Koffi Gangba

Bioherbicide to control agricultural weeds

Abstract
The used of bioherbicides to control agricultural weeds will be one of the most effective technology to take the use of chemicals (such as methyl bromide) which are revealed harmful for human being. In many cases, the use of chemicals as weed's controlling agent result in contamination of land, water and causes serious problems to the environment. Biohebicide technique is a way to provide sustainable solutions to agricultural weed management and therefore will meet current agricultural regulations through the use of natural biological agents such as fungi, bacteria, viruses to attack weeds.

Key Words: Weeds, bioherbicides, biocontrol, pathogens

Introduction
Weeds have severe negative impacts on agricultural productivity, economy, environment and ecosystem. Weeds reduce considerable quality and quantity of agricultural output. In the US, weeds can reduce crop yield by 12% corresponding to $32 billion in losses and all crops together $267 billion per year (United States Bureau of Census, 1998). The use of chemical as herbicide such as methyl bromide is found to be source of surface and ground water contamination. Although, chemical herbicides have significant effect on weeds, herbicide resistance is a serious challenge for the use of these chemicals. As agricultural productivity faces more challenges it is necessary to develop other technologies. The use of bioherbicides to control weeds is a potential alternative.

2-Weeds' impact on agricultural productivity

The use of chemical herbicides to control weeds degrades soils quality which in turn decreases agricultural output. As weeds develop resistance to chemicals, quantity and dosage of chemical have increased costing important funding issues. In the United States, agricultural producers spend about $3.6 billion each year for weed control at farm level (www.ncagr.com)**.**

3- Different categories of weeds

Weeds can be divided into broadleaved weeds, grassy weeds and sedges weeds. Weeds have complexes names and originated from different areas.

Table 1. List of weeds with released/available biocontrol agents (www.apsnet.org**)**

Latin Name	**Common Name**	**Where Available**
Acroptilon repens	Russian knapweed	mainland US
Ageratina adenophora	crofton weed	HI
Ageratina riparia	Hamakua pamakani	HI
Alternanthera philoxeroides	alligatorweed	mainland US
Calystegia sepium	hedge bindweed	mainland US
Carduus acanthoides	plumeless thistle	mainland US
Carduus nutans	musk thistle	mainland US
Carduus pycnocephalus	Italian thistle	mainland US
Carduus tenuiflorus	slenderflower thistle	mainland US
Centaurea cyanus	bachelor's button	mainland US
Centaurea diffusa	diffuse knapweed	mainland US
Centaurea maculosa	spotted knapweed	mainland US

Table 1b. List of weeds with available native biocontrol agents (www.apsnet.org)**.**

Cirsium arvense	Canada thistle	mainland US
Convolvulus arvesis	field bindweed	Canada
Cyperus rotundus	nut grass	mainland US
Diospyros virginiana	persimmon	mainland US
Eichhornia crassipes	water hyacinth	mainland US
Morrenia odorata	milkweed vine	mainland US
Myriophyllum spicatum	Eurasian watermilfoil	mainland US
Opuntia ficus-indica	Indian fig	HI
Opuntia littoralis	prickly pear	mainland US
Opuntia oricola	prickly pear	mainland US
Solanum elaeagnifolium	silverleaf nightshade	mainland US

4- Weeds' control
The use of chemical herbicides is prohibited in some places; therefore biological control to eliminate weeds will be the only possible alterative. Notice that the use of plant pathogen to eliminate weeds has been studied using classical and bioherbicide approaches (www.apsnet.org).

Classical approach
Known as inoculate biocontrol method, the classical approach consists of the use of pathogens brought from different locations to infest target weeds. The imported pathogens eliminate or significantly slow the growth and multiplication of target weeds. The pathogens spread diseases that may result in an epidemic and consequently result in a decline of weed population. For instance, the rust fungus *Uromycladium* has caused extensive gall on the branches of *Acacia saligna* in South Africa (Morris et al., 1999). The introduction of the same fungus into Western Cape leads to a widespread of disease resulting in a decrease of tree density by 90-95 % (Morris, 1997). Another encouraging result comes from the use of *Puccinia chondrillina* to control *Chondilla juncea* in Australia where the project yield an increase in the benefit cost ratio from1:100 to 1:200 (Cullen, 1985). The success of this approach depends on whether the pathogens are utilized along with other chemical herbicides or not. For example, when *Puccinia chondillina* was utilized along with chemical hebicides to control a *skeletonweed* biotype in the Western United States, the output was less satifactory (Lee, 1986).
"This technique takes months to years before showing significant result because the infestation takes place gradually." The classical approach rate of success is 57% and 21% for all project pathogen based weed control (Charudattan, 2005). Classical weeds' biocontrol is subject to strict regulations because the technique may result in the introduction to harmful pathogens to agricultural productivity. The introduction of foreign pathogens is controlled by TAG (Technical Advisor Group) which recommends grants permits. For instance," rust fungi are studied in their native range to determine their host specificity and virulence towards the target weeds (Charudattan, 2005)"**.** The classical weeds; biocontrol applications include the use of rust fungi *Uromycladium tepperianum* to control *Acacia saligna* (Charudattan) and the use of foliar smut fungus to control Hamakua pamakani (Charudattan, 2005)**.** In general, foreign pathogens produce better results if they were released on suitable sites with appropriate moisture content. The application of foreign pathogen can lead to rehabilitation of pasture land. Limitations to the classical approach come from: the inaccuracy to predict the "success of the introduced pathogen and safety concern (Charudattan, 2005)," the pathogen must be able to mutate or change genetically to infect new races of weed, lack of a commercial incentive for organizations to find new biocontrol agents (Brown et al. 1996).

Bioherbicide approach
The biolhebicide approach is termed "inundative" and requires application of large number of pathogens on a defined area (Masson et al. 2002). Pathogens are taken from

weeds to grow other infective agents capable to attack weeds. The bioherbicide approach offers diverse possibility of applications especially in agricultural, forestry lawn and garden and therefore is preferred over the classical approach(Masson et al. 2002).This technique requires new application each year due to the short cycle life of the pathogens and therefore will not be enough to new weed population.
Approximately "200 plant pathogens have been or are under evaluation for their potential as bioherbicides including fungi and bacteria (Boyetchko et al., 1999)". For this approach, plant pathogens face strict selection criteria bade on their ability to cause diseases to weeds, fitness with other pesticides and their capability to be commercialized (Barton, 2005)**.**
The efficacy of plant pathogens is conditioned by several factors that lead to finding strategies for improving their action.

5- Enhancing bioherbicides
Common bioherbicides are fungi and bacteria. Their role is to attack weeds through the spread of diseases. Enhancement of fungal and bacterial pathogens will severely damage weeds (Templeton, 1982). The use of microorganisms capable of secretion of amino-acids will produce pathogenic virulence against weeds.
Bioherbicide such as *DeVine* to control strangler vine used in Florida can be applied directly to the soil and lasts from 6 to 10 years with 90 to 100 percent efficiency (Charudattan).

Techniques for enhancing bioherbicides
Moisture reducing
Moisture is the main obstacle for fungal pathogens to attack effectively weeds. Reducing the moisture content will result in an increase of fungal pathogens virulence on weeds. "The utilization of formulations that minimize the influence of moisture is one approach to overcome this obstacle (Auld et al., 2003)". This technique consists of an addition of an invert oil emulsion to conidial suspensions of *collectotrichum truncatum* (Boyette et al., 1993). This practice results in 100% control of *hemp sesbania* in the absence of moisture in the greenhouse and 95% control of hemp sesbania in the field which produce similar result when chemical herbicide *acifluorfen* was used (Boyette et al.,1993) .
"Another example of improving bioherbicidal performance comes from the addition of oil emulsions with no or little exposure to moisture (Abbas et al., 1996)."

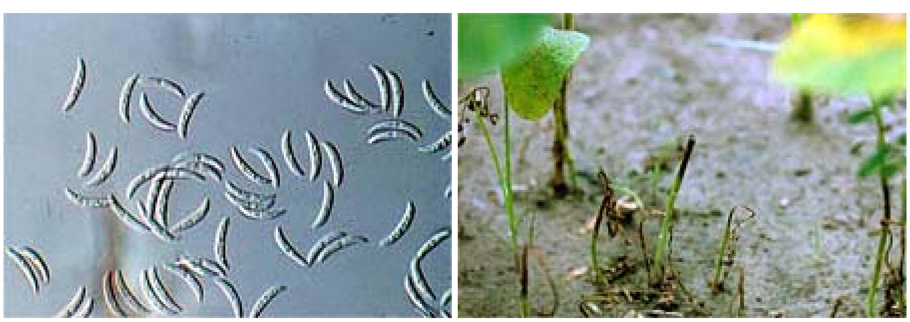

Fig1: Spore of Collectotrichum truncatum attack on hemp sesbania (Boyette, 1993).

Broadening the spectrum of bioherbicide

In this case, bioherbicides composition will be determined by the behavior of weeds in presence. Therefore it is important to apply bioherbicides with broad-spectrum able to control weeds showing different characteristics in a specific region.

Two methods are used to broad bioherbicide spectrum

- **via formulation**

Weeds such as hemp sesbania, showy crotolaria and eastern black nightshade are effectively controlled by Alternaria crassa which is obtained from composition of fruit pectin and plant filtrates (Boyette et al., 1994). These weeds were known as resistant to fungus in the absence of fruit pectin and plant extracts (Boyette et al., 1994) .

Fig2: *Colletotrichum gloesporiodes* isolated from *coffee senna* and combined with an oil-based formulation to control *scklepod* (Boyette,1993).

- **By combination of pathogens**

Control agents show more virulence on weeds if they were made by combining two pathogens (Chandramhan et al., 2003). For instance, weeds such as pigweed, *scklepod* and *showy crotolaria* are effectively controlled by the combination of *Alternaria cassiae*, *Phomospsis amaranthicola* and *Collectotrichum dematium* (Chanrdamhan et al., 2002).

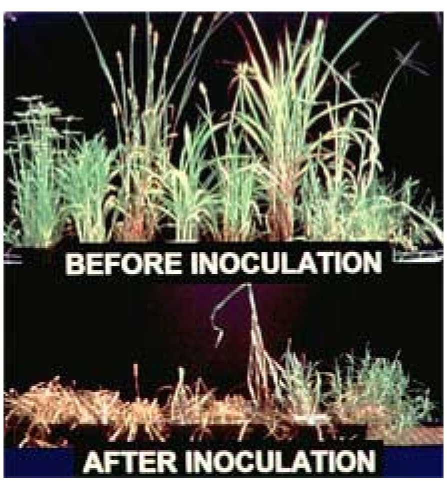

Fig3: Multiple pathogens application. (Chandramhan et al.,2003)

Application systems

This method is based on the quantity of bioherbicides being spread (Klein, 1992). The virulence of disease does not automatically depend on the volume of biohebicides being spread. “To be effective this method should take into account the spray droplet size, droplet retention and distribution and spray application volume and the equipment used (Klein, 1992)”.The type of sprayer is a key element resulting in reducing or enhancing biohebicidal efficacy (Yandoc, 2001). For instance, “The percentage of droplets without any spores was 67.3% for the hydraulic flat fan, 95% for the air blast sprayer, and 6.5% for the spinning disc (Yandoc, 2001).” The Application systems techniques have shown interesting result when controlling tropical soda apple (*Solanum viarum*) by using Tabaco mild green mosaic virus (Charudattan, 2004). Application technology offers the possibility to damage weeds either on the surface or below soil surface (Boyette et al., 1996)). The application technology used along with composted chicken manure result in production of *viridiol*, an antibiotic which has significant impact on weed destruction (Hutchinson, 1999).

Fig4: Field application methods (www.apsnet.org).

Selection and use of amino acid excreting strains

Amino acids in abundant quantity have the potential to eradicate the growth of plants (Tiourebaev et al.,2001). The new technique to increase weeds controlling agents requires a strict choice of strains able to produce important quantity of amino acids (Tiourebaev et al., 2001). For instance when the efficacy of Fusarium oxysporum was improved to control Cannabis sativa, the damage caused is estimated to be 70 to 90% compare to 25% without improvement (Tiourebaev et al., 2001). This performance is obtained in 2 to 3 weeks compare to 6 to 8 weeks with no improvement (Tiourebaev et al., 2001).

Table1: Amino acids Analogs (www.apsnet.org)

Amino Acid	Analog(s)
Valine	Valine hydroxamate, norvaline, penicillamine
Lysine	Aminoethyl-cysteine, hydroxylysine, aminocaproic acid
Methionine	selenoethionine, ethionine, selenomethionine,
Tryptophan	5-Methyltryptophane
Arginine	Canavanine
Proline	Hydroxy-proline, dehydro-proline
Leucine	Norleucine

Table2: Valine excretion and virulence of valine overproducing variants (www.apsnet.org)

Strain	Description	Valine Excretion[a] (mg/l)	% Kill	Mortality Rate[b] (weeks)
C95	Wild-type	0-0.18	25	6-8
4nv	Norvaline[R]	2.84	70	2-3
6pa	Penicillamine[R]	2.48	90	2-3
8pa	Penicillamine[R]	9.93	90	2

a. Valine excretion. Valine excretion was determined by spectrophotometric analysis of growth of *Pediococcus cerevisiae* ATCC8042 in culture supernatant.

b. Mortality Rate. Mortality rate is the duration between inoculation and the first appearance of severe disease symptoms or death.

Pathogen application and plant competition

"The negative impacts of plant disease on plant growth and development have been shown to inhibit the target weed's ability to compete with non-target plants (Groves et al., 1975)" . For example, the reducing of *Senecio vulgaris* ability's by *Puccinia lagenophorae* to compete with lettuce, lead to an increase in the lettuce production (Kennedy et al., 1991). Also, tomato production was increased when *Dactylaria higginsii* was combined with tomato plantings and purple *nutsedge* (Kadir et al., 1999). This technique offers sometimes permanent suppression of weeds and in turn allows desirable plants to grow where weeds were destroyed.

Fig5: Control of cogongrass, as seen in the pot on the left side, allows bahiagrass to flourish when compare to the uninoculated control on the right (Yandoc et al., 2004).

Combining pathogens and insects

Natural enemies (insects) are also weeds' controlling agents by feeding themselves on plants or when transmitting pathogens to plants (Blossey,1995). "The use of natural enemies is simple and does not imply high technology and is less disruptive ecologically (Blossey, 1995)." Control of some weeds such as leafy spurge using chemical herbicides did not show any interesting results, because these chemical were highly inappropriate. Therefore, the only alternative is to use a combine action of pathogens and insects to overcome that weed. This approach where pathogens and insects are combined result in more virulence on than some common methods such us regular use for fungi.

Fig6: Weeds-feedres (www.apsnet.org)

6. Bioherbicides and the future

Although, only few bioherbicides are available on the market, biological control technology will the leading approach to control weeds. As the use of chemical herbicides is less desired, because of their negative impact on crops, environment, ecosystem and human being, more funding need to be applied to encourage researches for bioherbicides.

7. Weeds' management.

Weeds' management requires the use of suitable technique and approaches to reduce economics expenses and an increase in crops productivity. In elaborating strategies to control weeds, one must take into account the type of weed in presence and define the most convenient controlling agent to be used. It is important to target vital elements that weeds need to live (water, nutrients, light).common weeds' management strategies include prevention, eradication and control.

8. Conclusion

The use of fungi, bacteria and insects to attack weeds will significantly reduce chemical herbicides in agricultural fields. These biological controlling agents are produce differently depending on fields' specificity. Although, very few biological controlling agents exist on the market this new approach will be the most valuable solution to meet agricultural regulations. As result, crops productivity will increase significantly with almost no damage to the environment. Crops quality will increase resulting in economic growth

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