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REVIEW

An Insight of Parasitic Weeds in Africa and Scientific Developments: A Review

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ABSTRACT

Parasitic weeds are a major threat to food security in Africa and control measures mostly done by smallholder farmers are not effective in eradicating the parasites. This results in a yield loss up to 100%. Parasitic weeds comprise *Alectra vogelii*, *Striga* spp., *Orobanche* spp., *Rafflesia* spp., and *Phoradendron* spp. Parasitic attachment is successful when three necessary conditions have been fulfilled namely the compatible host, suitable environment, and parasitic weed. These species parasite plant species through special attachment features such as modified leaves, suckers, haustoria, or modified roots. In Africa, the variability of parasitic weeds is largely driven by environmental factors such as temperature, rainfall, soil type, and crop husbandry practices. Warmer temperatures create more hospitable conditions for certain parasitic weeds, and allowing them to spread to new areas. Parasitic weed control is vital for effective crop production and the control strategies can be achieved through integrated weed control method that embraces mechanical, cultural, chemical, and biological methods. However, the most effective and crucial method is the cultivation of resistant varieties that provide long-term protection against parasitic weeds. Studies have been done on host-parasite attachment where dodder can send out new roots to infected neighbouring plants and spread their parasitic behaviour. More insight and knowledge should offer new goals for control within the life cycle of the parasitic weeds and their metabolic activities. Lastly, disciplines such as agronomy, plant breeding, nutrition, economics, and IT should play their roles effectively in combating parasitic weeds.

Keywords: *Alectra vogelii; Striga* spp.*; Orobanche* spp.; Haustoria; Food security; Environmental factors

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1. Introduction

1.1 Background information

Parasitic weeds comprise *Alectra vogelii*, *Striga* spp., *Orobanche* spp., *Rafflesia* spp., and *Phoradendron* spp., which are the main limitation to agricultural efficiency in Africa [1]. These weeds reduce crop yield up to 100% when susceptible cultivars are grown in infested farmland [2-4] which is common among resource-poor farmers. Interestingly, these parasitic weeds can extract nutrients and water from their host plants, resulting in compromised yield quality and quantity. Over the past few decades, significant research efforts have been dedicated to addressing this challenge [3,5-8] and minimising crop loss. The biology and ecology of parasitic weeds are complex, as they comprise multiple interactions between the compatible host plant, the parasite, and the suitable environment [9-12]. Therefore, the interaction of the three components results in either infestation of parasitic weeds or not and can be related to a disease triangle as illustrated below in the diagram (**Figure 1**).

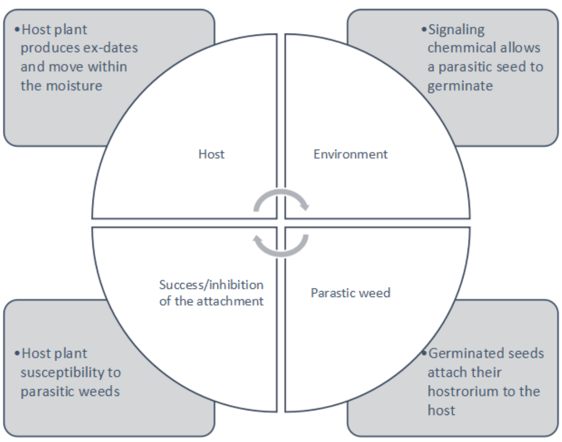

Figure 1. Host-parasite interaction.

This implies that the environment needs to be well nourished for the interaction to be successful. The interaction undergoes four stages: germination, haustorium formation, attachment, and vascular connection [10,13]. Interestingly, the use of trap crops induces the interaction but once cropped in the triangle interaction is disrupted (**Figure 1**). A deep understanding of these interactions is essential for effective management. Recent advances in molecular biology and bioinformatics have enabled researchers to gain insight into the molecular basis of parasitic weed interactions [14-16]. This has resulted in novel approaches to the management of these weeds, including the development of resistant crop varieties [17], the use of biocontrol agents [18], and the application of herbicides [19-21]. In addition, much research has been conducted on the economic and social impacts of parasitic weeds in Africa [22,23]. However, these weeds reduce crop yield and crop nutrition which also signifies why malnutrition problems continue to hamper African countries. This review provides an overview of parasitic weeds variability, their botany, host-parasite interaction mechanisms, climate change impacts, control strategies, roles of selected disciplines in agriculture, and education in the control of the parasitic weeds and highlights some advances in understanding and managing these weeds.

1.2 Strain variability of parasitic weeds in Africa

Parasitic weeds are a major threat to food security in Africa. The strain variability of these parasitic weeds in Africa is largely driven by environmental factors such as temperature, rainfall, soil type, and crop husbandry practices [24] as *Alectra* seed sourced from Mali, Nigeria, and Cameroon, was observed in attacking all groundnuts, cowpea genotype Blackeye, but not cowpea line B301, mung bean or Bambaranut. However, Botswana collections differed in attacking B301 and mung bean [24] while cowpea landrace B301 was resistant to *A. vogelii* in Kenya but susceptible to *Alectra* collections sourced from Malawi, Botswana, and some areas of South Africa which suggest apparent strain variability. The strain variability of parasitic weed can also be attributed to the presence of multiple host species in the same environment, as well as the presence of different species of the same weed in different areas [25,26]. Additionally, the spread of parasitic weeds in Africa may be impacted by changes in agricultural practices, such as the introduction of new crop varieties or the use of different herbicides or pesticides. Apparent strains of parasitic weeds in Africa include *Striga asiatica*, *Striga hermonthica*, *Cuscuta campestris*, *Orobanche* spp., *Striga gesnerioides*, *Striga lutea*, *Alectra* spp., *Rhamphicarpa fistulosa*, *Striga orobanchioides* and *Sesamia calamistis* [27,28].

1.3 Botany of parasitic weeds

Parasitic weeds are species of plants that use other plants as a source of photo-assimilates, water, and nutrients for survival [29]. The parasitic weed becomes a metabolic sink for photoassimilates and they encourage more transpiration for the translocation of growth resources [30,31]. These parasitic plants can be either root or stem parasites, and they are divided into two categories: Holoparasites and hemiparasites. Holoparasites, such as dodder, witchweed, and broomrape, are completely dependent on their hosts for sustenance and cannot survive without them [32]. Hemiparasites, on the other hand, can photosynthesize but still rely on their hosts for at least some of their nutrients. Examples of hemiparasites include mistletoe and Indian paintbrush [12].

Interestingly, parasitic weeds have a diversity of seed characteristics that help them to survive and compete with other plants in their environment. The traits consist of seed dormancy, seed longevity, seed size, seed dispersal, high seed production per plant, germination strategies, and seed coat structure [33,34]. Furthermore, parasitic weeds produce more seeds which also stay in the soil for a longer period compared to other normal weeds and the trait ensures generation succession. Seed dormancy is an attribute that allows seeds to remain quiescent for a while before germinating [35,36]. The character protects seeds from environmental shocks and increases their probability of survival and germination in the future. Seed longevity is another attribute that permits the seeds to remain viable for a longer period [37]. This trait helps ensure that the seeds are still viable when conditions become favourable for germination as illustrated by the parasitic triangle (**Figure 1**). Furthermore, prolonged longevity acts as a mechanism for survival in harsh environments. Seed size is a significant trait for parasitic weeds, as smaller seeds are more expected to be dispersed and travel farther distances through wind, animal bodies, agricultural implements, crop produce, and water [38]. Seed dispersal is important for parasitic seeds to spread and colonize new niches and once favourable conditions are available they germinate and attach themselves to the host plants.

Germination strategies are also important for parasitic weeds, as they need to be able to germinate quickly and effectively once signaling exudates of host plants have been released into the soil and they travel together with the soil moisture [39]. Once parasitic seeds germinate and attach to the host they compete with host plants for growth resources. However, germination is often influenced by the presence of other plants, which provide the necessary exudates, nutrients, and energy for the development and attachment of these parasitic weeds [40]. Sunlight, temperature, and moisture levels can also affect germination. The ideal conditions for the germination of parasitic weeds vary depending on the species, but they generally need warm, moist conditions with adequate light [41]. The best time of the year for parasitic weed seeds to thrive well is usually in the late spring or early summer when the soil is sufficiently moist and warm [42]. It also takes advantage of well-drained soil which prevents root rot.

Parasitic weeds have a seed coat structure that is adapted to the environment in which they live as such some can thrive there for a longer period [6,43]. In general, the seed coat of parasitic weeds is usually thicker and tougher than that of non-parasitic plants, which helps them to survive in harsh conditions. The seed coat may also be covered in tiny spikes or hooks that help the seed to attach itself to the host plant. In addition, the seed coat of parasitic weeds can also contain chemical compounds that help them to penetrate the host plant's tissues and extract nutrients [44]. Lastly, the seed coat structure of *Alectra vogelii* is an example that lacks a palisade layer of the macroscelerids making them easily permeable to water [45]. Postulated changes during the ripening and seed conditioning period are various structural and metabolic changes in the seed coat associated with increased softening of the seed coat making it more permeable to water, increased signaling enzymes, and protein changes [46]. However, when conditions are not favourable the seed coat facilitates seed dormancy which allows the seeds to stay in the soil for a long period.

2. An overview of parasitic weeds

2.1 Soil condition suitable for parasitic weeds

Soil low in organic matter and high in minerals is most suitable for parasitic weeds such as dodder, witchweed, and broomrape [27,47]. These weeds extract nutrients and water from the host plants they parasitise, and they thrive in soils that lack organic matter. Poorly drained, sandy soils with a high water table are also ideal for parasitic weeds as they become more competitive on available growth resources through an increased transpiration mechanism triggered. They also prefer soils with high levels of calcium, potassium, and phosphorus [48]. Additionally, parasitic weeds often require adequate moisture to develop and thrive.

2.2 Parasitic weeds vs non-parasitic weeds

Parasitic weeds are plants that derive their nutrition from the host plant, unlike other weeds which are capable of extracting minerals, and water from the soil [5,21] and undergoing photosynthesis. Parasitic weeds also have specialized roots/stems that penetrate the root/stem system of the host plant to absorb nutrients and water, while other weeds typically rely on the soil for minerals and water. Additionally, most parasitic weeds are highly specialized and are adapted to feed on specific plants, while most other weeds are generalists that can survive in a variety of settings. Furthermore, parasitic weeds produce more seeds that can stay in the soil for a longer period compared to non-parasitic weeds [3,41]. Significant crop yield reductions in parasitic weeds especially *Striga* and *Alectra* infestation occur before the weed sprouts above ground while with normal weeds it occurs mostly when both the crop and weeds are growing.

2.3 Commonly attacked crop specie by parasitic weeds

Parasitic weeds can attack a wide range of crops, including wheat, corn, cotton, soybeans, oats, barley, sorghum, alfalfa, cowpeas, beans, green gram, and vegetables [3]. Other crops commonly attacked by parasitic weeds include potatoes, tomatoes, peppers, and lettuce. Previously, pigeon peas were considered immune to *Alectra vogelii* but they were found to be infested in screen house experiments [49], and flax too as an introduced crop variety in Malawi.

2.4 Mechanisms used by parasitic weeds to attack host plants

Parasitic weeds attack host plant species by attaching themselves to the root/stem systems of the host plants and stealing their nutrients, water, and energy [3,4,50], and one of the attachments is illustrated on susceptible IT82E-16 cowpea cultivar (**Figure 2**). This process is known as parasitism and is facilitated by the presence of haustoria—specialized organs that the parasitic weed uses to penetrate the cells of the host plant. Parasitic weeds also employ other mechanisms such as allelopathy [34,51], in which they release chemicals that inhibit the growth of the host plant, and rhizomes, in which they can spread rapidly through the soil.

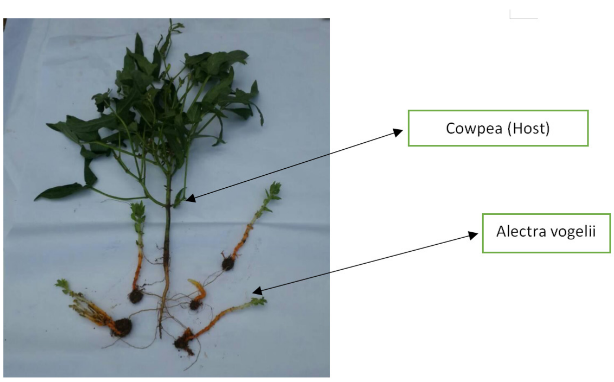

Figure 2. IT82E-16 cowpea variety attacked by *Alectra vogelii* (Parasitic weed).

2.5 Chemical compounds released by parasitic weeds

Parasitic weeds produce a variety of compounds that are specific to the crop species they are parasitic on. These compounds can include chemicals such as phytotoxins, allele chemicals, and enzymes [52,53]. Phytotoxins are toxic compounds that can inhibit the growth of crop species, while allele chemicals are chemicals that interfere with the growth of neighbouring plants of the same species [54] and they include alkaloids, polypeptides, amines, glycosides, oxalates, and resins. Enzymes, on the other hand, can break down cell walls in the crop species, allowing the parasitic weed to gain access to nutrients.

3. An overview of attachment mechanisms and control strategies for parasitic weeds

3.1 Pre-attachment mechanisms of parasitic weeds

Pre-attachment mechanisms of parasitic weeds are strategies used by parasitic plants to increase the likelihood of successful infection of their host plants [28,50]. These strategies are used to ensure that the parasites can obtain the resources they need to survive and reproduce. **Figure 3** illustrates pre-attachment mechanisms.

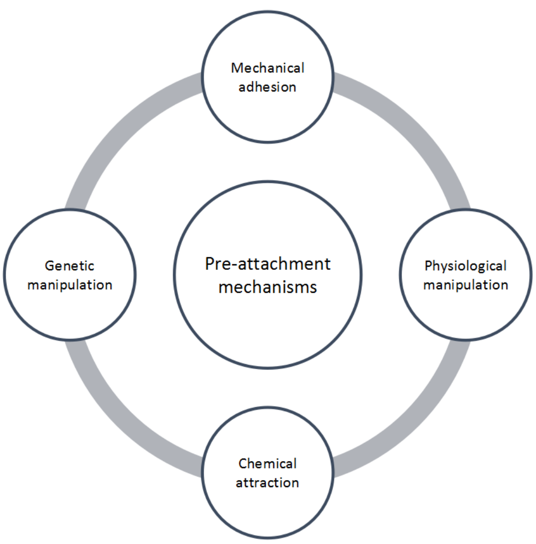

Figure 3. Pre-attachment mechanisms of host parasites.

- Chemical attraction is where parasitic weeds may produce volatile compounds that attract their host species [55]. This is common in parasitic plants that use animals as vectors to spread their seeds.
- Physiological manipulation generally occurs when parasitic weed release chemicals that interfere with the metabolic and physiological processes of their host species [56]. This can prevent the host from defending itself against the parasite or make it easier for the parasite to attach itself to the host.
- Mechanical adhesion occurs when parasitic weeds produce specialized organs, such as haustoria, that allow the parasite to attach itself to the host [44].
- Genetic manipulation involves the production of toxins that alter the genetic makeup of their host species, making them more susceptible to infection [13]. These pre-attachment mechanisms are essential for the survival and reproduction of parasitic weeds and are important for understanding how these plants interact with their hosts.

3.2 Attachment mechanisms of parasitic weeds

Parasitic weeds attach to their hosts using modified root structures called haustoria. Haustoria penetrate the host plant's vascular system, allowing the parasitic weed to steal nutrients, water, and other resources from the host [44]. The haustoria can also be used to transfer nutrients from the host to the parasite. Some parasitic weeds also produce tiny thread-like structures called 'sinkers' [57] which penetrate the host plant's epidermis and enable the parasite to gain access to its resources. Other attachment mechanisms include suckers, which are specialized structures that form on the stem of the parasite and attach to the stem of the host, and rootlets, which are specialized roots that attach to the root of the host.

3.3 Post-attachment mechanisms of parasitic weeds

The post-attachment mechanisms of parasitic weeds vary depending on their mode of attachment, which can be through seed, stem, root, or leaf organs [44,50,24]. **Figure 4** provides illustrations of some of these mechanisms.

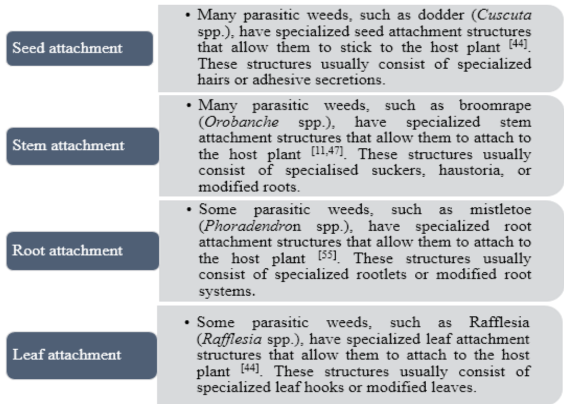

Figure 4. Depicts the various mechanisms that parasitic weeds use after attaching themselves to their host, including both physiological and structural adaptations.

3.4 Uniqueness of host-parasite interaction

The interaction between crop species and parasitic weeds is special as it involves a complex relationship between both species [58]. This relationship includes the exchange of resources, competition for resources, and the potential for both species to affect the other's survival and reproduction [4]. Parasitic weeds can cause significant damage to crops and can even cause crop failure [2,17]. Furthermore, the parasitic weeds produce more seeds at the expense of host species photo-assimilates and such seeds thrive well in the soil for a longer period. On the other hand, crop species can also benefit from the presence of parasitic weeds as they can provide them with nutrients and other resources [55]. The relationship between crop species and parasites is a complex and dynamic one, making it special.

3.5 Failure in attachment mechanisms of parasitic weeds

Failure in attachment mechanisms of parasitic weeds can be attributed to a wide range of factors, including environmental conditions, the physical characteristics of the host plant, the biology of the parasite, and biological control methods [10,14]. Environmental conditions, such as temperature and moisture levels, can affect the ability of the parasite to attach to the host plant. Physical characteristics of the host plant, such as its age, growth habit, and the presence of wax or other surface barriers, can make it difficult for the parasite to attach. The biology of the parasite, such as its life cycle (**Figure 5**), chemical signals, and the presence of specific receptors, can dictate how successful it is in attaching to the host plant [59]. Finally, biological control methods, such as the introduction of natural enemies, can disrupt the attachment process of parasitic weeds [12].

3.6 Impact of climate change on the spread of parasitic weeds

Warmer temperatures can increase the rate of germination and growth of parasitic weed seeds thereby, increasing soil seed bank [60,61]. Raising temperatures can also cause plants to become more vulnerable to infestations by parasitic weeds. Warmer temperatures can increase the survival of parasitic weed seeds in the soil, allowing them to remain viable for longer periods, and increasing the likelihood of infestations [50]. Climate change can also affect the spread of parasitic weeds by altering the habitats in which they thrive. Warmer temperatures can create more hospitable conditions for certain parasitic weeds, allowing them to spread to new areas. Warmer temperatures and increased levels of atmospheric carbon dioxide can lead to more favourable conditions for seed germination, allowing parasitic weeds to spread more quickly than they otherwise would. As temperatures increase, the range of some parasitic weed species can expand, leading to infestations in areas where they were previously uncommon.

Climate change can also affect the availability of resources, such as water, that can support parasitic weed growth [62,63]. In addition to temperature, precipitation patterns, and weather extremes can also influence the spread of parasitic weeds. Changes in precipitation patterns can cause weather extremes that can make some areas more vulnerable to infestations by parasitic weeds. Excessive rainfall can cause flooding, creating standing water that can provide more hospitable condi-

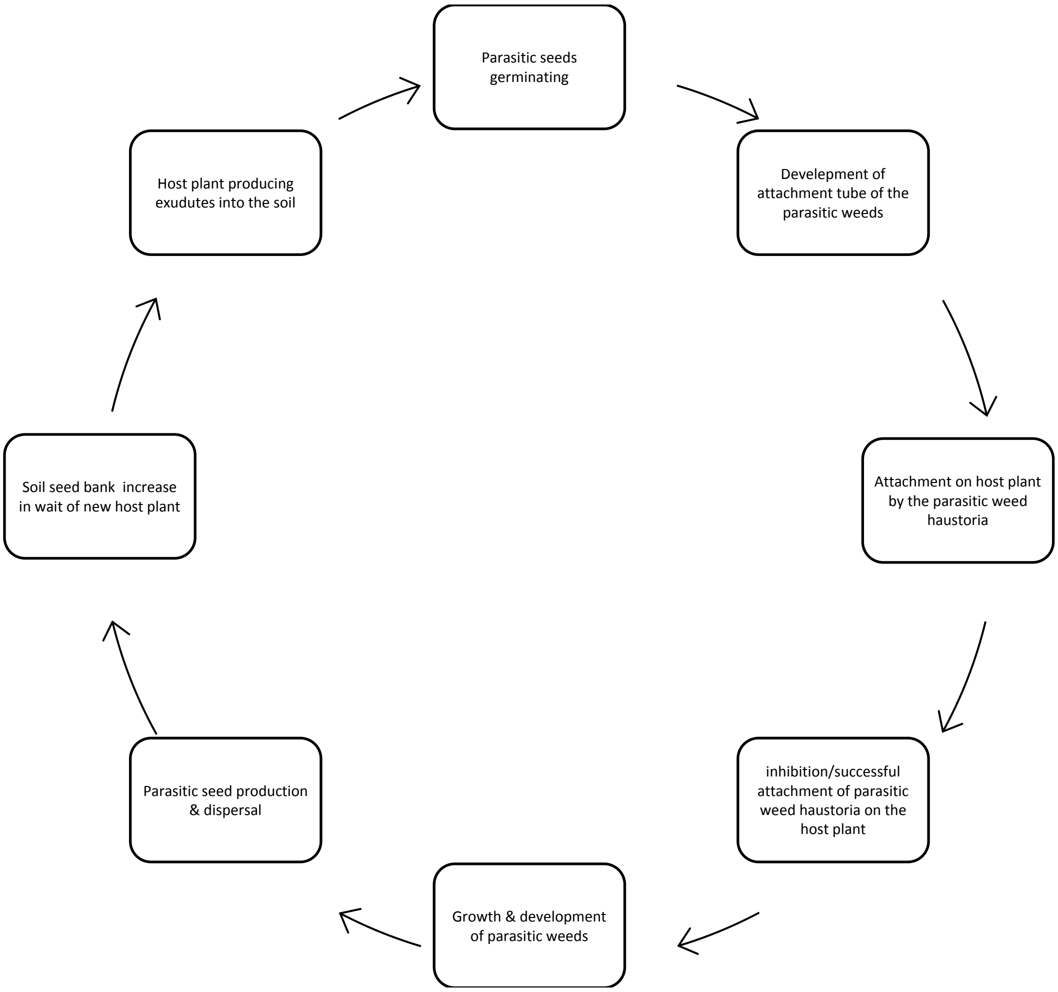

Figure 5. Life cycle of parasitic weeds (*Alectra vogelii*).

tions for parasitic weed growth [64]. On the other hand, drought conditions can reduce the soil moisture levels needed for crop species development. These impacts of climate change can lead to a decrease in crop yields and a decrease in the quality of agricultural lands. To combat the spread of parasitic weeds, farmers must implement practices such as crop rotation, tillage, and the use of herbicides [50].

3.7 Effects of parasitic weeds on crop species in Africa

Parasitic weed's effects on crops in Africa can be devastating and they also fuel malnutrition. Parasitic weeds, such as *Striga*, *Alectra*, *Orobanche*, and *Cuscuta*, attach themselves to crop roots and extract nutrients, water, and photo-assimilates from the plants, resulting in reduced growth, yield, and quality of the crop yield [65]. This can lead to reduced yields and decreased income for smallholder farmers who rely on the enterprise as means of survival. In addition, parasitic weeds can reduce the availability of nitrogen, phosphorus, and other essential nutrients, leading to soil degradation and loss of fertility. Furthermore, parasitic weeds can reduce crop diversity, which can limit the ability of farmers to adapt to changing environmental conditions [66]. Finally, parasitic weeds can create favourable conditions for other pests and diseases, increasing the risk of crop losses and resulting in economic loss [67]. Some governments opt to import certain crops for processing and consumption in fear of introducing parasitic weeds [67] in their farming community. This is considered so as there are increased costs in controlling and eradicating the parasitic weeds which make the yield products to be expensive as there are extra costs for farmers and producers. Parasitic weeds can disrupt ecosystems where in local ecosystems native plant species are displaced which creates an imbalance in the food chain thereby affecting biodiversity. This is why some communities will abandon the cultivation of certain crops as their yields are declining due to parasitic weeds. Lastly, parasitic weeds can spread disease from one plant to another, leading to decreased crop yields and increased pest infestations [50]. Parasitic weeds once infest crops they invite many troubles in crop production thereby, affecting the economy of the smallholder farmers.

3.8 Impacts of parasitic weeds on the nutrition of crop species

Parasitic weeds can have a significant impact on the nutrition of crop species. These weeds can compete with crops for nutrients, water, and light, reducing crop yields and quality [68]. Depending on the species of parasitic weed, some can reduce the availability of key nutrients like nitrogen, phosphorus, and potassium [55]. They can also negatively impact the quality and yield of grain crops, as they compete with the crop for available resources like water and light. In addition, they can reduce the grain's protein content which affects both human and animal dietary needs [69]. All these results in malnourished communities as food products are limited in terms of basic minerals for health wise. Therefore, managing parasitic weeds is essential for maintaining the quality and nutrient content of grain crops.

3.9 Common control measures of parasitic weeds in Africa

Parasitic weeds are a major agricultural problem throughout the world and cause significant crop losses and economic losses. Control of these weeds is essential for successful crop production and can be accomplished through a combination of cultural, mechanical, chemical, and biological methods [17,37]. The following are methods commonly used in the control of parasitic weeds in Africa:

- Crop rotation is a good way to reduce or eliminate the spread of parasitic weeds in Africa [19,23]. It involves planting a different crop in the same field each year and rotating them in a three- to four-year cycle plan. This prevents the weeds from becoming too well-established and reduces the amount of nutrients available to them. However, when host plants are cropped on the land they produce their seeds which will thrive in the soil and only germinate once new hosts are available. Additionally, intercropping can be used to reduce the spread of parasitic weeds on the farmland.
- Hand weeding is a labour-intensive but effective method of controlling parasitic weeds [70,71] in Africa. It involves manually pulling out weeds by their roots and disposing of them safely. This only controls the above-ground germinated weeds and reduces the chances of seed development but they are not more effective in parasitic weed controls as much of the damage is done below ground before emergence.
- Herbicides are used to selectively control certain types of parasitic weeds [72,3,50] in Africa. These chemicals must be properly applied and used by following the manufacturer's instructions to be effective. Although chemical control is used, it should be done with caution, as it can have negative impacts on the environment. However, the method is expensive as smallholder farmers fail to afford the inputs due to poverty.
- Cover crops are planted to prevent the spread of parasitic weeds in Africa [73]. They help to reduce the amount of nutrients available to the weeds and can also be harvested for livestock feed or other uses.
- Mulch is a great way to prevent the spread of parasitic weeds in Africa [50]. This acts as a barrier to keep the weeds from gaining access to nutrients, moisture, and sunlight.
- Crop resistance is a key part of controlling parasitic weeds. Crop resistance involves the development of crop varieties that are better able to resist or tolerate the effects of parasitic

weeds [19,74,21]. This can be done through breeding for specific traits or through the use of biotechnological approaches such as genetic engineering. Crop resistance is achieved through the selection of traits such as improved root growth, thicker cuticles, and enhanced photosynthetic capacity [75].

- The use of fertilizers in controlling parasitic weeds is a common practice [70,76]. Fertilizers are typically applied in a broadcast method, which applies the fertilizer evenly over the entire area. This helps to reduce the number of weeds that can be established, as the fertilizer helps to create a stronger, more competitive plant community. Additionally, certain nitrogen-based fertilizers can be applied in a banded method, which places the fertilizer directly onto the weed-infested area. This method can be especially effective for reducing the spread of parasitic weeds, as the fertilizer helps to reduce the nitrogen availability in the soil and make it less hospitable for the weeds [77]. Additionally, certain herbicides and other weed control methods can be applied in conjunction with the fertilizer application to help further reduce the spread of parasitic weeds.
- Genetic tolerance is a unique approach to the control of parasitic weeds. Genetic tolerance is an approach that involves breeding plants that are tolerant to the effects of the weed and thus better able to compete with it [25]. It involves using genetic engineering to introduce genes into the weed species that make them more resistant to the herbicides used to control them. This can reduce or even eliminate the need for chemical control and improve the overall health of the environment by reducing the use of herbicides. Genetic tolerance and resistance have the potential to provide a long-term solution for controlling certain species of parasitic weeds [19].
- Manure application is an effective tool in controlling parasitic weeds [8,50]. Manure is a natural source of organic matter which reduces soil compaction and improves soil fertility, thus helping to suppress the growth of parasitic weeds. Manure can also provide a physical barrier between the host plant and the parasitic weed, preventing the weed from attaching itself to the host plant [78]. Additionally, manure can be used to introduce beneficial microorganisms into the soil which can help to suppress the growth of parasitic weeds. Finally, manure can be used to introduce beneficial insects into the soil, such as ladybugs, which can help to control the spread of some parasitic weeds.

3.10 Discovery in parasitic weeds

A study found that some parasitic weeds, such as dodder (*Cuscuta* spp.), can send out new roots to infect neighbouring plants and spread their parasitic behaviour [79]. This is an important discovery because it discloses that parasitic weeds can spread even further than previously thought, potentially increasing the damage they cause to crops and native plants. The discovery could help researchers to develop better strategies to combat these weeds and reduce their negative impacts. *A. vogelii* attachment in the presence of a lectin, an adhesive protein that helps the parasite attach to its host [80,81]. This lectin was identified by researchers studying the behaviour of *A. vogelii*, a parasitic mite found on the leaves of various plants. The lectin is found to be a major factor in the attachment of the mite to its host, and it has also been shown to be involved in the transmission of viruses between the mite and its host. This discovery could lead to new treatments for various diseases, including those caused by *A. vogelii*.

A mechanism of attachment by *Orobanche* spp., a parasitic plant species was discovered [14]. The mechanism of attachment involves a series of tiny hooks found on the surface of *Orobanche* spp. [82]. These hooks can latch onto the surface of their host plant, giving the parasite a secure grip. This is the first time such a mechanism has been discovered in a parasitic plant species. The discovery could help researchers better understand the relationship between host and parasite, as well as how to control *Orobanche* spp.

in agricultural settings. It also has potential implications for the development of new crop protection strategies. *Cuscuta* attaches to its host plant by secreting a protein called Cuscutacin, which contains a lectin that binds to specific receptors on the host plant's cell surface [83]. The lectin acts as a 'glue', attaching the parasite to its host plant [84]. This discovery provides new insight into how parasites, such as *Cuscuta*, interact with their host plants and offers potential biotechnological applications.

4. Key discipline in the control of parasitic weeds

4.1 Roles of smallholder farmers in the control of parasitic weeds

Smallholder farmers have a crucial role to play in controlling parasitic weeds [21]. Firstly, they spread awareness among their peers and local governments regarding the negative impacts that parasitic weeds have on their crops and the importance of control measures. Secondly, they practice integrated pest management techniques, such as crop rotation and intercropping, to reduce the spread of parasitic weeds [85]. Thirdly, they monitor their fields regularly to detect and remove infestations before they spread. Finally, they use physical, cultural, and chemical control methods to reduce the spread and impact of parasitic weeds. By taking these steps, smallholder farmers play an important role in controlling parasitic weeds at the field level.

4.2 Roles of agronomists in the control of parasitic weeds

Agronomists play an important role in controlling parasitic weeds. They use a variety of methods to identify and manage these weeds, including crop rotation, tillage, soil solarization, and the use of herbicides [86]. Agronomists also work to identify and monitor weed populations and to develop cultural practices, such as crop rotations and crop selection, which limit or prevent the spread of parasitic weeds. Agronomists educate farmers and other land managers about the importance of monitoring and controlling parasitic weeds [87,22,88]. Finally, agronomists develop strategies for controlling parasitic weeds on a regional scale, such as the development of weed-free seed production zones.

4.3 Roles of plant breeders in the control of parasitic weeds

A plant breeder plays a significant role in controlling parasitic weeds by developing crop varieties that are naturally resistant to the parasitic weed and developing crop varieties that are tolerant to the presence of the parasitic weed and can compete with it [50]. They develop cultivars that have specific traits which reduce the ability of the parasitic weed to establish and spread develop cultivars that are adapted to specific environmental conditions which are aggressive to the parasitic weed but also develop agronomic practices that reduce the spread of the parasitic weed. Lastly, a plant breeder develops management practices and strategies for reducing the impact of the parasitic weed and developing integrated weed management systems that include the use of cultural, mechanical, and chemical control methods.

4.4 Roles of economist in the control of parasitic weeds

They are there to educate the public about parasitic weeds and their effects on crops and natural habitats but also facilitate the development of management strategies for controlling parasitic weeds. They analyse the economic costs [89] associated with parasitic weed infestations, develop economic incentives to encourage farmers to adopt practices that reduce the spread of parasitic weeds and establish legal and regulatory frameworks that limit the spread of parasitic weeds within the country. They monitor the spread of parasitic weeds and their effects on crop production [3] but also conduct new research methods for controlling parasitic weeds, designing economic systems that discourage the use of herbicides, and other chemical treatments, and advocate for sustainable agricultural practices that reduce the risk of parasitic weed infestations.

4.5 Roles of nutritionists in the control of parasitic weeds

Nutritionists play an important role in controlling parasitic weeds by providing advice on soil fertility management and crop selection [90]. They advise farmers on proper techniques for weed control, such as crop rotation and cover crops, as well as recommend organic or chemical weed control strategies. Furthermore, a nutritionist work with farmers to create strategies to prevent the spread of parasitic weeds, such as planting trap crops and deep ploughing. By providing the necessary knowledge and expertise, nutritionists can help farmers to reduce the impact of parasitic weeds on their crops and yield qualities.

4.6 Roles of the IT specialist in the control of parasitic weeds

These experts analyse data from field studies and experiments to assess the efficacy of different control methods [91]. They also develop predictive models to forecast the spread of parasitic weeds. GIS technicians create spatial maps and databases of infested areas. They create monitoring protocols to track the progress of parasitic weed control efforts. On the other hand, software developers create software tools and applications which assist in the management and monitoring of parasitic weeds. These software tools are used to track the spread of infestations, forecast the potential impacts of different control strategies, and share data with stakeholders.

4.7 Roles of research scientist in the control of parasitic weeds

They identify the most effective control methods for parasitic weeds. They undertake research on the biology, ecology, and management strategies of different weed species and design experiments to evaluate the effectiveness of various control options [92]. Furthermore, they identify, assess, and introduce natural enemies of parasitic weeds. Lastly, they research the best biological control agents and determine their efficacy in controlling parasitic weed populations.

4.8 Roles of education curriculum in the control of parasitic weeds

Education curriculum plays an important role in helping students to understand the environmental impacts of parasitic weeds and the need for control measures [93]. Educators use the curriculum to teach students about the biology and ecology of these parasitic weeds, including their effects on crops, native species, and habitats [94]. Additionally, the curriculum provides information on the methods available for controlling these parasitic weeds, such as manual, chemical, and mechanical removal, as well as strategies for prevention. Finally, the curriculum helps students develop an understanding of the importance of integrated weed management strategies, including the need for appropriate timing, coordination of efforts, and long-term planning. Ultimately, this knowledge helps students become better stewards of their environment and more effective in their efforts to manage and control parasitic weeds.

5. Conclusions

In this review, we have tackled the parasitic weeds common in Africa, the variability of parasitic weeds, and their biology. Parasitic weeds can significantly attack a wide range of crops, including wheat, corn, cotton, soybeans, oats, barley, sorghum, alfalfa, cowpeas, beans, green gram, and vegetables. Interestingly, control methods have been devised to control parasitic weeds as they have the potential of reducing yield up to 100%. The biology of host-parasite interaction foretells a unique trait as to why the interaction is so special. The use of resistant varieties has proved to be the most effective method for controlling parasitic weeds. However, the only way to cope with the parasitic weeds is through an integrated approach that employs a variety of measures in a concerted manner, starting with containment and sanitation, direct and indirect measures to prevent the damage caused by the parasites, and finally eradicating the parasite seed bank in the soil. Climate change significantly increases the rate of germination and growth of parasitic weed seeds which need mitigation strategies of the change. Rising temperatures cause plants to become more vulnerable to infestations by parasitic weeds. Research ideas have been discovered in host-parasite attachment and dodder (*Cuscuta* spp.), can send out new roots to infect neighbouring plants and spread their parasitic behaviour. The research ideas will likely help in an overall understanding of some key aspects of parasitism. Basic research ideas should offer new goals for control within the life cycle of the parasites and their metabolic activities. Lastly, the disciplines such as agronomy, plant breeding, nutrition, education curriculum, economics, and IT should play their roles effectively in controlling parasitic weeds.

Author Contributions

The first author developed the manuscript and arranged it. Co-authors guided the development of the review article.

Conflict of Interest

No potential conflict of interest was reported by the authors.

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