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Potential of Controlling Common Bean Insect Pests (Bean Stem Maggot (*Ophiomyia phaseoli*), Ootheca (*Ootheca bennigseni*) and Aphids (*Aphis fabae*)) Using Agronomic, Biological and Botanical Practices in Field

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Abstract

Common bean production in Africa suffers from different constrains. The main damage is caused by insect pest infestations in the field. The most common insects pests which attack common bean in the field are the bean stem maggot (*Ophiomyia phaseoli*), ootheca (*Ootheca bennigseni*) and aphids (*Aphis fabae)*. Currently, few farmers in Africa are using commercial pesticides for the control of these insect pests. Due to the negative side effects of commercial pesticides to human health and the environment, there is a need for developing and recommending alternative methods such as those involving agronomic and botanical/biological measures in controlling common bean insect pests. This review aim to report the most common insects pests which attack common bean (*Phaseolus vulgaris* L.) in the field and explore the potential of agronomic, biological and botanical methods as a low-cost, safe and environmentally friendly means of controlling insect pests in legumes.

Keywords

Field Pests, Damage, Pest Management, Plant Extracts, Explore, Potential

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is an annual leguminous plant that belongs to the family Leguminoaceae,

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with pinnately compound trifoliate large leaves. Common bean has high protein content and is a good source of energy and provides folic acid, dietary fiber and complex carbohydrates [1]. Common beans (*Phaseolus vulgaris* L.) contribute up to 57% of recommended dietary protein and 23% of energy to the nutrition of African people [2]. Regular consumption of common bean and other pulses is now promoted by health organizations because it reduces the risk of diseases such as cancer, diabetes or coronary heart diseases [3]. In Tanzania, bean is highly cultivated in the mid to high altitude areas which experience more reliable rainfall and cooler temperature. It is mainly grown in northern zone, the great lakes regions, west and southern zone [4]. Common bean production is constrained by several environmental stresses, notably biotic (field and post-harvest pests and diseases) and a biotic (drought, excessive rain/flooding, poor soil fertility, heat and cold).

In recent years, crop production trend has not kept pace with the annual growth rate (estimated above 2 percent) in population in some countries due to number of biotic, abiotic and socio-economic constraints [5]. Each of these constraints causes significant reductions in yield [6]. Amongst biotic constraints, insect pest infestation ranks higher in causing significant yield reduction in legumes. For example, the major important insect pests to common bean are stem maggot (*Ophiomyia phaseoli*) ootheca (*Ootheca bennigseni*) and aphids (*Aphis fabae*) which cause the yield loss of about 37% to 100% [7], 18% - 31% [4] and 37% [8] respectively.

In solving the problem of insect pest infestation, several national bean programs and other research organizations in the globe have identified chemicals (e.g. endosulfan, diazinon or lindane) that can be applied at low doses as seed dressing to provide protection to germinating plants at a time when they are most vulnerable to attacks [9]. Pesticides including cypermethion, carbany, and karate are useful and have shown efficacy on controlling the pest [9]. However, most commercial pesticides are very effective but are not ecofriendly to natural enemies, to human and wildlife safety, and have raised severe global environmental concerns [10]. Therefore, there is a need for adopting other new alternative in controlling common bean insect pest such as those involving the use of agronomic practices, biological and botanical control.

2. Selected Major Insect Pests Which Are Known to Cause Significant Damage to Common Beans at Various Growth Stages Include: Bean Stem Maggot (*Ophiomyia phaseoli*), Ootheca (*Ootheca bennigseni*) *and* Aphids (*Aphis fabae*)

2.1. Bean Stem Maggot (*Ophiomyia phaseoli*)

Bean stem maggots also known as bean flies are often considered as the most important field pest of beans in Africa. They account for yield losses ranging from 80% to 100% [7]. Most common species includes: *O. phaseoli*, *O. spencerella* and *O. centrosematis*. They attack the crop wherever it is grown [11]. *Ophiomyia phaseoli* is widely distributed pest of seedling bean in East Africa. The insect is also the principal pest of beans in Asia and Oceania [12]. Bean stem maggot adult oviposits eggs in leaves, stems and hypocotyls of young seedlings. Emerging maggots mine their way to the root zone where pupation takes place and where feeding becomes concentrated between the woody stem and the epidermal tissue [13]. Such feeding interferes with water and nutrient transport and creates avenues for entry of disease organism [12].

The damage caused by bean stem maggot is more serious during the seedling stage of the bean plant. The pest attack the plant at the beginning of the unfolding of the first pair of leaves, and it begin to attack as other new leaves unfold [14]. Bean stem maggot oviposits directly in the plant tissue and the emerging maggots feed in the stem and disrupt water and nutrient transport. Leaves of attacked plants turn yellow, wilt and the plant dies [15]. Due to high yield loss caused by this insect, and the inability of small-scale farmers to afford expensive chemical pesticides, there is a need of developing a sustainable strategy for controlling this pest such as those involving the use of agronomic, biological and botanical control methods.

2.2. Ootheca (*Ootheca bennigseni*)

Ootheca bennigseni is endemic to mainland Africa and is found almost exclusively on bean plants (*Phaseolus vulgaris* L.). Its biology has not been studied in detail [16]. Larvae emerge after 2 - 3 weeks and feed on the roots of beans. The larvae go through three instars, the teneral adults undergo diapauses until the onset of the following year's rainy season when they emerge (**Figure 1(a)**) and start feeding on leaves (**Figure 1(b)**) of the newly planted beans [17].

The adult beetle can cause extensive defoliation, and, with heavy infestation, may completely destroy a crop

(a) (b)

Figure 1. (a) Ootheca adult on bean plant; (b) bean plant affected by ootheca.

(**Figure 2(b)**). Additionally, the feeding of the larvae on lateral roots causes wilting and premature senescence in bean plants [17]. *Ootheca* spp. is also reported to be a key pest in Zambia [18], Malawi, Kenya, Burundi and Rwanda [19]. Over the years, African farmers have noticed increasing foliar damage by *O. bennigseni* to their young bean plants, but were unaware of the larval damage by the same insect until they were shown the larvae on the roots of the bean plants [12]. For example, yield losses in the range of 18% - 31% are attributed to *O. bennigseni* in Tanzania [4]. Since this insect has limited information about its biology, it becomes difficult to control using synthetic pesticides due to negative side effects. Therefore, there is a need of looking for other promising strategies such as agronomic, biological and botanical methods in controlling the pest.

2.3. Aphids (*Aphis fabae*)

The bean aphids *Aphis fabae* is the main aphid pest of common bean in Africa. Aphids have experienced some adaptation in relation to host plant so that many aphid taxa have biologically complex life cycle [20]. Bean aphids are found in colonies around the stem, leaves (**Figure 2**) and growing point [19]. Infested leaves are destroyed and yellowed by the aphids feeding and sucking activities. Plant become desiccated and may eventually die. Besides causing direct damage to the host by sucking the sap from various plant parts, they also indirectly transmit common mosaic viruses which result in early plant death. [21]. Yield loss due to Aphid is estimated to 37% [8].

Aphids also secrete honeydew which enhance the growth of sooty moulds and hence interferes with the photosynthetic ability of plants [22]. Plant response to aphid feeding has been reported to be specific to particular aphid system infestation. In different aphid plant combination, aphid attack induce reduction in biomass, leaf area and relative growth rate of plant, and have been reported to attack many legumes including cowpea, faba bean [23]; Pea [24] and soya bean [25]. Due to the complexity in life circle and high reproduction rate of this insect, it has become difficult to control using synthetic pesticides. Therefore, there is a need of developing other strategies such as use of agronomic, biological and botanical control methods which targets the insect during the specific time of damage.

3. Control Measures Used to Control Bean Stem Maggot, Ootheca and Aphids in Common Bean

3.1. Chemical Pesticides

Worldwide it is estimated that approximately 1.8 billion people engage in agriculture and most use pesticides to protect food and commercial products that they produce. Others use pesticides occupationally for public health programs, and in commercial applications, while many others use pesticides for lawn and garden applica-

Figure 2. Aphids feeding on bean plant.

tions and in and around the home [26]. Over 1 billion pounds/litres of pesticides are used in the United State (US) each year and approximately 5.6 billion pounds are used worldwide.

Several national bean programs and other research organizations in the globe have identified chemicals (e.g. endosulfan, diazinon or lindane) that can be applied at low doses as seed dressing to provide protection to germinating plants at a time when they are most vulnerable to attacks especially bean stem maggot [9]. Pesticides including cypermethion, carbany, and karate are useful and have shown efficacy on controlling the pest [27]. The relatively new insecticide imidacloprid has demonstrated considerable potential in faba bean IPM programs [28]. Its use is still the subject of research but it is effective against aphids, wireworms, thrips and broad bean weevil *Bruchus rufimanus* [29]. Controlling aphids with imidacloprid effectively reduces infection from bean leaf roll virus, faba bean necrotic yellows virus and soybean dwarf virus [28]. Applied as a foliar spray during podding, imidacloprid significantly reduced leaf miner *Liriomyza huidobrensis* (Blanchard) populations but also suppressed its parasitoid. Foliar sprays soon after plant emergence, soil treatment by chemicals such as Triazopho at 30 - 60 ml/100 lt, at 10 - 14 days intervals, or Chlopyrifos at 150 ml/100 lts at 7 days intervals also seed treatment with chemicals such as: Imidacloprid at 570 gm/100 kg of seeds, Cypermethrin at 100 ml/20 L at 2 weeks intervals Fenvalerate at 100 ml/20 lts at 7 days intervals can be used in controlling bean stem maggot [30].

These applications may effectively control the pest but many of the recommended chemicals are banned (e.g. endosulfan and lindane), or are too expensive or unavailable (e.g. abamectin) to the average small-scale bean grower in Africa. Synthetic pesticides are reported to be effective, reliable against a wide range of insect pests, quick acting and easy tested for new insect pest. In spite of the usefulness and effectiveness, synthetic pesticide have limited distribution in rural areas, often adultered or applied at inappropriate application rate due to illiteracy, poor labeling or use of old, expired products and lead to rapid evolution of pesticide resistance [31]. Human health and safety is also threatened by use of commercial pesticides with no mechanism to ensure food safety for consumers, and concern for the chronic effects of exposure [32]. Environmental impacts to wild life, crop pollinators and natural enemies are also severe [31]. Awareness regarding the food safety has increased the demand for organically produced food, which necessitates evaluating the performance of biopesticide as safer alternatives to conventional insecticides [33]. Therefore, evaluating non-chemical pesticides that are affordable and with health benefits to the applicators, consumers and the environment is recommended.

3.2. Agronomical Practices

Common bean production is generally difficult in the tropics because of the favorable conditions which promote pest development [34]. According to [17], considerable evidences have emerged over the past twenty years to suggest that pest populations and problems are much greater in crop grown in monoculture than those grown with intercropping. Growing two or more crops in the same field at the same time enhances natural enemy abundance and generally keeps pest number at low levels [17]. Cultural practices that include site selection, crop rotation, and cultivar and seed selection, preferential sowing date may to a certain degree reduce the infestation of certain insect pests. For example, [35] reported reduced aphid infestation in wheat by early sowing. Similarly,

[36] showed that sowing date had an effect on population of ootheca, bean stem maggot and aphids and other arthropods attacking common beans. Studies by [37] also showed higher infestation by bean stem maggot in late or off-season planted crops.

In other agronomic studies, row spacing and plant density, weed control and stubble retention have been used to control bean stem maggot [37]. Other studies have demonstrated that sloping sites and border hedgerows that reduce wind speed promoted aphid landing and affected aphids and *Ootheca* distribution [38]. High plant density (that is increasing plant density from 22 bean plant/m^2 to 33 bean plant/m^2) was found to decrease common bean virus incidence transmitted by aphids by 10% - 20% [28]. Also [28] demonstrated that planting cereal border around faba bean field reduces the spread of non-persistently bean transmitted virus. The use of straw and mustard mulches can reduce bean stem maggot and other bean insect pest population by up to 80% and 75% [39]. Since these methods are safe and cheap, there is a need of conducting detailed research to understand mechanism involved in providing protection and hence advocating well their usage.

3.3. Biological Control

Biological control is a bio effecter method of controlling pests (including insects, mites, weeds and plant diseases) using other living organisms [40]. This relies on predation, parasitism, herbivore, or other natural mechanisms [40]. Biological control aims to reduce the abundance of pest below its economic threshold. Aphids are attacked by parasitoids, predators [41] and pathogens [42].

In some instances, both larvae and adults of predators belonging to the family Coccinellidae (ladybird beetles) feeds on aphids [43]. With regards to parasitoids, some species will pupate within or below the aphid cuticle forming mummies [43]. All species in the braconid subfamily Aphidiinae develop as endoparasitoids (inside) of aphids with one larva completing development in each host. Some species of entomopathogenic fungi infest aphids through the cuticle eventually killing the host. Ladybirds are stronger, larger and usually more intelligent than the prey and may attack several hosts in a short period [44].

Spinosad is another biological control of aphids which is a biologically derived insecticide produced by the actinomycete *Saccharopolyspora spinosa*, a bacterial organ isolated from soil [45]. The mode of action of spinosad is through stomach and nerve poisoning [46]. Spinosad is recommended for the control of a very wide range of caterpillars, leaf miners and foliage-feeding beetles [45].

Other known biological method is the use of *Bacillus thuringiensis* to control lepidopteron larvae, including *Helicoverpa* spp., *Spodoptera* armyworms, diamondback moth *Plutella xylostella*, and *Chrysodeixis loopers* in legumes [28]. Biological control is safe and eco-friendly. Therefore, more research is needed to develop bio control packages in controlling common bean insect pests. Once achieved and upscale, this will provide sustainable solution in plant protection programmes.

3.4. Botanical Pesticides

Pesticidal plants have great potential for impact in developing countries [47] [48]. The use of botanical insecticides is more sustainable and has a low environmental impact than synthetic insecticide. Typically, it comprises a mixture of bioactive compounds with many advantages in terms of efficacy short span and preventing the development of resistance [49]. They are mostly affordable to farmers than synthetic products and their costs are almost calculated in terms of time to harvest and process [50]. The value of pesticidal plants comes from the harnessing of plant defense strategies based on the production of repellency antioxidant growth retardant and toxic chemicals that target insect pests and microorganisms [51] [52].

In the middle of the 17th century, pyrethrum, nicotine and rotenone were recognized as effective insect control agents [53]. The most economically important of the natural plant compounds used in commercial insect control are the pyrethrins from the flower heads of pyrethrum *Chrysanthemum cinerariaefolium* [54]. Nicotine isolated from number of species of *Nicotiana* is also insecticidal. Botanical products like tobacco extract, neem oil and extract, which can be easily and cheaply collected in rural farmers, have been found promising and useful for common bean pest control [55]-[57]. Likewise, *Tephrosia vogelii*, *Azadirachta indica*, *Annona squamosa*, chilli paper *Allium sativa* have been used successfully in controlling insect pests in common beans and cowpea [58]. For example, plants such as Tobacco, *Nicotiana tabacum*, Neem, *Azadirachta indica*, Garlic, *Allium sativum*, Eucalyptus, *Eucalyptus camaldulemsis* and Mehogony, *Swietenia mehagani*, have been used in controlling aphids attacking in yard-long bean plants [59]. Due to the need for the alternative to synthetic insecticide, it is therefore essential to evaluate the potential of locally practices such as those involving agronomic, biological and botanical practices in controlling legume insect pests.

3.5. Using Agronet

The use of agronet has been used as a means of controlling insect pests in French bean. Agronet have been reported to lower the populations of, aphid [Lipaphis erysimi (Kaltenbach)], borer [Hellula undalis (Fabricius)] and diamondback moth [*Plutella xylostella* (L.)] on cabbage as compared with cabbage treated with foliar insecticide and untreated controls [60]. Insect pest pressure and modified microclimate have leaded to improve tomato [*Solanum lycopersicum* (L.)] with net covering crops [61], cabbage [*Brassica oleracea* (L.)] and var. capitata (L.)] [62]. Under tropical field conditions, agronet also have showed the potential in modifying microclimate conditions together with improving tomato yields and quality [63].

4. Conclusion

Common bean production in Africa suffers most from the damage caused by insect pest infestations in the field. The use of agronomic, biological and botanical practices is believed to be a promising strategy in controlling legume pests in the field and storage. Due to inadequate information on the importance of these practices to farmers, there is a need of testing these practices widely to ascertain their potential and finally disseminate useful information on their validity to farmers in order to overcome the use of synthetic insecticide in controlling crop insect pest.

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