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Report on new selected and tested legume local varieties

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FOODLAND has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement (GA No 862802).

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Executive Summary

Among the objectives of the FoodLAND project and especially for Work Package 4 (WP4) is to strengthen agrobiodiversity and food diversity to producers so as to enrich dietary diversity and filling the nutritional gaps in the diets of the urban and rural consumers. Legume crops have been part of diets of many people in African countries as a source of dietary protein. They can therefore be used both to enhance agrobiodiversity and food diversity of people in the project areas. Common beans (*Phaseolus vulgaris* L) is one of the commonest legumes cultivated and consumed in East Africa. It is the source of several nutrients including protein and minerals. It is well known that Fe and Zn minerals are crucial to human well-being and an adequate supply of these nutrients helps to prevent iron deficiency anaemia as well as zinc deficiency, which are the two prevalent health concerns of the developing world. This Subtask (ST4..1) is aimed at selecting improved bean lines that combine acceptable agronomic traits, short cooking time, and appreciable levels of zinc and iron. The activities in this subtask started in M10 of the project by collecting beans seeds from various sources, multiplying them to get adequate seeds for field experiments. The on-station experiments were conducted using the collected bean genotypes/lines (90) at two research stations. This was done with the aim of selecting few genotypes/lines that perform well and 25 have been selected for further evaluations in the on-farm experiments. Selection was based on yield performance, level of Fe and Zn and other important traits for beans. The selected 25 bean genotypes together with five checks are currently being tested in the on-farm stations in four locations (Ndole, Mlali, Rondo, Kikatiti). Further selections will be made based on the performance of the lines. Farmers in each location are expected to be involved in evaluation and selection of suitable bean lines which will be proposed for official release. The results from this work will involve two bean varieties, which will be exploited in different ways including officially releasing and registering them in the improved varieties catalogue. Other activities will involve carrying out demonstrations and seed multiplication in collaboration with seed companies and groups of farmers to commercialize them. The bean varieties will also be used in making mixed grain flours (Subtask 4.4.2 - Milling).

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1. Introduction

1.1 Background information

The overall objective of WP4 is to develop small-scale prototypes and improve the entrenched technologies aiming at: (1) enabling producers to strengthen agrobiodiversity and food diversity so as to increase their competitiveness and their socio-economic conditions, with special reference to women empowerment, and (2) enriching the dietary diversity and filling the nutritional gaps in the diets of urban and rural consumers. Where appropriate, food characterization by physical, chemical, and sensory evaluation will be carried out along with quality assurance in conformity with national standards bodies and EU food safety standards. Therefore, WP4 is in charge of formulating technological concepts, running experimental proof of concepts, and implementing and testing of the pilot innovations at lab-/small-scale.

One of the subtasks in the WP4 tasks of Technological research for agricultural and horticulture production focuses on the *selection of new improved legume varieties* (Subtask 4.1.1). The aim of doing this task is to select improved common bean lines (*Phaseolus vulgaris* L.) that will contribute to the improvement of nutrition status of the people in the project areas (the Food Hubs) and beyond.

Legume crops have been part of diets of many people in African countries as a source of dietary protein. The consumption of common bean (*Phaseolus vulgaris L.*) in developing countries is reported to be higher as is the case in the developed countries due to the high price of meat and fish (Beebe et al., 2000, 2013; Broughton et al., 2003). In sub-Saharan Africa, common bean meets more than 50% of the dietary protein requirements (Broughton et al., 2003); while in East Africa, it is a major staple, the second source of dietary protein, and the third most important source of calories after maize and cassava (Amongi et al., 2018; Hillocks et al., 2006). Common beans are a valuable source of protein, vitamins, and minerals such as calcium, potassium, phosphorus, iron, copper, zinc, and magnesium. The mineral contents in bean grains can vary largely depending on the varieties and on the environmental factors, such as soil acidity (Blair and Izquido, 2012; Blair et al., 2009; Hummel et al*.,* 2018). Genetic differences have been reported for seed Zn and Fe concentrations (Cichy et al., 2019,20; Cichy et al., 2012, 2010; Tryphone and Msolla, 2010). Zinc and Iron minerals are crucial to human well-being and an adequate supply of these nutrients helps to prevent iron deficiency anaemia and zinc deficiency, which are the two prevalent health concerns of the developing world (Blair et al., 2009,). For example, rates of iron deficiencies in Tanzania among pre-school aged children and pregnant women can reach up to 72% and 58%, respectively (WHO, 2008). The prevalence of zinc deficiency in Tanzania has been found to be as high as 70% among children aged 6 months to 5 years (MHSW, 2015).

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The International Centre for Tropical Agriculture (CIAT) has developed some common bean lines, which are in high iron and zinc. These genotypes have been introduced in Tanzania and together with others identified in the country have been evaluated for adaptability and preference and those with combinations of desirable traits will be selected for release.

1.2 Objectives

The main objective of this task is selection for bean lines that combine acceptable agronomic traits, short cooking time, and high levels of zinc and iron, while the specific objectives are: (i) to identify bean lines that combine high levels of iron and zinc and other agronomic traits including yield; (ii) to determine the overall performance of bean lines with farmers in the on- farm experiments and select the best for official release as improved variety or further use by plant breeders (Participatory Variety Evaluation).

1.3 Concept and flow of work in selecting and releasing new improved varieties

The concept underlying this work is based on the idea of contributing to improved nutrition of people in the food hubs through the use of beans that are improved in levels of Fe and Zn together with other important traits (e.g., yield, disease resistance, early maturity). Figure 1 below describes the flow of activities for this task.

A stage by stage selection of the bean lines is being implemented from a diverse improved common bean population that will also include on-farm participatory evaluation to obtain bean lines with a combination of desirable traits including high levels of Fe and Zn. These bean lines will then be released for use to contribute to improved nutritional status of people in the food hubs and beyond.

2. Approach and Methodology

The overall approach to selecting bean lines involves conducting field experiments first in the research stations and using bean population comprising bean lines that are diverse in various traits. Selection of a few lines based on their performance will be made from that population which will then be evaluated in farmers' fields and further selection will be made in a participatory manner by involving farmers in selection of bean lines in the on-farm experiments.

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2.1 Source of seed

Seed for conducting experiments for this activity were collected from various sources that included SUA germplasm, Tanzania Agricultural Research Institute (TARI) and International Centre for Tropical Agriculture (CIAT). From the collection a total of 90 bean lines were obtained for evaluation (Appendix 1). After collection, seeds were planted in the screenhouse so as to multiply them to get enough seeds for field experimentation.

2.2 Field experiments

Experimental sites

The on-station field experiments were conducted at SUA Morogoro and Selian Agricultural research station in Arusha. This was done so as to obtain data from the two sites for comparison. The on-farm experiments are being conducted in Ndole and Mlali villages (Mvomero Food Hub), Morogoro region; Rondo (Lindi Food Hub) and also in Kikatiti in Arusha region (Fig 2.).

On-station

With regard to the on-station experiments, 90 bean lines were grown in a Randomized Complete Block Design (RCBD). Each plot contained a single row of 3m and three replications. One seed per hill was sown at a spacing of 20cm x 50cm. Crop management was applied as recommended for bean crop. Data on growth and yield performance were collected at specific intervals based on the trait and according to the standard evaluations for beans (CIAT, 1987). The harvested grains were analysed for Fe and Zn content. Data was analysed so as to determine the differences in performance among the bean lines, which was used to assist in doing selection. Bean lines that performed well in the on-station experiments have been selected for the on -farm experiments conducted in farmers' fields.

On farm

From the 90 bean lines that were tested in the on-station experiments 25 were selected based on their agronomic and yield performance (e.g. earliness in maturity, high yield, low disease) together with high levels of Fe and Zn content for further evaluations in on-farm experiments i.e. in farmers' fields. Each bean line was planted in two rows of 3m, spacing 20 x 50 cm and replicated three times. The experiment is researcher- and farmer-managed where farmers are taking part in managing them and in participatory evaluation. This experiment is currently going on in the field and from which data is being collected.

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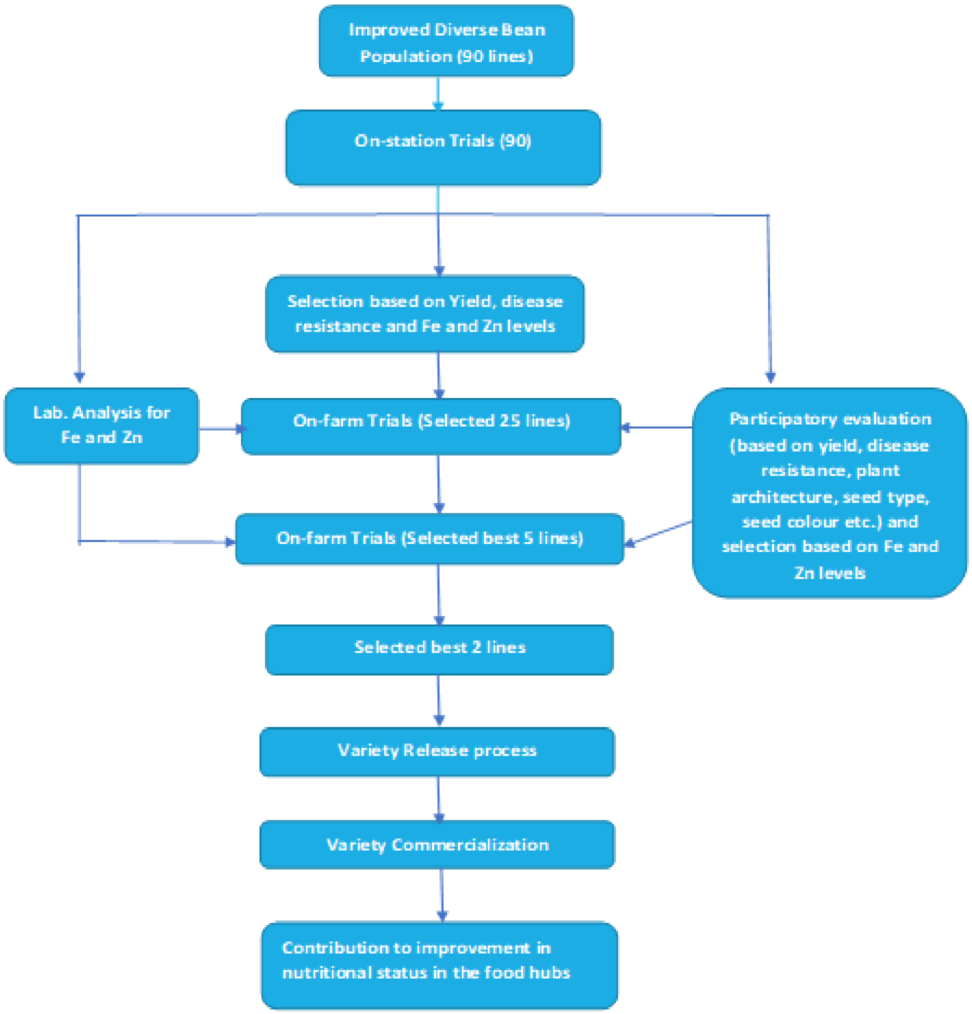

Figure 1: Flow of activities

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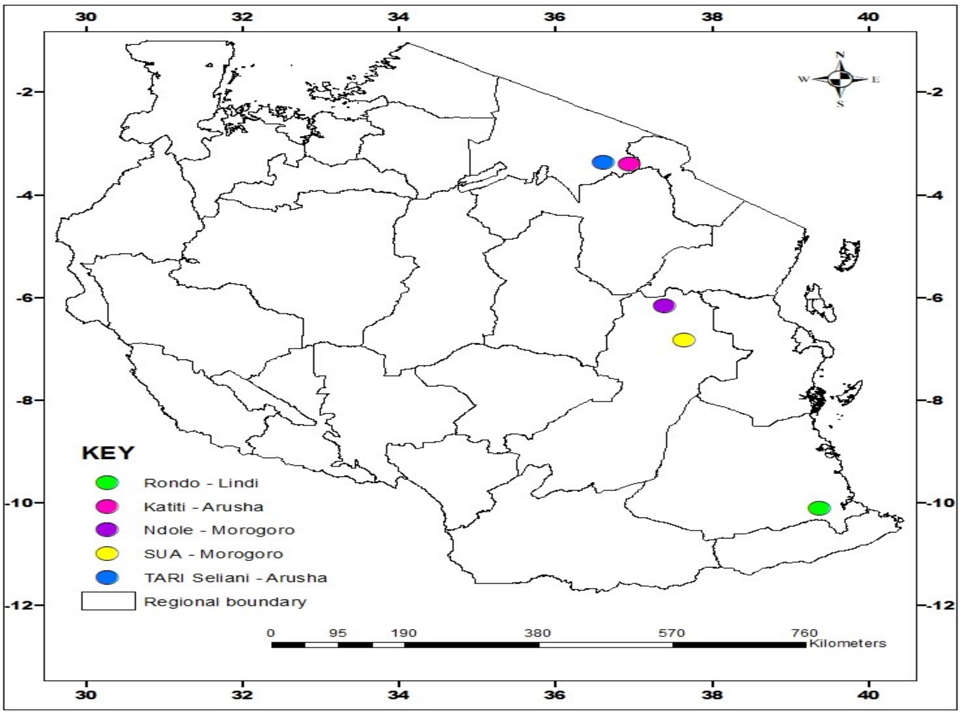

Figure 2: Map showing sites for field experiments

2.3 Laboratory analysis for Fe and Zn in the seeds

Bean seeds were oven-dried at 72°C for 48hours before being subjected to the sample milling machine. A sample of 0.5 g of dry bean powder was obtained using a sample mill machine and weighed in digestion tubes. Then, 5 ml of 68% nitric acid was added into each tube and the mixture was left to stand overnight. The digestion tubes were then placed in the digestion block and the temperature was 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% H2O2 was again added and heated at 70°C. The treatment was repeated until the digest is 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 the

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solution was ready for determination of iron and zinc as per the Atomic Absorption Spectroscopy (AAS) method (AOAC, 1995).

2.4 Data analysis

Analysis of variance (ANOVA) was performed for all data including days to 50 % flowering, disease reaction, days to 85 % maturity, number of pods per plant, number of seeds per pod, the weight of 100 seeds (g), yield per plot (kgha-1), Fe and Zn content and analysis by using the GenStat (16th Edition) Statistical package. Means were separated by Duncan's New Multiple Range Test (DNMRT).

3. Results

3.1 Performance of the lines and selection

There was variation in the performance of the 90 bean lines for the traits that were assessed in the on-station experiments. Figure 3 shows how bean lines were performing in the field and Table 2 gives the summary of performance of these lines.

Figure 3: Bean lines in the field at SUA

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Table 2: Summary of performance of 90 bean lines evaluated in the on-station field experiments

Variable	Mean	Range	LSD	S. E	F-value	Sign.
Fe (mg/kg)	58.8	24.1 - 153.3	49.4	30.65	0.402	NS
Zn (mg/kg)	27.3	16.04 - 59.4	15.3	9.487	0.03	*
Flowering	39.73	30.6 - 47.8	4.3	2.678	<0.001	***
Maturity	86.63	61.5 - 91-7	5.7	3.545	<0.001	***
ALS	1.627	1.0 - 2.5	1.0	0.616	<0.01	**
CBB	1.819	1.0 - 3.3	1.1	0.704	<0.001	***
BCMV	1.464	0.8 - 2.5	1.2	0.723	0.193	NS
LeafRust	1.306	0.7 - 2.8	0.5	0.333	<0.001	***
100 Seed wgt (g)	42.25	20.0 -77.4	8.1	5.028	<0.001	***
Yield (Kg/ha)	1140.5	209.6 - 1954.2	600.1	372.265	<0.001	***

NS: No significan t difference

There were some lines that showed good combinations of the traits of importance namely Fe and Zn content, earliness in maturity and seed yield. In this experiment diseases were not important since all lines had equally lower scores for disease reaction. Therefore, selections for lines to be carried on for further experiments was based on the above three stated traits. Out of 90 lines evaluated 25 were then selected for further experiments (Table 3). These selected lines are now in the field planted together with five checks lines making a total of 30 lines. The bean lines that have been selected are of variable seed colour, size and shape (Fig. 4). Further selections will be conducted with the farmers in a participatory manner to remain with only five best lines.

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Table 3: The 25 selected bean genotypes with high levels of Fe and Zn and good seed characteristics.

Genotype	Fe(mg/kg)	Zn(mg/kg)	Maturity (DAP)	100 seed weight (g)	Yield kg/ha
ADP-190	54.6	37.7	88	45	1661
SUA-90	46.2	41.1	83	29	1466
NUA-660	73.8	25.0	89	57	1453
Selian 94	70.4	32.2	88	37	1440
NUA-672	68.9	29.3	88	42	1432
NUA-682	68.2	32.7	88	56	1416
NUA-256-4	72.8	21.2	87	47	1358
NUA-527	69.3	27.9	88	43	1284
Maini Ndefu	66.8	42.8	89	39	1255
NUA-714	69.6	25.4	87	54	1232
Mashamba-PYT-4	42.0	35.5	84	38	1207
NUA-735	77.0	20.6	87	50	1152
Calima	74.7	26.2	83	47	1146
Rojo	96.9	31.2	84	39	1125
NUA-708	74.3	24.3	88	48	1107
NUA-692	75.4	36.4	88	44	1078
NUA-695	66.5	39.4	88	52	1077
NUA-636	89.4	29.1	87	47	1029
NUA-746	73.5	34.3	86	41	992
NUA-590	72.0	20.9	86	48	947
NUA-629	69.7	24.1	85	48	884
KT-002	66.6	59.4	88	44	840
Lyamungo 90	75.6	33.0	83	48	661
NUA-642	86.7	34.8	85	46	546
Selian 10	52.1	33.7	92	21	291
Mean	57.3	27.25	87	42	1141
LSD	35.3	15.3	6	8	600
SE	30.65	9.487	4	5	372

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Figure 3: Seed types of some of the selected bean lines showing the variability in seed characteristics

4. Exploitation of results

Key exploitable results (KERs) expected

The key exploitable results that are expected from this work are two improved varieties of beans that combine good agronomic characteristics, high yield and increased levels of Fe and Zn.

Planned exploitation route

i. First the final two selected bean lines will be officially released and registered for use by farmers. The procedures for variety release and registration in Tanzania will be followed.

ii. To conduct demonstration plots so as to promote the released varieties. This will be conducted in villages and the food hubs. Also, field days will be organised such that farmers will have the opportunity to visit and learn from the plots.

iii. Seed multiplication in collaboration with seed companies and other partners. For commercialization of the released varieties the seeds of the two released varieties will be increased to adequate amounts for distribution to the farmers.

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iv. Use of processors to incorporate in the mixed grain flours. Some amount of seed will be used by researchers in another subtask (4.4.2) to characterize the nutrient in beans and use them in formulating mixed grain flours.

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Appendix 1: Ninety common bean genotypes and their sources.

Genotype	Source	Genotype	Source	Genotype	Source
Maini Ndefu	TARI-Selian	Selian 05	TARI-Selian	NUA-633	CIAT
Cheupe	TARI-Selian	NUA-712	CIAT	Fibea-PYT-25	TARI-Selian
Uyole 16-PYT-60	TARI-Selian	NUA-645	CIAT	NUA-627	CIAT
NUA-703	CIAT	Mashamba-PYT-9	TARI-Selian	NUA-735	CIAT
Maini	TARI-Selian	Kibugu-PYT-46	TARI-Selian	Uyole-17	TARI-Selian
Selian 97	TARI-Selian	NUA-720	CIAT	NUA-714	CIAT
NUA-708	CIAT	NUA-683	CIAT	NUA-646	CIAT
Selian 94	TARI-Selian	NUA-629	CIAT	ADP-447	SUA
NUA-692	CIAT	NUA-746	CIAT	NUA-256-4	TARI-Selian
NUA-194	TARI-Selian	NUA-648	CIAT	NUA-638	CIAT
Uyole-98	TARI-Selian	Izo-2015110	TARI-Selian	NUA-605	CIAT
Uyole-18	TARI-Selian	Calima	TARI-Selian	Selian 11	TARI-Selian
NUA-642	CIAT	NUA-693	CIAT	Zawadi	SUA
NUA-636	CIAT	NUA-211	TARI-Selian	DOR 662	TARI-Selian
Selian 14	TARI-Selian	NUA-691	CIAT	NUA-711	CIAT
Kigoma-PYT-52	TARI-Selian	Jesca	TARI-Selian	Selian 06	TARI-Selian
KT-002	SUA	NUA-686-A	TARI-Selian	NUA-527	CIAT
Lyamungo 85	TARI-Selian	NUA-717	CIAT	NUA-736	CIAT
NUA-67	TARI-Selian	NUA-704	CIAT	NUA-660	CIAT
NUA-273	TARI-Selian	ADP-190	SUA	NUA-682	CIAT
G5686	TARI-Selian	Selian 13	TARI-Selian	NUA-658	CIAT
KG97-11	TARI-Selian	Mshindi	SUA	Pesa	SUA
NUA-639	CIAT	Selian 12	TARI-Selian	NUA-664	CIAT
Selian 09	TARI-Selian	NUA-590	CIAT	NUA-672	CIAT
KT-013	SUA	Selian 15	TARI-Selian	NUA-702	CIAT
NUA-686-B	TARI-Selian	KT-020	SUA	NUA-744	CIAT
NUA-17	CIAT	Selian 10	TARI-Selian	KT-018	SUA
DDP-094	SUA	Mashamba-PYT-4	TARI-Selian	SUA-90	SUA
NUA-207-2	TARI-Selian	Uyole-04	TARI-Selian	NUA-695	CIAT
Lyamungo 90	TARI-Selian	Rojo	SUA	NUA-655	CIAT

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