A review of the genus Crotalaria L. (Crotalarieae, Fabaceae)

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Abstract- A review of the genus Crotalaria is presented, the genus is one of the largest genera in angiosperms with ca. 700 species distributed globally. The main centre of biodiversity is Africa with ca. 540 species. Carolus Linnaeus was the first to describe the genus Crotalaria; he named 13 species in his Species Plantarum of 1753. The first infrageneric classification of the species within the genus was given by (Lamarck 1786), he divided the genus into two groups which are simple leaved group and trifoliate, digitate leaved group. Polhill gave an account of the history and development of the classification systems for African Species and reported eleven sections and seven sub sections based on vegetative and floral parts. Later Ansari accommodate Indian species and revise Polhll’s classification, he reported nine sections. Recently, Le Roux used morphological and molecular data and reported global Infrageneric classification of the genus. She classified the species into eleven sections and raised some sub section of Polhill into sections due to non monophyly. This system is the one currently in use.

Index Terms- Crotalaria, Review, Infrageneric classification, Molecular data, Morphology.

I. INTRODUCTION

The family Fabaceae taxonomically comprises of three subfamilies which includes Ceasalpinioideae, Mimosoideae and Papilionoideae. The family is considered to be more closely related to Connaraceae and Sapindaceae based on anatomy, morphology and biogeographical distributions (Polphil and Raven 1981). The emergence of the three subfamilies is based on the floral parts which include the size and symmetry of the flower, arrangement of petals in the flower bud, having united or free sepals, number of stamens, presence of plegram, embryo radicle shape and presence of rood nODULES (Lewis et al., 2005).

Based on the differences in the above mentioned characteristics, it is believed that Mimosoideae and Papilionoideae are unique distinct lineage in the family which arose independently within a paraphyletic basal caesalpiniod assemblage (Polhill, 1994).

Before the advent of family-wide molecular phylogenetic studies, Polhill (1994) in his last formal classification recognized 39 tribes, 670 genera and 16, 850 species within the family. After intensive research of more than 10 years in molecular phylogenetics studies of the family, the tribal and generic classification of the family has been updated which recognizes 36 tribes, 727 genera and 19, 327 species (Lewiz et al., 2005). The genera with 500 or more species within the family includes (Acacia, Astragalus, Crotalaria and Indigofera) and about 40 genera have 100 species or more, the family also contain nearly 500 genera that contain up to 10 species (Lewis et al., 2005).

There has been disagreement on whether the family Fabaceae should be treated as one (composed of Ceasalpinioideae, Mimosoideae and Papilionoideae) or each sub family should be treated as individual family, evidence from morphology and molecules support the legumes being one monophyletic family. This view has been supported by recent molecular phylogenetic studies (Doyle et al., 2000; Kajita et al., 2001; Wojciechowski, 2003; Wojciechowski et al., 2004) showing strong support for a monophyletic group that is more closely related to Polygalaceae, Surianaceae and Quillajaceae, which together form the order Fabales (Sensu Angiosperm Phylogeny Group, 2003)

II. TAXONOMIC HISTORY OF THE TRIBE CROTALARIEAE

The tribe Crotalarieae (Benth.) Hutch. is a member of the sub family Papilionoideae (Fabaceae) (Lewis et al., 2005). Members of Crotalarieae are monophyletic believed to have evolved from the tribe Liperieae (Goldblatt (981, Boatwright et al., 2008). It is the largest tribe within the papilionid legumes in Africa and also within the genistoid alliance, comprising about 51% of the genistoid legumes (Lewis et al., 2005). The reason why the tribe is large is because the genus Crotalaria which is a member in the tribe contains ca. 690 species (Polhill 1982). The tribe belongs to the core genistoids (Crisp et al., 2000) and currently comprises of 11 genera and ca. 1204 species (Van Wyk 2005) and ca 83% occurs in African continent and the other four genera (Aspalathus L., Thunb., Rafnia Thunb. And Wiborgia Thunb.) occurs in the Cape Floristic Region (Van Wyk, 1991; Boatwright et al., 2008).

The members of the tribe occur largely in Africa, with some of the species like Crotalaria, Lotonis and Rothia occurring on other continents. Aspalathu, Rafnia and Wiborgia are endemic to the Cape Floristic Region, while the genus Lebeckia is widely distributed throughout the cape and extends to some parts of Namibia (Boatwright et al., 2008).

Polhill (1976) excluded the tribe Crotalarieae from Genistae (Adans.) Benth. s.l., following an in depth study of Geniseae He excluded the tribe based on the presence of a stamina tube that is open along the upper side (forming a closed tube in the Genisteae s.s.). Anarthrophyllum Benth., Dichilus DC., Melolobium Eckl. and Zeyh. and Sellocharis Taub. were
also included in the Crotalarieae, but (Van Wyk and Schutte, 1995) moved back the genera to their previous tribe Genistaeae.

Results from morphological, chemotaxonomic studies (Van Wyk and Schutte, 1995) and recently molecular systematic studies (Boatwright et al., 2008, 2009, 2011) lead to the change in the generic delimitations within the tribe. Some lineage are raised to generic status and some there is also some nomenclatural changes (Boatwright et al., 2008, 2011). Currently 16 genera in three valid clades are recognized.


The Lotononis clade comprises of six genera: Lotononis (D.C) Eckl. and Zeyh., Leobordea Del., Listia E. Mey., Pearsonia Dummer, Robynsiophytont R. Wilczek and Rothia Pers

The Crotalaria clade comprises of only three genera: Euchlora Eckl. and Zeyh., Crotalaria L., and Bolusia Benth.

III. TAXONOMIC HISTORY OF THE GENUS CROTALARIA

Carolus Linnaeus was the first to described the genus Crotalaria, he named 13 species in his Species Plantarum of 1753 which are Crotalaria perfoliata L., C. sagittalis L., C. juncea L., C. triflora L., C. villosa L., C. verrucosa L., C. lotifolia L., C. lunaris L., C. laburnifolia L., C. micans L., C. albanand L. C. quinquefolia L. (Linnaeus 1753). The number of the species within the genus increased to 37 (Lamarck, 1786). De Candolle (1825) reported 137 species. Thereafter the numbers increased to the total of 700 species that is accounted for at present (Le Roux et al., 2013). The genus is listed as one of the fifty largest seed plant genera (Mabberley, 2008).

Detailed review of African species was given by (Baker, 1914), He revised and described 309 species in the continent. The most extensive study in the history of Crotalaria taxonomy was by (Polhill 1982), he conducted a thorough taxonomic revision on species in Africa and Madagascar where he reported 511 species. In Africa Thunberg (1823), reported 11 species from the Cape, South Africa. Similarly Harvey (1862) described 24 new species from the same region, which are now seen in other part of Africa (Le Roux et al., 2013). 21 species are enumerated from region of Empire of Ethiopia which comprises of Southern Egypt, Eastern Sudan, Yemen and Western Saudi Arabia by (Richard 1847). Verdoorn (1928) published a taxonomic revision of the genus where he recognized and reported 124 species in Southern Africa and South Tropical Africa, excluding Angola. Baker (1876) in his work on the genus in Tropical Africa, he treated 106 species. 24 species were collected in East Africa by Hildebrand and their description was published by (Vatke 1879). 24 years later, Taubert (1893) increases West African species to 56 in his publication. Milne-Redhead (1961) and polhil (1968, 1976) conduct an in depth studies and revised the species within the genus in East Tropical Africa and reported 199 species in the area, 56 species from the same region were also published by (Taulbert 1895). In Angola 62 new species were described by (Wilczek, 1953a), he also revised 189 species from the same country (Wilczek, 1953b).

Hepper (1958) revised the species of West Africa and reported 51 species and Da Torre (1960) described 36 new species and revised 138 species (1962) from the region, 26 species were treated in Namibia. In Ethiopia 85 species were treated (Thulin, 1983) similarly he reported enumerated 39 species in Somalia (Thulin, 1989). Du Puy and Labat (2002) conducted a research on Madagascar species and enumerated 53 species.

Roy and Sharon (2005) described and illustrated new species of the genus Crotalaria mwangulangoi from the Udzungwq Mountains, Tanzania.

Two new species of Crotalaria, C. cupricola Leteinturier and C. serpentinicona Leteinturier are reported from metalliferous sites in Zimbabwe by (Leteinturier and Polhill 2003).

A new species known as Crotalaria arrecta Hemp and Polhill was reported from Kenya, the species was previously

Figure 2. 1. A cladogram showing the relationships of the three clades and 16 genera from an analysis of combined morphological and molecular evidence (Boatwright et al., 2008 and Le Roux et al., 2013)

Some of the species within the tribe are of important commercially such as Aspalathus linearis, which is used for the production of rooibos tea (Van Wyk et al., 1997), and Lotononis bainesii Bak., is used as important fodder for animals (Bryan 1961). While some of the species within genus Crotalaria and Lotononis have been reported to have medicinal properties (Van Wyk 2005) and a few of the species are in traditional medicine in Lesotho to cure or ease a broken heart (Moteetee and Van Wyk 2007), other species from the same genera are toxic (WHO, 1988)

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confused with C. rhizoclada Polhill, the new species was described and illustrated by (Andreas and Polhill 2009). Odowo et al. (2015) reported 36 species in Nigeria in their studies on ecological distribution of the genus Crotalaria in Nigeria.

Several literatures have been reported from Asia continent. Wight and Walker-Arnott (1834) conducted taxonomic revision of Indian species and reported 58 species in the country. Roxburgh (1832) described 7 new species in his Flora Indica. Descriptions of 77 species in British India were published by (Baker, 1876). 15 species are listed in the Red Data Book of Indian Plants (Nayar and Sastry 1987). According to (Ansari, 2008; Sibichen and Nampy, 2007) Crotalaria is the largest Fabaceae genus in India with 92 species. De Munk (1962) in his revision of Malaysian legume, he published a list of 38 species that are endemic in the country. Wu et al., (2003) reported 6 species in their study on herbarium records, actual vegetation and reproductive morphological characters to further divide the species within the trifoliate group into Oliganthene and Racemosae, based on number of flower per raceme, thereby dividing the genus into three sections.

Baker (1876) followed Harvey system of classification and adopts it but used fruit shape, flower arrangement and excluded Racemosae and create four additional groups (Chrysocalycineae, Sphaerocarpaceae, Oocarpaceae and Cylindrocarpaceae). Four sections were created based on leaf character (Simplicifoliales, Unifoliolatae, Trifoliolatae and Multifoliolatae) by (Taubert 1893) following Bentham’s classification. He also used vegetative and reproductive morphological characters to further divide the Simplicifoliales into seven series and Trifoliolatae into ten series. Baker (1914) adopted previous sections Simplicifoliales, Sphaerocarpaceae and Chrysocalycineae reported by (Baker 1876) and created three additional new sections and five subsections, the sections are Spinoseae, Farctae and Eucrotalaria and the subsections are (Grandifloraei, Mediocriflorae, Oliganthae, Parviflorae and Stipulasae).

Harms (1915), Senn (1939) and Peltier (1959) adopted the previous system of classification which was based on leaf, but Harms (1917) modified the section Chrysocalycinae. He removed C. niginas from the section and placed it in the newly created section Tetralobocalyx. Harms. Wilczek (1953b) is not satisfied with using leaf as a tool for sectional classification because some species have both unifoliolate and trifoliolate leaves, therefore he disagreed with previous classification systems. He erected seven groups using petiole length, presence or absence of stipules and their size, which he named the groups “Group I-VII”.

Polhill (1968) is not satisfied with any of the classification systems, and he also reported the difficulty of infrageneric classification of the species within the genus. He gave an account of the history and development of the classification systems for African Species (Polhill, 1968). He used a combination of flower morphology, legume and bracteole shape and divided the genus into 11 sections and seven sub sections.

Bisby (1970, 1973) included 273 species and 52 characters that are similar to those used by Polhill (1968) which include floral characters, habit and stipule characters and conducted taximetric analyses. His findings were similar to that of Polhill’s (1968) classification system. Data from Polhill (1968) and Bisby (1973) were combined for the infrageneric classification system and found some discrepancies that were re-evaluates (Bisby and Polhill, 1973). Their finding resulted to an improved classification system (Bisby and Polhill, 1973; Polhill, 1982) which comprised of eight sections and nine subsections. The sections are: Grandiflorae, Chrysocalycineae, Incanae, Stipulasae, Hedriocarpae, Geniculatae, Schizostigma, Calycinae, and Crotalaria.

IV. INFRAGENERIC CLASSIFICATION

The first infrageneric classification of the species within the genus was given by (Lamarck 1786), he divided the genus into two groups which are simple leaved group and trifoliate, digitate leaved group. Wight and Walker-Arnott (1834) used reproductive characters and reported 13 sub divisions with the two groups reported by Lamarck. Bentham (1843) used leaf shape and divided the genus into two groups which are simple leaved and trifoliate leaved, he further divided the simple leaved into seven sections and trifoliate leaved into 11 sections, this classification is similar to (Wight and Walker-Arnott 1834). Harvey (1862) maintained the simple leaved group and divides the species within the trifoliate group into Oliganthene and Racemosae, based on number of flower per raceme, thereby dividing the genus into three sections.
Ansari (2008) used modified infrageneric classification system of (Wight and Walker-Arnott, 1834; Bentham, 1843 and Baker 1876) which are based on leaf and revised the taxonomy of Indian species. In his publication Ansari (2002) he reported nine sections and six subsections; which are not formally described. He considered Polhill’s classification system and updated his previous system of 2002 using the same sections as Polhill (1982), but listed only sections that are in India and included six sections and 12 subsections (Ansari, 2006, 2008). In his work he recognized four subsection within section Calycinae and four subsection within the section Crotalaria.

Le Roux et al., (2013) proposed sectional classification system for the entire genus for the first time based on morphological and morphometric studies and phylogenetic approach. Her new system comprises of eleven sections: Amphitrichae, Calycinae, Crotalaria, Geniculatae, Glaucae, Grandiflorae, Hedriocarpae, Incanae, Schizostigma, Borealigeniculatae and Stipulosaes. She modified Geniculatae, Calycinae and Crotalaria sections. The subsections Stipulosaes, Glaucae and Incanae are raised to sectional level, while some groups previously recognized as subsections are abandoned due to non-monophyly (subsections Chrysocalyctinae, Hedriocarpae, Macrostachyea and Tetraboboclyx). Two new sections are recognized, Amphitrichae and Borealigeniculatae.

V. ECONOMIC IMPORTANCE OF CROTALARIA

Crotalaria species are annual shrubs very useful in agriculture (Magingo, 1992), as green manure and cover plants in plantations. They are also used as a source of diet for livestock. Many of the species are known to be nodulated with soil Rhizobia (Allen and Allen 1981, Faria et al., 1989) and they are also good in fixing atmospheric nitrogen. Sustainable crop production is achieved through the management of soil fertility and cover crops play a key role in soil fertility through a reduction in synthetic nutrients applied. Legumes are effective in the fixation of nitrogen and can accumulate large amounts of biomass that help to increase the nutrient availability and organic matter in the soil. Some of the long term benefits obtained from the use of cover crops include weed suppression through competition or allelopathy and possible insect control (Phatak et al., 2002). While some species of Crotalaria are poisonous, others like C. retusa, C. micronata, C. falcata and C. vogelli remain some of the important fodder plants for cattle and small ruminants. (Nuhu et al., 2000) also reported that Crotalaria species are widely used in Zaria, Nigeria in feeding of sheep and cattle.

Crotalaria species are widely used in veterinary pharmacy in preventing liver disease (Nwude and Ibrahim, 1980, Nuhu, 1999). In Tanzania Crotalaria comosa Bak provides nitrogen to the crops intercropped with and assist in the control of weeds and nematodes (Mukuras, 1986). The species within the genus like Crotalaria recta L. are used as food source by larvae of Lepidoptera species, the insect also used the plant as defense against their predators (Thomas 2003).

Cook and White (1996) revealed that C. retusa L. seeds as source of fibres, silage and green manure when removed from pods by pounding. According to Akintayo, (1997) oils derived from Crotalaria bongensis Bak, C. naragutensis Hutch and C. lachnophora Desu. Seeds are not suitable for use as edible oil and soap production but many however, are useful for the production of paint and shampoos. Crotalaria is also used in the treatment of diabetics (Pullaiah and Chandrasukha, 2008), skin infection, snake bit and stomach ache prevention (Verdhana, 2008).

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