International Journal on Food, Agriculture, and Natural Resources
Volume 05, Issue 04, Page 8-16
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Performance of NUA45 bean variety between two generations for seeds grown under farmer management at Rupike Irrigation Scheme in Masvingo, Zimbabwe

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Received: 17 July 2024; Revised: 15 November 2024; Accepted: 06 December 2024
DOI: *https://doi.org/10.46676/ij-fanres.v5i4.371*

***Abstract*— Among bean legumes, there are recently developed varieties known as nutritionally enhanced beans such as NUA 35 and NUA 45 sugar beans. The objective of the research was to assess the performance of NUA 45 foundation, certified and commodity seeds grown under farmer management at Rupike Irrigation Scheme in Masvingo. Concentrations of zinc (2.75-4.45mg/kg) and iron (70.85-104.5 mg/kg) in the soils were below expected levels of 100 mg/kg and 150 mg/kg respectively. The NUA 45 sugar bean missed the target potential yield (2400 kg/ha for Highveld) by between 54% and 62%. The 100 seed mass of second generation seeds ranged from 62.13 to 78.47 g. Protein concentration of the seeds which range from 19.79 to 22.86% increased from first generation (F1) to second generation (F2) for each of Foundation, Certified and Commodity seeds. The concentration of fibre with minimum and maximum levels of 5.76% and 8.43 % respectively increased from first generation to second generation for Foundation and Certified seeds. The 95% confidence interval for Zinc concentration at F1 (planted) is $10.84 \leq \mu Zn \leq 11.18$ mg/kg and also the 95% confidence interval for Zinc concentration at F2 (harvested) is $11.79 \leq \mu Zn \leq 12.12$ mg/kg and lower than CBI claim of 38.00 mg/Kg. The 95% confidence intervals for iron concentration ranged from $28.50 \leq \mu Fe \leq 30.57$ mg/kg with the highest being $30.59 \leq \mu Fe \leq 32.34$ mg/kg are below the CBI claim of 93.00 mg/kg. The nutrients levels increased from the first generation to the second generation of seeds for each of foundation, certified and commodity seeds.**

Keywords*— *Fibre, iron, NUA 45 bean, protein, Rupike Irrigation Scheme, zinc

I. Introduction

Beans belong to a family of plants known as legumes. Examples of legumes are sugar bean (Phaseolus vulgaris), peas (Pisum sativum) and cow peas (Vigna unguiculate) [1]. Among bean legumes, there are recently developed varieties known as nutritionally enhanced beans such as NUA 35 and NUA 45 sugar beans [2]. Legumes are sources of nutrients and have acted as source of protein since the onset of civilisation [3]. Dry form of legumes meant to be used for food are referred to as pulses. Pulses are also incorporated in the diet as condiments, milk, cheese and snacks [1]. The uses point to the pulses' important role in human nutrition.

Beans are rich in dietary fibre when compared to other unrefined plant based foods. Earlier studies revealed that beans are among the best sources of soluble fibre [4]. Other studies showed the beneficial effect of bean consumption on regulation of blood cholesterol, glucose and insulin levels in addition to prevention of cancers of the gastrointestinal tract, breast and prostate gland [5]. It was demonstrated that individuals who regularly take fibre rich food have lower risk of cardiovascular disease compared to individuals who do not consume adequate quantity of fibre [6]. Such properties have been attributed to the unique nutritional composition of bean that is rich in fibre and phenolic compounds and low in fat [7, 8, 9]

Common bean is a known source of micronutrients such as iron, zinc and calcium. The bean provides health benefits of interest to nutrition that include growth, prevention of zinc deficiency and anaemia the same way as enriched beans. The world's population is at risk of zinc deficiency, with higher risk of 34.6 % in Sub-Saharan Africa [10]. The risk of zinc deficiency is likely high among pregnant women in developing countries, as typical diets often supply inadequate bioavailable zinc [11]. More than 2 billion people, essentially women and young children are thought to be iron deficient [12, 13]. Iron deficiency is mostly prevalent in South Asia and Sub-Saharan Africa, though not limited to developing countries [13].

To address the nutritional inadequacies relating to iron and zinc, biofortification of food crops including beans was initiated [14, 15]. Biofortification is a procedure designed to enrich crops with micronutrients such as zinc, iron and vitamin A. Iron, zinc and vitamin A deficiencies in children have been identified by the World Health Organisation (WHO) as contributors to stunting, blindness, immune response suppression and impaired cognitive ability [16]. Nutrient enriched beans, NUA varieties that include NUA 45 were developed. The NUA 45 variety is enriched with iron and zinc for inclusion in the diet of consumers who are mainly deficient in the two minerals. Zimbabwe has made progress in promoting NUA 45 beans by developing contracts with seed companies such as Zimbabwe Super Seeds and Sandbrite Seeds to produce foundation seed [16]. The bean variety is being grown in parts of Zimbabwe as both seed and commodity and one of such sites is Rupike Irrigation Scheme in Masvingo under

the Seed and Market Project (SAMP). A study conducted in Zambia revealed that decision by smallholder farmers to participate in bean production and collective marketing was influenced by age, gender, household size, farm size, output prize, farm income, hybrid seed, access to market information, ownership of a bicycle, radio and a mobile phone [17]. The same factors may also impact bean production by small scale farming communities in Zimbabwe.

SAMP is an initiative instituted to empower smallholder farmers and Community Owned Enterprises (COEs) to grow nutritious seeds and commodities [18]). SAMP is set to pursue the 2030 Agenda for Sustainable Development through ending hunger, achievement of food security, improved nutrition and sustainable agriculture in line with Goal 2. SAMP which is being implemented in Zimbabwe, Swaziland and Lesotho embraces nutrition sensitive agriculture and incorporates interventions to improve consumption of food in project targeted areas [19]. Communal farmers from the three countries participating in the project have been assisted with seeds, farming inputs such as fertilisers and insecticides and training to grow the nutrient enhanced NUA 45 sugar beans as part of the larger project [19]. The farming community members received training on preparation of nutritious foods from NUA 45 bean and other crops such as maize and wheat. Through this initiative, the nutrition and dietary diversity of vulnerable groups such as women, children and the elderly were promoted via increased capabilities and opportunities of the groups to participate in farming activities [19]. The project imparted knowledge of value of nutritious foods to mothers, infants and children attending school. The programmes implemented are set to provide food products with enhanced nutrients to communities through use of NUA 45 bean seeds as one of the ingredients of the recipes.

The increase in level of production of NUA 45 bean seed by farmers and its use for food requires precise knowledge of the nutrient content of the seed. Farming communities growing the seeds for food and nutritionists recommending it for use as a source of nutrients such as protein, iron and zinc need a record of nutrient levels in the seeds. Before the advent f nutrition sensitive agriculture, there were research programmes designed to increase yield of common bean varieties, disregarding breeding for protein, minerals, fibre and fatty acids [20]. The objective of the current study was to assess the performance of NUA 45 foundation, certified and commodity bean seeds between two generations. The assessment of performance of the seeds between generations will allow farmers to attain optimum yields with acceptable levels of nutrients. The nutrient content of the seeds is important for the benefit of farmers, nutritionists, policy makers and consumers.

II. Materials And Methods

A. Study Area

Rupike irrigation scheme is located in Nyajena area, about 80 km South East of the City of Masvingo. It is in Ward 23 of Masvingo Rural District. The irrigation scheme was established in 1990 through funding provided by Renco Gold Mine, a subsidiary of Rio Zimbabwe Limited. The project was designed to promote smallholder farmers in the area where rainfall is generally low. The major source of water for crops is Tugwane Dam, which was built across Tugwane River. Crops grown by farmers in the scheme are sugar bean, wheat, maize and horticultural produce like tomato, onion, butternut, carrot and peas. The size of irrigated land is 100 ha on which 200 small scale farmers were each allocated plots of 0.5 ha. Of the 200 farmers, 84 grew NUA 45 bean variety under irrigation. Maps illustrating the study area are presented in (figure 1).

Fig 1. (A) Map of (A) Zimbabwe showing the location of Rupike Irrigation Scheme in Masvingo, (B) Masvingo District illustrating the position of the Irrigation Scheme and (C) Local area showing location of the Irrigation Scheme.

Six out of the 84 farmers growing NUA 45 bean seeds on the irrigation scheme volunteered to participate in the programme. The farmers were grouped into 3 pairs. One pair designated as 1A and 1B were assigned to grow the foundation seed, while the second pair coded 2A and 2B were allocated to grow certified seeds and the third pair designated as 3A and 3B were assigned to grow commodity seed. Each farmer had set aside 0.042 ha for growing the seeds. Locations of the farmers’ plots are presented in Table 1.

TABLE 1 SELECTED PLOTS FOR NUA 45 BEAN AT RUPIKE IRRIGATION SCHEME IN MASVINGO

Sampling Site			**Location of plot**		
Farmer	**Seed grown**	**Bloc on Scheme**	**Longitude**	**Latitude**	**Altitude (m)**
1A	Foundation	D14	S 20° 33’ 43.12’’	E 31° 6’ 48.63’’	672.1
1B	Foundation	D14	S 20° 32’ 56.70’’	E 31° 7’ 16.68’’	697.0
2A	Certified	C49	S 20° 33’ 37.81’’	E 31° 6’ 53.14’’	671.0
2B	Certified	C49	S 20° 33’ 11.80’’	E 31° 7’ 9.06’’	683.0
3A	Commodity	B19	S 20° 33’ 26.69’’	E 31° 7’ 7.14’’	678.0
3B	Commodity	B19	S 20° 33’ 7.73’’	E 31° 7’ 23.04’’	697.0

Land tillage was done using ox drawn plough. The seed was manually planted at 0.45 m x 0.1 m spacing and Compound D was applied during planting at a rate of 200 kg/ha by broadcasting method. Manual weeding was used for control of non-crop plants or weeds. The crop was furrow irrigated after every 3 to 4 days depending on the level of moisture stress. Plants in other plots were watered using sprinkler irrigation system. Ammonium nitrate fertilizer was applied at 150 kg/ha by broadcasting at the initial flowering stage, which was approximately 4 weeks after planting. Pests and fungi were controlled by spraying the crop with dimethoate and copper oxychloride respectively. The second generation of seeds (F2) was grown over a period of 15 weeks. The seeds are shiny maroon in colour with white spots as illustrated in (Figure 2).

Fig 2. Second generation (F2) of Foundation seed (a), Certified seed (b) and Commodity seed (c) harvested from Rupike Irrigation Scheme

B. *Soil sampling and characterisation*

Fifteen (15) g of sieved air dried soil were mixed with 30 ml of 0.5M CaCl2 followed by measurement of pH which was done using a pH meter (Milwakee, USA) [21]. The total soluble salts (TSS) of the soil were extracted using distilled water [22] and measured using a conductivity meter (Adwa, Hungary). The soil samples were extracted using 1M KCl solution [22] and analysed for nitrates by uv-visible spectrophotometry (Biobase, China)[23]. Available phosphorous was resin extracted [24] and quantified by the molybdenum blue method as described by Nasukawa et al. [25]. Exchangeable bases (Ca, Mg, K and Na) were extracted from the soils into aqueous ammonium acetate at pH 7 [24, 26]. Micronutrients (Cu, Zn, Fe and Mn) were extracted from the soil samples using aqueous EDTA at pH 7 [27]. Ca, Mg, Cu, Zn, Fe and Mn in the extracts were determined by flame atomic absorption spectrophotometry while K and Na were quantified by flame atomic emission spectrophotometry (Agilent Technologies, USA) [28].

The assessment of selected soil nutrients described in this study is based on criteria that were developed from long-term soil fertility experiments in Zimbabwe [29, 30, 31, 32)]. The criteria are general for most crops commonly grown in Zimbabwe and the current fertilizer recommendations given to farmers are also based on these criteria, although special considerations are given to specific nutrient requirements of crops and to site potential or soil moisture adequacy.

C. *Plant sampling*

One kg of samples of foundation, certified and commodity bean seeds were obtained from farmers at Rupike Irrigation scheme in Masvingo. The samples were coded Foundation seeds (F1), Certified seeds (F1) and Commodity seeds (F1). F1 represents first generation or planted seeds. The seeds were part of the seeds planted on plots belonging to the farmers participating in a programme aimed at establishing the nutrient content of the seeds from one generation to the next generation. The seeds were weighed into clearly labelled paper envelopes, transported to Harare and stored in a room at ambient temperature of 20 to 25°C in a dry environment before analysis.

The second generation (F2) NUA 45 bean samples were collected from each of the farmers 1A, 1B, 2A, 2B, 3A and 3B during harvesting. Dry bean pods due for harvesting were collected into polyethene bags used for bagging 50 kg of grain. The bags were transported to Harare and stored in a cleaned dust free room. Dry pods of beans filling half of the grain bag were collected from each farmer. Bean pods obtained from each of the six farmers were unshelled and bean seeds collected were weighed into plastic bags previously soaked in 10% nitric acid, rinsed with distilled water and dried. After weighing, Foundation seeds, 1A and 1B were mixed to form one composite sample (Foundation seeds (F2). Similarly, as for foundation seeds, Certified and Commodity seeds were constituted into composite samples, (Certified seeds (F2)) and (Commodity seeds (F2)) respectively. F2 represents second generation or harvested seeds. The mass of each composite sample is the sum of the individual masses of seeds collected from farmers assigned to grow a specific seed either foundation, certified or commodity seed.

After mixing the different bean seeds, 601 g each of Foundation seed (F2), Certified seed (F2) and Commodity seed (F2) samples were weighed into clean plastic bags. Samples of the planted seeds (F1-first generation) and harvested seeds (F2-

second generation) were analysed for protein, moisture, crude fibre, iron and zinc.

D. Analysis

(i) Analysis of bean samples Yield (100 seed mass)

After harvesting mature seeds of the second generation, 100 seed mass was measured for each of the Foundation (F2), Certified (F2) and Commodity (F2) seeds of the NUA 45 Bean seed. The masses of the seeds were measured in triplicates using a top loading balance (Kerro BL10002A Precision Electronic Balance No 10123002 KJS Series, Taiwan; Range: 0.01- 1000g)

(ii) Sample preparation

For each of the dry NUA 45 bean samples, Foundation seed (F1), Certified seed (F1), Commodity seed (F1), Foundation Seed (F2), Certified seed (F2) and Commodity seed (F2), 100g of seeds were milled using a laboratory mill to produce a floury textured sample for use in determination of moisture, crude fibre, crude protein, zinc and iron.

TABLE II CHARACTERISTICS OF SOILS FROM FARMERS PLOTS AT RUPIKE IRRIGATION SCHEME USED IN THE STUDY

Parameter	**Value**			**Interpretation of soil fertility**				
	Block C49	**Block B19**	**Block D14**	**AD[1]**	**D[2]**	**M[3]**	**A[4]**	**R[5]**
pH ($CaCl_2$ scale)	7.0	6.8	6.9			5.3-7.5		
Total Soluble Salts (mg/kg)	233.60	163.20	211.20					
Mineral N (mg/kg)	3.65	5.32	3.95	<20	21-30	31-40		>40
Available P (mg/kg)	9.52	8.05	9.52	<7	8-15	16-30	31-50	>50
Exch. Ca ($cmol_c$/kg)	3.83	4.48	3.70			10		
Exch. K ($cmol_c$/kg)	0.47	0.70	0.76			5		
Exch. Mg ($cmol_c$/kg)	1.23	2.47	1.81			-		
Exch. Na ($cmol_c$/kg)	0.16	0.20	0.14			-		
Available Cu (mg/kg)	1.05	0.50	0.90			-		
Available Zn(mg/kg)	2.75	2.85	4.45			100		
Available Fe (mg/kg)	104.50	85.75	70.85			150		
Available Mn (mg/kg)	84.95	57.20	114.30			-		
Total exch. Bases ($cmol_c$/kg)	5.69	7.84	6.41			-		

(iii) Moisture content

Three crucibles were dried in an oven at 105oC for three hours, cooled to room temperature in a desiccator and weighed. A sample of milled beans (5g) was accurately weighed into each cooled crucible which was placed in an oven set at 105oC overnight followed by cooling in a desiccator and weighing to determine moisture content [33]. The moisture content of the pulverised beans was calculated on a fresh weight basis by expressing mass of moisture of the sample as a percentage of fresh mass of the original sample.

(iv) Protein and Fibre

Protein and fibre were analysed using FT-NIR Spectrophotometer (Thermo Fisher Scientific Model Antalis II, USA) based on a method described by Ismail et al. [34]. Twenty (20) g of milled dry beans were weighed into a multipurpose analyser plate provided for sample handling in the instrument. The plate containing sample was placed in a confined space in the spectrophotometer after which the analyse key was pressed to begin the analysis. The NIR ray scanned through the sample as it rotated within its confinement. Results of the crude protein and crude fibre were displayed on the instrument's read out screen within 1 to 2 minutes. Each sample was analysed for each nutrient in triplicates.

(v) Iron and Zinc

The method used was previously described by other investigators [35, 36, 37, 38]. Five grammes of dry bean flour in triplicate were dried to constant weight in an oven at 105ºC, heated until charred using a Bunsen burner and transferred to a muffle furnace at 550ºC and heated until a white ash formed. After cooling of furnace to room temperature, crucibles containing samples were transferred to a fume hood. Each sample was digested by adding 75 ml of aqua regia (HNO3: HCl) in the ratio of 2:1 with respect to HNO3 and HCl filtering the mixture into a 100 ml volumetric flask through glass wool. The crucible was rinsed with 5 ml portions of distilled water adding rinses to the volumetric flask through the glass wool. The flask was made to the mark with distilled water. The metals in the bean flour samples were measured by Inductively Coupled Plasma atomic emission spectrophotometry (Model ICAP 6000, Thermo-Fischer Scientific, USA). Working standards for the metals were prepared by serial dilution of the standard solutions with concentrations of 1000 mg/L for each metal.

E. Data Analysis

Graphs presenting the data were plotted using Excel 2013 Version. Statistical analysis of results was done with the aid of Prism Graph Pad Version 5.0.

III. Results And Discussion

A. Initial soil characteristics

Table 2 shows the results of soil analysis from the farmers' plots. The pH of the soils was in the neutral range that is optimum for legume production, although making the availability of micronutrients such as Zn and Fe relatively less.

No challenges of salinity or sodicity were found, although the soils had typically low amounts of exchangeable bases. The levels of mineral N and available P were both in the deficient ranges and hence both basal and top-dressing fertilizer applications were necessary. The soils also had typically low levels of Zn and Fe.

B. Yield and 100 seed mass

Commodity seeds (F2) had the lowest grain yield but highest 100 seed mass, while Foundation seed (F2) had the highest grain yield (Table 3). The NUA 45 sugar bean missed the target potential yield of 2400 kg/ha [39] by between 54% and 62%, despite basal application of 200 kg/ha of Compound D (7:14:7) and top-dressing with ammonium nitrate (34.5% N) at 150 kg/ha. However, the 100 seed mass of NUA 45 bean ranging from 62.13 to 78.47g exceeded the target potential of 55 g/100 seed for all the seeds according to the DR&SS [39].

Results of one way ANOVA analysis showed that there are significant differences ($P < 0.05$) among means of 100 seed mass values of Foundation, Certified and Commodity seeds of the second generation. However, the 100 seed mass values of Certified seeds (F2) (62.13 g/100 seeds) is comparable to values reported for NUA 45 seeds (60.39 to 62.68 g/100 seeds) and Gloria bean seeds (58.44 to 62.21 g/100 seeds) [40]. The results show that farmers who plant commodity seeds expect to get the highest values of 100 seed mass on harvesting.

C. Moisture content

The moisture contents of the first generation (planted) seeds ranged from 7.37±0.09 to 7.54± 0.09 % with foundation seeds (F1) recording the highest moisture content while commodity seeds had the lowest level of moisture (Table 3).

A one way ANOVA treatment showed no significant differences among moisture contents of foundation, certified and commodity seeds of the F1 generation ($P > 0.05$). The closeness of the moisture contents of the samples implies that the seeds were possibly stored under similar environments. Among the second generation (harvested) seeds, commodity seeds had the highest moisture content of 13.19± 0.09 % followed by certified seeds (8.93± 0.06%) and foundation seeds (8.83±0.24 %). There was no significant difference between the moisture contents of foundation (F2) and certified (F2) seeds ($P>0.05$). The moisture contents of harvested seeds are comparable to moisture content of lima bean varieties that range from 9.19 to 11.83 % [41]. For each of the foundation, certified and commodity seeds, the second generation (harvested) seeds had higher moisture content than the corresponding first generation (planted) seeds. The differences in moisture contents may be attributed to differences in growing and storage environments of planted and harvested seeds.

TABLE III. Grain Yield, Moisture, Protein And Crude Fibre Content Of Foundation, Certified And Commodity Seeds Of NUA 45 Bean From Rupike Irrigation Scheme.

	Foundation		**Certified**		**Commodity**	
	F1	**F2**	**F1**	**F2**	**F1**	**F2**
Grain yield (kg/ha)	-	1094 ± 3^b	-	1024 ± 0^a	-	917 ± 1^c
100 Seed mass (g)	-	69.83±0.74^b	-	62.13±1.90^a	-	78.47± 0.14^c
Moisture (%)	7.42±0.15^a	8.83±0.24^b	7.54± 0.09^a	8.93± 0.06^b	7.37±0.09^a	13.19± 0.09^c
Protein (%)	20.82±0.03^a	22.86±0.15^b	21.34±0.05^c	22.18±0.06^d	19.79±0.00^e	21.93±0.03^f
Fibre (%)	5.76±0.01^a	8.43±0.04^b	7.04±0.05^c	7.64±0.05^d	7.68±0.05^d	7.66±0.02^d

D. Protein

Of the first generation seeds, Certified seeds (F1) had the highest concentration of protein (21.34± 0.05 %) followed by Foundation seeds F1(20.82±0.03 %) and Commodity seeds (F1) (19.79±0.00 %) (Table 3). For the second generation consisting of harvested seeds, Foundation seeds (F2) had the highest concentration of protein (22.86±0.15 %) followed by Certified seeds (F2) (22.18±0.06 %) and Commodity seeds (F2) (21.93±0.03 %). For each of the Foundation, Certified and Commodity seeds, the second generation seeds had higher protein concentration than the first generation seeds. Statistical analysis of the data showed that the protein contents of the bean seeds are significantly different ($p<0.05$). The level of protein obtained in the first generation seeds F1 ranging from 19.79±0.00 to 21.34±0.05 % is comparable to values ranging from 19 to 23 % obtained for Brazilian bean cultivars [5], but higher than 7.77 % reported for Lima beans [42]. However, second generation seeds (F2) protein concentrations ranging from 21.93±0.03 to 22.86±0.15 % were higher than levels of protein reported for African yam bean [1]. NUA 45 bean seeds may be used as an important source of protein for consumers on the basis of its levels of protein which are comparable to traditional bean varieties. The NUA 45 bean seeds which can be sustainably grown by both commercial and subsistence farmers are potentially useful in reducing the prevalence of protein malnutrition among populations. The Recommended Dietary Allowance (RDA) of protein for children, adult males, adult females, pregnant women and lactating mothers are 28, 63, 50, 60 and 65g respectively [38]. The higher protein needs of humans demonstrate that 100 g of the bean seeds provide an inadequate source of proteins for consumers.

E. Fibre

Among the first generation (F1) NUA 45 Bean seeds, Commodity seeds had the highest concentration of fibre of 7.68±0.05 % followed by Certified seeds (7.04±0.05 %) and Foundations seeds (5.76±0.01 %) (Table 3). For second generation seeds (F2), Foundation seeds had the highest concentration of fibre of 8.43±0.04 % followed by Certified seeds (7.64±0.05 %) and Commodity seeds (7.66±0.02 %). The contents of crude fibre of NUA 45 bean seeds from the first and second generations were significantly different ($p<0.05$). However, fibre contents of certified (F2) and Commodity (F1 and F2) seeds were not significantly different ($p>0.05$). The concentration of fibre increased from the first generation (planted) to the second generation (harvested) seeds for each of Foundation and Certified seeds indicating possible nutrient biofortification. However, a drop in fibre concentration from the first generation to the second generation was observed for the Commodity seeds which implies that a farmer needs to plant either a foundation or certified seed in order to produce a seed with enhanced content of fibre. The fibre content of the harvested Foundation seeds (F2) (8.43±0.04 %) is comparable to levels of 7.88 and 7.5 % reported for Lentils and Chick peas respectively [42]. Second generation of Certified seeds (F2) and Commodity seeds (F2) concentrations of fibre are similar to fibre concentrations of 6.44 % obtained for Kidney beans, but lower than 9.01 % reported for Pinto beans [42]. The comparison indicates that NUA 45 Bean may be used as a source of fibre like other available bean varieties. Dietary guidelines from the American Heart Association recommends that consumption of different types of foods should translate to levels above 25 g of fibre per day [43]. The recommended Daily Allowance (RDA) for fibre is 18 to 35g [38], implying that 100g of NUA 45 bean seeds do not meet the daily fibre requirements of the body.

F. Zinc

(Figure 3) shows that zinc concentration is higher for F2 (harvested) than F1 (planted) seeds and the zinc concentration seems to be the same across the three seed types.

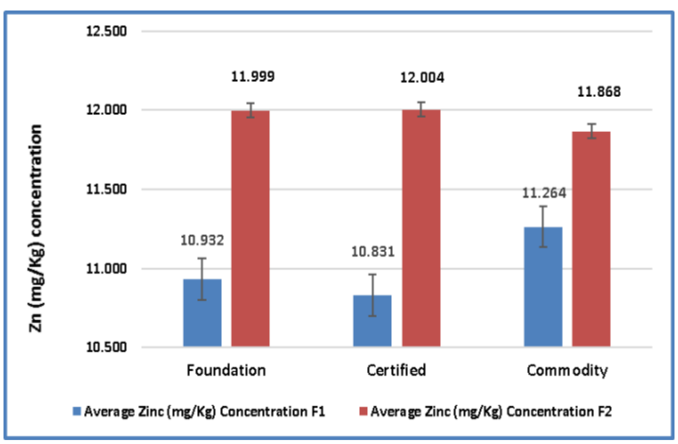

Fig 3. Average concentration of zinc by Generation by Seed Type of NUA 45 bean grown at Rupike Irrigation Scheme in Masvingo

The Box plot (Figure 4) shows clearly that zinc content is lower in first generation (F1) than second generation (F2). The next analysis checks the significance of zinc between F1 and F2, and finally check the significance of zinc among seed types at both F1 and F2.

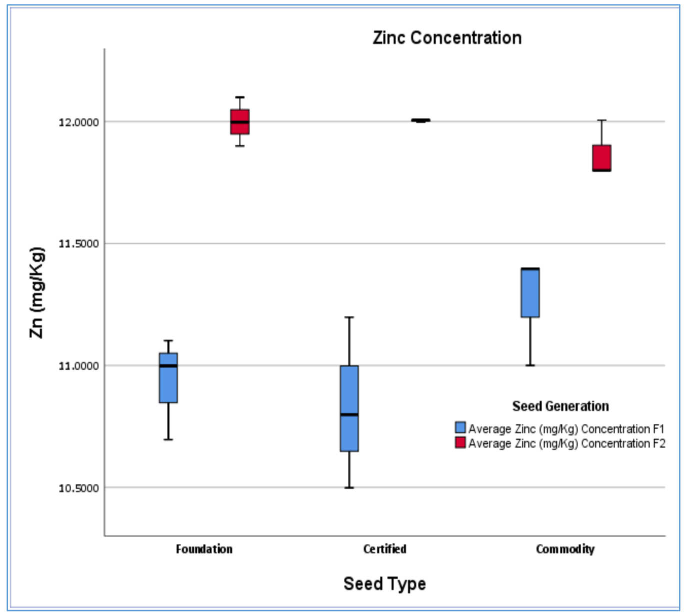

Fig 4. Box plots showing average zinc concentration by Generation by Seed Type of NUA 45 bean grown at Rupike Irrigation Scheme in Masvingo.

There was a significant difference ($p<0.05$) in the concentration of zinc between the first generation (F1) and second generation (F2) of NUA45 seed (Figure 4). However, there was no significant difference among the seed types grown, for both first generation and second generation. This is clear from the figure as the two plots are not crossing showing that Zinc content difference between generations is significant. Further ANOVA tests among the different seed types within a generation showed foundation, certified and commodity seeds had the same zinc content ($p>0.05$) for both generations.

The insignificant difference in the concentration of zinc between the harvested seeds (F2) imply that the content of zinc in the seeds is negligibly affected by the type of NUA 45 Bean seed planted. Among the first generation of seeds (F1), Commodity seeds had the highest concentration of zinc which is 11.26±0.13 mg/kg followed by Foundation seeds (10.93±0.12 mg/kg) and Certified seeds (10.83±0.20 mg/kg). Concentrations of zinc in harvested seeds (F2) which ranged from 11.86±0.07 to 12.00±0.01 mg/kg are comparable to concentrations of the nutrient in Lentils (13.13 mg/kg) [44], but lower than levels reported for Chick peas (14.63 mg/kg) and Adzuki beans (17.3 mg/kg) [42]. The contents of zinc for NUA 45 bean seeds considered in the current study fall within the range of 10 to 35 mg/kg published for NUA genotypes [45]. However, the concentrations of zinc in all seeds considered are much lower than the CBI claim of 38 mg/kg in NUA 45 seeds [39]. Since NUA 45 bean seeds compare well with other seeds in their content of zinc, they serve as a useful source of the nutrient for consumers. For each of the Foundation, Certified and Commodity seeds, there is an increase in the concentration of zinc from the first generation (planted) seeds to the second generation (harvested) seeds pointing to nutrient enhancement through bio fortification. RDA values of Zn for Males 19-50 years and Males 51+ years are each 14mg/day for Australia and New Zealand [38]. The RDA values of Zn for Females 19-50 years and Females 50+ years are each 8 mg/day for Australia and New Zealand, USA and Canada [46]. The levels of zinc in NUA 45 bean seeds which ranged from 1.172± 0.031 to 1.367±0.011 mg/100g show that 100g of seeds do not provide adequate daily needs of the mineral to consumers of the stated countries. Consumers in Southern Africa may equally get inadequate quantities of zinc on inclusion of the bean seeds in their diet.

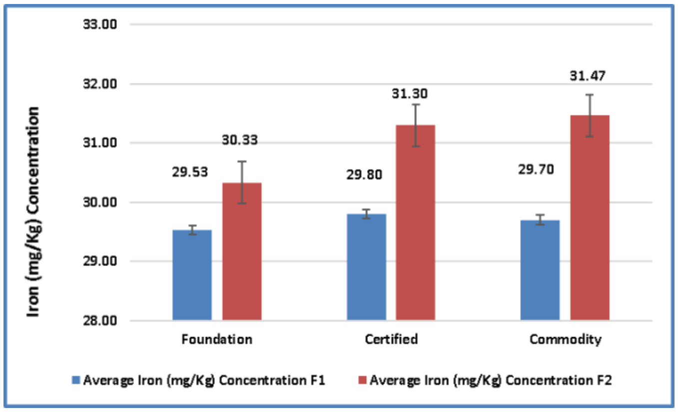

Fig 5. Average Iron concentration by generation by seed type of NUA 45 bean grown at Rupike Irrigation Scheme in Masvingo

G. *Iron*

Iron was the predominant nutrient in the bean seeds, with concentrations ranging from 29.53±0.24 to 29.80±0.12 mg/kg and 30.33±0.22 to 31.47±0.20 mg/kg for first generation (planted) and second generation (harvested) seeds respectively (Figure 5).

(Figure 5) clearly shows that there is difference in iron concentration between F1 and F2. The next analysis is a statistical test of significance on the iron content between F1 and F2 and amongst the seed types (foundation, certified and commodity) at both generation levels.

(Figure 6) show Box plots of iron content amongst the seed types at F1 and F2 levels. Iron content is different at F1 and F2 levels. However, within F1, seed types seem to have the same iron content and same for F2.

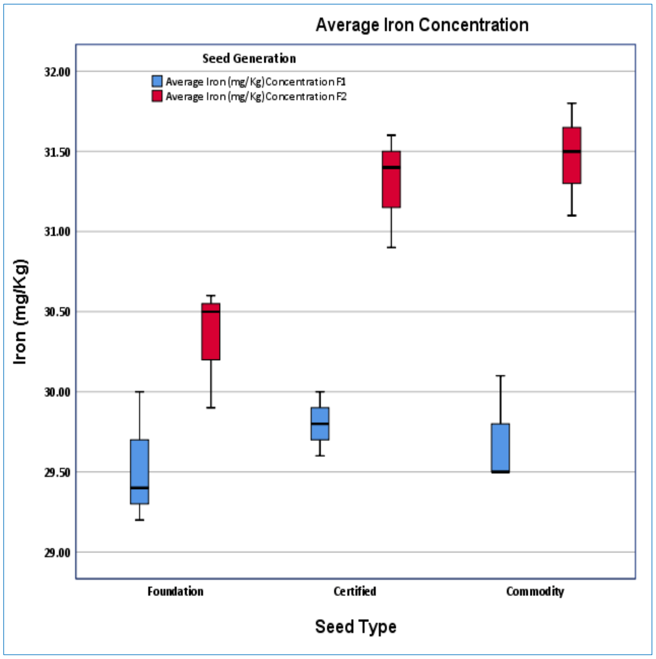

Fig 6. Box plot showing average iron concentration by generation by seed type

There is significant difference ($p<0.05$) of iron content between F1 and F2. This conclusion leads to further tests in iron content amongst foundation, certified and commodity seed types at the F1 and F2 levels. There were no significant differences among concentrations of iron in first generation of Foundation, Certified and Commodity seeds ($P> 0.05$). Statistical analysis of results of the second generation (F2) of the seeds revealed significant differences among their iron concentrations ($P< 0.05$). The results of the statistical assessment imply that the type of bean seeds planted has a significant effect on the concentration of iron in the harvested seeds. The concentration of iron recorded in the present study are higher than values of 24.5 to 26.7 mg/kg reported for Lima beans [41], but lower than 64.75 mg/kg obtained for NUA 45 Bean seeds [2]. Both the first and second generation seeds 'concentrations of iron were lower than 93 mg/kg reported by CBI [39]. Differences in the concentrations of nutrients may be attributed to environmental factors like soils and climate which influence uptake of the mineral by the seeds. For each of the Foundation, Certified and Commodity seeds, there is an increase in iron concentration from the first generation (planted) to the second generation (harvested) seeds implying nutrient enrichment through biofortification. Recommended Dietary Allowance values of iron for males 19-50 years, males 51+ years, females 19-50 years and females 51+ years were 8, 8, 18 and 8 mg/day respectively for Australia and New Zealand, USA and Canada [46]. The concentrations of iron in the NUA 45 bean seeds ranging from 2.953±0.024 to 3.147±0.020 mg/100g indicate that 100g serving of the seeds falls short of providing daily requirements of the nutrient for consumer groups in the cited countries. Similarly, the iron requirements for consumers of Southern Africa may not be met by NUA 45 bean seeds.

IV. CONCLUSION AND RECOMMENDATIONS

The soils had typically low levels of Zn and Fe compared with expected levels of the minerals. At the current fertiliser input of 200 kg/ha Compound D and 150 kg/ha ammonium nitrate, the farmers growing irrigated NUA 45 in Masvingo are not able to achieve the target yield potential of this variety. The soils are also inherently poor to sustain the target Zn and Fe uptake. Farmers at the scheme in Masvingo should increase their basal fertilizer application up to 300-350 kg/ha. The farmers should apply the fertiliser as Compound Z (7:14:7) that also contains 0.5% Zn. Commodity (F2) seeds had the highest 100 seed mass while Foundation (F2) seed had the highest grain yield. For each of protein, fibre, iron and zinc, the nutrient level increased from the first generation to the second generation of seeds. A 100 g serving of the bean seeds is inadequate in meeting the daily requirements of each nutrient. Consumers of NUA 45 bean seeds grown in the area considered are advised to include other foods in their diet for provision of additional nutrients in order to meet daily requirements of the nutrients.

ACKNOWLEDGEMENT

The researchers are grateful for the funding availed by Seeds and Markets Project (SAMP) to carry out the field experiment as part of the Nutrition Study. SAMP was fully funded by the Swiss Agency for Development and Cooperation (SDC) and managed by GRM Zimbabwe. We would like to thank the project staff, District Agricultural and Technical Extension Office and the smallholder farmers from Rupike Irrigation scheme who willingly offered their pieces of land for the experiment.

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