samples were obtained at 0-20 cm depth. The samples were analyzed for, pH, exchangeable magnesium (Mg), calcium (ca), potassium (K), available phosphorus (P), total organic carbon, and total nitrogen (N); at Kawanda Agricultural Research Laboratories (KARL) following the Soils and Soil Fertility Management Programme protocol of National Agricultural Research Laboratory, Kawanda. The soil pH was determined using the H1 9017 Microprocessor pH meter in 1:2.5 suspension of soil and water. Exchangeable bases (Ca, Mg, K and Na) in the soil were determined in 1.0 M ammonium acetate extract (Okalebo *et al*., 2002) by flame photometry (K^+, Na^+) and atomic absorption spectrophotometry (Ca^{2+}, Mg^{2+}). Available P was extracted using the Mehlich-3 extraction method with pH 2.5. Soil organic matter was analyzed using the Walkey Black method, nitrogen was analyzed using sulphuric/selenium digestion mixture, digested at 330°C and later quantified calorimetrically using the Nesler method. For Fe (Fe^{2+}) and Zn determination, undiluted sample extracts were

Table 1 : Description of germplasm used in this study

Origin	Official Name	Desired trait
BURUNDI	AND10, BIHOGO, G685, KATX69**, KATB1**, KATB9**, KATX56**, MSO'LE**, MUKUNGUNGU, VCB81013, GASIRIDA, GLP2**, HM21-7, MAC 44**, NAKAJA**, NGWAKU-NGWAKU**, RWR2154**, RWR2245**	Drought tolerant High Fe and Zn content, high yield,
D.R. CONGO	ACC714, AFR708, AND10** CAL143, CNF5520 G685**, G2858, G2333, JESCA MAHARAGI SOJA, CODMLB001, G858, GLP2**, MLB49-89A, M'SOLE, NAKAJA NGWAKU-NGWAKU, ROBA-1, NUA45, ZEBRA**, HM21-7, RANJONOBY**	High Fe and Zn content, pest and disease resistant, high yield, adaptation, short maturity time, market type, low soil fertility tolerance
ETHIOPIA	AWASH 1, AWASH MELKA, ROBA-1	Market type, drought tolerant
MADAGASCAR	RANJONOMBY*	Disease resistant
KENYA	G2333, G685**, GLP2**, KATB1**, KATB9*, KATX69, KATX56, KK20, KK8, MLB-49-89A, RWR1092, SCAM-80CM/15, ZEBRA**	Pest and disease resistant, high yield, adaptation, short maturity time, market type
RWANDA	G2333, GASIRIDA, MAC42, MAC44**, MLB49-89A, RWR2154**, RWR2245**, RWV2887, RWV3006, RWV3316, RWV1129	High Fe and Zn content, and market type, yield, drought tolerant
TANZANIA	A197 (S.TZ), JESCA* (N.TZ), ROBA-1	High yield, fast cooking and drought tolerant
UGANDA	K131, K132, GLP2**, NABE1, NABE10C, NABE12C, NABE13, NABE14, NABE16, NABE17, NABE18, NABE19, NABE2, NABE21, NABE22, NABE23, NABE3, NABE4, NABE5, NABE7C, NABE8C, NABE9C, NABE26C	Market, high yield, pest and disease drought tolerant

directly aspirated into the atomic absorption spectrophotometer (SHIMADZU AA-6800) and read at 248.3nm and 213.86nm (Gerwing & Gelderman, 2005).

Cooking Time Estimation

Seed samples for cooking time estimation were obtained on plot basis, thus every entry was replicated thrice. The plants were harvested by uprooting the whole plant by hands per plot basis followed by machine threshing and cleaning. Thereafter, the seeds were bulked per plot then sun dried to 12-13% moisture content. Twenty-five seeds per plot were randomly picked and weighed using a top-pan balance to obtain weight before soaking. The seeds were then soaked for twelve hours in distilled water and re-weighed to obtain the weight after soak. The amount of water absorbed was scored by obtaining the difference in weight before and after soak and expressed as a percentage (Elia, 2003). Thereafter the seeds were placed in each of the 25 cylindrical holes of an automated Mattson Bean cooker developed by Canadian Grain Commission (Winnipeg, Canada) (Proctor & Watts, 1987) using a burner set at 350 °C and cooking timing started. A Mattson cooker consists of 25 plungers or pins and a cooking rack with 25 reservoir-like perforated saddles, each of which holds a pulse seed and a plunger calibrated to a specific weight. Each plunger terminates in a stainless steel probe 2.0mm in diameter. The cooker is a stand-alone machine monitored by a computer and the test results are automatically recorded on the computer. Cooking time is calculated as when 80% of the beans are soft enough to be pierced through by the plunger, this is an equivalent of when the 20th of the 25 pins of the cooker has penetrated the seed (Wang & Daun, 2005).

Seed Iron (Fe) and Zinc (Zn) Analysis

Samples consisting of forty to fifty seeds (depending on the seed size) were randomly picked from each plot bag and packed in small envelopes after being surface cleaned by rubbing between clean cotton cloths dampened with distilled water for 60 seconds. A new piece of clean cloth was used for each sample and care was taken to thoroughly clean hands before conducting the activity. According to Paltridge *et al.* (2011) this process reduces Aluminum (Al) contamination from approximately 15 ppm to 2 ppm and by about 5 ppm for Fe contamination while Zn remains unchanged. Thereafter, each sample was oven-dried at 60ºC for at least 12 hours, and then ground using a Sunbeam Conical Burr Mill EM0480 Grinder (Sunbeam, Australia). Ground samples were stored in newly labeled paper bags and transported to the Rwanda Agricultural Board – Rubona station at the National Gene bank of Rwanda for XRF analysis. Care was taken to clean the grinder between samples using a brush and vacuum (Stangoulis, 2010). The ground sample to be analyzed was then carefully transferred into small sample cups on the tray, positioned in the XRF machine's tray (Acute instruments, Mumbai, India) and identified by labeling samples on the screen tray with the sample number. The amount of Fe and Zn was determined by XRF spectrometry by scanning each sample for 100 seconds with spinning of sample cup to analyze Fe and Zn content and records intensities of emitted X-rays (Oxford Instruments, 2009). Standard samples were run after every 100 samples to standardize the machine and to have confidence in results.

Data Analysis

Genotype effects for all data including cooking time, Fe and Zn were subjected to analysis of variance (ANOVA) statistical procedure of Gen Stat (12th Edition, VSN International Ltd. Copyright, 2009). Differences in means between genotypes were separated using the Least Significant Difference (LSD) test.

RESULTS

The experimental soils had acidic soils, low soil phosphorus 7.7-7.9 ppm (though not critical) and low K ppm during both seasons. The concentration of minerals such as Ca, Mg and Zn were not sufficient. Organic matter (6.5%), nitrogen (0.31%) and Fe (259.0ppm) concentrations were high to very high and sufficient. The sites did not differ significantly in terms of the soil properties (Table 2).

The analysis of variance revealed high significant differences ($P<0.001$) in genotypes, seasons and genotype by season interaction for cooking time in bush beans and significant ($P\leq0.05$) genotype effects for climber beans (Table 3). There was a wide variation in cooking time among the 152 test genotypes in both seasons. For the first season (2015B) which is a normal rainy season with an average rainfall of 690 mm, cooking time ranged between 35 (Awash melka) and 100 minutes (VAX4) with an average of 56 minutes. Twenty-four percent (24%) of the genotypes had cooking time of less than 45 (<45) minutes, 49% with 46-60 minutes and 27% with >60 minutes.

In the second season (2015D), a normal rainy season with an average of 489 mm, the cooking time among the 152 genotypes

Table 2: Status of the soil from the experimental site

Soil component	2015B Measurements	2015D Measurements	Critical values	Sufficient levels for beans
pH	4.95	4.2	5.2	5.2-7.0
OM (%)	6.5	5.7	0.2	0.3
N (%)	0.31	0.38	3	6
P (ppm)	7.9	7.7	5	20
Ca (ppm)	1488	1598.77	150	500
Mg (ppm)	408.8	389.64	100	600
K (ppm)	35.11	339.64	350	2000
Fe (ppm)	259.9	161	5.5	50
Zn (ppm)	1.65	5.4	4	20

*Ppm -parts per million; OM –Organic matter

Table 3: Mean squares for cooking time (minutes) of 121 bush and 31 climbing bean genotypes

SOV	Bush		Climbers	
	DF	CT	DF	CT
Season	1	99126*	1	665
Rep/Season	4	2522***	4	665*
Genotype	120	1075***	30	674*
Genotype. Season	120	462***	30	217
LEE	99	311.0	31	127.8
SED		9		9
%CV		19.6		16

Ns=non-significant, ** =significant at P=0.01 and ***= significant at P=0.001, % cv- coefficient of variation (percentage)

ranged between 43 (CNF5520) to 122 minutes (RWR2154) with an average time of 73 minutes. This represented 1% (<45 minutes), 24% (46-60 minutes) and 74% (>60 minutes). Awash melka and VAX4 cooked for 51 and 114 minutes, respectively.

A total of 15 genotypes (Amahunja, Awash melka, Bihogo, CAB 2, ECAPAN021, G858, Icaquimbaya, KK20, NABE12C, NABE4, NABE6, ROBA-1, RWR1873, RWV3006) were consistent in short cooking time for the two seasons and had a Fe content above the low Fe check (CAL96 – 55mg/kg). However, some genotypes were long cooking (>60 minutes) for both seasons (Table 4).

The analysis of variance (Table 5) showed that the genotypes differed significantly for Fe and Zn seed content. The genotype effect was highly significant (P≤0.001) for both seed Fe and Zn contents in the bush type but non-significant for climbers. Season effect was only significant for Fe concentration in bush beans, though effect of replications within seasons was significant for both Fe and Zn in bush and climber (P<0.001) and (P< 0.05) respectively. However, the interaction between genotype and season was not significant for both bean types. The analysis was done on plot basis hence the replications ensured good experimental precision.

For season 2015B, Fe content ranged from 46-88 mg/kg, with an average of 64 mg/kg while Zn content varied at 24-40 mg/kg with an average of 30 mg/kg. During the season 2015D, Fe content ranged from 39-75 mg/kg with an average of 58 mg/kg while Zn content was between 26-42 mg/kg with an average of 33 mg/kg.

Across the two seasons (Table 6), the 152 common bean genotypes showed a wide variability in both the Fe and Zn content. The Fe content ranged between 39-86 mg/kg with an average mean of 60 mg/kg for bush beans while the Zn content ranged between 24-40 mg/kg with an average of 31mg/kg (Table 6). A total of 61 bush genotypes had Fe content above the universal high Fe check (RWR2154) which had an average of 69 mg/kg. On the other hand, Fe and Zn seed content among the climbers ranged between 46-88 mg/kg with an average of 66mg/kg for Fe while Zn ranged between 27-42 mg/kg and average of 34 mg/kg. Two genotypes (Nakaja and CAB2) had Fe content higher than the universal high Fe check (MIB 465) which had a concentration of 80 mg/kg for the first season while Nakaja (79 mg/kg) performed at per with the check (MIB 465 -79 mg/kg).

Table 4: Seasonal performance of genotypes for cooking time

GENOTYPE	Season 2015B		Season 2015D		Average	
< 60 minutes	CT (mins)	Rank	CT (mins)	Rank	CT (mins)	Rank
Amahunja	42	6	52	6	47	6
Awash melka	35	1	51	5	43	2
Bihogo	45	9	53	7	49	8
CAB 2	45	9	41	1	43	2
CNF5520	41	5	43	2	42	1
ECAPAN021	47	11	59	13	53	12
G858	44	8	58	12	51	10
Icaquimbaya	46	10	57	11	52	11
KK20	50	14	57	11	53	12
NABE12C	42	6	60	14	51	10
NABE4	45	9	59	13	52	11
NABE6	42	6	49	4	45	5
ROBA-1	44	8	60	14	52	11
RWR 1873	38	3	58	12	48	7
RWV3006	46	10	54	8	50	9
> 60 minutes						
VAX4	100	47	108	53	104	55
KATX56	92	46	106	52	99	53
Kanyebwa	84	42	98	47	91	49
NABE8C	71	32	110	55	91	49
NABE3	71	32	109	54	90	48
RWR 1092	75	36	105	51	90	48
TO	83	41	94	44	88	47
AND 1062	68	30	115	59	92	50
KATB1	70	31	79	31	75	34
KATB9	63	26	103	50	83	43
KATX69	63	26	69	21	66	25
M'sole	73	34	78	30	76	36
Masindi Yellow Short	71	32	90	40	80	40
NABE15	74	35	70	22	72	31
NABE16	77	37	108	53	93	51
NABE19	78	38	85	37	82	41
GLP585	88	45	70	22	79	39
FLOR DE MAYO	87	44	92	42	90	48
RWR 719	85	43	84	36	84	44

Table 5: Mean squares for seed Fe and Zn content (mg/kg) of 121 bush and 31 climbing bean genotypes

SOV	Bush			Climbers		
	DF	Fe	Zn	DF	Fe	Zn
Season	1	11347*	330	1	491	1124
Rep (Season)	4	1144***	846***	4	334*	95**
Genotype	120	308***	43***	30	151	20.7
Genotype. Season	122	1750	6.9	30	69	21
LEE	65-77	15.4	3,4	28-30	35,7	2.3
SED		3	2		5	1
%CV		6	5		8	4

Ns=non-significant, ** =significant at P=0.01 and ***= significant at P=0.001, % cv- coefficient of variation (percentage)

Across the seasons, the genotypes varied in the Fe and Zn concentration. The genotypes level of Fe content decreased from season one to the second season while Zn content levels increased. Six genotypes (CAB 2, RWR2154, CNF5520, Awash melka, KATB9) had high mineral content across the two seasons and a short cooking time (Table 7). A strong positive correlation existed between Fe and Zn content, r = 0.71 (P<0.001). Nevertheless, the correlation

Table 6 : Distribution of seed Fe and Zn concentration in tested bean genotypes

Bean type	Number of genotypes	Season	Fe (ppm) range	Zn (ppm) range	Fe content of high Fe check	Number of genotypes with Fe>high Fe check
Bush	121	1 (2015B)	46-86	24-37	81 (RWR2154)	2
		2 (2015D)	39-75	26-40	59 (RWR2154)	59
Climber	31	1 (2015B)	55-88	27-40	85 (MIB465)	1
		2 (2015D)	46-75	30-42	74 (MIB465)	1

Table 7 : Seasonal performance in Iron and Zinc for selected genotypes

Genotype	Micronutrient content					
	2015B Fe	2015D Fe	Average Fe	2015B Zn	2015D Zn	Average Zn
ACC714	86	75	81	33	35	34
NAKAJA	84	75	79	34	37	36
MIB 465	85	74	79	35	40	37
JESCA	84	72	78	34	37	35
CAB 2	**88**	**66**	**77**	**38**	**38**	**38**
VAX5	80	69	74	31	33	32
VAX1	73	74	74	34	39	37
Mexico 142	79	67	73	33	37	35
VAX2	77	67	72	32	34	33
AND620	74	69	71	35	40	38
RWR 719	73	68	71	32	36	34
VCB81013	73	68	71	33	42	38
GITANGA	71	70	71	32	40	36
MCM 2001	71	69	70	30	32	31
RWV3006	80	59	70	40	30	35
NABE29C	74	65	69	31	37	34
NABE3	72	67	69	30	34	32
RWR2154	**81**	**57**	**69**	**34**	**32**	**33**
NABE26C	72	65	69	31	38	35
VAX6	74	63	68	32	32	32
CNF5520	**73**	**63**	**68**	**36**	**40**	**38**
RWR 2245	70	67	68	31	37	34
NABE22	71	64	67	37	36	37
MAC 44	71	63	67	29	36	32
Awash melka	**69**	**64**	**67**	**29**	**32**	**30**
A344	71	62	67	32	36	34
ROBA-1	70	62	66	32	33	33
BIHOGO	70	60	65	33	35	34
SAB 686	69	56	63	31	34	32
Kanyebwa	57	49	53	26	28	27
KATB9	**56**	**45**	**51**	**28**	**28**	**28**
NUA8	53	48	51	24	29	27
NABE20	52	46	49	26	30	28
Mean	72.8	63.5	68.1	32.0	34.8	33.4
SED	7.9	7.5	7.2	3.2	3.6	3.0

* Names in bold indicate genotypes with high Fe and short cooking time, SED= standard error of difference

between cooking time and Fe and Zn was negative (-0.04 and 0.04, respectively).

DISCUSSION

This study was done to ascertain the variability for cooking time, Fe and Zn content in common bean genotypes and to identify genotypes with short cooking time, high Fe and high Zn content. The genotypes evaluated showed a great diversity for these traits. Cooking time ranged from 35 to 100 minutes during the first season and between 43 to 122 minutes during the second season with an average cooking time of 56 and 73 minutes respectively. Across the two seasons, the average cooking time was 66 minutes, Seasonal differences might have resulted from variations in the amount of rainfall, temperature and relative humidity. The first season experienced a higher amount of rainfall (690 mm) as compared to second season (489 mm).

The genotype by season interaction was significant for cooking time implying a contribution of seasons to differences in cooking time. This interaction may be explained by the possibility of interference of environmental conditions with genotypes in alteration of the grain tegument integrity, resulting in changes in their ability for water absorption and cooking time as reported by Carbonell (2003). Zilio *et al.* (2014) showed that temperatures lower than 30°C and air humidity higher than 40% during grain filling is ideal for lower cooking time in beans. Cooking time is also affected by the amount of rainfall per season. The first season had higher rainfall hence short cooking time among the genotype unlike the second season where the cooking time increased among the genotypes.

The test genotypes showed a wide range for both Fe and Zn content indicating the possibility of breeding for increased Fe and Zn content in common bean genotypes. The range of Fe and Zn observed in this study was comparable to one reported by Mukamuhirwa *et al.*, (2015) and Blair *et al.*, (2010). There were notable differences in the micronutrient concentration of the seeds between the seasons. These differences could have resulted from the seasonal variations (amount of rainfall) and the soil characteristics during each season. In addition, the climbers had a higher Fe concentration than the bush bean for the two seasons. This is attributed to the longer days taken in the field by climber beans denoting the differences in the uptake and loading of Fe and Zn in common bean (Mukamuhirwa *et al.*, 2015).

In this study Fe and Zn showed a strong positive correlation (r = 0.71) supporting the study of Nchimbi-Msolla and Tryphone, (2010) who observed the strong positive correlation of Fe and Zn in what in common bean. In addition, a study by Mukamuhirwa *et al.*, (2015) reported a positive strong correlation between Fe and Zn (r = 0.75). The positive and highly significant correlation between the Fe and Zn concentrations in seeds of bean suggests that genetic factors that increase Fe concentration co-segregate with genetic factors that increase Zn concentration, therefore selecting for bean seeds with high concentration of either Fe or Zn may contain high amounts of both elements (Nchimbi-Msolla and Tryphone, 2010). The correlation between cooking time to both Fe and Zn was relatively low.

The wide genetic variability observed in this study might be revealing a possibility of a diversity of bean genotypes in the greater Eastern Africa region; and therefore existence of valuable alleles for bean improvement including nutritional breeding. Great variability among genotypes allows selection of those with reduced cooking time. Among these, a total of 35 genotypes had good combination of high Fe and Zn content with short cooking time.

CONCLUSION

From this study, it is concluded that genetic variability for the cooking time, Fe and Zn content traits is sufficient to make breeding progress. In addition, some genotypes were short cooking and had high Fe and Zn content. This signifies the ability to combine these traits in a genotype. However, more studies are necessary to exploit any possible interactions of these traits at advanced generations probably F_4 to F_6. The biochemical components as well as other factors both genetic and environmental affecting cooking time, Fe and Zn content should as well be exploited.

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