Vol. 13(26), pp. 1338-1348, 28 June, 2018
DOI: 10.5897/AJAR2018.13222
Article Number: BE1E89F57590
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Characteristics of three morphotypes of *Solenostemon rotundifolius* [(Poir.) J. K. Morton] based on qualitative morphological traits

Romaric, K. Nanema[1*], Pauline Bationo-Kando[1], Mahamadi Hamed Ouedraogo[1], Nerbewendé Sawadogo[1], Daniel Nyadanu[2], Aminata Hamidou[1], Renan Ernest Traore[1], Zakaria Kiebre[1], Mahamadou Sawadogo[1] and Jean-Didier Zongo[1]

[1]Department of Plant Biology and Plant Physiology, Faculty of Earth and Life Sciences, University of Ouagadougou, Ouagadougou, Burkina Faso.
[2]Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Received 3 May, 2018; Accepted 30 May, 2018

***Solenostemon rotundifolius* [(Poir.) J. K. Morton] (Lamiaceae) is commonly called Fabirama, Frafra potato or Innala. It is a tuber crop cultivated in many countries in Africa and Asia. Its tubers contain significant rate of carbohydrates, proteins, fibers, vitamins and antioxidants. Besides its nutritional attributes, *S. rotundifolius* has also strong agronomic and economic potentialities and could be financially rewarding to the farm economy. However, *S. rotundifolius* is currently a minor crop in African agro ecosystem. It is a priority to contribute to a better preservation and a sustainable use of its genetic resources. Understanding morphological variability is a key step for *S. rotundifolius* genetic resources management. Previous studies identified three morphotypes based on tuber skin color but a complete description of these morphotypes is not yet done. This study is a contribution to a better description of the main morphotypes of *S. rotundifolius* cultivated in Burkina Faso. Three accessions representing three morphotypes were described based on twenty five qualitative morphological traits assessed at different stages of plant growth. Significant variability between the morphotypes was observed for young plant color, leaves morphology, color and form of inflorescence as well as tuber skin and flesh color. This work provided useful tools for the characterization of *S. rotundifolius* genetic resources.**

Key words: Frafra potato, neglected crop, diversity, qualitative morphological traits, Burkina Faso.

INTRODUCTION

Solenostemon rotundifolius [(Poir.) J. K. Morton] (Lamiaceae), is commonly called Chinese potato, Innala, Hausa potato, Zulu round potato, Sudan potato, Saluga, Fabirama or Frafra potato. It is believed to have originated from Central or East Africa but spread throughout tropical Africa and into South-east Asia. It is cultivated as tuber crop in many African countries including Burkina Faso, Ghana, Nigeria, Togo, Mali (in west Africa), Cameroon and Chad (in central Africa) and some parts of South and East Africa (Schippers, 2000; Gouado et al., 2003; Sugri et al., 2013). In Asia, *S. rotundifolius* is reported to be cultivated in Sri Lanka, South India and Java (Jayakody et al., 2005).

S. rotundifolius is an annual herbaceous plant, 15 to 30 cm high, with ascending or prostrate stems and thick leaves having aromatic smell (Sugri et al., 2013). It is specially adapted to the Sahelian region of West Africa. Local varieties of *S. rotundifolius* produce many (up to 70/plant) small sized tubers; 3.78 cm long and 1.53 cm width (Nanéma et al., 2009). The potential yield reported in West Africa ranged from 7 to 20 T/ha (Enyiukwu et al., 2014). The tubers contain significant rate of reducing sugar (26 mg/100g), protein (13.6 to 14.6 mg/100g), crude fat (1.2%), crude fiber (1.6%), phosphorus (36 mg/100g), calcium (29 mg/100 g), vitamins A and C, respectively 13.6 mg/100 g and 10.3 mg/100g, and antioxidants (Anbuselvi and Balamurugan, 2013; Anbuselvi and Priya, 2013). They are commonly consumed as a curry, baked or fried, or cooked (Agyeno et al., 2014).

Besides its nutritional attributes, *S. rotundifolius* holds strong economic potential and could be financially rewarding to the farm economy (Enyiukwu et al., 2014). During the period of availability, the quantity of tubers sold varied from 16 to 32 Kg/day/person in the main markets of Ouagadougou in Burkina Faso. According to the period and the tubers availability, the prices varied from 1.2 to 3 USD/Kg. This important variation of prices (250%) showed the economic potential of frafra potato (Nanéma et al., 2017).

S. rotundifolius is a very important food crop which can contribute to improving food security. Besides its agricultural importance, it has ornamental, medicinal, culinary and many other uses (Kwarteng et al., 2017). Therefore, as mentioned by Chivenge et al. (2015) and Mamadalieva et al. (2017), there are many neglected crops that have the potential to contribute to food security but investigation should be done to clearly demonstrate their potentialities and the priorities in term of research on these crops. It is now a consensus that understanding variability within plant genetic resources is one of the key steps for a sustainable use and conservation of its potentialities. Some research activities were already carried out on *S. rotundifolius* germplasm and contributed to identify a set of useful traits that could be used as descriptors for this crop (Opoku-Agyeman et al., 2007; Nanéma et al., 2009). Some other works focused on the identification of the main morphotypes within *S. rotundifolius* genetic resources based on tuber skin color (Prematilake, 2005; Sugri et al., 2013).

A description based on one trait could lead to some confusions between the morphotypes. The objective of this study is to contribute to a better description of the main morphotypes of *S. rotundifolius* cultivated in Burkina Faso based on a set of qualitative morphological traits. This will give some useful tools for the identification of the morphotypes for research activities on agronomic, economic or nutritional potentialities of *S. rotundifolius*.

MATERIALS AND METHODS

Plant material

Three accessions (E02, E35 and E20) representing three morphotypes of *S. rotundifolius* (respectively A, B and C) were used for this study (Table 1). These accessions were identified based on morphological variation observed during our previous research on *S. rotundifolius* genetic resources. The accession E02 was collected in the province of Passoré in the North region of Burkina Faso. The accessions E35 and E20 were collected in the province of Nahouri in the South region of Burkina Faso. For each accession, 30 tubers were randomly selected for the experiment (Table 1).

Study area and experimental design

The research was carried out in the research farm of the Faculty of Earth and Plant Sciences of the University Ouaga I Joseph KI-ZERBO in Ouagadougou (12°21′56″ N; 1°32′01″ W). A total rainfall of 665.1 mm was registered during the period of the experiment (July 2016 to January 2017). The experiment was laid out in Fisher blocks with three replications. The replication consisted in three lines of height plastic buckets perforated at the bottom to improve drainage. Each plastic buckets (9 L) contained a mix of sun (1/3) and potting soil (2/3). The spacing was 50 cm between the lines, 40 cm between the plants and 50 cm between the blocks. One tuber was planted per bucket on 25 July 2016. An additional irrigation was bring after the rainy season from October 2016 to January 2017.

Morphological traits

A total of 25 qualitative morphological traits were assessed at different stages of plant growth. These traits were identified during our previous research activities. The different variants were identified and scored per plant. At all, the morphological traits were observed on 24 plants per morphotype.

*Corresponding author. E-mail: nanemaromaric@gmail.com.

Table 1. List of the accessions used for the morphological characterization of the morphotypes of *S. rotundifolius.*

Accession's number	Province of origin	GPS coordinates	Morphotype
E02	Passoré	12° 58' 00'' N 2° 16' 00'' W	A
E35	Nahouri	11° 15' N 1° 15' W	B
E20	Nahouri	11° 15' N 1° 15'W	C

Legend: A, B and C are names of the morphotypes of *S. rotundifolius;* E02, E35 and E06 are accessions' numbers in the genes bank of the University Ouaga I Pr Joseph KI-ZERBO (Burkina Faso)*;* GPS: Global Positioning System.

Table 2. Morphological traits observed on the morphotypes of *S. rotundifolius.*

Stage	Morphological traits
Young plant	Color of stems (COSt) Color of leaves (COL1)
Vegetative growth stage	Foliage color (FCO) Thickness of leaves (TLE) Color of apical leaves (CAL) Variation of leaves color when injured by insects (LCI) Stature of main stem (SMS) Stature of secondary stems (SSS)
Flowering stage	Number of flower buds per cluster (NFB) Color of flower buds (CFB) Type of inflorescence (TIN) Level of branching of inflorescence (LBI) Arrangement of clusters of flowers on the rachis (AFR) Flowers persistence on the rachis (FPE) Color of sepals (COSe) Color of petals (CPE) Color of rachis (CRA) Shape of the section of main stems (SSS) Color of leaves of adult plant (COL2)
After harvesting	Position of tuberous roots (PTR) Tuber shape (TSH) Tuber skin color (TSC) Tuber flesh color (TFC) Presence of lateral tubers (PLT) Texture of tuber skin (TTS)

Morphological traits observed at vegetative stage

Height morphological traits were observed during the vegetative stage. The color of stems (COSt) and the color of leaves (COL1) of young plant were scored at juvenile stage (Table 2). During the plant growth, the foliage color (FCO), the thickness of leaves (TLE), and the color of apical leaves (CAL) were observed. The variation of leaves color when injured by insects (LCI), the main stem (SMS) and the secondary stems (SSS) stature were observed before flowering period.

Table 3. Variability between morphotypes at juvenile stage.

Morphological trait	Morphotype		
	A	B	C
Color of stems (COSt)	Green	Red	Green
Color of leaves (COL1)	Green	Red	Green

Figure 1. Young plant of *S. rotundifolius* presenting green stems (morphotype A).

Figure 2. Young plant of *S. rotundifolius* presenting green leaves (morphotype A).

Morphological traits observed at flowering stage and after harvesting

A total of seventeen morphological traits were observed on the inflorescence, the stems and the tubers after flowering. Nine of them were observed on the inflorescence. These traits were the number of flower buds per cluster (NFB), the color of flower buds (CFB), the type of inflorescence (TIN), the level of branching of inflorescence (LBI), the arrangement of clusters of flowers on the rachis (AFR) and the flowers persistence on the rachis (FPE). The color of sepals (COSe), and the color of petals (CPE) were observed on three randomly selected flowers per plant. The color of rachis (CRA) was also observed. Besides the morphological traits observed on the inflorescence, two were observed on the stems and the leaves. These were the shape of the section of main stems (SSS) and the color of leaves of adult plant (COL2). Six traits were observed on the tubers. After harvesting, the position of tuberous roots (PTR), the tuber shape (TSH), the tuber skin color (TSC), the tuber flesh color (TFC), the presence of lateral tubers (PLT) and the texture of tuber skin (TTS) (Table 2).

Data analysis

The individuals with missing data were eliminated. A consensus value for each morphological trait was identified based on the individual score of each plant. The morphotypes were then described based on the consensus value for all the morphological traits.

RESULTS

Variability of the morphotypes at juvenile stage

A variability was observed between young plant of the morphotypes for stems and leaves color (Table 3). The stems and leaves of young plants of morphotypes "A" and "C" were green (Figures 1 and 2) while the young plants of morphotype "B" were red (Figures 3 and 4).

Variability of the morphotypes at vegetative growth stage

Variability was observed between the morphotypes at vegetative stage (Table 4). The color of foliage was green

Figure 3. Young plant of *S. rotundifolius* presenting red stems (morphotype B).

Figure 4. Young plant of *S. rotundifolius* presenting reddish leaves (morphotype B).

for morphotype “A”, dark green for morphotypes “B” and light green for morphotype “C”. The color of apical leaves did not vary from the color of whole foliage. No particular color was observed on the leaves when injured by insects. The morphotypes also varied for the level of leaves thickness. The leaves of the morphotype “A” were very thick while those of the morphotypes “B” and “C” were relatively less thick (Figure 5).

Variability of the morphotypes at flowering stage

The morphological traits observed at flowering stage revealed important variability between the morphotypes. The inflorescence was an apical spike. Some inflorescences with primary branching were observed for the morphotypes “A” and “B” (Table 5). The flower buds color was green with reddish pigmentation for the morphotype “B” (Figure 6) but it was green for the morphotypes “A” (Figure 7) and “C” (Figure 8). The number of flower buds per cluster was four for the morphotypes “A” and “C” but it was three for the morphotype “B”. The clusters of flowers were opposite on the rachis for all the morphotypes. The flowers buds and the flowers were no persistent on the rachis. After flowering, the color of rachis was reddish for the morphotype “A” but was green for the morphotypes “B” and “C”. The morphotype “A” developed elongated flowers with green-reddish sepals and white-purple petals (Figure 9). The sepals of the flowers of the morphotype “B” was reddish and the petals were very purple (Figure 10). For the morphotype “C”, the sepals were green and the petals were reddish (Figure 11). The morphological traits observed on the stems and the leaves after flowering did not vary. The section of stems was quadrangular for all the morphotypes and the leaves were dark green.

Variability of the morphotypes for the morphology of the tubers

The tuber skin and flesh color, and the tuber shape were the discriminant traits observed on tubers (Table 6). The tubers of the morphotype “A” were black skin (Figure 12) and the flesh color was white (Figure 13). The tubers of the morphotype B, skin color was red (Figure 14) and the tuber flesh color was white-yellow (Figure 15). The tubers of the morphotype “C” skin color was white-yellow (Figure 16) and the flesh color was yellow (Figure 17). Tubers were oblong for morphotypes “A” and ovoid for the morphotypes “B” and “C”. For all the morphotypes, the tuberous roots were observed on the upper parts of the roots. The tubers were rough and some tubers presented lateral tubers.

DISCUSSION

Three morphotypes of *S. rotundifolius* were described

Table 4. Variability between morphotypes at vegetative growth stage.

Morphological trait	Morphotype		
	A	**B**	**C**
Foliage color (FCO)	Green	Dark green	Light green
Color of apical leaves (CAL)	Green	Dark green	Light green
Variation of leaves color when injured by insects (LCI)	No	No	No
Thickness of leaves (TLE)	Strong	Low	Low
Stature of main stem (SMS)	Ascending or prostrate	Ascending or prostrate	Ascending
Stature of secondary stems (SSS)	Prostrate	Prostrate	Prostrate

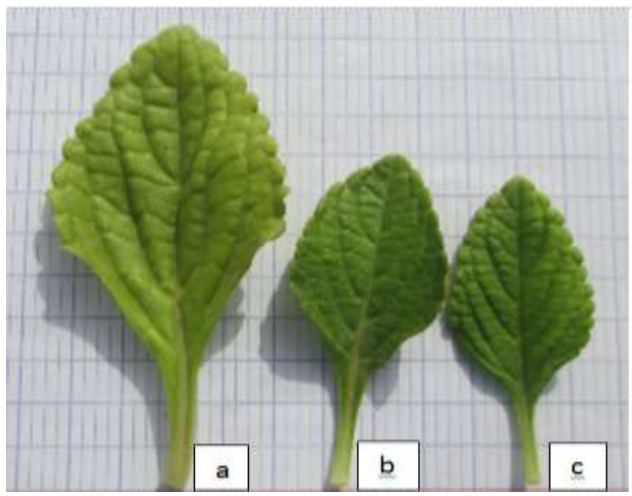

Figure 5. Thickness of leaves of *S. rotundifolius;* a: leaf of morphotype A; b: leaf of morphotype B; *c:* leaf of morphotype *C.*

The main stem was ascending or prostate for the morphotypes "A" and "B" and generally ascending for the morphotype "C". The secondary stems of all the morphotypes were prostrate.

Table 5. Variability between morphotypes at flowering stage.

Morphological trait	Morphotype		
	A	**B**	**C**
Type of inflorescence (TIN)	Spike	Spike	Ear
Level of branching of inflorescence (LBI)	Primary branching	Primary branching	No branching
Color of flower buds (CFB)	Green	Green-reddish	Green
Number of flower buds per cluster (NFB)	Four	Three	Four
Arrangement of clusters of flowers on the rachis (AFR)	Opposite	Opposite	Opposite
Flowers persistence on the rachis (FPE)	No persistent	No persistent	No persistent
Color of rachis (CRA)	Purple	Green	Green
Color of sepals (COSe)	Green-reddish	Reddish	Green
Color of petals (CPE)	White-purple	Purple	Reddish
Shape of section of the main stem (SSS)	Quadrangular	Quadrangular	Quadrangular
Color of leaves of adult plant (COL2)	Dark green	Dark green	Dark green

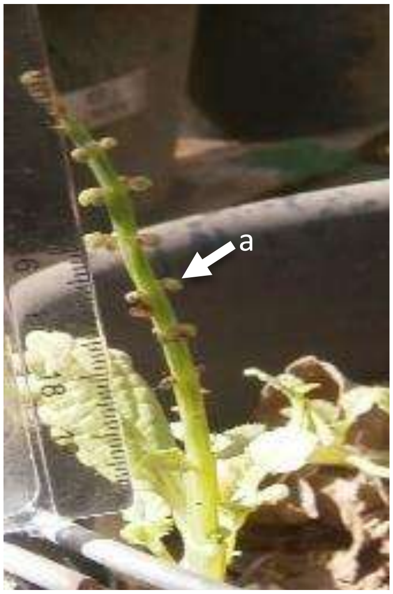

Figure 6. Spike of morphotype B of *S. rotundifolius* presenting flower buds; a: flower buds.

Figure 8. Spike of morphotype C of *S. rotundifolius* presenting flower buds; a: flower buds.

Figure 7. Spike of morphotype A of *S. rotundifolius* presenting flower buds; a: flower buds.

Figure 9. Spike of the morphotype A of *S. rotundifolius* sowing flowers; a: flower.

based on morphological traits observed on leaves, stems, inflorescences and tubers. At juvenile stage, the presence red coloration on young plant was identified to be the main difference between the morphotypes. The variation of young plant color was also observed by Nanéma et al. (2009) as a discriminant traits within *S. rotundifolius* genetic resources. According to Price and Sturgess

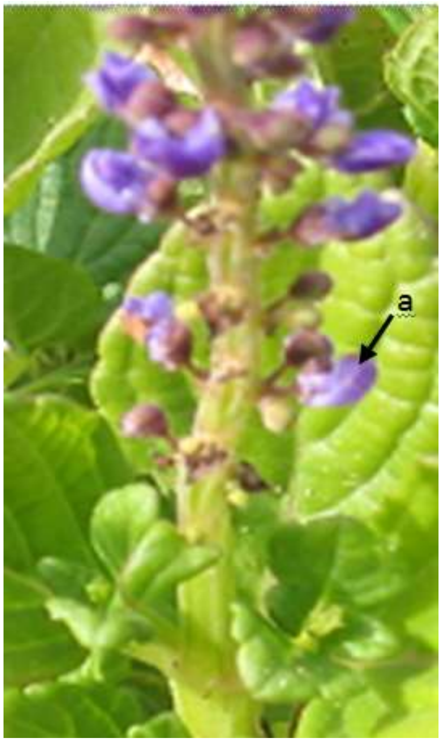

Figure 10. Spike of the morphotype B of *S. rotundifolius* sowing flowers; a: flower.

Figure 11. Spike of the morphotype C of *S. rotundifolius* sowing flowers; a: flower.

(1938), the reddish color observed on *Lamiaceae* species are due to the presence of anthocyanins (mainly cyanidine saccharides).

During the vegetative growth stage, the main variation was observed for leaves thickness and the stature of main stem. All the morphotypes produced thick leaves. As suggested by Edison *et al*. (2006), leaves morphology is an important parameter for water regulation in plant tissues. The strong thickness of leaves of the morphotype "A" could be considered as a particular adaptation potential of this morphotype to water scarcity conditions. Besides the leaves morphology, the stature of stems was identified as a discriminant parameter. Previous research activities revealed the presence of pigmentation on *S. rotundifolius* leaves (Agyeno et al., 2014).

The most significant discriminant traits were observed on the inflorescence. These parameters can be sufficient to identify the morphotypes. Previous works on *S. rotundifolius* variability mentioned the color of the petals of the morphotypes "A" and "B" (Nanéma et al., 2009). This work is the first report on the flowering of the morphotype "C". The other morphological traits observed after flowering did not reveal differences between the morphotypes. It was the stem section, that was quadrangular and the color of leaves that was green. The quadrangular stem section of *S. rotundifolius* was also mentioned by Agyeno et al. (2014). However, variability of stem section can be observed within the same morphotype (Nanéma et al., 2009). Pigmentation on leaves was also mentioned at flowering stage. These traits seem to be influenced by *S. rotundifolius* growth conditions.

In addition to the tuber skin color, variability was observed for tuber flesh color. Current literature mentioned three morphotypes according to the tuber skin color: - the morphotype with white skin tuber; the morphotype with red skin tuber; and the morphotype with black or brown skin tuber (Prematilake, 2005; Nanéma, 2010; Sugri et al., 2013). Chevalier and Perrot (1905) mentioned these morphotypes respectively as varieties "*alba*", "*rubra*" and "*nigra*". These authors suggested the presence of a fourth variety with black skin tuber called "*javanicaminum*". Some research activities were carried out on *S. rotundifolius* based on the tuber skin color as the main criteria of identification of the varieties (Jayakody et al., 2005; Priya and Anbuselvi, 2013, Taye et al., 2012). After harvest, the tuber skin color is the most accessible criteria for identification of the morphotypes but any error of color appreciation could lead to ambiguous results. Additional morphological traits could be the tuber flesh color and tuber shape.

The tubers of all the morphotypes were rough and glabrous. Other research activities in West Africa also mentioned the lack of hairiness on tubers of *S. rotundifolius* (Opoku-Agyeman et al., 2007; Agyeno et al., 2014).

Table 6. Variability of the morphotypes for the morphology of the tubers.

Morphological trait	Morphotype		
	A	B	C
Position of tuberous roots (PTR)	Upper part of roots	Upper part of roots	Upper part of roots
Tuber skin color (TSC)	Black	Red	White-yellow
Tuber flesh color (TFC)	White	White-yellow	Yellow
Tuber shape (TSH)	Oblong	Ovoid	Ovoid
Presence of lateral tubers (PLT)	Present	Present	Present
Texture of tuber skin (TTS)	Rough	Rough	Rough

Figure 12. Black skin color of tubers of the morphotype A.

Figure13. White flesh color of tubers of the morphotype A.

Figure 14. Red skin color of tubers of the morphotype B.

Figure15. White-yellow flesh color of tubers of the morphotype B.

Figure 16. White-yellow skin color of tubers of the morphotype C.

In Asia, some varieties of *S. rotundifolius* produce hairy tubers (Jayakody et al., 2005). This difference could be due to genetic factor or to growth conditions. For all the

Figure 17. Yellow flesh color of tubers of the morphotype C.

morphotypes, many branched tubers were identified. *Solenostemon rotundifolius* produced small size tubers and the presence of branched tubers make peeling very difficult. According to Enyiukwu et al. (2014), branched tubers make the crop unattractive and reduce the marketability of the tubers.

The described morphotypes were identified in *S. rotundifolius* germplasm in Burkina Faso. Based on some morphological traits used in previous works, the three morphotypes were reported to be cultivated in West Africa (Sugri et al., 2013; Agyeno et al., 2014). The morphotype "A" and "B" are cultivated in Sri Lanka respectively as "Bola" and "Dik" (Prematilake, 2005, Jayakody et al., 2005). Some research activities highlighted the influence of genetic variability on tuber nutritional, medicinal potentialities and their behavior in conservation (Jayakody et al., 2005; Priya and Anbuselvi, 2013; Parmar et al., 2017; Mamadalieva et al., 2017; Azad et al., 2017). A clear classification of accessions used in future research on *S. rotundifolius* could contribute to a better analysis of the results. This include nutritional, agronomical and economical potentialities as well as genetic diversity.

Future research activities could also be focused on the existence of variability within the morphotypes. Other aspects could be the description of flower morphology. Similar studies already led to the revision of *Borassus* classification (Bayton et al., 2006).

Conclusion

This study described three morphotypes of *S. rotundifolius* cultivated in Burkina Faso based on a set of qualitative morphological traits. These morphological traits can be used as descriptors for *S. rotundifolius*. It is an important step towards full description of the morphotypes of this important tuber crop. The future studies on morphological variability could focused on flower structure and microscopic description of plant tissues. A complete description of the morphotypes will provide useful information for a sustainable management of genetic resources of *S. rotundifolius*.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

This work was supported by the University Ouaga I Pr Joseph KI-ZERBO.

REFERENCES

Agyeno OE, Jayeola AA, Ajala BA, Mamman BJ (2014). Exo-morphology of vegetative parts support the combination of *Solenostemon rotundifolius* (Poir) J. K. Morton with *Plectranthus esculentus* N. E. Br. Natal (Lamiaceae) with insight into infra-specific variability. Advances in Agriculture and Botanics-International Journal of the Bioflux Society 6(1):16-25.

Anbuselvi S, Balamurugan T (2013). Nutritional and antinutrional consituents of *Manihot esculentus* and *Plectranthus rotundifolius*. International Research Journal of Pharmacy 4(9):97-99.

Anbuselvi S, Priya HM (2013). Nutritional and anti-nutritional constituents of *Plectranthus rotundifolius*. International Journal of Pharmaceutical Sciences Review and Research 22(1):213-215.

Azad AK, Kabir H, Eaton TEJ, Soren EB (2017). Storage potentialities of some exotic potato varieties at farmers' condition in Bangladesh. Agricultural Sciences 8(2):183-193.

Bayton RP, Ouédraogo A, Guinko S (2006). The genus *Borassus* (Arecaceae) in West Africa, with a description of a new species from Burkina Faso. Botanical Journal of the Linnean Society 150:419-427.

Chevalier A, Perrot E (1905). Les *Coleus* à tubercules alimentaires. In : Les végétaux utiles de l'Afrique Tropicale française. Etudes scientifiques et agronomiques, Fascicule I, Paris 1:100-152.

Chivenge P, Mabhaudhi T, Modi AT, Mafongoya P (2015). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in sub-saharan Africa. International Journal of Environmental Research and Public Health 12(6):5685-5711.

Edison S, Unnikrishnan M, Vimala B, Pillai SV, Sheela MN, Sreekumari MT, Abraham K (2006). Biodiversity of tropical tuber crops in India national biodiversity authority. National Biodiversity Authority Chennai, Tamil Nadu, India 31 p.

Enyiukwu DN, Awurum AN, Nwaneri JA (2014). Potentials of Hausa Potato (*Solenostemon rotundifolius* (Poir.) JK Morton and Management of its tuber rot in Nigeria. Greener Journal of Agronomy, Forestry and Horticulture 2(2):027-037.

Gouado I, Fotso M, Djampou EJ (2003). Potentiel nutritionnel de deux tubercules (*Coleus rotundifolius* et *Solenostemon ssp*.) consommés au Cameroun. 2ème atelier international, voies alimentaires d'amélioration des situations nutritionnelles, Ouagadougou 13-28/11/2003, pp. 85-90.

Jayakody L, Hoover R, Liu Q, Weber E (2005). Studies on tuber and root starches. I. Structure and physicochemical properties of innala (*Solenostemon rotundifolius*) starches grown in Sri Lanka. Food Research International 38(6):615-629.

Kwarteng AO, Ghunney T, Adu Amoah R, Nyadanu D, Abogoom J, Nyam KC, Ziyaaba JZ, Danso EO, Whyte T, Asiedu DD (2017). Current knowledge and breeding avenues to improve upon Frafra potato (*Solenostemon rotundifolius* (Poir.) J. K. Morton). Genetic Resources and Crop Evolution 65(2):1-11.

Mamadalieva NZ, Akramov DK, Ovidi E, Tiezzi A, Nahar L, Azimova SS, Sarker SD (2017). Aromatic medicinal plants of the Lamiaceae family from uzbekistan: ethnopharmacology, essential oils composition, and biological activities. Medicines 4(8):1-13

Nanéma KR, Traoré RE, Bationo/Kando P, Zongo JD (2009). Morphoagronomical characterization of *Solenostemon rotundifolius* (Poir J. K. Morton) (Lamiaceae) germplasm from Burkina Faso. International Journal of Biological and Chemical Sciences 3(5):1100-1113.

Nanéma KR (2010). Ressources génétiques de *Solenostemon rotundifolius* (Poir.) JK Morton du Burkina Faso : Système de culture, variabilité agromorphologique et relations phylogénétiques entre ses différents morphotypes cultivés au Burkina Faso. Thèse de Doctorat Unique, Univ. Ouaga., Burkina Faso. 122p.

Nanéma KR**,** Sawadogo N, Traoré ER, Ba AH (2017). Marketing potentialities and constraints for frafra potato : case of the main markets of Ouagadougou (Burkina Faso). Journal of Plant Science 5(6):191-195.

Opoku-Agyeman MO, Bennett-Lartey SO, Vodouhe RS, OSEI C, Quarcoo E, Boateng SK, Osekere EA (2007). Morphological characterization of frafra potato (*Solenostemon rotundifolius*) germplasm from the savannah regions of Ghana. Plant genetic resources and food security in West and Central Africa. Regional Conference, Ibadan, Nigeria, 26-30 April, 2004, pp. 116-123.

Parmar A, Gebre BA, Legesse A, Demelash Y, Fladung K, Hensel O (2017). Nutritional comparison of white and red *Coccinia abyssinica* (Lam.) Cong. accessions: an under-utilised edible tuber of the ethiopian highlands. Foods 6(8):71.

Prematilake DP (2005). Inducing genetic variation of innala (*S. rotundifolius*) via in vitro callus culture. Journal of the National Science Foundation of Sri Lanka 33(2):123-131.

Price JR, Sturgess VC (1938). A survey of anthocyanins. VI. Biochemical Journal 32(9):1658-1660.

Priya HM, Anbuselvi S (2013). Physico chemical analysis of *Plectranthus rotundifolius*. Journal of Chemical and Pharmaceutical Research 5(3):12-14.

Schippers RR (2000). African indigenous vegetables. An overview of the cultivated species. Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation, Chatham, United Kingdom 214 p.

Sugri I, Kusi F, Kanton LAR, Nutsugah KS, Zakaria M (2013). Sustaining frafra potato (*Solenostemon rotundifolius* Poir.) in food chain ; current opportunities in Ghana. Journal of Plant Sciences 1(4):68-75.

Taye M, Lommen MWJ, Struik PC (2012). Ontogeny of the tuber crop *Plectranthus edulis* (Lamiaceae). African Journal of Agricultural Research 7(30):4236-4249.