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Congolese Medicinal Plant biodiversity as Source of AntiCOVID-19 Compounds: Economic goods in the light of Comparative Advantages Theory of Ricardo

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Abstract: *Since the outbreak of Covid-19 (Corona virus) in China in December 2019, the disease has killed more people in Europa, America and Asia according to official sources. Less impacted than the rest of the world, Africa as well as Oceania has less confirmed cases and less deaths. In countries whose health systems are among the most fragile in the world, with far less resources than those mobilized in Europe, China or the United States, the situation in Africa is potentially catastrophic. Since human and material resources, such as hospitalization and intensive care beds, are largely insufficient, the mortality rate linked to Covid-19 is likely to be 3 to 5 times higher than in the rest of the world. In the face of this evidence, scientific research based on medicinal plants would be seen as no less important part of the solution to the Covid-19 pandemic, based on plant biodiversity. The Malagasy Institute of Applied Research (IMRA/Madagascar) on the basis of the Artemisia annua has set up Covid-Organics; The Congolese plant biodiversity offers undeniable advantages for the setting up of an Improved Traditional Medicine following the example of Covid-Organics. This would constitute for the Democratic Republic of the Congo a comparative advantage to be put forward in its multiple international exchanges.*

Keywords: *COVID-19; plant biodiversity; phytomedicine; comparative advantage; Democratic Republic of the Congo*

I. Introduction

SARS-CoV-2 is the pathogen agent of the new corona virus disease that appeared at the end of 2019 in China. There is, currently, no effective treatment against COVID-19. Recent findings revealed that plant secondary metabolites interact with the main protease (3CLpro) responsible for the replication of coronaviruses (Mpiana et *al*., 2020a, b). While the world has been facing one of the most serious health crises of the century, Africa had so far seemed to be spared. The countries of the continent had then announced very few cases, about ten for some and none for others.

However, as time goes by, Africa is finding itself with more and more cases, first exported from Europe and America and then resulting in local contamination. This is not the only health crisis Africa has faced in recent years. The Ebola health crisis, which killed tens of thousands of people, has, on the other hand, provided countries with experience in crisis management. This explains, in part, the severity of the measures put in place when only a few cases were reported by a large majority of countries. If it is experience that motivates African decision-makers to be strict, it is also the fact that they are aware that they would be outweighed by the coronavirus if it were to spread as it has in Europe. In Africa, where the political situation in some countries is tense, a health crisis of this magnitude and its management by decision-makers could reconfigure their relationship with the population. Health crises affect every country in the world, but the impact is greater in fragile states (Flahault, 2009) due to inefficient institutions, lack of resilience or precarious economies (OECD, 2016). The case of Ebola in Guinea is an example of the gaps in the prerequisites of resilience that led to difficulties in crisis management (Boozary et al., 2014; Kekulé, 2015; Kruk et al., 2015; Diakite, 2015). The Democratic Republic of the Congo (DRC) is a richness country with varied ecosystems and harbors a large number of medicinal plant species (Ngbolua et al., 2011a, b). In view of the above, the DRC, which has the necessary resources and all the assets, must, through its Ministry of Scientific Research, enhance its plant biodiversity by contributing all its endogenous knowledge to benefit from it in its various international exchanges, as required by the Ricardian theory of comparative advantages. Thus, the aim of this work is to presente Congolese medicinal plant biodiversity as a comparative advantage to be presented in its exchanges with other countries in Africa and across the world in order to ensure its socio-economic development.

II. Research Methodology

The literature review was based mainly on the COVID-19 resources that have been made freely available to the scientific community (COVID-19 open research dataset https://pages.semanticscholar.org/coronavirus-research), but also on the usual databases such as Pubmed and Google scholar. COVID-19 African plant biodiversity in general and Congolese plant biodiversity in particular, as well as the theory of the English economist Ricardo: "The Theory of Comparative Cost", were used as keywords for the search.

III. Discussion

Before starting this study, it seems important and necessary to understand some basic operational concepts: Biodiversity and COVID-19.

3.1 Biodiversity

Biodiversity is defined as the variability among organisms living in terrestrial and aquatic ecosystems. This definition encompasses diversity within and between species as well as at the species level (Ngbolua, 2020a). The main emphasis of this work is on plant biodiversity as source of antiCOVID-19 drugs.

3.2. Corona virus or COVID-19

a. Origin and Evolution

Coronaviruses are viruses that cause Middle East Respiratory Syndrome (MERS), Severe Acute Respiratory Syndrome (SARS) and cold-like illnesses. This new virus first appeared in Wuhan, in the Chinese province of Hubei. On 7 January 2020, China confirmed

the presence of several cases of Covid-19 of the Coronavirus family in the city of Wuhan; On 30 January 2020, the World Health Organization (WHO) declared the emergence of a new coronavirus (designated as 2019-nCoV) as a public health emergency of international concern. In a very short period of time, the virus has spread to 159 countries around the world. The World Health Organization declares the pandemic and declares an emergency of international concern. Having failed to take into account the severity of the crisis from the outset, several European countries, first Italy, then Spain and France, found themselves submerged. As of today, almost all African countries report having been affected by the virus, bringing the number of infected people on the continent to more than 100,000.

However, the main focus of Covid-19 remains the Maghreb countries, namely Morocco, Egypt and Algeria (https://pages.semanticscholar.org/coronavirus-research).

b. Contamination statistics by region

The number of deaths due to Covid-19 since the outbreak of the Pandemic until 20 May 2020 is presented in the table 1.

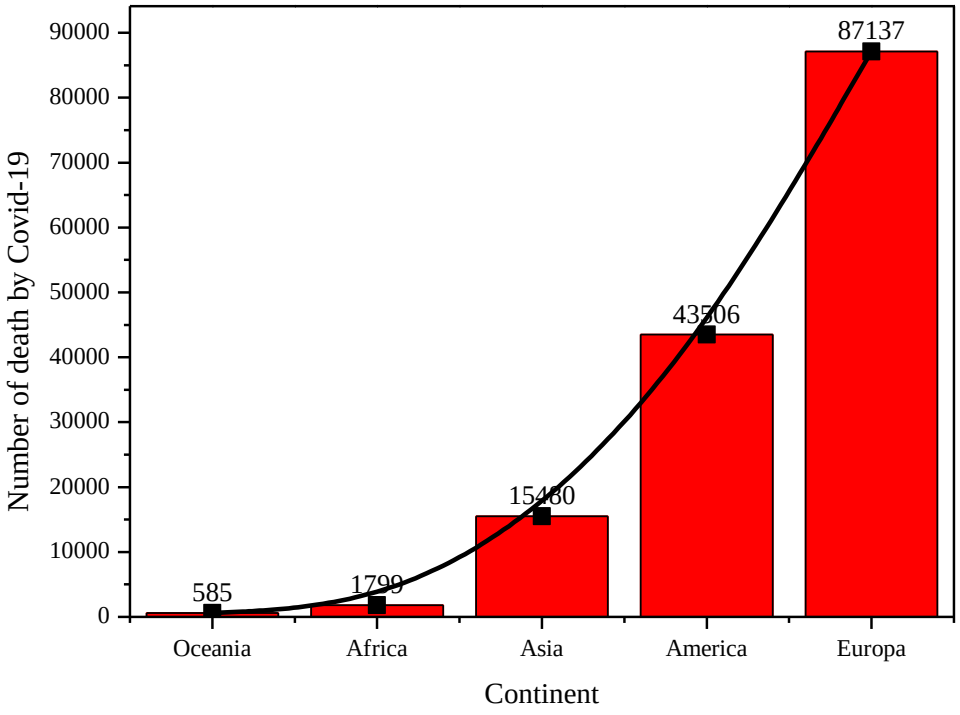

Figure 1. *Number of deaths due to Covid-19 since the outbreak of the Pandemic until 20 May 2020 (Villalobos, 2020)*

The evolution of Coronavirus pandemic showed that Oceania and Africa are the less affect continents as revealed by the figure 1.

c. Contamination statistics by State

The table 1 gives the number of both infected cases and deaths due to Covid-19 by country on June 31, 2020. The most affected country is the USA following by Brazil.

Country	No of infected cases	Nomber of deaths
USA	2312302	120402
Brazil	1106470	51271
Russia	598878	8349
Great Britain	306761	42731
Spain	246504	28324
Italy	238720	34657
France	197127	29666
South Africa	101590	1991
China	84624	4639
Egypt	56809	2278
Algeria	11920	852
Senegal	5970	86
DRC	5924	135
Madagascar	1640	15

(Source: Villalobos, 2020)

d. Preventive and curative measures

The mostly preventive measures taken by African countries are legitimate and welcome. However, some of them make the movement of humanitarian personnel and the delivery of materials, which are essential for humanitarian aid, almost impossible, while the need to fight against Covid-19 will increase and periods of malnutrition and malaria occur profilent. African countries might therefore be able to prevent a wide spread of the virus, but it would be difficult for them to detect and respond adequately if the virus were to multiply. Several countries have banned all international and sometimes intercontinental flights: sending experts or doctors from one African country to another has become impossible and medical equipment can no longer be transported to the affected areas, given the high risk of contamination in the epicentres, which are moreover considered as supply centres (Timothy et *al*., 2020).

3.3 David Ricardo's Theory of Comparative Advantages

The Theory of Comparative Advantages or Comparative Cost Theory was developed by David Ricardo, an English economist of the classical school. This theory is the most general and powerful economic argument to demonstrate the value of international exchange and specialization. It said that a country benefits from free trade if it specializes in the production of goods in which it has an absolute advantage. According to this theory, it does not matter whether a country has absolute advantages or not: it benefits from specializing in the production of the goods for which it has the highest comparative advantage, i.e., the lowest relative costs, and from trading the goods it does not produce. So it's an argument for free trade: all countries can gain from free trade if they specialize. This principle is one of the few propositions in the social sciences that are logically true without being trivial. It is, on the other hand, clearly counter-intuitive, and therefore difficult to understand and get accepted. Indeed, in relations between nations of unequal economic and technological power, common sense leads to the view that there is little mutually beneficial exchange, but that exchange results in a zero-sum game of gains and losses, with the strongest being the winners and the weakest the losers, leading to the idea of economic warfare and protectionism, justified by the defence of the national production and employment of the weakest. It must be said that since

1817, when the English economist David Ricardo demonstrated this theory, international trade has changed slightly... But more than its applicability, it is the economic logic behind the gains in specialization and the benefits of free trade that is really interesting (Costinot & Donaldson, 2012**).**

3.4 Benefits of COVID-19

a. On the health front

If the health systems of European countries are overwhelmed because of their limited reception capacity, such a spread to African countries would be difficult, if not impossible, to manage. African governments took more than four years to contain the Ebola crisis. The vectors of transmission of the latter are less important than those of the coronavirus. If the latter were to gain more ground in these countries, health systems would quickly become overwhelmed. Although some African countries have isolation centres that they inherited from the previous health crisis, it would be in their best interest to act upstream by, for example, prioritizing isolation and border closures. It would also appear that the correlation established between age and severity of the virus provides an advantage to the continent's young population.

The latter would, according to this claim, be better able to fight the virus. On the continent, only 3% of the population is over 65 years of age, compared to nearly 12% in China. With the youngest population on the African continent, with a median age of 18 years (less than half the median age in Europe), Africa is probably the youngest in the world. It is no coincidence that the mortality rate in Italy - with a median age of 47.3 years - has reached 9%, compared to a world average of 3.4% centres (Timothy et *al*., 2020).

b. What does the outbreak tell us about health safety?

China's response to this epidemic has both positive and negative aspects for Africa. The world's second largest economy has built new hospitals but struggles to provide basic supplies such as face masks. China's experience reinforces the centrality of confiance and transparency in public health. In most African countries, detection of outbreaks would likely take longer, laboratories with limited capacity would take longer to test, and supplies of basic supplies would be more difficult to obtain. In China, epidemiologists have linked some of the early patients to the wholesale seafood market in Huanan, although many questions remain about the origin of the virus. Africa too has experienced the emergence of zoonotic (animal-borne) diseases, and with the increase in human presence in forest areas, the continuing bushmeat trade and climate change, it is likely that new diseases will emerge and known diseases will emerge in unexpected areas. Finally the main risk for Africa during the Covid-19 pandemic lies in the weakness of health networks. While modern health networks in developed countries such as Italy have been overwhelmed by the virus, no one knows what will happen in an African country with a health network that is already weakened and under-equipped. As the rapid spread of Covid-19 around the world makes clear, the problem is not confined to Africa. If the virus gains a foothold on the continent, it could re-infect the rest of the world, creating new waves of epidemics in countries that have controlled it. The only solution is for external actors to work with African governments to fill the major gaps (on the one hand) and to mobilize the funds needed to identify biomedical and biopharmaceutical research laboratories on the continent to develop both preventive and curative remedies (on the other hand) before it is too late (Wafaa et *al*., 2020).

c. On the economic front

As elsewhere, Africa, like everywhere else, will not escape the negative impact on the economies of its countries. Very quickly, and without even having been confronted with the scale of cases found elsewhere, African economies began to feel a slowdown.

According to the United Nations Economic Commission for Africa, African countries should prepare to see their growth halved to just 2% instead of the 4% initially forecast. Thus, countries dependent on their natural resources, as is the case for many on the continent, will see their incomes negatively impacted. Indeed, a drop in the price and demand for raw materials results in lower revenues. This is the case of Guinea, which depends on its bauxite exports, mainly to China, but also to oil-dependent economies such as Angola and Nigeria (Fernandes, 2020).

The price of a barrel of oil has indeed fallen well below the break-even point on which countries forecast their annual budgets, thus worrying the governments of these countries. For Nigeria, for example, the reference price on which the budget was designed is $57, while the forecasts for the second and third quarters of the year 2020 put the price of a barrel at $30, which represents a hard blow for the West African giant. The International Monetary Fund announced in February that the economies of African countries were in danger. This can be explained, on the one hand, by the decline in demand from China, the continent's main trading partner, but also by the decline in demand from Europe, which is very close to African countries. Moreover, the fight against the virus requires increased spending in the most affected sectors, which suggests injecting money into SMEs, households and helping workers in the informal sector. This, coupled with declining incomes, would undoubtedly lead to an accumulation of deficits that could result in unsustainable debt for some of these countries. With the partial or total closure of the borders of several African countries, several priority economic sectors on the continent will be impacted. The agricultural sector is losing momentum due to the lack of intermediate goods, and the infrastructure sector is suffering the same fate. The spread of the virus has forced some countries to reconsider the priority placement of their budgets. Tourism, the main economic lever in several African states, will also experience a considerable decline. This sector is considered to have a catalytic effect on the economy as a whole in terms of job creation and foreign exchange earnings. Therefore, with the sharp decline in the sector, the effect will be immediate not only on the formal sector but also on the informal sector which is largely dependent on it in these countries. Airlines are also strongly affected as a result of the suspension of a large part of their flights. Since the beginning of the epidemic, the Moroccan national airline Royal Air Maroc has lost nearly $400 million in two months. This is also the case for several airlines on the continent that were already struggling to develop. Whether Africa is affected by the coronavirus or not it is already affected by the epidemic. These developments and the expected Chinese economic losses will affect trade between China and Africa, as well as booming tourism.

Mauritius alone attracts 5,000 Chinese tourists per month. Producers of commodities such as copper will be affected by the slowdown in China's manufacturing industry, which normally progresses after the Lunar New Year. African currencies and stock exchanges are also vulnerable. In previous global economic downturns, Africa had been more or less protected. However, the development of relations with China has increased its exposure to such shocks, both human and economic. The economic consequences of the epidemic may well be more important for Africa than the epidemiological impact. As China's economic growth is expected to increase from 6.1% to 5.6% as a result of the coronavirus, African economies will also be affected. African countries must therefore reflect both to economic responses and health protection measures (Marie-Josée et *al.*, 2020)

The DRC, which has taken health protection measures, also finds itself in a worrying economic situation, which is immediately noticeable by the increase in the rate of the foreign currency (the dollar) in relation to the local currency; from an extroverted economy, the Covid-19 pandemic has put it in a situation of stagnation; This could lead the country into an unprecedented economic recession if this scourge persists. With its important biological diversity represented by an imposing plant complex and varied facies, ranging from dense forest type to more or less wooded savannah and open forests; with its approximately 200 million hectares, the forest massif of the Congo Basin is the second largest contiguous tropical massif in the world (Ngbolua, 2019a). DRC alone holding about 56% of this area; it should be affirmed that the DRC is capable of proposing a sustainable solution to the eradication of the Covid-19 pandemic because of the richness of it medicinal plant biodiversity. Indeed, the role of Traditional Medicine in the treatment of COVID-19 has recently been reported in the literature. Medicinal plants are an important source of molecules with various pharmacological properties including antiviral properties that can be used in the search for the solution against COVID-19 (Mpiana et *al*., 2020a, b; Ngbolua et *al*., *in press*).

3.5 Congolese Plant Biodiversity as Major Asset for Integral Development

DRC is one of the 16 countries in the world qualified as mega biodiversity (high rate of endemism). This situation is linked as much by the vastness of its territory (234.5 million hectares) as by the variety of physical and climatic conditions affecting biological richness. Forests represent a biome that contains important habitats in terms of biological diversity.

Recent estimates put the area of forests at 155.5 million hectares, covering nearly 67% of the national land area. DRC represents about 10% of the world's forests and more than 47% of Africa's and 6% of the world's tropical forest area. Its important biodiversity is represented by an imposing plant complex with varied facies, ranging from dense forest type to more or less wooded savannahs and open forests. Out of more than 50,000 known plant species in Africa, the DR Congo is in first place in terms of local plant species. DRC harbors flora of a remarkable originality comprising 9,142 species of spermatophytes. The specific endemism rate of this flora is very high, with more than 952 Phanerogams (MECNT, 2014). The main region of endemism in the DRC is the Central Congolese Basin with 952 endemic spermatophyte species or 10.7% of the total known species in this group. Two other centres of endemism are the eastern mountainous region and the Katanga highlands region in the south-east of the country.

3.6 AntiCOVID-19 potential of plant biodiversity in the DRC

Medicinal plants are an essential product for the Congolese population, but there is little overall information on this subject. The Congolese population traditionally uses several hundred species of food and medicinal plants. Almost all Congolese populations, both urban and rural, use medicinal plants (Ngbolua et *al*., 2011a, b). In the markets, there are always stands reserved for medicinal plants. However, apart from a few plantations of cinchona and Rauwolfia, medicinal plants are not cultivated in DRC, the national pharmacopoeia; markets and the pharmaceutical industry are supplied by spontaneous gathering in natural forests and savannahs. Mpiana and coworkers (2020a, b) reported that the medicinal plant *Aloe vera* is active against a number of viruses (DNA and RNA) could virtually cure Covid-19. A review on the Phytochemistry and Pharmacological properties of Picralima nitida Durand and H. (Apocynaceae family) as potential AntiCOVID-19 medicinal plant species revealed that extracts from *P. nitida* were very efficient in the treatment of several diseases including malaria. Thus, authors anticipate that it may be effective against COVID-19 virus also (Inkoto et *al*., 2020). A recent literature review on some belonging to the Zingeberaceae family revealed that these edible plants have antiviral properties on different types of viruses

(Rhinovirus, hepatitis B and C viruses, Herpes simplex viruses type 1 and 2, Human immunodeficiency viruse, Enterovirus 71, Ebola Virus, Human cytomegalovirus, Chikungunya virus, Epstein-Barr Virus, Japanese Encephalitis Virus, Respiratory syncytial virus, Fish viral hemorrhagic septicemia virus, Influenza A virus, Epstein-Barr virus, Coronavirus SARSCoV-1, etc.).

In addition, the literature indicated that these plants are a significant source of nutrients, which can boost the immune system and are safe according to the existing toxicological data (Mbadiko et *al*., 2020). Ngbolua et *al*. (*in press*) reported also that the plants of the Solanum genus are potential bio-resources for therapeutic management of COVID-19.

3.7 Legal and Institutional Framework for Biodiversity Management in DRC

a. Constitutional Framework

The Constitution of the DRC promulgated in February 2006 stipulates that every person has the right to a healthy environment that is conducive to his or her full development, and the State shall ensure the protection of the environment (Article 53). Furthermore, it specifies that a law determines the fundamental principles concerning environmental protection and tourism (Article 123) and establishes as part of the concurrent competence of the central power and the Provinces: the protection of the environment, natural sites, landscapes, site conservation, the water and forest regime and the regulation of forest regimes (Humman & Boer, 2002).

b. Legal framework

Ratified international legal instruments

The DRC is a party to a significant number of multilateral environmental agreements including the Convention on Biological Diversity, the Cartagena Protocol on Biosafety, the Nagoya Protocol on Access to Genetic Resources and Benefit Sharing, the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Convention on the Conservation of Migratory Species of Wild Animals and the Ramsar Convention on Wetlands. The DRC is also a member of the Central African Forest Commission (COMIFAC). For all these international legal instruments, DRC has developed national implementation frameworks. With particular regard to the Cartagena Protocol on Biosafety, the national biosafety framework has been developed since 2008 but is still not operational due to lack of financial resources. In forestry, important work has been undertaken since 2000 with the help of the World Bank and the FAO to improve management. A new forestry code containing several innovations in forest management was promulgated in 2002 and a new vision for a national forest policy is being put in place. A priority agenda for the revival of the forestry sector has been developed to plan the various interventions in the forestry sector.

In the context of training and capacity-building, mention should be made of UNESCO's commendable initiative, which led to the establishment in Kinshasa in 1999 of ERAIFT (Regional Post-Graduate Training School on Integrated Management of Forests and Tropical Territories), a regional institution for the training of managers with a systemic vision of natural area management. Indeed, without the consideration and involvement of all stakeholders in management, without a sustained effort to reduce poverty and strengthen the sustainability of natural resource management, the sustainability of natural resources, even renewable ones, will not be ensured.

3.8 Plant Biodiversity Put to the Test of the Theory of Comparative Advantages

The legal and institutional framework of biodiversity being ready, the DRC, a country that claims to be a state governed by the rule of law, is willing to implement its endogenous knowledge in the fight against COVID-19; Thus, the exceptional plant biodiversity and the eminent professors and researchers are able to propose a preventive and curative remedy following the example of Covid-organics obtained by the researchers of the Malagasy Institute of Applied Resaerch, Republic of Madagascar. The Congolese University is effectively at work in the fight against COVID-19 including the research protocol of Professor Jean-Paul Ngbolua Koto-Te-Nyiwa (PhD) is a national effort to support the management of COVID-19 using herbal medicines made from the Congolese plant biodiversity. As we can see, more than 80% of the populations in Africa in general and in the Great Lakes region in particular use Traditional Medicine to solve the primary health problem. As a party to the Convention on Biological Diversity, DRC is committed to pursuing and achieving the objectives of the Convention with a view to taking advantage of its comparative advantages, particularly in plant biodiversity. Given the ethno-medical importance medicinal plants for the population and their scientifically validated pharmacological properties, it is therefore desirable to develop sustainable strategies for the conservation of the medically validated species. One option to be explored is their domestication with a view to their use as material for drugs manufacture. Thus, the cultivation of such plants in agro-ecosystems in forest and savannah environments of DRC, particularly in the Nord Ubangi Province, would allow a better comparative study with species from other part of Africa, as is the case for some ongoing studies (Randrantoarimbola et *al*., 2020).

This part of DRC belongs to the Ubangi eco-region, a subgroup of Northeastern Congolian lowland forests. This eco-region is one of the 200 globally priority terrestrial eco-regions known as the "G200" (Ngbolua et *al*., 2020b, c, Ngbolua et *al*., 2019b, c, d; Gbolo et *al*., 2019; Ngunde-te-Ngunde et *al*., 2019).

IV. Conclusion

The Covid-19 Pandemic proved Africa's weaknesses to the world; today, research and fundamental studies are more necessary than ever for the establishment of local pharmaceutical industries. In addition to helping to take stock of events, these studies will identify gaps in national, regional and global response processes, identify ways to strengthen preparedness, early warning and response processes, and identify possible strategies to improve response and resilience to similar health crises. At a time when the whole of humanity is resorting to natural products to guarantee its existence in a sustainable way, we find ourselves affected by the Covid-19 pandemic, causing enormous loss of human lives, disrupting the economic and commercial circuits of States, imposing the proclamation of a state of health emergency with negative impact (closure of Schools and Churches; Bars and Restaurants) sources of household income and others. The DRC must make an inventory and rational exploitation of its vast, rich and varied flora, which constitutes for it a comparative advantage to be exploited in its free trade at sub-regional, regional and global levels, in the creation of biomedical and biopharmaceutical research centres in order to solve many of the health problems for the Congolese population in particular and for Africa and the world in general through the production and marketing of these plant-based medicines; This will bring enormous benefits to the DRC for its national economy and hence the social well-being of its population.

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