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Effects of agroecological practices on nutrient contents in bean and maize grains, in South Kivu (DR Congo)

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ABSTRACT
Objective: The strategies for improving crop quality include improving micronutrients availability. The objective of this study was to evaluate the effect of the agroecological practice consisting of a mixture of leguminous shrubs, grasses, and *Mucuna pruriens* cover crop on nutrient contents in maize and bean grains in different sites.
Methodology and Results: The experiments were carried out on two degraded sites using a split-plot design, with the main plot treatment consisting of agricultural practices. These practices consisting of planting mucuna cover crop, grasses and shrubs. The common practices of burning crop residues and weeds by resource-poor farmers served as control treatments. They were subdivided into four subplots, each corresponding to one variety of beans intercropped with three varieties of maize. The agroecological treatment improved micronutrient contents in both beans and maize grains compared to the common practices at both sites. This practice improved the iron of 14.5 % (69.7 mg/kg against 63.8 mg/kg) and zinc of 26.0 % (42.6 mg/kg against 33.8 mg/kg) content in bean grains. Similarly, for maize, an increase of 7.0 % (18.4 mg/kg against 17.2 mg/kg) for iron and 0.5 % (21.7 mg/kg against 21.6 mg/kg) for zinc was observed in maize grains harvested in the plots with the agroecological practice. In addition, the micronutrient content varied with the site. Zinc content in bean grains was significantly higher in Mulungu (46.6 mg/kg) compared to Mushinga (33.8 mg/kg).
Conclusion and application of results: Micronutrient contents in the grain beans and maize were enhanced with agroecological practices. The application of this practice in the condition similar to those of these trials could contribute to reducing the rate of malnutrition because of the performance of this practice in improving micronutrient contents in harvest products, especially in maize-bean cropping system.
Keywords: Agroecology, biofortified crops, burning, improved fallow, cove crop, micronutrient.

INTRODUCTION

The quality of food products depends on many factors. It is mainly influenced by genetic and climatic factors, but also by soil quality, the latter allowing plants to approach their genetic potential (Ntamwira, 2021). The agricultural practices can affect the quality of the product as nutrients play different roles in plant production. For example, the addition of N generally has the greatest effect on plant growth and a significant influence on product quality, including increasing protein concentration and quality. It also increases the concentration of several other valuable substances (FAO, 2006; Ambrin *et al.*, 2017). The strategies for improving crop qualities include, improving soil fertility and micronutrient availability, adopting conservation agriculture and adapting to climate change. Organic agriculture improves the quality of food products. It produces food with higher concentrations of nutrients compared to conventional agriculture (Kareem, 2013). For example, better quality of soybean and bean grains were produced under no-till using cover crops compared to burning with ploughing (Lal, 2009; Serafim *et al.*, 2019; Ntamwira, 2021).

MATERIALS AND METHODS

Site Description: Field experiments were established on degraded soils in two agroecological zones in South Kivu province of the Democratic Republic of Congo (DR Congo). The first site was located at the INERA Mulungu Research Station (02° 19' 907" S, 028° 46' 540" E, 1,825 masl) in the territory of Kabare, while the second site was in the territory of Walungu, groupement of Mushinga (02° 45' 592" S, 028° 39' 591" E, 1,592 masl). The soils at both INERA-Mulungu and Mushinga are Ferralsols (Heri-Kazi and Bielders, 2020; Ntamwira *et al.*, 2023). Variation in clay content is limited across the soil profile, except in the B-horizon where it can range from 6 to 83%. The silt content varies from 1 to 23%. Their pH generally varies between 4.0 and 5.5. Most Ferralsols have base saturation rates below 50% with a large proportion of exchangeable aluminium (Luíz *et al.*, 2002). The Mushinga experimental site was located on a modestly sloping (1 to 3%) plot with poorer soils and was severely degraded. Cinchona trees (*Cinchona officinalis*) had been grown commercially on this site for over 50 years. The Mulungu experimental site was located on a steep slope (7 to 9%). Multiple years of crop production without specific efforts to control soil erosion resulted in severe soil degradation and low yields, and ultimately the abandonment of the land (Ntamwira *et al.*, 2023).

Methods

Treatment: The split-plot design, with the main plot treatments consisting of agricultural practice, with 8 and 10 repetitions, respectively, at Mulungu and Mushinga was used. They were subdivided into 4 subplots, each corresponding to one variety of beans intercropped with Maize. The first treatments (control) mimicking farmers practice; it combined the burning of weeds and crop residues, and a weed fallow. The second was a novel agroecological practice that included, (i) a mixture of leguminous shrubs (*Calliandra calothyrsus*, and *Leucaena diversifolia*) and grasses (*Pennisetum purpureum* and *Setaria sphacelata*) planted as hedges and in relay with the food crops and (ii) a *Mucuna pruriens* cover crop only established in the dry season months (January to March and May to September) instead of a weed fallow. Within each of the treatment plot, four bean (*Phaseolus vulgaris*) varieties (‘Nanamulenga’, ‘VCB81013’, ‘M211’, and ‘Cuarentino’ and three maize (*Zea mays*) varieties ‘Sam4 Vita A’, ‘Sam4 Vita B’ and

'Gv664'were planted as intercrops. The shrubs and grasses used were selected according to their performance and biomass production from field trials carried out by Ntamwira *et al.* (2019) in eastern DR Congo. In both treatments, composted cow dung manure at a rate of 20 t DM ha^{-1} and micro-doses of NPK (17:17:17) fertilizer at 50 kg ha^{-1} were applied in the planting holes. The two grass species were planted in two parallel rows, 25 cm apart, with each grass species occupying a row. The two parallel rows were planted as a hedge around the plot and in alleys spaced at 2 m apart within the whole plot to increase overall plot biomass carbon sequestration, maximize erosion control and water infiltration. Within the rows, the grasses were spaced 25 cm apart. The two shrub species were planted at a spacing of 1m within rows and 5 m between rows of the shrubs. Plants of the two shrub species were alternated across a line. A total of 33 plants for both shrub species were planted per plot (this comprised 3 lines of 11 plants), resulting in a total of 330 plants across the entire experimental field at Mushinga and 264 across the plots in Mulungu. The grasses (within plot and hedge) were cut at the beginning of each annual cropping season, when the land was being prepared for bean and maize sowing. During the annual crop growing season, grasses were cut every two weeks at 30 cm aboveground, just before sowing the beans to reduce shade for annual crops and to provide mulch. Cutting of shrubs (50 cm aboveground) was done at the onset of the annual cropping season. A large number of stakes were obtained from the first pruning of the shrubs and used to support the climbing beans, while the remaining shrub biomass and subsequent biomass from shrub pruning were applied as mulch within the same plots. In the agroecological plots, *Mucuna pruriens* was planted at trial establishment, and subsequently, at one month before the harvest of beans (i.e., in May and December) and allowed to grow during the subsequent dry season months. It a was planted between the grass and shrub alleys at a plant spacing of 0.5 x 1 m. Beans were planted at a spacing of 25 cm x 50 cm, while maize had a spacing of 50cm x 100cm.

Micronutrient Analyses in Grains: Zinc and iron were determined according to the method of Stangoulis (2010). The collection of samples for the analyses consisted of randomly 5 well-filled pods per plot per block, i.e. 20 pods per variety and a total of 80 pods per agricultural practice in a site. Thus, 320 dry pods were harvested per site. The pods were stored in a paper envelope to avoid dust contamination. In the laboratory, the pods were dehulled, the grains were washed with distilled water and placed in new labelled envelopes and dried in an oven at 60°C for 12 hours. They were then crushed. A sub-sample of 15 g was weighed and placed in a plastic capsule inserted in a metal capsule. A polyethylene paper placed between the two capsules serves to cover the plastic capsule and to facilitate the uniform circulation of ultraviolet rays in the sample during analysis. In addition, this plastic film protects the sample from contamination with iron oxide, which may be due to the oxidation of the methane capsule, which is crossed by the x-ray during the analysis. Before placing the samples in the spectrometer, it was switched on one hour before. A total of 10 capsules each containing 15 g of bean grain powder were placed in the X-ray fluorescence spectrophotometer (SFX or XRF) and sealed. The samples were arranged in practiceatic order according to their numbers noted on the labels. All that was required to press the F8 key on the spectrometer keyboard to validate the sample name, which contained the variety name, and number that was on the card until the last sample. To start the analysis, after the coding of the last sample, it consisted in pressing the start key of the spectrometer keyboard. The machine analyses sample by sample, so 21 minutes are enough to analyse 10 samples.

After 21 minutes, the machine displayed the iron and zinc contents on its screen. The results are saved by pressing the "save all" button on the machine's display. For the determination of iron and zinc content, samples of Maize grains were collected from each variety by taking 3 ears of Maize, i.e. 9 ears per treatment per site. The dehulled grains were washed with distilled water and oven dried at 70°C. In addition, the grains were crushed and analysed for iron and zinc content. The analysis was performed by the same method as the beans by the same spectrometer at the HarvestPlus laboratory in Bukavu, DR Congo. Nutrient analysis of the grains was done by the same spectrometer. Data analysis was carried out using the statistical software R version 4.0.2 (R core team, 2020). The significance level was established at a p-value <0.05. To determine the effects of treatment on observed parameters a one-way ANOVA was used. This analysis was followed by a post-hoc Tukey test for multiple comparisons of means.

RESULTS

Effect of agricultural practices on micronutrient contents in bean grains: The results show that the nutrient contents varied significantly between cropping practices and varieties (P=0.01). The average iron content was significantly high (P=0.05) in the agroecological practice compared to the burning practice. It varied from 64.1 to 74.7 mg/kg and from 60.5 to 67.3 mg/kg for the agroecological and burning practices respectively (Table 1). Regarding the varieties, the nutrients contents varied significantly between them (P=0.01), the varieties NAMULENGA and GUARANTINO gave grains with significantly higher average nutrients than M211 and CODMLVO59. The results presented in Table 1 show that the average zinc content in grains was slightly higher (P=0.281) under agroecology than under burning. They were 38.1 and 35.8mg/kg for agroecology and burning respectively. In terms of varieties, generally, zinc varied slightly between varieties in both practices (P=0.1). However, a significantly higher zinc content was observed in the grains of CUARANTINO variety (42 mg/kg) than that obtained in the COD MLV059 (35.6mg/kg) in the agroecology and between COD MLV059 and M211 in the burning practice. No significant differences were observed between CUARANTINO and NAMULENGA and between COD MLV059 and M211 in both practices (Table 1).

Table 1: Effect of agricultural practices on iron and zinc contents in bean grains

Practices	Varieties	Iron (mg/kg)	Zinc (mg/kg)
Agroecological practices	COD MLV059	64.10b	35.60b
	Cuarantino	74.50a	42.00a
	M211	65.50b	36.60ab
	Namulenga	74.70a	38.20ab
	Average	69.70	38.10
Burning crops residues and weeds	COD MLV059	60.50b	32.60b
	Cuarantino	67.30ab	41.10ab
	M211	60.80b	33.57b
	Namulenga	66.50ab	36.10ab
	Average	63.80	35.80b
	Fpr	0.94	0.99

Effect of sites on iron and zinc contents in bean varieties: The examination of the results presented in this table 2 shows that site and variety significantly influenced the iron and zinc contents in bean grains (p <0.001). Significant differences in mean iron and zinc contents were observed between the two sites (p <0.001), i.e. 73.18mg/kg of iron; 42.68mg/kg of zinc and 64.78mg/kg of iron; 33.88mg/kg of zinc for Mushinga and Mulungu respectively. In addition, the levels of these two micronutrients were higher in the grains produced in Mushinga compared to Mulungu for all varieties.

Tableau 2: Effect of sites on iron and zinc contents in bean grains

Sites	Varieties	Iron (mg/kg)	Zinc (mg/kg)
Mushinga	COD MLV059	72.00ab	42.60a
	Cuarantino	73.80ab	43.30a
	M211	68.50bc	41.80a
	Namulenga	78.00a	42.50a
	Average	73.10	42.60
Mulungu	COD MLV059	57.60d	29.90b
	Cuarantino	72.50a	40.80a
	M211	60.60cd	30.80b
	Namulenga	67.90bc	33.60b
	Average	64.70	33.80
	Fpr	0.20	0.05

Effect of cropping practices on micronutrient contents in maize grains: Iron and zinc levels did not vary significantly between the two practices. However, the results show that the agroecological practice, compared to burning, improved the levels of these nutrients in the grains (18.4 against 17.2 mg/kg of iron and 21.7 against 21.6 mg/kg of zinc for agroecological and burning respectively) (Table 3). Similarly, the varieties did not show significant differences between them for these two micronutrients.

Table 3: Effect of cropping practices on micronutrient contents in maize grains

Practices	Varieties	Iron (mg/kg)	Zinc (mg/kg)
Agroecological practices	GV664	19.10a	23.10a
	SamVitaA	17.50a	20.10a
	SamVitaB	18.50a	22.10a
	Average	18.40	21.70
Burning crops residues and weeds	GV664	19.90a	25.20a
	SamVitaA	11.80a	18.60a
	SamVitaB	19.90a	20.90a
	Average	17.20	21.60
	Fpr	0.52	0.76

Effect of sites on iron and zinc contents in maize grains: There is an interaction between iron content in maize grain and sites. The average iron content (19.4 mg/kg) was significantly higher (p=0.05) in grain produced at Mulungu compared to Mushinga (16.9

mg/kg). In contrast to iron, the sites did not influence the average zinc content in maize grains. It was 21.5 mg/kg at Mulungu and 22 mg/kg at Mushinga (Table 4).

Table 4: Effect of sites on micronutrient contents in maize grains

Practices	Varieties	Iron (mg/kg)	Zinc (mg/kg)
Mulungu	GV664	21.50 a	22.30a
	SamVitaA	14.40b	20.10a
	SamVitaB	22.20a	22.20a
	Average	19.40	21.50
Mushinga	GV664	16.00b	25.30a
	SamVita4A	19.80ab	19.40a
	SamVita4B	14.80b	21.30a
	Average	16.90	22.00
	Fpr	0.01	0.52

DISCUSSION

Effect of agricultural practices on micronutrient contents in bean grains: Considering the nutritive value of bean grains, agroecological practices improved micronutrients in grains of all varieties. Thus, an average increase of 5.9 mg/kg of iron and 2.3 mg/kg was observed in the grains harvested in the plots with agroecological practices compared to those with burning practices. Since the quality of food products is influenced mainly by genetic factors that determine the basic quality, the agroecological practice coupled with better crop management may allow the crops to approach their genetic potential. These results are in agreement with previous researchers that have reported some factors that contribute to the improvement of micronutrient contents in bean grains. The soil organic matter plays a role of facilitating the absorption, transport, translocation and deposition of micronutrients, especially Zn and Fe (Niyigaba, *et al.,* 2019). It was also reported a good quality of soybeans grains produced with no-till practice compared to tillage (Lal, 2009; Serafim *et al.*, 2019). Thus, the adoption of conservation agriculture and adaptation to climate change can lead to the production of adequate and nutritious food for present and future populations.

Site effect on micronutrient contents in bean grains: We noted that iron and zinc levels varied significantly between sites and varieties (P=0.01). The bean grains produced at Mushinga had iron and zinc contents 1.13 and 1.26 higher than those produced at Mulungu. This may be related to the low iron content in the soil observed at this site (Ntamwira *et al.*, 2017). These results show that the content of different nutrients in bean grains would vary across soil types.

Effect of agricultural practices on micronutrient contents in maize grains: The results in the table 3 show that agroecological practices increased the average iron content by 7%., Zinc content was also increased by 0.5% in grain harvested in the agroecological plots. Some explanatory factors for this performance reported in the literature support our results. Bonanomi *et al*. (2020) showed that long-term organic amendment improved the quality of harvested products.

Effect of sites on micronutrient contents in maize grains: Contrary to beans, iron was significantly higher in maize grains in Mulungu and lower in Mushinga (p=0.01). It was 1.15 times higher in Mulungu than in Mushinga. It was also observed by Divyashree *et al,* (2018) that cereal cultivation on marginal land with less or no fertilizer application not only leads to lower soil fertility and productivity, but also mineral nutrient poverty. However, zinc content did not differ significantly between the two sites (p=0.529).

CONCLUSION AND APPLICATION OF RESULTS

Micronutrient contents in the grain beans and maize were enhanced with agroecological practice. Residue burning as is often done by farmers in DR Congo during field management reduce nutrient contents in harvest crops, it is therefore not advisable. However, the agroecological practice is thus an effective approach that can be used to improve micronutrient contents in bean and maize grains. The application of this practice in the condition similar to those of these trials could contribute to reducing the rate of malnutrition because of the performance of this practice in improving micronutrient contents in harvest products, especially in maize-bean cropping system.

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REFERENCES

Ambrin R, Mehrunisa M, Kazi SM, Shamsuddin T, Tanveer AS. and Muhammad AK: 2017. Nutrient composition of banana fruit as affected by farm manure, composted pressmud and mineral fertilizers. *Pak. j. bot; 49, 1: 101-108*.

Bonanomi G, Filippis F, Zotti M, Idbella M, Cesarano G, Al-Rowaily S. and Gawad AA: 2020. Repeated applications of organic amendments promote beneficial microbiota, improve soil fertility and increase crop yield. *Ap. Soil Eco., Vol. 156, Dec. 2020, 103714*.

Divyashree KS, Prakash SS, Yogananda S. and Chandrappa B: 2018. Grain Yield and Nutrient Content of Mungbean and Soil Nutrient Status as Influenced by Application of Micronutrients Mixture in an Alfisol. *International Journal of Current Microbiology and Applied Sciences;* 7, 9*: 1706-1713.*

FAO: 2006. Plant nutrition for food security. A guide for integrated nutrient management. Fertilizer and plant nutrition. *Bulletin*; *16: 366* p.

Heri-Kazi B. and Bielders L. C: 2020. Dégradation des terres cultivées au Sud-Kivu, R.D. Congo: perceptions paysannes et caractéristiques des exploitations agricoles. *Biotechnol. Agron. Soc. Environ;* 24 (2), 99-116.

Kareem I: 2013. Fertilizer Treatment Effects on Yield and Quality Parameters of Sweet potato (*Ipomoea batatas*). *Research Journal of Chemical and Environmental Sciences; 1, 3: 40-49.*

Lal R: 2009. Soil degradation as a reason for inadequate human nutrition. *Food Sec. 1: 45–57.*

Luíz CB, Brossard M, Leprun JC. and Bruand A: 2002. Mise en valeur des Ferralsols de la région du Cerrado au Brésil et évolution de leurs propriétés physiques: une étude bibliographique. *Etude et Gestion des Sols, Association Française pour l'Etude des Sols*, 9, 83-104.

Niyigaba E, Twizerimana A, Mugenzi I, Ngnadong WA, Yu Ping Y, Bang MW. and Hai JB: 2019. Winter Wheat Grain Quality, Zinc and Iron Concentration

A_ected by a Combined Foliar Sprayof Zinc and Iron Fertilizers. *Agronomy;* 9, 250 p.

Ntamwira J, Ocimati W, Blomme G, Lubobo AK, Mwarabu Lolonga Pyame D and Dhed'a Djailo B: 2023. Innovative agroecological practices can restore degraded farmlands and revive crop yields. *Front. Sustain. Food Syst.* 7:1017341. doi: 10.3389/fsufs.2023.1017341.

Ntamwira B: 2021. Effets d'un système agro forestier de type "Tapis vert" sur la productivité et les propriétés agronomiques des agrosystèmes à base de bananiers- haricots-maïs au Sud-Kivu montagneux. Thesis, Kisangani University, Democratic Republic of Congo.

Ntamwira J, Ocimati W, Kearsley E, Safari N, Bahati L, Amini D, Lubobo A K, Waswa B. and Blomme G: 2021. The Integration of Shade-Sensitive Annual Crops in Musa spp. Plantations in South Kivu, Democratic Republic of Congo. *Agronomy*, 11, 368. https:// doi.org/10.3390/agronomy11020368.

Ntamwira BJ, Mirindi CT, Pyame ML, Dhed'a DB, Mariam BE, Moango MA, Kazadi WJ. and Kanyenga LA: 2017. Évaluation agronomique des variétés de haricot volubile riches en micronutriments dans un système intégé d'Agroforesterie sur deux sols contrastés à l'Est de la RD Congo. *Journal of Applied Biosciences*; *114: 11368-11387*.

R Core Team: 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/.

Serafim ME, Zeviani WM, Ono FB, Neves LG, Silva BM. and Lal R : 2019. Reference values and soil quality in areas of high soybean yield in Cerrado region, Brazil. *Soil & tillage research, Vol. 195*about:blank, *Dec. 2019, 104362*.

Stangoulis J: 2010. Technical aspects of zinc and iron analysis in biofortification of the staple food crops, wheat and rice. World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia; *42: 1-6*.