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Jackal Food (*Hydnora* spp.): A Review of some Botanical Aspects

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Abstract*: Hydnora species (Hydnora spp.), holoparasitic flowering plants belong to the family Aristolochiaceae, growing on the roots of some species of the families Euphorbiaceae, Fabaceae and Burseraceae in arid and semiarid regions of Africa, Madagascar and Arabian Peninsula. The objective of this article was to review and evaluate the past and current status of knowledge of some botanical aspects regarding Hydnora spp. and to identifying gaps in this knowledge. Available literature on this plant was carefully reviewed in details. The results of this reviewing showed that several studies have been carried and out and made some significant advances in the understanding of the taxonomy, identification, description, distribution and host range of the Hydnora species as well as biology, physiology, anatomy and ecology in addition to the management. Moreover, Hydnora plants have an economic importance, as it can be used as human food and animal feed, as well as medical, health and pharmaceutical uses in addition to energy production and the preservation of biological diversity. On the other hand, the plants are parasitic on the trees of Acacia and Euphorbia, which are known for their economic importance. In conclusion, much remains to be learned about the botany of this strangest plant. More studies are also necessary to evaluate the economic importance of Hydnora plants.*

Keywords: *Acacia*; Aristolochiaceae; *Euphorbia*; Jackal; *Hydnora*

1. INTRODUCTION

Jackal food (*Hydnora* spp.), belong to the family Aristolochiaceae, is a genus of herbaceous, perennial, obligate and holoparasitic flowering plants [1, 2]. This plant is known by different common names such as jackal food (Eng.), jakkalskos and bobbejaankos (Afr.) [3]. The genus name "*Hydnora*" was derived from the Greek word "*Hydnon*" which means fungus-like, because this parasitic plant is resemblances to the fungus "*Hydnum*" [4]. This genus currently includes eight species, although more than 12 have been described [5]. These plants grow on the roots of some species belonging to the families Euphorbiaceae, Fabaceae and Burseraceae. Being holoparasitic, the plant is completely lacking chlorophyll and entirely rely on its host for inorganic and organic compounds [6]. The plant body is excessively reduced to rhizome and flower [7]. The extreme reduction of the vegetative body of the plants and the absence of clearly distinguishable root, stem or leaf parts limits the number of useful taxonomic characters.

Several reports demonstrated that these plants spend their entire life below the soil surface and only emerge for flowering and fruiting [4, 8, 9]. However, the hidden way of life of the parasites makes it difficult to study the biology and physiology, anatomy and ecology of the plant. Not much is known about the seed germination and seedling development of *Hydnora* spp. [10]. Due to their holoparasitic habit, the adult plants form haustoria, intimate connections between the host root and the parasite rhizome, by which all nutritional requirements are met [11]. The plant has such an unusual physical appearance and it looks astonishingly similar to fungi, and is only distinguishable from fungi when the flower has opened [3]. The genus *Hydnora* is widespread in arid and semiarid regions of Africa, Madagascar and the southwestern part of the Arabian Peninsula. It follows the distribution of its hosts [12, 13].

Furthermore, *Hydnora* plants have an economic importance, as it can be used as food and medicine for humans and animal, as well as medical, health and pharmaceutical uses in addition to energy production and the preservation of biological diversity [7, 14, 15, 16]. On the other hand, the plant is considered a parasite on the trees of *Acacia* and *Euphorbia*, which are known for their economic importance [17]. The genus *Hydnora* is not endangered and although not often encountered, is thought to be fairly common in semi-arid vegetation which is associated with its host species [18]. Therefore, the objective of this article was to review and evaluate the past and current status of knowledge of some botanical aspects regarding *Hydnora* spp. and to identifying gaps in this knowledge.

2. ORIGIN OF THE GENUS *HYDNORA*

The genus name "*Hydnora*" was derived from the Greek word "*Hydnon*" which means fungus-like, because the somatic structure of this parasitic plant is resemblance to the fungus genus "*Hydnum*" [4]. The vegetative body of this plant is greatly reduced and consists of only rhizome-like structure, pseudo-rhizome or root and flowers without leaves or scales of some sort. The plant is only seen when the tips of the flowers come out of the ground [11]. Plant species belonging to the genus *Hydnora* are native to southern Africa. *Hydnora* plant was introduced to science in 1774 by the botanist, Carl Thunberg. He discovered and collected the *H. abyssinica* plant for the first time in the Hantam District, South Africa and he thought it was a fungus and named it

"*Hydnus*" after the fungus taxa. Then later the genus name "*Hydnus*" was renamed *Hydnora* [18].

3. TAXONOMY AND IDENTIFICATION

The genus *Hydnora* (Jackal Food) along with other parasitic genera once placed in the Hydnoraceae are now considered part of the Aristolochiaceae, based on molecular studies [1, 2]. It is a genus of holoparasitic flowering plants growing on the roots of some species belonging to the families Euphorbiaceae, Fabaceae and Burseraceae. This genus currently includes eight species, although more than 12 have been described. These species are almost entirely African in distribution, with some reports from the Arabian Peninsula [5, 19]. Aligning with the subgeneric sections delineated in the monograph by [20], based on the host preference and several major synapomorphies, the eight species have been identified in two major lineages [1, 5, 21]. The Euphorbia-parasitizing *Hydnora* species which are characterized by osmophores recessed near the midpoint of the tepals, distributed in southern Africa and comprise *H. triceps*, *H. longicollis*, *H. africana* and *H. visseri*. The Fabaceae-burseraceae parasitizing *Hydnora* which are characterized by apically positioned osmophores, distributed in ranges from South Africa to Ethiopia, the Arabian Peninsula, Madagascar and comprise *H. esculenta* Jumell and Perrier, *H. sinandevu* Beentje and Luke, *H. abyssinica* Braun (= *H. johannis* Beccari = *H. solmsiana* Dinter) and *H. arabica* [5]. Although several efforts have been payed to the taxonomy and identification of the *Hydnora* species by many scientists, the extreme reduction of the vegetative body of the plants and the absence of clearly distinguishable root, stem or leaf parts limits the number of useful taxonomic characters.

In general, *Hydnora* species are identified and separated on the basis of the cross-section shape of the mature rhizome, tepal lobe shape, size and merosity, and include some variation in tepal margin ornamentation. *H. esculenta* mature rhizomes are angular in cross section. Tepal margin ornamentation ribbed and with setae, a root parasite of Fabaceae, spongy osmophore on ventral surface of tepal apex, aroot parasite of Fabaceae including *Alatsylodendron decaryum*, *Albizia tulearensis* and *Pithocellobium dulce* [5, 22]. *H. triceps* mature rhizomes are angular in cross section. Tepals margins not ribbed, spongy osmophore recessed onto the ventral surface of tepal and not a root parasite of Fabaceae. Tepals fused and forming a hood, flowers 3-merous, a root parasite of *Euphorbia dregeana* [5, 9]. *H. longicollis* mature rhizomes are angular in cross section. Tepals margins not ribbed, spongy osmophore recessed onto the ventral surface of tepal, not a root parasite of Fabaceae. Tepals free at apex not fused and forming a hood, flowers 3- or 4-merous (rarely 5), not a root parasite of *Euphorbia dregeana*. Tepal lobes less than 2.2 cm, generally less than 1/5 of flower length protruding above ground, commonly root parasite of *Euphorbia damarana* and only known from Namibia and Angola. *H. africana* mature rhizomes are angular in cross section. Tepals free at apex not fused and forming a hood, flowers 3- or 4-merous (rarely 5). Tepal lobes between 2.2 cm and 4.5 cm and generally more than 1/5 of flower length protruding above ground. Not a root parasite of *Euphorbia damarana*, but a root parasite of *E. mauritanica*, *E. chersina*, *E. caput-medusae*, *E. decussata*, *E. grandidens*, *E. lignosa*, and *E. trigona*. *H. visseri*, and mature rhizomes are angular in cross section. Tepals margins not ribbed, spongy osmophore recessed onto the ventral surface of tepal and not a root parasite of Fabaceae. Tepals free at apex not fused and forming a hood and flowers 3- or 4-merous (rarely 5). Tepal lobes more than 4.5 cm, generally more than 1/5 of flower length protruding above ground. Not a root parasite of *E. damarana*, but a root parasite of *Euphorbia gregaria* and *E. gummifera*. *H. sinandevu* mature rhizomes are terete to sub-terete in cross section. Tepal lobe margins not setose, root parasite on *Commiphora africana*. *H. abyssinica* mature rhizomes are terete to sub-terete in cross section. Tepal lobe margins with well-developed setae, strigose to diffuse at setae apices and a root parasite on Acacia spp. Androecial chamber inner surfaces white to light pink, tepal margins white to light pink, occasionally red to orange, tepal lobe margins partially covered with strigose setae or partially to entirely covered by diffuse setae, setae apices often remote [5]. *H. arabica* mature rhizomes are terete to sub-terete in cross section. Tepal lobe margins with well-developed setae, strigose to diffuse at setae apices and a root parasite on Acacia spp. Androecial chamber inner surfaces red to orange, tepal margins and internal surfaces red to orange, tepal lobe margins entirely covered by dense strigose setae and setae apices not remote [5].

4. DESCRIPTION

Hydnora is a genus of herbaceous, perennial and holoparasitic flowering plants that grow on the roots of mainly *Euphorbia* and *Acacia* species [19]. Due to being a holoparasitic, it is completely free of chlorophyll and totally dependent on its host for water, minerals and organic compounds [6]. The plant body is a rhizome, a root-like rhizome or a root with extremely reduced vegetative features [11, 13]. It is reduced to rhizome and buds, with no leaves or even leaf-like structures [6, 15]. These plants spend their entire life below the surface of the soil and only appear for flowering and fruiting [3, 8, 9]. Due to their holoparasitic habit, the adult plants form haustoria, which are close links between the root of the host and the rhizome of the parasite, through which all nutritional requirements are met [11]. The plant has such an unusual physical appearance and it looks strikingly similar to a fungus, and it can only be distinguished from a fungus when the flower opens [3] (Fig. 1.).

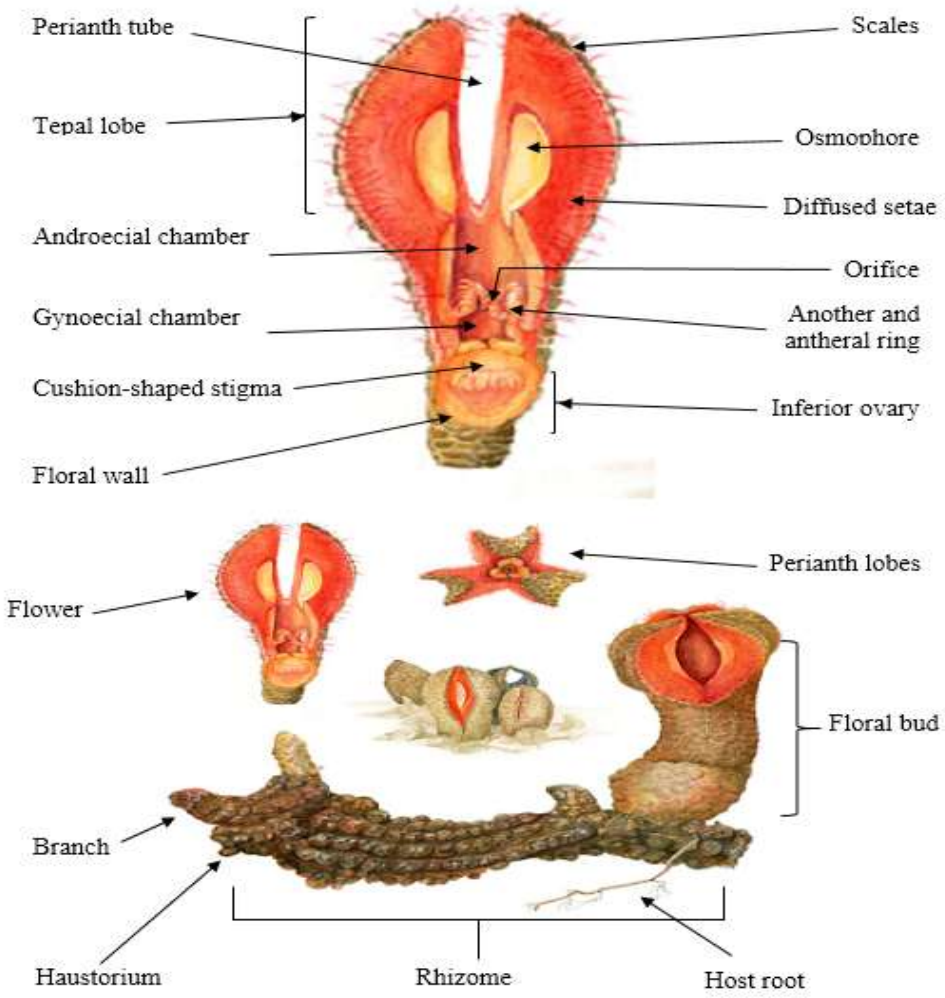

Figure. 1. Description *Hydnora africana* plant, After [23].

Based on anatomical observations, [11] suggested that the *Hydnora* vegetative body is a rhizome with a root-cap-like structure required for its subterranean habit. Observations of xylem characters, absence of cambium between vessels and the collateral arrangement of the vascular bundles supports relationship of *Hydnora* to the Aristolochiaceae and general Piperalean stock. On the other hand, the nature of the subterranean axis (stem or root) in *Hydnora* is not easy to determine with certainty, because there are no close relatives of *Hydnora*, and *Hydnora* is very specialized in parasitism. On the other hand, there are reasons for preferring the concept that the *Hydnora* axes are roots rather than stems. The growing ends show no evidence of reduced leaves at all, and there are no reduced leaves close to the bases of the flowers. The five or six longitudinal rows of stubby roots on the axis remind one of the patterns of lateral root formation on roots, while lateral roots that form on stems of plants do not tend to form neat longitudinal rows. Flowering plants other than *Hydnora* that are root parasites form roots (as in *Orobanche*), not underground stems, that interconnect with roots of host plants.

Mature rhizomes are tubercles, obtuse, angular, terete, subterete or compressed in cross section depending on the species and the widths range from 0.6 cm in *H. africana* to 5 cm *H. arabica* [24]. The surface of rhizome is crusty, dark brown to light tan and lighter colored near growth tip when fresh. Rhizomes are warty, simple or branched, usually spreads laterally and may bifurcate or branch irregularly. They are ornamented with numerous lateral tuberculate appendages that can form haustoria, branches of the rhizome, or flower buds, numerous flowers and flower buds on single rhizomes. Rhizome swollen and irregular at haustorial interface with host root and rhizome fleshy, pink to red internal tissue when broken and lighter colors at the growing tip [5].

Flower emerges only partially from soil reaching a height of about 100 to 150 mm and it is solitary, erect, sessile or shortly pedunculated, flesh-colored and scaly [3]. Flowers actinomorphic, usually bisexual (functionally unisexual in *H. esculenta*), with a more or less cylindrical flower tube, often bulging at the base and apically with 2–5 valvate, fleshy lobes. Perianth tissues fleshy, internal perianth tube and tepal

lobe vary in color. Perianth tube is about 5–28 cm long and 1.0–3.6 cm wide [5, 25]. The tepal lobe length from apex to point of connection with adjacent tepal is about 4.0–8.5 cm, tepal lobe width at the midpoint is about 1.9–3.5 cm, tepal lobes are long, oblong-ovate, subacute, clavate to elongatelinear and typically curved. Tepal lobes are free at apex in some species, while not fused and forming a hood in the other species. Tepal margin ornamentation is ribbed or not ribbed and with or without setae that might cover the entire tepal lobe margin from ventral to dorsal edge. Two floral chambers, an androecial chamber subtended by a gynoecial chamber, inner surfaces of chambers glabrous and rarely with filaments, perianth chambers joined by antheral ring with a central orifice, formed by connate anther lobes. Osmophores are oriented on the ventral surface of the tepal apices or recessed near the midpoint of the tepals. Osmophore is spongy, white in color, generating fetid odor and darkens to tan when dried. Osmophores were first called "bait bodies" by Harmes. Reference [26] stated that the odor is made up of dimethyl disulphide and dimethyl trisulfide. The ovary is inferior, usually subterraneous, 3–4(−5) carpellate, unilocular with numerous apical or parietal placentas bearing abundant ovules that are orthotropous, tenuinucellate and unitegmic. The ovary is about 25–45 mm in width, lobed and cushion-like stigma on the floor of the gynoecial chamber, and stigma is stalkless, often rudimentary width is about 19–22 mm. Stamens are 3-5 in number, inserted on the tepal tube and united to form a ring around the stigma. Anthers are numerous, stalkless and about 2.5-3 x 2-2.5 cm with numerous pollen sacs. Pollen very sticky, adhering to the anthers [5, 25].

The *Hydnora* plant produces berry like fruits, that develop below the soil surface, underground, with abundant brown seeds [3]. The size of the fully grown or ripe fruit ranged from 7 cm to 15 cm in diameter. The fruits are fleshy, brown and globose or subglobose, half-round [3, 18]. The outer layer of the pericarp; wall, skin, epidermis or periderm is thick, leathery and scaly. The inner layer of the pericarp is mealy, white, and very sweet. Fruiting placentae is similar to inner layer of the pericarp in taste and texture. Fruit pedicel is very short and easily separated from the root-like rhizome [3]. The fruits are edible and gelatinous pulp with a slightly sweet and starchy taste, similar in taste and texture of a potato. The fruit pulp produces soft and strong odors that attract animals and humans to eat the fruit. Moreover, the fruit is extremely astringent and has been used as a source of tannins [5, 27, 28].

The seeds are numerous, i.e. about 20000 seeds per fruit, very small, i.e. about 0.7-2 mm in diameter, irregularly shaped, i.e. globular, ovate, spherical or oblong and brown or black-brown in color with a very hard and thick testa. Seeds are embedded in a fleshy or gelatinous edible pulp or berry like fruit which is rich in starch and slightly sweet in taste. The embryo is small and surrounded by endosperm and perisperm [3, 18, 25]. It turns out that there is a lot of reference literature related to the accurate description of the different species of the genus *Hydnora*, however, as a result of the advanced progress in the science of morphology, much remains to be learned about this strangest plant.

5. DISTRIBUTION

The genus *Hydnora* is widespread in arid and semiarid regions of Africa, Madagascar and the southwestern part of the Arabian Peninsula. It follows the distribution of its hosts [12, 13]. *H. esculenta* is a poorly known perennial herb described from southwestern Madagascar [22]. *H. triceps* is distributed in the northwestern Cape region of South Africa and southern Namibia [9]. *H. longicollis* was described from the Mossamedes District of southwestern Angola and southern Africa. *H. africana* is restricted to Angola, Namibia and South Africa. *H. visseri* was described as a new species from the Karas Region of Namibia and the Northern Cape Province of South Africa [21]. *H. sinandevu* was described from Tanzania, Kenya and Madagascar [29]. *H. abyssinica* is the most widespread and frequently collected *Hydnora* species. It has a wide distribution from western Namibia, northern Botswana, Zimbabwe, Zaire, Tanzania, Kenya, Uganda, Eritrea, Ethiopia, Somalia, Malawi, Mozambique, South Africa, along the Blue Nile to Khartoum in Sudan; and in the Arabian Peninsula in southern Saudi Arabia, northern Yemen and the Dhofar region of Oman [7, 12, 15, 16, 24]. *H. arabica* is distributed throughout the Arabian Peninsula in Oman and Yemen [5]. Although the distribution and prevalence of the different *Hydnora* species are known, there are many factors that control and influence this distribution which await studies.

6. HOST RANGE

Hydnora species are parasitic on the roots of the members of the families Euphorbiacae, Fabaceae and Burseraceae [5, 12]. *H. esculenta* is parasitic on the roots of host trees, especially *Acacia* spp**.,** *Tamarindus indica* L. and other legumes [12]. The most common observed host of *H. esculenta* was the invasive tree *Pithocellobium dulce*. The range of *H. esculenta* may be increasing due to the spread of *P. dulce* in riparian areas and disturbed habitats in southern Madagascar [22]. *H. triceps* a rare parasitic angiosperm growing on the roots of *Euphorbia dregeana* E. Meyer ex Boissier and *Zygophyllum orbiculatum* Wel. [9, 12]**.** The genus *Euphorbia*, in general, as the preferred host of *H. longicollis* in Angola. In Namibia, *E. damarana* is evidently the favored host. *H. africana* parasitizes a variety of shrubs and arborescent *Euphorbia* spp. It is parasitic on the roots of *Albizzia lebbek* (L.) Benth.**,** *Euphorbia caputmedusae* L.**,** *E. decussata* E. Meyer**,** *E. gregaria* Marloth**,** *E. gummifera* Boiss., *E. karroensis* (Boiss.) N.E. Br.**,** *E. lignosa* Marloth, and *E. mauritanica* L. [12, 21]**.** *H. visseri* has an obligate relationship with its hosts *E. gregaria* and *E. gummifera* [21]. *H. sinandevu* has a variety of Fabaceae hosts and it is reported to parasitize *Commiphora* spp. [12, 29]. The hosts for *H. abyssinica* are species of Acacia. It is found parasitizing the roots of *Acacia*

albida Del.**,** *A. cyanophilla* Lindl., *A. karoo* Hayne**,** *A. luederitzii* Engl.**,** *A. nilotica* (L.) Willd.**,** *A. seyal* Del. and *A. tortilis* (Forssk.) Hayne [12, 25, 30, 31]**.** *H. arabica* is known to parasitize two leguminous trees: *Acacia tortilis* and *Pithocellobium dulce*, but may parasitize additional Fabaceae [5]. Despite that *Hydnora* species have a narrow host range, however, the host-parasite relationships have received very little attention.

7. ECONOMIC IMPORTANCE

Reports on the economic importance of the *Hydnora* spp. showed that the fruit is a traditional food and it is delicious when baked on a fire and has a sweetish taste. It is used in a series of Cape dishes as recorded in the recipe book of Betsie Rood, Kos uit die veldkombuis [32]. One of the recipes describes how the fruit pulp can be mixed with cream to make a delicious dessert [18].

Ethnobotanical work on the plant revealed that rhizomes, flowers and fruits of *Hydnora* spp. are used in folk medicine to treat infectious-related diseases such as poor kidney and bladder conditions [33]. Sudanese traditional medical practitioners use it for curing severe bacterial infections, while in East Africa it is used as anti-diarrheal medicine. Traditional medical practitioners in Kenya use the root decoction as a cure for throat complaints, as an astringent in dysentery, for treatment of stomach ache and for removing retained placenta during child birth [7, 16]. Moreover, the plants are reportedly used to treat cholera, swelling tonsillitis, piles, acne, menstrual problems and to stop bleeding. Other reports indicate that it is used for the treatment of diarrhea, amoebic dysentery, typhoid, anthrax, East Coast Fever and cancer. The high tannin concentration in the *Hydnora* spp. rhizomes impart a strong astringency and bitterness, and this may be the reason for its efficacy in treating intestinal ailments [7, 14, 15, 16].

Several reaches indicated that *Hydnora* spp. plants possess antioxidant, antibacterial and antifungal activities that could be attributed to the presence of bioactive compounds [34, 35, 36, 37]. Recently, phytochemical screening of the Rhizome and flower extracts of *Hydnora* spp. revealed presence of alkaloids, glycosides, tannins, phenols, steroids, flavonoids, terpenoids, saponins and fatty acids [7, 16, 38, 39].

It was reported that the fruit is extremely astringent and has been used for tanning and preserving fishing nets [18]. The high tannin content also renders the rhizomes useful for tanning leather [25]. In Sudan, the dried roots are used like charcoal [40].

The flower buds and fruits of *H. johannis* are eagerly sought and eaten by monkeys [40], whereas those of *H. africana* are eaten by many other mammals [6]. The fruits of *Hydnora* spp. are reportedly consumed by a variety of mammals; including jackals, baboons, humans, rhinos, elephants, porcupines and small mammals in southern Africa [12]. Goats are known to eat the buds of the plant in Sudan. Since the rhizomes contain large amounts of water, they are often excavated and eaten by animals during the dry season. In the Namib Desert, evidence of foraging for *H. africana* is often found in small mammals. Nevertheless, extensive excavations of *H. johannis* by elephants have been observed in Etosha Pan National Park. Rhinoceroses are reported to forage for *H. johannis* [25].

On the other hand, *Hydnora* species are parasitic plants on different economical host plants. The parasite plants may be more common than recorded, as they are only visible when flowering. It is reported that in the Dire Dawa region of Ethiopia, *H. johannis* damages asphalt streets by breaking through the surface to flower [17].

It is evident that the plant has an economic importance, as it can be used as food and medicine for humans and animal, as well as medical, health and pharmaceutical uses in addition to energy production and the preservation of biological diversity. On the other hand, the plant is considered a parasite on the trees of *Acacia* and *Euphorbia*, which are known for their economic importance. Therefore, more studies are necessary to evaluate the benefits and harms of *Hydnora* plants.

8. BIOLOGY AND PHYSIOLOGY

The hidden way of life of the parasites makes it difficult to study the biology and physiology of the plant. Neither no much studies are known about the seed germination nor seedling development of *Hydnora* spp. [10]. The seeds are more likely to germinate in close proximity to the host plant [18]. It is recommend planting the seeds on the surface of well-drained soil and sprinkling a seed starting mix such as peat moss on top of the seed and watering thoroughly. Germination can take up to 180 days to occur. Best planted in an environment which does not get a large amount of wind and best planted in pots. Reference [41] observed seed germination of *H. triceps* after 30 days when the seeds were maintained at ambient laboratory temperatures (23-27 °C) in darkness and the radicles were observed up to 3 mm long. However, the germination rates were low, less than 20.0 %, and only occurred when seeds were exposed to the root extracts of their exclusive host *E. dregeana* and not for co-occurring species *E. mauritanica* and *E. gummifera*.

The germinated seed develops a primary haustorium that establishes the first attachment point to the host. After the plant has grown and spread, it may develop several secondary haustoria, attaching itself to the same host or another close host [18]. The haustorium is directly connected to the xylem and the phloem of the host's roots. It is thought that the plant excretes powerful enzymes that dissolve away the hard tissue of the host in order to attach itself. Once established, the plant is able to live off the nourishment from the host and quickly develops a matrix of underground rhizomes from which the flower buds develop and eventually emerge above the ground [18, 42]. The structure of the rhizome bearing the flowers and the haustoria remains unclear [6, 43]. However, its anatomical structure shows the characteristics for stems [44].

From buds along this vegetative body the flowers are developed externally and slowly. Under favorable conditions, specially the adequate rainfall, the plant takes at least one year for a bud to develop into a mature flower [3]. Within one year the flower grows to a height of 10 to 15 cm. Flowering time is about four to six months and the flower opening is about 6-7 days. Due to the hypogeous nature *Hydnora* plants, it was difficult to assess the number of flowers per plant, however, one to three flowers open simultaneously for each individual plant were observed [41, 42]. The osmophores, bait bodies, play a very important role in the life cycle of the plant. They release unpleasant odors that attract various carrion beetles and other insects which become trapped in the flowers. The odors were of identified as dimethyl disulfide and dimethyl trisulfide [26]. Many stiff bristles are recognized on the inner surface of the perianth lobes, which prevent the trapped insect from escaping. After feeding on the osmophores, the trapped insect falls below the flower tube onto the anthers collecting pollen all over its body. Then it falls further onto the soft cushion-shaped stigma thus pollinating the flower [18]. The beetles sometimes crawl onto the stigmatic surface, which is receptive a few days before anthesis. Because pollen-bearing beetles have been trapped before anthesis, *H. africana* may be an outcrossing species. This hypothesis is also supported by the fact that flies are sometimes found inside the flower buds.

Fruits are very slow to mature and are often observed concurrently with flowering suggesting maturation periods of 9-12 months or even more than one year [41]. Fruits of *Hydnora* plant are favored by mammals such as porcupines, moles, baboons, jackal and also birds. The seeds are not digested and thus are in an ideal state for germination when excreted by animals [18] (Williamson, 2000).

Some Hydnoraceae plant species are thermoregulatory, i.e. they are able to modulate changes in flower temperature by increasing heat production as ambient temperature decreases [45, 46]. In relation to thermogenesis, reference [47] assessed the intensity and regulation of respiration in three *Hydnora* species. Long-term respirometry and thermometry were performed on intact flowers of *H. africana*, *H. abyssinica* and *H. esculenta* in the field. Whereas |short-term measurements were made on floral parts during the protogynous flowering sequence. The results showed that there was no increase in temperature in either the osmophores or the gynoecial chamber in any stage, and mass-specific respiration rates of the flower parts were low. Respiration tracked ambient and floral temperatures, eliminating the possibility of the inverse relationship expected in thermoregulatory flowers. *H. abyssinica* flowers had higher respiration and a slight elevation of osmophore temperature in the female stage. Respiration by gynoecial tissue was similar to that of osmophores in both species, but there was no considerable elevation in gynoecial chamber temperature. Gynoecial chamber temperature of *H. esculenta* could reach 3.8 °C above ambient, but there are no respiration data available. Antheral tissue respiration was maximal in the male stage in *H. africana* and *H. abyssinica*, but it did not raise the antheral ring temperature, which demonstrated that thermogenesis is not a by-product of pollen maturation or release. Reference [47] concluded that the exceptionally low thermogenesis in *Hydnora* appears to be associated with odor production and possibly gynoecial development, but has little direct benefit to beetle pollinators. The current literature indicates that there is a little information about the biology and physiology of the *Hydnora* plants are available, especially those regarding the seed germination, the early developmental stages of the parasitism and the seedling growth which are remain to be explored (Fig. 3).

9. ANATOMY

The description of the vegetative and haustorial anatomy of this highly reduced group of plants is a goal for the scientists. One of the *Hydnora* species that gained anatomical and histological studies is *H. triceps*. It is highly reduced, and as with many holoparasites, the vegetative body is difficult to interpret. The vegetative body of *Hydnora* species has long been historically considered a pilot root studded with lateral appendages known as haustorial roots. Reference [11] found that the vegetative body of *H. triceps* consists of a rhizome with a thickened root-cap-like structure that covered a vegetative shoot apical meristem. From the apical meristem, procambial strands originated and developed into endarch collateral vascular bundles arranged radially around a pith without an interfascicular cambium. Xylem vessels had scalariform pitting and simple perforation plates. A continuous periderm without root hairs was observed. Increase in girth was attributed to cork and fascicular cambia. Haustorial roots or bumps on the surface of the vegetative body were exogenous, contained meristems and were the origins of vegetative branching, budding, and haustoria. The haustoria of *H. triceps* were cylindrical and penetrated the host root stele. Phloem and xylem elements were observed within the endophyte, and direct xylem to host-xylem contacts were observed. The arrangement of vascular tissues and xylem anatomy of *H. triceps* are likely plesiomorphic features in light of Hydnoraceae's placement in the Piperales. Moreover, the *Hydnora* endophyte could be distinguished from the surrounding host root cortical cells by the presence of tannins in some of its parenchymatous cells and the contrasting perpendicular arrangement of host and parasite vascular tissues. Penetration may be due to a combination of mechanical and enzymatic activities as suggested for several unrelated groups of parasitic plants [48].

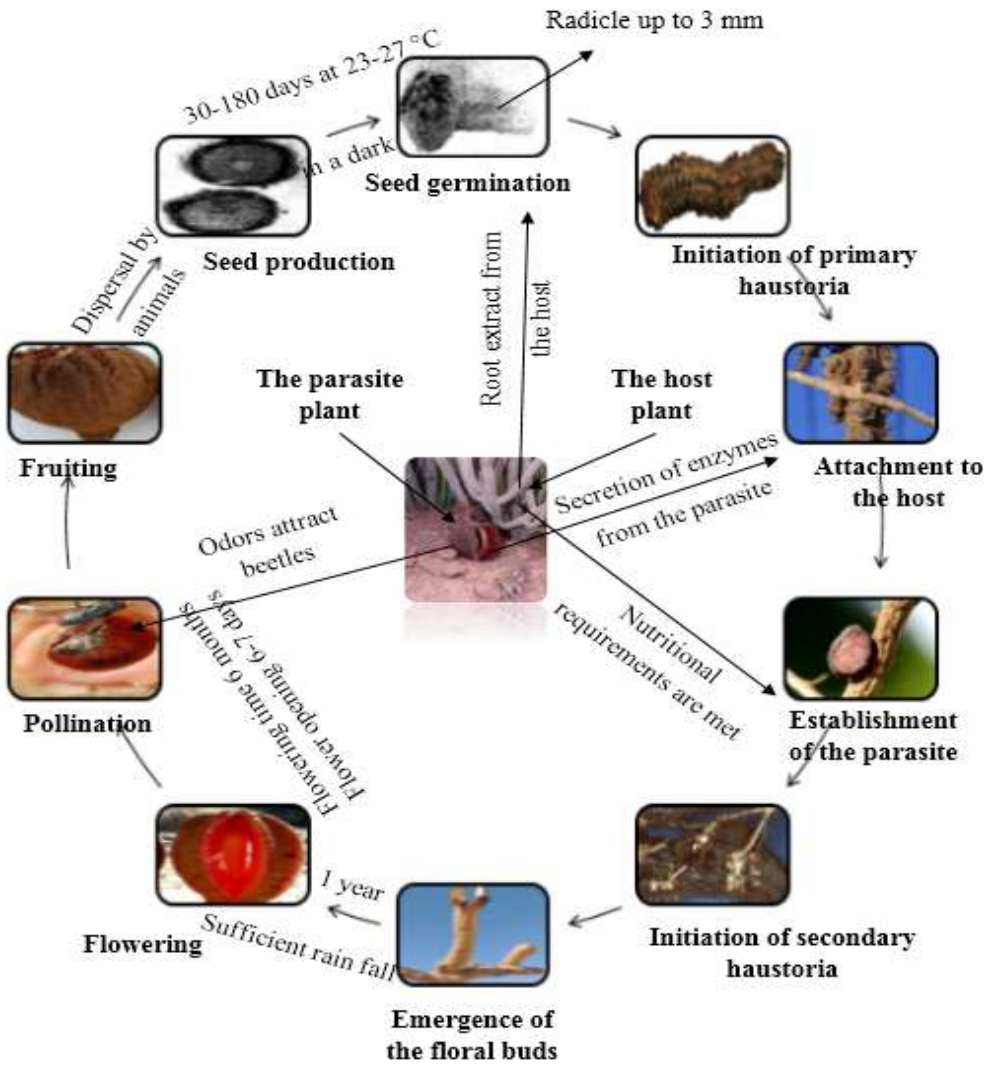

Figure. 2. Suggested life cycle of the *Hydnora* species based on the current available information about the biology of the parasite.

10. ECOLOGY

Hydnora species are distributed throughout the tropical and sub-tropical regions in the world on a wide range of different ecological zones in arid and semiarid regions of Africa, Madagascar and Arabian Peninsula [13]. The plant grows at 100-1500 m above sea level in a region varying in a mean annual precipitation of 50-300 mm/year [49]. The mean annual air temperatures are 30-38 °C during the day and 12-17 °C during the night [41]. Moreover, the plant survives in a range of temperature from 3.1 to 41.98 °C over 24 h. The plant is noted in clay and sandy alluvial soils as well as sandy coastal plains, stony slopes and ridgelines [11]. It grows very close to its host plant, but may not be seen in the drier parts of the year. It occurs in both winter and summer rainfall areas with a most common vegetation [49]. Most of the ecological studied focused on the pollination biology, germination ecology and parasite-host nutritional relationships of this group of the plant. However, other ecological studies related to ecophysiology, population, community, ecosystem, landscape, molecular and historical ecology have to receive more attention.

11. MANAGEMENT

The genus *Hydnora* is not endangered and although not often encountered, is thought to be fairly common in semi-arid vegetation which is associated with its host species [18]. However, diamond mining and other human activities may threaten its existence.

CONCLUSION

Several studies have been carried on the taxonomy, identification, description, distribution and host range of the *Hydnora* species as well as the biology, physiology, anatomy and ecology in addition to the management. Although these studies made some significant advances in the understanding of this strangest plant, much remains to be learned about the

botany and more studies are also necessary to evaluate the economic importance of *Hydnora* plants.

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