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Research Paper

Implications of seed ergastic substance–based diversity in some polygonaceae taxa

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Abbreviations: GIA, Global Industrial Analysts; **FAO,** Food and Agriculture Organization; **(NWFPs),** Non-wood forest products; **BV,** Biological value.

ABSTRACT

The importance plant ergastic products have predispose seeds as major food, medicinal and industrial resources and ultimately have made plant seeds target of researches on different platforms. Seeds of 27 Polygonaceae species of five genera were analyzed for ergastic substances deposits as well as to ascertain the degree of diversity within the family using rescaled Euclidean distance cluster analysis. High degree of similarity (77%) and less than 30% diversity was observed amongst the study population, which points out the inter-specific difference within the family and thus the abundance of related and novel traits for improvement of important species. Starch, fats and oils, inulin and proteins were recorded in all the species, 10 species (37%) excluding members of the *Fallopia, Polygonum* and some *Rumex* recorded tannins. Starch characteristics were cereal-like; round, polygonal with a small percentage of irregular shaped granules. Granule size were similar to regular cereal granule size (< 38 μm) with a few species; *Rumex undelatum, Rumex confertus, Rumex crispus and Rumex woodsii* had large granules (64.4 – 67 μm) and segregated into 66% A-type size starch granules (>9.9μm) and 34% B-type size starch granules (<9.9μm). The interest in Polygonaceae starch is connected with the species as important pseudocereals coupled with the fats, oils, proteins, inulin and tannins contents; the plants species constitute a considerable potentials as major non-wood forest products (NWFPs) that will improve rural livelihoods, household food security and nutrition, as well as represent authentic compliments or alternatives to cereal starches for global food and industrial consumption.

Key words. Seeds, ergastic substances, genetic diversity, starch, polygonaceae, food security, human health.

INTRODUCTION

Plant species hold an important place in all aspects of human lives, this is mainly due to the derivatives they produce, which man have employed in several ways for man's good. Plant metabolites and derivatives are different in types, volume and complexity in which they exist in different plants and constitute the way they are utilized. This has endeared a number of plant species to human over others (Satin, 2006).

Polygonaceae, buckwheat, smartweed or knotweed is a cosmopolitan family of climbers, herbs, shrubs and small trees geographically distributed from the arctic to tropical West Africa (Hutchinson and Dalziel, 1954; Brummit, 1992; Ayodele and Olowokudejo, 2006; Heywood et al., 2007). The family is considered to be made up of 30 to 49 genera with about 1,200 dicot species diverse in habits, ranging from annuals to perennials. Members are characterized by simple leaves, small dry endospermic fruit almost entirely one-seeded. A number of species are cultivated as ornamentals, few *Erogonium* make excellent additions to native gardens, two species of *Fagopyrum* are cultivated as buckwheats; some members of the *Rhuem* and *Rumex* are food items and members of the *Persicaria, Rumex, Polygonum* constitute some of the worst weeds known to man (Huxley, 1992; Freeman and Reveal, 2005; Staples and Herbst, 2005; Heywood et al., 2007). Variations of obvious taxonomic and genetic diversity value are said to occur among species based on several evidences (Kim and Donoghue, 2008; Nowicke and Skvarla, 1979). The present study seeks to examine the diversity relationship amongst members of five genera in the family Polygonaceae based on ergastic evidences and discuss the importance and possible applications of the ergastic substances.

MATERIALS AND METHODS

A total of 27 herbaceous species seeds obtained from the Botanischer Garten and Botanisches Museum, Berlin-Dahiem, Germany; the South-East Asia Weed Information Centre, Indonesia through seed exchange programme and the others from seeds collection surveys through Southern Nigeria in 2009 were analysed for the present study. Seeds vouchers are stored at the seed germplasm bank of the Department of Biological Sciences, Covenant University, Ota, and the Department of Plant Biology and Biotechnology, University of Benin, Benin City, Edo State, Nigeria.

Seed ergastic analysis

Tests for various ergastic substances; fats and oils, protein, tannins, inulin and starch were analysed according to Gill et al. (1991) and Idu and Onyibe (2011). Starch granule characteristics; granule shape, granule size, hilium striations and hilium size, were recorded to the nearest decimal (0.00 µm). Starch granule size were as designated by Li et al., (2008); as A type diameter > 9.9µm, and B-type granules diameter < 9.9 µm. Data matrix was analysed to generate a relationship dendogram with SPSS 15.1 for Windows.

RESULTS

Ergastic substances profile

Analysis of the 27 species recorded fats and oils, inulin and proteins and a considerable amount of starch (Table 1). However, 10 species (37%) excluding members of the *Fallopia, Polygonum* and some *Rumex* recorded tannins.

Starch grain characteristics

Starch grain characteristics varied to some extent between species. Starch granule shape was generally circular (round, polygonal). A few species; *Persicaria alpina, Rumex acetosella, Rumex augusifolius , Rumex crispus, Rumex hydrolapathum, Rumex nepalensis, Rumex obtiussifolius, Rumex pulcher, Rumex traingulivalvis* and *Rumex woodsii* recorded irregular shaped starch granules alongside circular starch grains; accounting for 37% difference amongst the species. Oblong, triangular and reniform shaped starch granules were not recorded amongst the species studied. A few species (11%) like *Rumex acetosa, Rumex bucephalophorus and Rumex confertus* showed hilium striations on starch granules present in the seeds.

Starch granules size determination segregated the study population into 66% A-type size starch granules (>9.9µm) group comprising *Fallopia convolvulus, Fallopia dumetorum, Persicaria alpina, Persicaria hydropiper, Persicaria minor, Polygonum divaricatum, Polygonum arenastrum, Rheum undelatum, Rheum acetosa, Rheum augusifolius, Rheum aquaticus, Rheum confertus, Rheum crispus, Rheum hydrolapathum, Rheum maritimus, Rheum obtiusifolius, Rheum triangulivalvis* and *Rheum woodsii;* and 34% B-type size starch granules (<9.9 µm) comprising *Persicaria lapathifolia, Rumex acetosella, Rumex bucephalophorus, Rumex induratus, Rumex kerneri, Rumex nepalensis, Rumex patientia, Rumex pulcher* and *Rumex sylvestris.*

Cluster analysis

The cluster analysis of the seed lot generated three clusters that are not entirely delimited along the starch characteristics lines; showing the influences of other ergastic substances in separating the population (Figure 1). In addition, cluster membership did not follow traditional demarcation lines (Sanchez, 2009; Burke et al., 2010; Mosaferi and Keshavarzi, 2011); with members of different genera clustering alongside other species. 77% of the seed population and 90% of the genera studied clumped in one cluster showED a high level of similarity amongst the study population based on ergastic evidences.

DISCUSSION

Ergastic substances in polygonaceae

The analyses of ergastic substances in the family Polygonaceae, revealed a considerably level of similarity amongst the taxa studied. The degree of closeness from the cluster analysis links directly with the level of similarity in ergastic substances amongst members of the family and thus the similarity in the biochemical pathways of the species. This indicates that the use of members of the family as pristine sources of fats and oils, inulin, protein and starch or as alternative to already known species is a possibility based on the commonality of ergastic substances within the family.

Table 1. Ergastic substances profile of 27 Polygonaceae species.

TAXON	Life form	Fats & oil	Inulin	Protein	Tannin	Starch			
						Circular	Irregular	Hilium & Striations	Size (µm)
F. convolvulus	+	+	+	+	-	++++	-	-	19.5
F. dumetorum	+	+	+	+	-	++++	-	-	19.5
P. minor	+	+	+	+	+	++++	-	-	9
P. lapathifolia	+	+	+	+	-	++++	-	-	16
P. alpina	+	+	+	+	+	+++	+	-	16
P. hydropiper	+	+	+	+	-	++++	-	-	16.8
P. arenastrum	+	+	+	+	-	++++	-	-	10
P. divaricatum	+	+	+	+	-	++++	-	-	13
R. undelatum	+	+	+	+	-	++++	-	-	65
R. acetosa	+	+	+	+	-	+	-	+	13
R. acetosella	+	+	+	+	-	+++	+++	-	9
R. angusifolius	+	+	+	+	-	++++	+	-	12
R. aquaticus	+	+	+	+	-	++++	-	-	23.8
R. bucephalophorus	+	+	+	+	+	++++	-	+	8.4
R. confertus	+	+	+	+	+	++++	-	+	64.4
R. crispus	+	+	+	+	+	++	++	-	64.4
R. hydrolapathum	+	+	+	+	+	+	+++	-	12
R. induratus	+	+	+	+	-	++++	-	-	6
R. kerneri	+	+	+	+	+	++++	-	-	6
R. maritimus	+	+	+	+	-	++++	-	-	10
R. nepalensis	+	+	+	+	-	++	++	-	6
R. obtiusifolius	+	+	+	+	-	+++	+	-	12
R. patientia	+	+	+	+	+	++++	-	-	3.6
R. pulcher	+	+	+	+	+	+++	+	-	4.8
R. sylvestris	+	+	+	+	-	++++	-	-	3.6
R. triangulivalvis	+	+	+	+	-	+	+++	-	27
R. woodsii	+	+	+	+	-	+++	+	-	67

The level of similarity recorded for the taxa may point to the low level of utilization and modification of the family members for food and related purposes by humans, which is often responsible for the high degree of diversity recorded for domesticated plant species. The similarity notwithstanding, the dissimilarity recorded (< 30 percent) may reflects the degree of adaptations to the difference eco-geographical regions that have resulted within the family over time.

Ergastic substances and weediness of polygonaceae

The type and level of use plant species was determined by the diversity and abundance of ergastic substances present in the plant tissues; hence the predominance of certain type of ergastic substances, predispose the plant species to the type of derivatives they will be use for by humans. Similarly, presence and abundance of these substances ultimately reinforces a plant species' ecological disposition and interactions with other organisms. The weedy posture of members of the Polygonaceae across the genera may be connected to the similarity in the type of ergastic substances amongst the taxa (Table 1); such are proteins, inulin, tannins and even oils, which may underline the weediness of the group through a competitive advantage in the allelochemical-centred interaction between plant species of the family and other plants (Watson, 2005)

Taxonomic relevance of ergastic substances in polygonaceae

Applying ergastic substances in taxonomic consideration

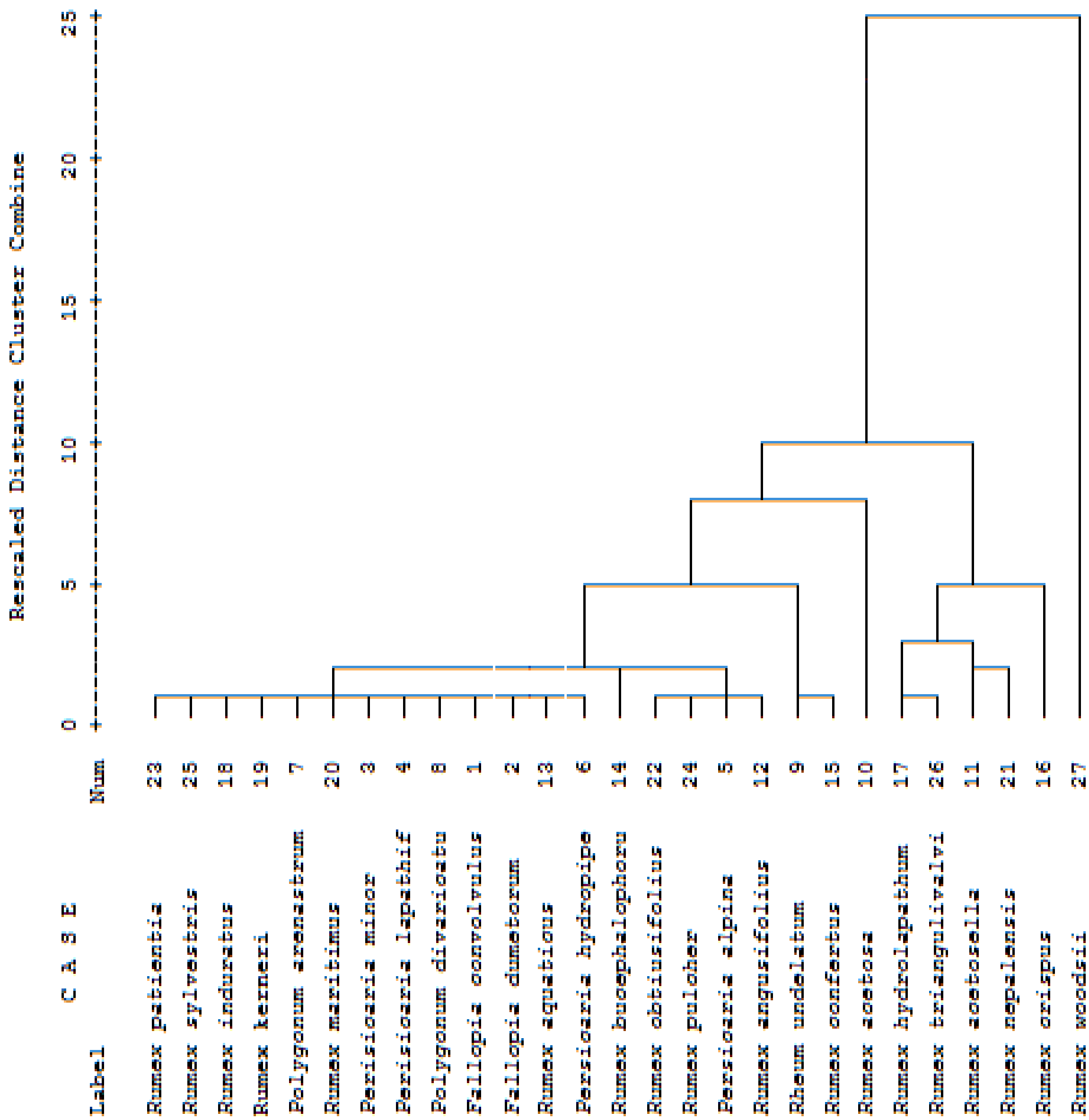

Figure 1. Between group cluster analyses of ergastic substances of 27 species showing 3 clusters at 10 rescaled Euclidean distance.

can be of considerable importance for review of existing taxonomic delimitation for clearer circumscription and evolutionary history of the taxa (Idu and Onyibe, 2011).

The Similarity and divergence in the ergastic substances of the Polygonaceae resulted in the dendogram following a rescaled Euclidean distance matrix (Figure 1). The clumping of the taxa following the ergastic substances profile segregated the species alongside taxa that are not traditionally congruent. However, the short distance between the species and the number species that form the largest cluster reflect a closeness that indicates the taxa are of a common family line, though the divergence are indicative of the level of differences (Mosaferi and Keshavarzi, 2011).

Ergastic substances profiling and its prospective medicinal applications

The ergastic substances profile amongst Polygonaceae that may have driven their weedy status can conversely point to a reservoir of phytochemicals for medicinal application. The growing area of phytomedicine is built on the presence and abundance of one or several phytochemicals that constitute the active components of such preparations and the target of myriads of research efforts as a significant alternative for global health delivery (Okoegwale and Omefezi, 2001). Prebiotics substances like inulin are known to influence processes in the digestive tract, immune responses and the palatability of food and products (EFSA

GMO Panel, 2008), these influences can be channelled for therapeutic applications. Tannins have high antioxidant properties, as well as implicated for anti-fungal and anti-viral properties because of the ability of tannins to form non-infectious complexes with viruses (Dhiraj et al., 2005). The importance of these compounds is integral to global health delivery, particularly for forest-dependent and other demographics. The production and sales of nutraceuticals are on the rise and this encourages the search for new materials.

Ergastic substances profiling and its prospective applications for food

Inulin as a carbohydrate is considered indigestible, which necessitates extensive processing (i.e., roasting) prior to consumption, hence the above effect if unprocessed or form a large percentage of diet (Fowler, 1986). Tannins are usually non-bioavailable and like inulin show some degree of anti-nutritive properties; as they can bind and precipitate proteins and carbohydrates (Chung et al., 1998). The type and functions of the protein recorded for the study taxa are unknown, hence their application. These facts regardless, the utilization of the group Polygonaceae food for or industrial applications is highlighted by the presence of starch.

Polygonaceae as prospective source of food and industrial starch

Starch is one of most omnipresent biomaterials, with unique biodegradability and solubility characteristics for food and non-food applications. The growing demand for starch exerts increasing pressure on scientist to decipher reliable compliments or alternatives to the present sources.

The types of starch granules in Polygonaceae were cereal-like; round, polygonal with a small percentage of irregular shaped granules (Hoover and Ratnayake, 2005; Zhongdong et al., 2005), devoid of reniform pulses starch and voluminous, oval roots and tuber starch granules. Similarly, the size range of the starch granules were within granule sizes regular for cereals (< 38 µm) with a few species; *R. undelatum, R. confertus, R. crispus and R. woodsii* with large granules (64.4 – 67 µm). The similarity to common cereal starch granules in shape and size range underlines the use of two species of *Fagopyrum* (buckwheats) as pseudocereals.

Though mainly cereal-like, two starch grain types (A, B) are recorded and this segregation into two starch granule types has being employed differently for food and non-food purposes (Tang et al., 2001; Stoddard, 1999; Langeveld et al., 2000; Soh et al., 2006); showing the Polygonaceae house a rich diversity of starch forms to serve as good complimentary starch source both in volume and peculiarity to mainstream cereals.

Digestibility of starch granules

Starch digestibility is a fundamental factor in the use of starch from any source, particularly for food purposes. Generally, granule size correlates with digestibility, which is largely the susceptibility to the hydrolyzing strength of digestive enzymes. Following this, smaller granules hydrolyse faster than larger granules (Kasemwong et al., 2008; Noda et al., 2005). The percentage of small size granules have endeared cereals to man as food and Polygonaceae starch like cereal starch show similar features and thus will posses similar digestibility properties (Dhitaj et al., 2010).

Irregular shaped grains

In addition, some species have been shown to possess a sizeable amount of irregular starch granules. These irregular granules may be surface fragments of larger granules; however, the highlight of these irregular shaped starch granules is their ease at damage, during normal milling process (Tester et al., 1994; Tester and Karkalas, 2001); which predisposes them for better use in flouring process.

The presence of round, polygonal and small diameter starch granules and the erstwhile use buckwheat as food, points to the polygonaceae as possible source of nutritional starch, or the adoption of some taxa as hidden harvest plants as well as possible source of genetic improvement traits for other taxa like the Poaceae.

Global relevance of ergastic substances profiling in polygonaceae

The Global Industrial Analysts in 2010 announced the consumption of starch to reach 80 million metric tons by 2015 (GIA, 2010). The interest in the Polygonaceae particularly its starch deposit is connected with the increasing importance of buckwheat and possibly other members of the family as pseudocereals. This interest as alternative crops of renewed interest by global bodies like the Food and Agriculture Organization (FAO), has led to the recognition of buckwheat as one of the major non-wood forest products (NWFPs), of immense socio-economic and environment importance with the potential to improve rural livelihoods, household food security and nutrition. Though marginally utilized at present, if engaged at a larger scale their exploitation will expectedly have less harmful effect than the destructive timber business and will provide greater benefits for forest-dependent communities (FAO, 2010; FAO forestry, 1999).

Similarly, buckwheat is considered a functional food with attributes that are as consistent with those of known food (starch) materials like cereals, pulses and tubers (Paulíčková, 2004). Also buckwheat is reputed to have nutritive and health promoting values and is effective against a number of diseases such as diabetes, obesity, hypertension, and hypercholesterolemia. In addition it has a protein biological value (BV) comparable to BV of other protein sources; an array of antioxidants, dietary fibre as well as trace elements. Coupled with these attributes is the possible global utilization of buckwheat and its relatives for food and industrial uses, the economics of switch of sources of starch, oils, fats, proteins, tannins, and inulin materials and hence the possible balance of income that can result. Polygonaceae species offers authentic alternative and/or complementary option to major starch sources (Brunori et al., 2004; Christa and Soral-Śmietana, 2008).

Conclusion

Ergastic substances profiling from the present study showed a predominance of starch, fats and oils, proteins, and inulin in seeds of members of the family; with tannins recorded for only 10 species. The predominance of these four ergastic substances should spur further researches to determine the quality and quantity of these substances and the possible exploitation for pharmaceutical, nutritional and industrial uses.

Species of the family Polygonaceae are popular as weeds, with only a few known for use as food. The commonality in the ergastic substances present and the high degree of similarity in the taxa based on the ergastic evidences demonstrates the family as a close one. Introducing a Polygonaceae species whether inadvertently as weed, or as a new food or medicine source or as an alternative to known food taxa, should always instigate interest as the similarity in ergastic substances deposit may indicate a corresponding weediness prowess amongst the species

Nevertheless, the Polygonaceae attracts attention in the right direction as veritable resources for improve food security and human health as well as sources of novel traits for improvement of Polygonaceae crop species – *Fagopyrum,* and other starch taxa like the Poaceae. This assertion should erase the stereotype regarding the Polygonaceae as nuisance weeds; rather the sturdiness of the plant species should be considered as traits for survival in adverse conditions and also its competitive advantage over other plant species that can be harnessed for improvement.

With the GIA reports there is the likelihood that the demand for starch will exceed the proposed tonnage, finding alternative sources of starch for global consumption is imperative and the Polygonaceae with a large number of species and starch with cereal-like characteristics are good substitutes.

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