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Le comportement des lianes adventices dans la culture de la canne à sucre à Maurice une approche biologique, écologique et agronomique

Azaad Gaungoo

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2 Place Viala, 34060 Montpellier, France

THESE

**Pour l'obtention du grade de
Docteur en Biologie Intégrative des Plantes**

Délivrée par Montpellier SupAgro

**Préparée au sein de l'Ecole Doctorale : Systèmes Intégrés en Biologie, Agronomie, Geoscience,
Hydroscience et Environnement**

Présentée par Azaad GAUNGOO

**GROWTH AND DEVELOPMENT HABITS OF VINE WEEDS IN
SUGARCANE FIELDS IN MAURITIUS: A BIOLOGICAL, AN
ECOLOGICAL AND AN AGRONOMIC APPROACH**

**LE COMPORTEMENT DES LIANES ADVENTICES DANS LA
CULTURE DE LA CANNE A SUCRE A MAURICE : UNE APPROCHE
BIOLOGIQUE, ECOLOGIQUE ET AGRONOMIQUE**

Soutenance le 19 décembre 2014 devant le jury composé de :

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To my parents

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ABSTRACT

Vine weeds are creeping, climbing and twining plant species that depend on neighbouring plants and objects for their support and development. This thesis reports on the findings from studies carried out on their ecology and distribution, and biology of germination and emergence in the sugarcane cropping system in Mauritius. The main objective is to understand the biological, ecological and agronomic interactions of the factors which influence the growth and development habits of vine weeds in sugarcane, with the aim of formulating sustainable management practices for their control.

Vine weed surveys carried out in sugarcane fields of small growers (area < 10 ha) and large estates (area > 1000 ha) in the three agro-climatic conditions of the island had revealed the occurrence of 26 species of vines, with more than 35% of them coming from the Convolvulaceae family. Although *Passiflora suberosa* was found to be the most frequent species, field observations had shown that *Ipomoea hederifolia*, *I. nil* and particularly *I. triloba* were the most troublesome. GIS mapping had shown they were present in distinct agro-climatic zones where mechanized green cane harvesting was practiced. It was also found that small growers tended to have fewer vine weed in their fields than those of the large estates.

The biology of germination and emergence of vine weeds, focused on *Ipomoea* spp., had firstly established, through laboratory investigations, the minimum temperatures required to initiate seed germination in six important vine weed species of sugarcane fields. These ranged from 7°C for *I. nil* and *I. obscura* to 17°C for *Cajanus scarabaeoides*, *I. hederifolia* and *I. quamoclit*; that for *I. triloba* was around 9.5°C. Secondly, tests conducted in fiberglass tanks under controlled conditions have shown that *I. hederifolia*, *I. nil*, *I. obscura*, *I. quamoclit* and *I. triloba* seeds were able to germinate and emerge from a depth of 12 cm in soil. This capacity was explained by their large-seeded property (10-21 mg per seed) and their ability to produce longer hypocotyls when found deeper underground. These capacities also enabled the seedlings to emerge through a sugarcane trash thickness of 5 cm. This layer of trash was also conducive to the germination and emergence of *Ipomoea* spp. seeds whereas thicker trash cover (> 10 cm)

suppressed them. Finally, field trials had shown that control of vine weed emergence in GCTB fields would either require application of specific herbicide combinations or appropriate trash management practices involving increased mulch on some interrows whereas cleared ones would be treated with pre-emergence tank-mixes.

The main implications of the above findings for the Mauritius sugarcane industry would involve a review of the timing of weed control practices with particular regard to the growth and development habits of vines. This would require new and innovative approaches when establishing management strategies. Hence, knowledge acquired on the ecology and distribution of vine weeds would enable a proper management of the different species in sugarcane fields through GIS mapping. A better understanding of their germination and emergence capacities would help to rationalize the use of pre-emergence herbicides and the mulching of sugarcane trash residue.

Keywords: infestation, vines, biology, development, interactions, trash blanket, agro-ecological conditions, twining ability, management strategies.

RÉSUMÉ

Les lianes adventices sont des espèces qui se développent en rampant jusqu'au moment où elles atteignent un support, par exemple les plantes cultivées, pour poursuivre leur développement en grimpant et/ou en s'enroulant autour de celles-ci. Cette thèse présente les résultats de différentes études ayant trait à l'écologie, la répartition, et la biologie de la germination et de l'émergence des adventices lianescentes dans la culture de la canne à Maurice. L'objectif principal étant de comprendre les interactions biologiques, écologiques et agronomiques qui influencent les comportements des lianes adventices dans la canne à sucre, afin de formuler des stratégies de luttés durables pour leur maîtrise.

Des relevés floristiques effectués dans des champs de cannes de petits agriculteurs (superficie < 10 ha) et de grandes exploitations (superficie > 1000 ha) dans les trois zones agro-climatiques de l'île ont démontré qu'il y a 26 espèces de lianes, dont plus de 35% appartiennent à la famille des Convolvulaceae. Même si *Passiflora suberosa* est l'espèce la plus courante, les observations au champ ont montré que *Ipomoea hederifolia*, *I. nil* et plus particulièrement *I. triloba* sont les plus abondantes. Grâce à la cartographie SIG, leur présence a été démontrée dans des zones agro-climatiques distinctes où la récolte en vert est mécanisée. Il a aussi été constaté qu'en générale, il y a moins de lianes adventices dans les champs des petits agriculteurs que dans les parcelles des grandes exploitations.

La biologie de la germination et de l'émergence des lianes adventices, concentré sur les espèces d'*Ipomoea*, a permis d'établir premièrement, à travers des études de laboratoire, quelles sont les températures minimales requises pour initier la germination des graines de six adventices principales des champs de canne. Celles-ci vont de 7°C pour *I. nil* et *I. obscura* à 17°C pour *Cajanus scarabaeoides*, *I. hederifolia* et *I. quamoclit*; celle de *I. triloba* étant d'environ 9.5°C. Deuxièmement, des tests effectués dans des bacs en fibre de verre sous conditions contrôlées ont montré que les graines de *I. hederifolia*, *I. nil*, *I. obscura*, *I. quamoclit* et *I. triloba* sont capables de germer et d'émerger à partir d'une profondeur de 12 cm dans le sol. Cette capacité est due à la grande taille de leurs graines (10-21 mg par graine) et à leur capacité à produire des

hypocotyles plus longs quand elles se trouvent enfouies plus profondément. Ces propriétés permettent aussi aux plantules de traverser une couche de paille d'une épaisseur de 5 cm. Cette couche de paille favorise aussi la germination et l'émergence de graines des espèces d'*Ipomoea* alors qu'une couche plus épaisse (> 10 cm) les réprime. Finalement, des essais au champ ont montré que la suppression de l'émergence des lianes dans des champs récoltés en vert sous paillis complet nécessite soit l'application de combinaisons spécifiques de produits herbicides, soit des pratiques de gestion incluant un mulch plus épais sur certains interlignes alors que les interlignes sans mulch doivent être traités avec des mélanges d'herbicides de pré-levée.

Les implications majeures de ces résultats pour la production cannière de Maurice nécessitent de revoir la période des actions de lutte contre les mauvaises herbes, avec une attention particulière portée au comportement de croissance et de développement des lianes. Ceci demande des approches nouvelles et innovantes par rapport aux stratégies de gestion. Ainsi, les connaissances acquises sur l'écologie et la répartition de lianes adventices doit permettre de mieux cibler la gestion des différentes espèces dans les champs de canne à travers une cartographie SIG. Une meilleure compréhension de leur germination et de leur capacité de levée aidera à rationaliser l'utilisation des herbicides de pré-levée et le mulch des résidus de paille de canne.

Mots-clés: infestation, vines, biologie, développement, interactions, paillis complet, conditions agro-écologiques, capacité volubile, stratégies de gestion.

GENERAL INTRODUCTION

Vines as weeds in agriculture

Weeds are one of the major impediments to crop development and productivity. They compete directly with crops for water, fertilizers and light. Man has therefore had to fight against them right from the day when he started to grow crops for food. Progress achieved since the advent of modern agriculture has allowed us to devise better techniques for weed control. In addition, access to scientific knowledge in agronomy and weed science has led to a better understanding of the various interactions between weeds and crops for more efficient and rational management. However, studies have also highlighted weeds ability to adapt and evolve in new situations in order to compete against cropped plants for their own survival. This is the case for vine weeds growing in tropical crops.

Vine weeds are creeping, climbing and twining plant species that depend on neighbouring plants and objects for their support and development. They have an extensive type of growth, making them fundamentally different from classical weeds which are generally more localised. The sprawling nature of vine weeds together with other biological traits makes their control difficult and ineffective in sugarcane, especially when the crop is tall. This seriously affects the crops, causing yield losses and/or restricting cultural operations. The competitive ability of vine weeds is therefore fundamentally different to general or classical weeds. Their competition strategies and their negative impact on the sugarcane crop were first reported in 1954 by (Thakar *et al.* 1954) in the framework of their study on the behaviour of *Ipomoea hederacea* Baker & Rendle. During the last five decades, a number of publications have reported on the issues of vine weeds in peanuts (Lancaster *et al.* 2005), wheat (Stone *et al.* 2005), sugarcane (Azania *et al.* 2002; Gaungoo 2010; Lebreton 2010; Viator *et al.* 2002), rubber (Alif 1992), cotton (Buchanan *et al.* 1971), maize (Messersmith *et al.* 1999), oil palm (Chiu *et al.* 2002, Chiu *et al.* 2004), rice (Gealy 1998), soya bean (Barker *et al.* 1984; Cordes *et al.* 1984; Norsworthy 2004; Norsworthy *et al.* 2002) and tea (Bhattacharya *et al.* 2001, Dutta 1977) across the world and more specifically in tropical regions.

The outcomes of the various research work show that *Ipomoea* species are more harmful for crops grown in the tropical and subtropical regions of America. On the other hand, *Mikania micrantha* Kunth is more invasive in South-East Asian plantations. These results also highlight the difficulties encountered in developing efficient methods for a better control of infestation by these species in different crops.

In sugarcane at Mauritius, vine weed infestations have been associated with green cane trash blanketing (GCTB). This agronomic practice results from mechanized green cane harvesting by chopper-harvesters which reduce the cane leaves into pieces and spreads them over the whole field, leaving the soil surface covered with a trash layer of 10 to 15 cm thick. The practice of GCTB has a number of agronomic benefits and it has been shown to be an economically and ecologically viable cultural operation (Morandini *et al.* 2005; Seeruttun *et al.* 1992). Thus GCTB is very effective in suppressing the emergence of most classical weeds leading to a reduction of herbicide use. However, it does not satisfactorily control certain species, particularly vine weeds, hence compromising this cultural practice (Azania *et al.* 2002, Correia *et al.* 2004, Manechini *et al.* 2005). Moreover, the ineffectiveness of GCTB on vine weeds results into severe infestations in the fields leading to a massive seed production, further aggravating the problem. The difficulties in properly identifying the problems linked to vine weeds in crops bring us to the general research questions:

What are the biological, ecological and agronomic factors that influence the development and spread of vine weeds in sugarcane cropping systems in Mauritius?

How can we act on these factors within the framework of rational cultural operations to repress the development of vine weeds?

The extent of vine weed infestations, particularly in agricultural environments, and the complexity of the processes that occur therein justify the adoption of a holistic approach. This is based on biological, ecological and agronomic studies to understand the growth and development habits of these species within cropping systems. The lack of knowledge and appropriate information to understand the interactions of these different factors in sugar cane

crops is a gap that needs to be filled in order to set up sustainable control strategies. Thus, the specific research questions can be spelt out as follows:

- **How do the growth and development habits of these vine species currently allow them to proliferate in the current sugarcane cropping system?**
- **Which biological, ecological and agronomic factors influence the development of vine species in sugarcane fields?**
- **How to take into account holistically the knowledge acquired to devise adequate control strategies against vine weeds problems?**

From these research questions, we elaborated several hypotheses. The hypotheses of this research are based on the «weed-crop ecosystem» model, as outlined by (Aldrich 1984) (Fig I). The latter conceives the agricultural system as composed of four interdependent factors, namely the crop, the weeds, the natural environment and anthropogenic activities. The interaction among these different components of this system gives rise to agro-ecological conditions which influence crop and weed development. The increasing vine weed infestations in sugarcane fields is showing that current available control methods are not managing the problem effectively. Knowledge on the ecology and the biology of the species will be needed as ‘weed management’ techniques are developed, while taking into account the complexities of the agricultural environment (Fig II).

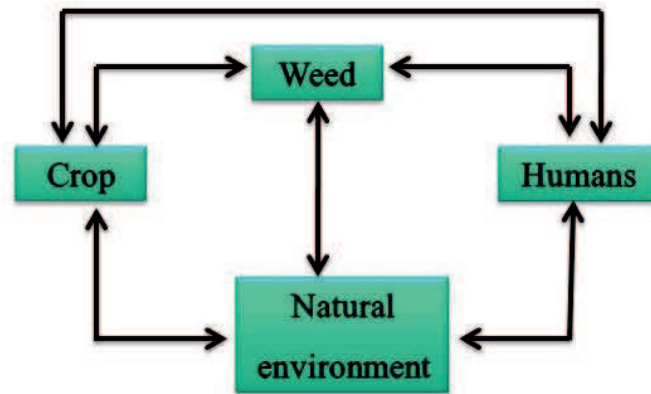


Figure I 'Weed-crop eco-system' (Aldrich 1984)

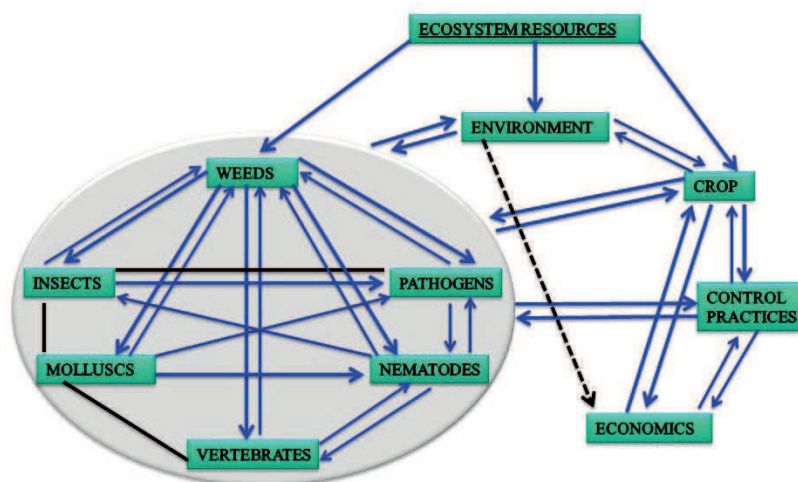


Figure II The interaction among weeds and other components of the agricultural production system (Norris 2005; Norris *et al.* 2000)

In the framework of this study, the general hypothesis being put forward is that vine weeds are benefiting from an advantage at the expense of the crop following an imbalance in the interdependency of the different factors (Fig. I). It is specifically assumed that:

Hypothesis 1

Vine species demonstrate biological traits which allow them to better exploit the new environmental conditions, making them more competitive against other plants that grow along.

Hypothesis 2

Anthropogenic activities associated with changes in cultural practices in a specific environment give rise to new agro-ecological conditions which would favor the development of vine species in sugarcane cropping.

The main objective of this PhD study is

to understand the interactions between biological, ecological and/or agronomic factors which influence the growth and development habits of vine weeds in sugarcane cropping systems, the aim being to devise sustainable strategies for their control.

This general objective is sub-divided into several specific objectives which involve

1. Identifying the main vine weeds in the sugarcane crop in Mauritius
2. Determining the agronomic and abiotic factors which influence vine weed distribution
3. Creating a GIS database on the spatial distribution of vine weeds in the sugarcane crop in Mauritius
4. Demonstrate the germination and emergence capacities of vine weed seeds buried at different soil depths
5. Demonstrate the capacities of vine weed seeds to germinate and emerge through various thickness of postharvest sugarcane trash mulch
6. Determine the minimal temperature requirement for germination of the main vine weed species of sugarcane fields

The manuscript of this PhD thesis is organized into four chapters in order to understand the growth and development habits of vine weeds in the sugarcane crop in Mauritius, namely

(i) ***Context of study***

The first chapter will describe the agronomic and ecological context where this study will take place. Information will be provided about the cultural practices of sugarcane, and the weed flora and control methods will be detailed.

(ii) ***Ecology and distribution of Vine Weeds***

Vine weed surveys will be carried out in sugarcane fields found in the three agro-climatic zones of Mauritius among the two main categories of sugarcane growers, namely the small (< 10 ha) and the large growers (> 1000 ha).

(iii) ***Biology of Germination and emergence of Vine Weeds***

This chapter will consist of four sub-chapters that will deal with the following aspects centered on the biology of germination and emergence of *Ipomoea* spp in order to demonstrate their various capacities with regards to the

- (a) Influence of temperature
- (b) Effect of sowing depths
- (c) Mulching effect of sugarcane trash
- (d) Post-harvest trash management studies

(iv) ***General Discussions, Agronomic Considerations and Perspectives***

The results in the above chapters will be discussed in relation to the various agronomic practices undertaken in sugarcane cropping.

1 Chapter 1

CONTEXT OF THE STUDY

1.1 Vine weeds

Vines are plant species that grow by producing flexible, climbing stems. They are thus solely dependent on their environment for support in order to achieve the optimal development for light interception. As a result, they are either creepers at ground level or climbers on existing supports. The ability of vines to creep or climb to optimize the use of space during their growth is specific to this group of plants, allowing them to develop in an efficient manner. Furthermore, some botanical families possess metamorphic organs such as tendrils, adhering roots and thorns, which increase their climbing ability to better compete with the surrounding vegetation. Other species, such as those belonging to the Convolvulaceae family, are even better at applying this strategy in spite of the lack of these morphological characteristics, due to their capacity to twine around their supporting structure in search of more favorable growth conditions.

Vines can be differentiated into two distinct classes according to the histology of their stems (Gentry 1985). The first class consists of all the species whose mature stems are mainly made up of supporting tissues (sclerenchyma), which later develop into wood. The diameter of these so-called lianas generally exceeds 1 cm and they are very frequent in equatorial and tropical forests (Gerwing *et al.* 2006; Schnitzer *et al.* 2008). They contribute in a number of ways to the diversity and dynamics of these ecosystems; there has been an increasing interest for the ecology of these species in the last few years (Schnitzer *et al.* 2006).

The second class is characterized by smaller stem diameter, < 1 cm, and where the species are often herbaceous but sometimes semi-ligneous (Gentry 1985). This type of vine is frequently found in habitats disturbed either by natural phenomena or human activities – river banks, abandoned lands, hedges and agricultural environment. Most of these species are characterized by fast and invasive growth habits, leading to environmental problems that are difficult to manage (Chiang *et al.* 2002a; Feng *et al.* 2002a). Thus, given the right climatic conditions, they rapidly produce significantly more biomass, at the expense of other plants. In

natural or secondary environments, the establishment of a specific, dominant vine population leads to a loss of vegetation diversity. The increasing importance of this second class of vines in crops, particularly sugarcane (Bhullar *et al.* 2012; Lebreton *et al.* 2009), gives rise to economic and agronomic problems that are difficult to manage. Managing vine weeds in large agricultural holdings for long cycle crops found particularly in tropical regions is becoming a difficult task. The problems are linked to the specific biological characteristics of these plants, which develop in a very different manner compared to other weeds growing in cropped environments (Lebreton 2010).

1.2 Geographical and agronomical context

1.2.1 The island of Mauritius

Mauritius was discovered on 20 September 1598 when a Dutch fleet under admiral Wybrandt van Warwijk sighted the uninhabited island in the course of a journey to India. It is a small volcanic island which emerged in the south-west Indian Ocean about 8 million years ago. It is located around 850 km east of Madagascar at latitude 20°15' S and longitude 57°30' E. Measuring roughly 60 km long and 40 km wide, Mauritius covers an area of 1 872 km² with its highest peak culminating at 828 m above sea level. Its topography is characterised by a coastal plain rising gradually towards a central plateau bordered by mountain ranges.

Mauritius is situated in the inter-tropical zone and subject to the north-west monsoons between approximately November and May. This season is characterised by hot conditions with frequent cyclonic weather bringing heavy rain and severe storms. The winter months between approximately June and October are characterised by cooler drier weather and dominated by the south-east trade winds. The mean daily temperature ranges from about 22 °C in the upland to 28 °C on the coast in summer and 16 °C to 22 °C in winter (Fig 1.1). The island receives a mean annual rainfall of 2,010 mm which ranges from 750 mm on the leeward coast to 4,350 mm on the highest grounds (Padya 1989; Willaime 1984).

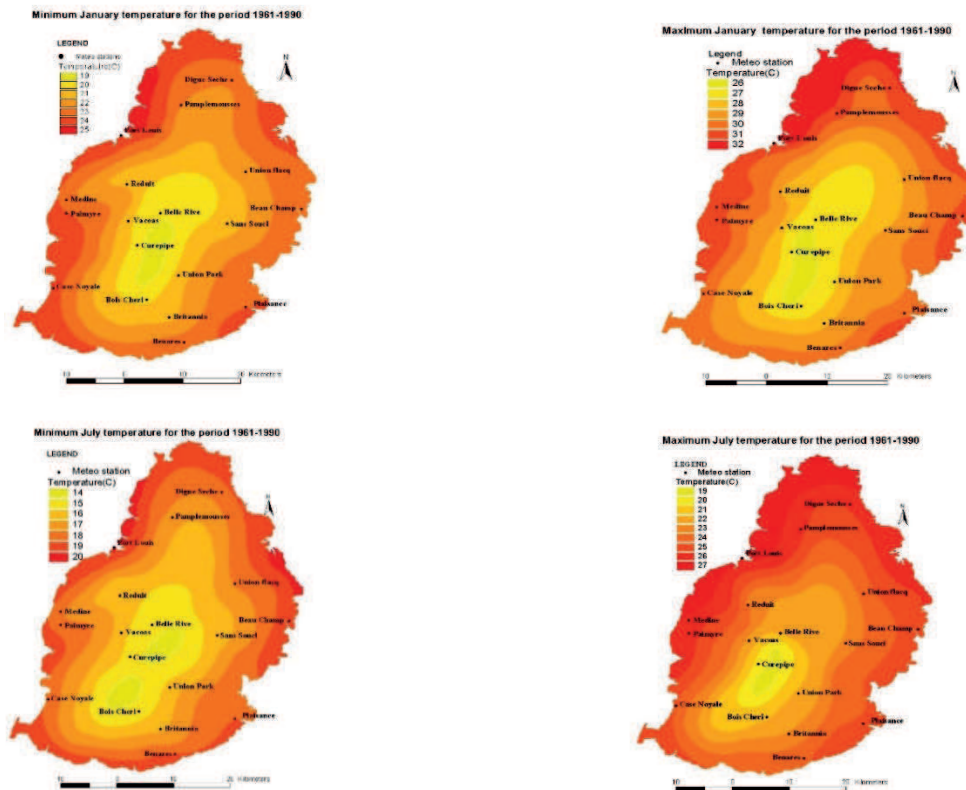


Figure 1.1 Seasonal temperature in Mauritius for the period 1961-1990 (Source: MSIRI GIS Lab)

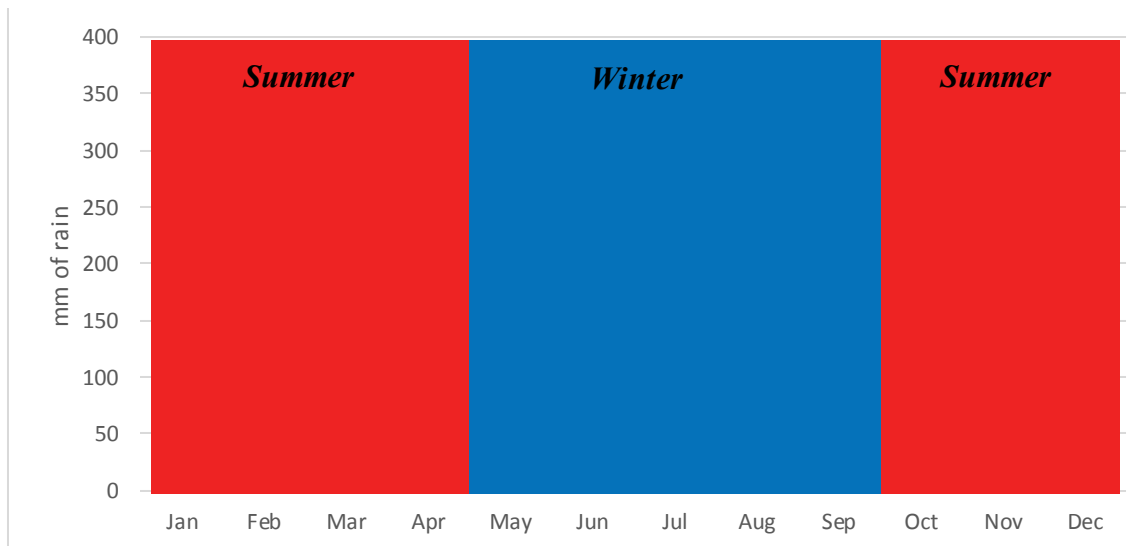


Figure 1.2 Long term mean (1971-2000) monthly rainfall in Mauritius

Moreover, two-third of the yearly precipitation is obtained in the summer months, particularly from December to April (Fig. 1.2). The characteristic topography further dictates the rainfall distribution across the island, resulting in the division of three distinct agro-climatic zones. The sub-humid zone receives less than 1500 mm of rain, the humid zone 1500–2500 mm whereas the super-humid zone obtains more than 2500 mm (Fig. 1.3).

In addition to the typical topography and rainfall distribution, each agro-climatic zone is characterized by different soil types. This information is well documented in the soil map of Mauritius which Parish and Feillafé produced in 1965. The map has a scale of 1:100 000 where they classified the soils of Mauritius within homogeneous groups characterised by an area of fairly uniform climate and topography. Sugarcane cultivation is carried out in the five main soil groups below (Fig 1.3):

- L - Low Humic Latosols: a silty clay to silty clay loam texture with kaolinite as dominant mineral. This soil group covers approximately 16% of the island.
- H - Humic Latosols: clay texture consisting of equal quantities of kaolinite, goethite and gibbsite, and covers some 5% of the total area.
- F - Humic Ferruginous Latosols: strongly weathered soil occurring in the high rainfall regions and are rich in organic matter. The clay fraction is mainly gibbsite and goethite, with little kaolinite. This group is present on approximately 11.4% of the island.

SOIL MAP OF MAURITIUS AND SUGAR MILLS (2013)

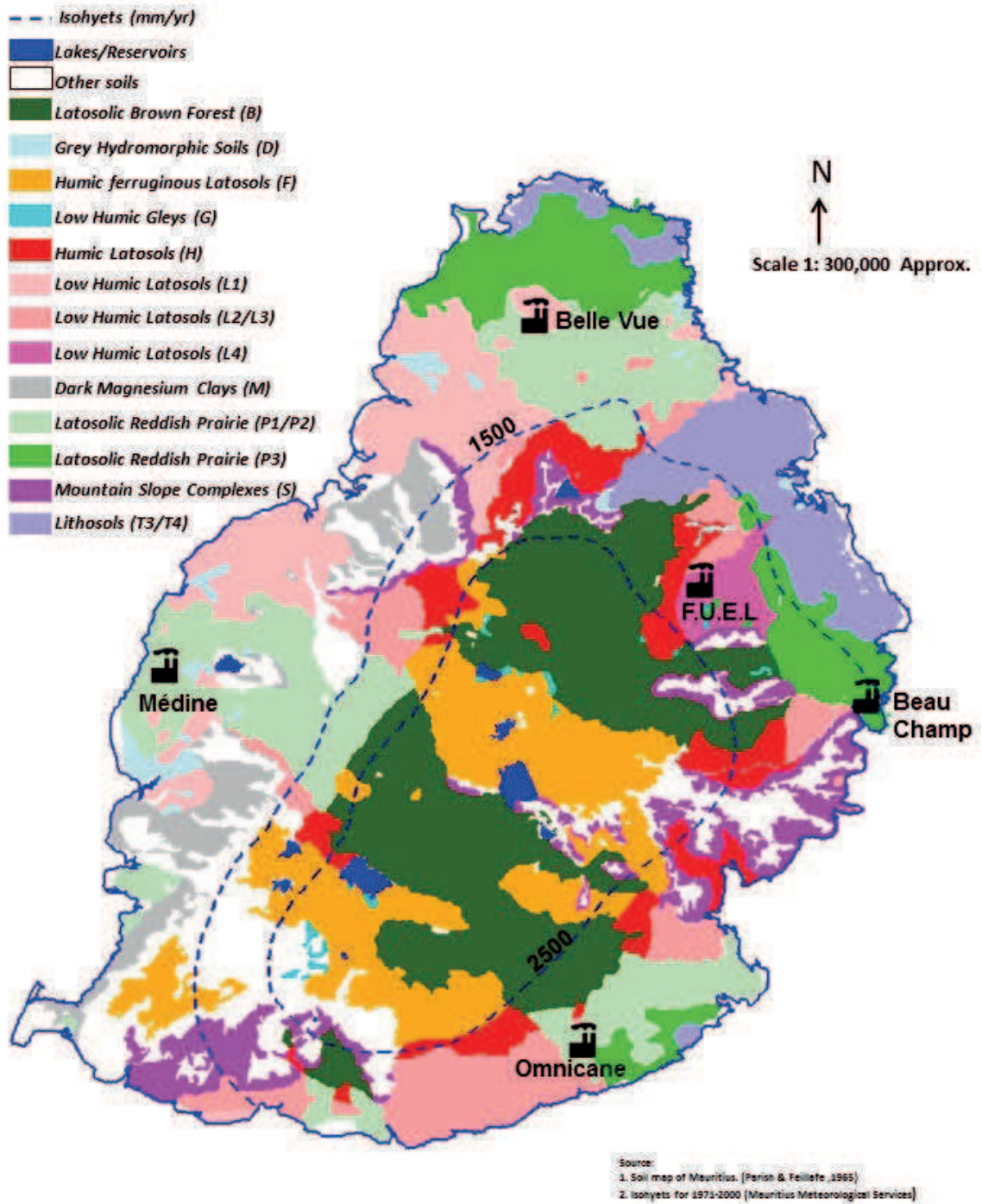


Figure 1.3 Agro-climatic soil map of Mauritius according to (Parish *et al.* 1965)

- P - Latosolic Reddish Prairie: soil group found in lower rainfall areas and the texture varies from clay loams to silty clays. The clay fraction is dominantly kaolinite and this group covers some 20% of the total area of the island.
- B - Latosolic Brown Forest: the texture of the B soils varies from clay loams to clay. The clay fraction has lesser amounts of kaolinite and more gibbsite and goethite. This soil group is present on 17% of the island.

The combined effect of rainfall and temperature also leads to numerous micro-climates which together with soil types create complex ecological conditions, thus determining the types of vegetation which develop in the specific zone. The development of the natural vegetation is greatly disturbed every year by the occurrence of tropical cyclones during the summer months, with winds exceeding 120 km hr^{-1} , and which also represent a severe threat to the island and its agriculture.

1.2.2 Sugarcane: Introduction and cultivation in Mauritius

Sugarcane (*Saccharum* spp. L.) is a large perennial grass of the tribe Andropogoneae, family Poaceae (Roach *et al.* 1987). Known to be one of the oldest cultivated plants in the world, sugarcane has been intensively hybridised and selected for its ability to accumulate sucrose (Alexander 1973). Modern commercial varieties of sugarcane are derived from complex interspecific crosses between the wild canes (*S. spontaneum* L.) and the noble canes (*S. officinarum* L.).

The Dutch first settled the island in May 1638 and introduced sugar cane on 8 November 1639 when the “*Cappel*” brought the first plants from Batavia (North Coombes 1993; Rouillard 1989) They also established two sugar processing plants in 1641 (Koenig 1988), but by 1652 the manufacture of sugar was abandoned. However, the cultivation of sugarcane was continued for the production of ‘arrack’ (an alcoholic beverage similar to rum). The Dutch left the island in 1710 and during the French occupation (1721–1810), great impetus was given to sugarcane production and the first sugar factories were created; some 3 000 tons of sugar and

300 000 gallons of arrack were produced by the beginning of the 19th century. The British captured the island in 1810 and realized that sugar production could be the greatest asset of Mauritius; as a result the area under cane increased steadily and reached 11 000 ha in 1825. The island was already producing some 107 000 tons of sugar in 1854. The sugar industry has since undergone further expansion through increased acreage of sugarcane and significant technical progress due to research and development.

The country recorded its maximum sugar production in 1973 when 718 464 tons were yielded from a cultivated area of 87 384 ha (Koenig 1988). Since then, owing to the conversion of cane land to other uses and small-growers abandoning their production due to increasing costs, average production has been falling from 706 839 tons in 1986 to 435 300 tons in 2011 (MSIRI 2012b). The current area under cane is less than 62 000 ha (MSIRI 2012a). The decrease in area and production has been faster within the last five years as more lands have been converted to other new emerging sectors such as manufacturing (mainly textile), the information and telecommunication technologies (ICT) and integrated resort schemes (IRS).

1.3 Sugarcane cultural practices

Sugarcane is usually propagated by planting portions of the stems, called cuttings or setts; each of which usually has three to five buds (STASM 2003). The setts are planted in furrows approximately 0.15 m deep and spaced between 1.30 m and 1.62 m. The total number of setts varies between 25 000 to 30 000 per hectare, representing between 6 and 9 tons of planting material. Cane is ideally planted when both optimum temperature (25-30 °C) and soil moisture are present (Van Dillewijn 1952). Germination of the buds (primary shoots) starts a few days after planting and secondary shoots, called tillers, are produced a few weeks later (tillering phase). Shoots start to elongate while in the tillering phase; peak tillering is reached between 22 to 36 weeks and is followed by suppression of excessive tillers. The final number of cane stalks (millable stalks) is a characteristic of the variety; Mauritian varieties reach the harvesting stage with 80 000 to 100 000 millable stalks per hectare. Under favourable conditions, sugarcane can produce more than 200 t ha⁻¹ of total biomass of which 70% to 80%

would consist of millable cane stalks. The elongation phase is overlapped and followed by the cane maturation phase. Cane maturation is favoured in winter when cane growth is slowed and the lower night temperatures and dry conditions enhance sucrose accumulation. In Mauritius, the average cane and sugar yields were 74.7 t ha⁻¹ and 9.05 t ha⁻¹, respectively, in 2011 (MSIRI 2012b).

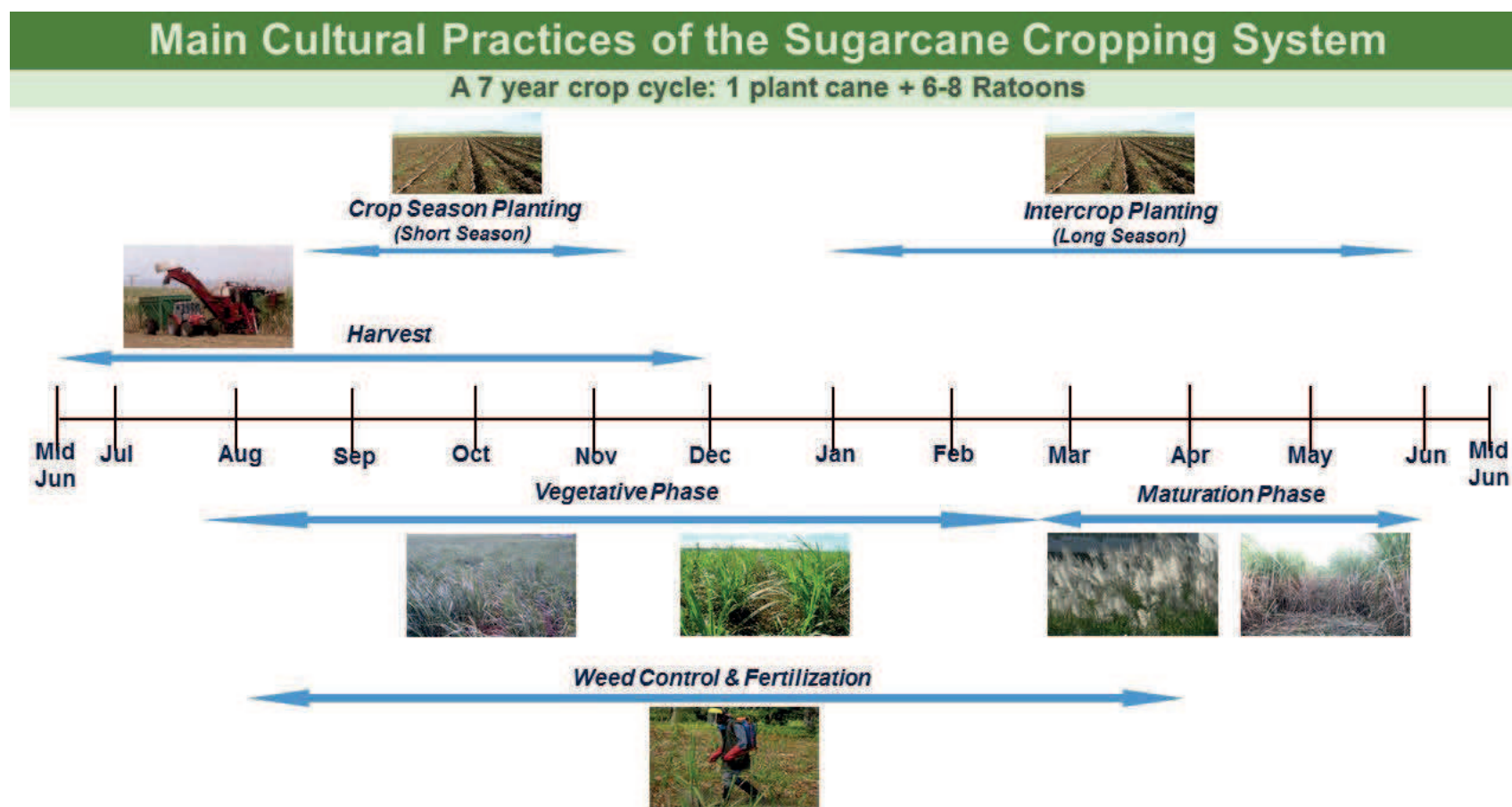


Figure 1.4 Yearly pattern of the main cultural operations practiced by most sugarcane growers in Mauritius.

The different cultural operations of cane husbandry that are generally practiced by all sugarcane growers in Mauritius take place according to a definite pattern during the year (Fig. 1.4). Harvest extends from June to December; the plant cane is usually harvested after undergoing development for 12 to 14 months (short season: crop season planting) or 16 to 20 months (long season: intercrop planting) (STASM 1990). The ratoon crop (cane regrown from stools left after the previous crop was harvested) is normally harvested every 12 months over a period of 6–8 years.

Weed control is the main operation after planting or harvest, representing around 8% to 15% of the total cost of production. Weeds are controlled mainly using recommended herbicide mixtures, handweeding being restricted for very specific tasks due to labour shortage and its high cost. The standard practice of weed control in Mauritius has been the application of a pre-emergence herbicide in the weeks following harvest (ratoons). But nowadays, with the availability of more effective pre/post-emergence tank-mixes, growers tend to delay the first spraying until there are enough weeds present before they can apply the required herbicide mixtures that will provide maximum post-emergence and pre-emergence control. New crops established in the short and long seasons (virgin cane) receive pre-emergence herbicide treatments that are applied just after planting. However, in both ratoons and newly planted fields, a single herbicide application is generally not enough as the long period of sugarcane growth before complete crop canopy formation may result in the crop being exposed to several flushes of weeds. A second herbicide application consisting of a post-emergence tank-mix is therefore needed some 10 to 12 weeks after the first spraying; occasionally a third one, with the same post-emergence effect, or some manual weeding may be required (Fig. 1.5).

The different herbicide treatments that are applied in the various crop situations are listed in Appendix 1. These treatments have been recommended by the MSIRI after they have undergone several tests. Actually, more than 130 herbicide molecules have been tested in sugarcane during the last 60 years and some 31 of them (Table 1.1) have been recommended for commercial use.

Months after planting or harvest	1	2	3	4	5	6	7	8	9	10	11	12						
Plant cane	<table border="1" style="width: 100%; text-align: center;"> <tr> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">1st spraying (Pre-em)</td> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">2nd Spraying (Post-em)</td> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">3rd Spraying (Post-em) /manual weeding</td> </tr> </table>												1st spraying (Pre-em)	2nd Spraying (Post-em)	3rd Spraying (Post-em) /manual weeding			
1st spraying (Pre-em)	2nd Spraying (Post-em)	3rd Spraying (Post-em) /manual weeding																
Ratoon cane	<table border="1" style="width: 100%; text-align: center;"> <tr> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">1st spraying (Pre-em)</td> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">OR 1st spraying (Pre/post-em)</td> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">2nd spraying (Post-em)</td> </tr> <tr> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">Manual weeding</td> <td style="width: 33%; height: 40px;"></td> <td style="width: 33%; height: 40px; background-color: #4CAF50; color: white;">3rd Spraying (Post-em) /manual weeding</td> </tr> </table>												1st spraying (Pre-em)	OR 1st spraying (Pre/post-em)	2 nd spraying (Post-em)	Manual weeding		3rd Spraying (Post-em) /manual weeding
1st spraying (Pre-em)	OR 1st spraying (Pre/post-em)	2 nd spraying (Post-em)																
Manual weeding		3rd Spraying (Post-em) /manual weeding																

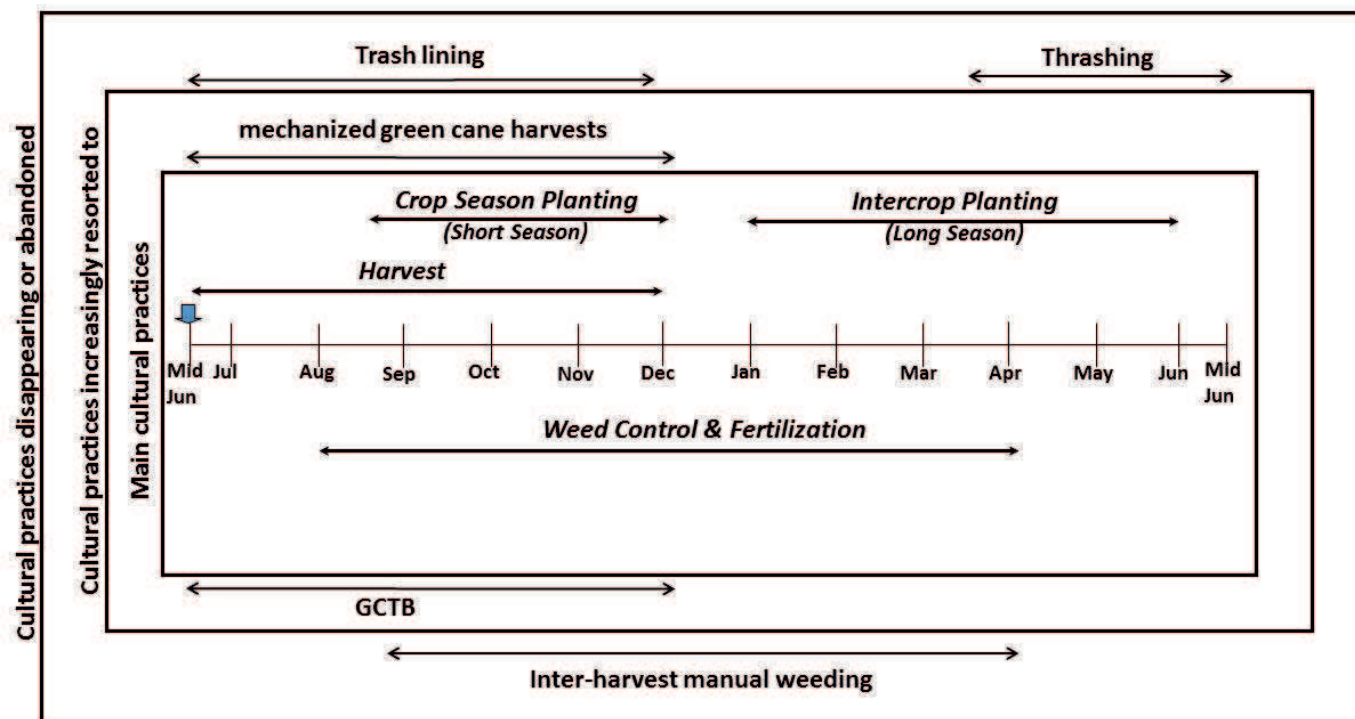
Fig. 1.5 Timing of weed control and herbicide applications in sugarcane. In some situations, the 3rd spraying is not required, a mere manual weeding can keep the field clean up to harvest.

Table 1.1 Herbicide molecules recommended and used in sugarcane in Mauritius*. The various mixtures and their rates are presented in details in Appendix 1.

Period recommended	Herbicides	
	Pre-emergence	Post-emergence
1950 - 1959	diuron	TCA, MCPA, 2,4-D derivatives, sodium chlorate
1960 - 1969	atrazine	picloram, paraquat
1970 – 1979	metribuzine, hexazinone, linuron	2,4-D ester + ioxynil, asulam, glyphosate
1980 – 1989	acetochlor, metolachlor, oxyfluorfen	
1990 – 1999	tebuthiuron	glufosinate-ammonium, triclopyr, halosulfuron, metsulfuron methyl
2000 – 2009	sulfentrazone, diclosulam, isoxaflutole, amicarbazone, mesotrione + s-metolachlor + ametryne	terbuthylazine + bromoxynil, fluroxypyr, ametryne + trifloxysulfuron
2010 - 2014	saflufenacil + dimethenamid-P	imazapyr

* Sources: Rochecouste (1967), MSIRI Recommendation Sheets 1981-2013 (www.msiri.mu).

Application of fertilizer is carried out in furrows at the time of planting in short and long season plant cane whereas in ratoon this is performed in the weeks following harvest. The main cultural practices were previously complemented with subsidiary crop husbandry operations that were labour intensive and they included thrashing, trash lining and inter-harvest manual weeding (Fig. 1.6). Over the years, due to labour shortage and its high cost, these have been gradually left out to make room for more economically mechanized operations.



(1) The time scale starts at mid-June and coincides with the beginning of sugarcane harvest (blue arrow). (2) The scale completes one calendar year and ends in June of the succeeding year. (3) The inner box encloses the main cultural practices that are presently performed by all sugarcane growers. (4) The outer box highlights the cultural practices that are gradually being left out whereas mechanized green cane harvest and GCTB (Green Cane Trash Blanketing) are gradually being resorted to (intermediate box).

Figure 1.6. Changes in the sugarcane cultural practices in Mauritius.

However, the cultural practices of sugarcane vary according to agro-climatic conditions and the level of field mechanization. The latter is directly related to the size of the estate of the grower: the bigger the size, the more adapted it is for mechanization (Refer to chapter 2 for a definition of the different categories of sugarcane growers present in Mauritius). Therefore large growers have a higher level of mechanized operations than the small ones and can resort to the new cultural practices more easily. On the other hand, small growers have to rely on manual labour for cropping sugarcane in their fields which vary from 0.5 to 10 ha in size. They also depend on family labour to make the cane growing activity economically viable and this allow them the possibility to still practice some of the operations like thrashing, manual weeding and trash lining.

There has been considerable progress with mechanization of cultural practices, particularly harvest, during the last two decades among large growers; more than 20 000 ha (representing around 33% of the total surface of production) were harvested mechanically in 2011 (MSIRI 2012b), a large proportion of which (>85%) was in green (Fig 1.7). Mechanized harvesting is considered as one of the reasons for direct and indirect reduction in cane productivity in recent years because this operation results in more plant material being left in the fields than with hand harvesting. The machines also cause some physical damage on the cane stools and harvesting under humid conditions increases the risk of soil compaction.

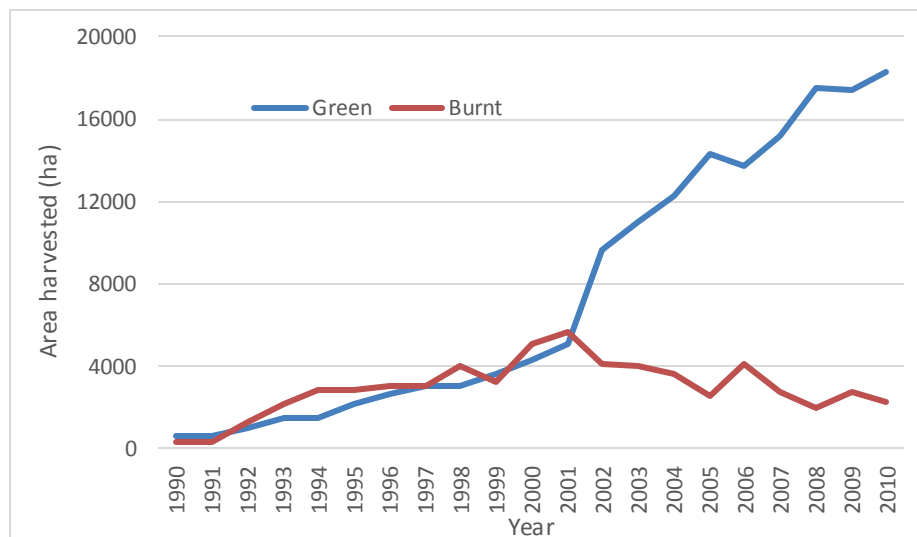


Figure 1.7 Trend in the area (hectare) under green and burnt cane mechanized harvests

The agro-ecological conditions prevailing in Mauritius for sugarcane cropping results in weed control being one of the most important cultural practices of sugarcane. The length of

its growing period allows the development of several flushes of weeds before cane canopy formation helps to suppress them by causing shading of the interrow space. For plant cane, canopy closure occurs between 18 and 28 weeks after planting, depending on growth conditions (agro-climatic conditions). For ratoon cane, as tillering and elongation start earlier, canopy closure is reached between 12 and 24 weeks after harvest (Van Dillewijn 1952). This depends on the dates of harvest, it is shorter for late harvest (October-December) due to favourable temperature and rainfall conditions that prevail afterward whereas it is longer for early harvest (June-July) as a result of the cooler period of winter. The different changes in cultural practices throughout the history of sugarcane (De Sornay 1936; Ismael *et al.* 2008) have greatly influenced the weed flora.

1.4 Weeds flora: Composition, distribution and control practices

The pristine vegetation of Mauritius by the end of the 16th century consisted mainly of native palm and lataniers trees growing along woody species that have evolved over thousands of years and densely populated the island (Rouillard *et al.* 1999). This was noted by the very first visitors: *'The soil is extremely rocky but fertile as can be judged from the large number of trees which are so close to each other that one can hardly walk in the forest'* (Van Warwick 1601 cited in Vaughan and Wiehe 1937). Man's activity during the Dutch settlement (1598-1710) eventually and irreversibly disturbed the habitats when he introduced animals and other plant species to meet his needs. The cultivation of sugarcane and other crops created agro-ecological conditions for the development of a local weed flora composed mainly of exotic species. Agricultural activities associated with sugarcane cropping were further intensified under the French (1721-1810) and British (1810-1967) colonizations (Rouillard, *et al.* 1999). This process along with the recurrent movement of people from African and European continents, Madagascar, India and China added to increase the momentum of weeds introduction and their proliferation in various agricultural habitats of Mauritius. Nowadays, over one hundred and fifty alien weed species have been identified in cropped fields, one hundred of which are directly linked with sugarcane production (Le Bourgeois *et al.* 2008).

The distribution of these weeds is greatly influenced by edaphic factors and rainfall. During three and a half centuries, sugarcane cropping has undergone various agronomic changes in order to optimize its production. Weed control is a cultural practice that has

contributed to cane yield increase. This used to be a manual practice until the introduction of herbicidal products at the end of the 1940's (Roche Couste 1967). Chemical weeding has gradually replaced hand weeding which had become very expensive, and at present, almost all the 62 000 ha under cane cultivation in Mauritius (MSIRI 2012a) is sprayed at least once with herbicides.

Some weeds are more specific to certain regions whereas others may be found growing in all climatic zones. For example, *Cyperus rotundus* L. and *Cynodon dactylon* (L.) Pers., which are considered as two of the world's worst weeds (Holm *et al.*, 1977), grow under all agro-climatic conditions of the island. On the other hand, species such as *Drymaria cordata* (L.) Willd and *Colocasia esculenta* (L.) Schott are mostly found in the superhumid areas whereas *Panicum maximum* Jacq. are adapted to the humid and subhumid zones. However, some weeds have developed a wider adaptation with time; e.g. *Digitaria horizontalis* Willd var. *porrantha* (steud.) Henr., which was known to be particularly adapted to the high rainfall areas, is now also found growing in lower rainfall areas. The competitive effect of weeds also varies with the season; e.g. *C. rotundus* is more competitive during the summer months, and then particularly in the lowlands.

For weed control purposes, weeds are usually grouped into three broad classes, namely: broad-leaved weeds, grasses and sedges (Colvin, 1980). Grasses are more troublesome to control in sugar cane due to the difficulty of achieving good selectivity from available herbicides. This was confirmed in a survey carried out (unpublished data) in 2004 among the large sugar cane producers, and covering an area of 48 000 ha, where eight grasses were listed among the ten weeds identified by the growers as difficult to control. These eight grass weeds were *Brachiara eruciformis* (J.E.Sm) Grisab, *C. dactylon*, *D. horizontalis*, *P. maximum*, *Panicum subalbidum* Kunth., *Paspalum paniculatum* L., *Paspalum urvillei* Steud and *Digitaria timorensis* (Kunth.) Balans. The other two weeds listed were *C. rotundus* and *Ageratum conyzoides* L. The grass weed *P. maximum* is mostly found at lower altitudes and is controlled principally at planting and with localised application of glyphosate. Similarly, *B. eruciformis* is largely found in the warmer and drier parts of the island. Furthermore, *P. subalbidum* has emerged as an important weed in the humid zone after not being controlled by the standard herbicide treatments applied between 1985 and 1995 but a change in the treatments thereafter has brought satisfactory control.

As from 1952, the use of herbicides, mainly hormone-based types, led to a progressive evolution in the weed population in favor of annual and perennial grasses (Rochecouste 1967), as well as tolerant monocotyledons and dicotyledons. The introduction of new herbicidal molecules such as triazines, substituted ureas, glyphosate, fluroxypyr and more effective pre-emergence herbicidal molecules have subsequently brought the control of a larger spectrum of weeds in the field (Mc Intyre *et al.* 1988; Mc Intyre *et al.* 1980a; Mc Intyre *et al.* 1980b; Mc Intyre *et al.* 1983; Mc Intyre, 1995; Barbe *et al.* 1997; Seeruttun *et al.* 2005, Seeruttun *et al.* 2007; Seeruttun *et al.* 2008). However, the changes that the sugarcane industry have experienced over the last twenty years have created new agro-ecological conditions and other weed species have been noted to become more troublesome. These include large-seeded species like some of the vine weeds, *Litsea monopetala* (Roxb.) Pers., *Hibiscus surattensis* L., *Rottboellia cochinchinensis* (Lour.) W. Clayton or a few semi-woody plants namely *Clidemia hirta* L. and *Eupatorium pallescens* DC.

1.5 Socio-economic changes in the sugarcane industry

Sugarcane cultivation in Mauritius has experienced constant socio-economic changes since it was cultivated by the Dutch as from 1639 (Rouillard *et al.* 1999; Lamusse 2011). The sugar industry has gone through an important evolution since the beginning of the 1980's. Various socio-economic and political changes have taken place to maintain the competitiveness of this sector on the international market following the European Union's decision to terminate the sugar protocol (Berkum *et al.*, 2005). Thus, several agronomic practices have had to be reviewed and mechanization has been promoted in order to reduce production costs (Ministry of Agriculture Food Technology and Natural Resources 2001, Ministry of Agro-Industries and Fisheries 2006). With the reduction in manpower (Fig 1.8) and the high costs of weed control, it was important to optimize herbicide use with the development of a new philosophy in 'weed management' (Seeruttun *et al.* 2008).

The changes that occurred during the last two decades have given rise to new agro-ecological conditions which have greatly influenced the weed flora in sugarcane fields. The surveys of species from the years 1950 and 1980 (Rochecouste 1967; Mc Intyre 1991) show that *Paederia foetida* L. and to a lesser extent *Passiflora suberosa* L. were the main vine weeds and that they were found occasionally in sugar cane fields. At that time, these species which

reproduce essentially in a vegetative manner could be easily controlled. The vine weeds that have become a cause for concern during the last decade (Le Bourgeois *et al.* 2008) actually multiply by seeds, which allow them to spread rapidly in the field. Species of genus *Ipomoea* have become particularly aggressive and are poorly suppressed by current control methods.

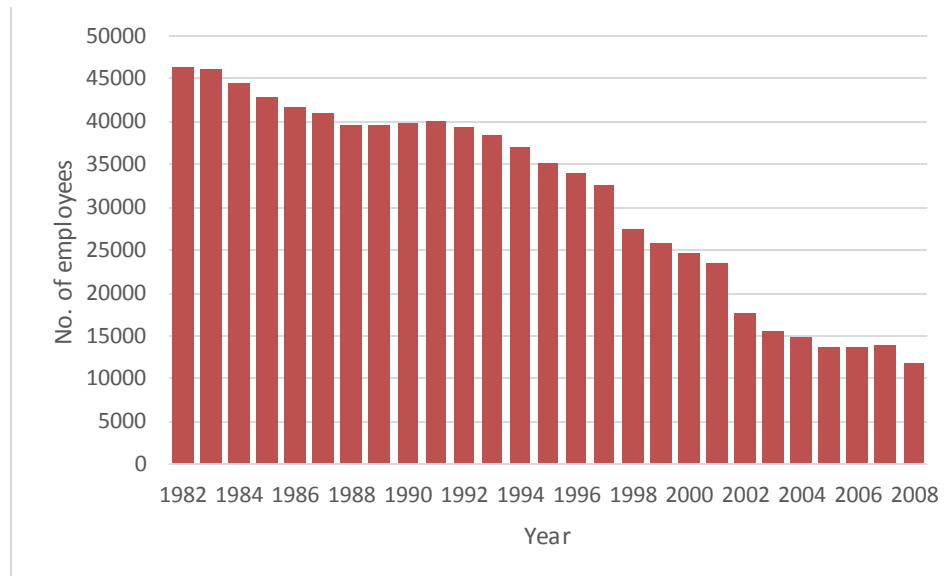


Figure 1.8 Reduction of employment in the sugarcane industry; manual labour represents a large proportion of the data and it is much involved in field operations, particularly handweeding of difficult weeds. (Source: Reports Mauritius Chamber of Agriculture 1982-2008)

1.6 Current status of vine weed problems in sugarcane fields

The issue of vine weeds within cropping systems is not a recent one; in 1954, Thakar and Singh reported that *I. hederacea* infestations were causing losses of 20-25% in sugar cane in the region of Pusa in Bihar (India). This species would entwine itself around several stems, leading to cane lodging and upper stem breakages, impacting on their development and causing obstructions to harvest. Several reports from Australia note that infestations by vine weeds in sugar cane and their ability to emerge through trash blankets from September to February were serious problems (BSES 1989; Calcino 1986; Shannon 1999). In Louisiana (USA), *I. coccinea* L. is the most common species in sugar cane fields, competing severely with the crop and leading to possible yield losses of the order of 30% over one season (Jones 2006; Millhollon 1988).

Studies from Brazil have shown that the mulching of sugarcane trash consisting of 9-15 t ha⁻¹ dry matter do not affect the emergence of *Ipomoea* spp., whereas a cover of 20 t ha⁻¹ dry matter was not enough to totally prevent the plantlets of these species from emerging in the fields (Azania *et al.* 2002; Manechini *et al.* 2005). In Mauritius, seeds of *I. obscura* (L.) Ker Gawl and *I. triloba* L. were able to emerge from a depth of 8 cm in the soil while the emergence of *I. nil* (L.) Roth was reduced beneath 4 cm (Gaungoo 2010). These trials have also shown that a trash layer 5 cm thick (14±1.5 t ha⁻¹ dry matter) promotes the germination and development of *Ipomoea* spp. seeds found on the soil surface.

The species *M. micrantha* is currently the most common vine weed in the natural and agricultural habitats of South-East Asian countries, particularly in China, Taiwan, Indonesia and Malaysia (Chee *et al.* 1993; Chiang *et al.* 2002b; Chiu *et al.* 2004; Feng *et al.* 2002b, Hsu *et al.* 2003, Huang *et al.* 2000, Lian *et al.* 2006). This species develops in an aggressive and invasive manner, causing important damages in natural environments and severely restricting agricultural production (finding a means to mitigate infestations by this species remains one of the major concerns of the weed agronomists from these countries).

Most vine weeds competing with crops across the globe produce large numbers of generally big fertile seeds, except for some species such as *Cynanchum callialatum* Buch.-Ham. ex Wight, *M. micrantha* and *P. suberosa*. Factors associated with the germination and emergence of these seeds have been the subject of a number of studies (Gaungoo 2010; Gomes *et al.* 1978; Hardcastle 1978; Hsu *et al.* 2003; Sobrero *et al.* 2003; Suwanketnikom *et al.* 2004; Suwanketnikom *et al.* 2005). From these studies, it appears that the size of the seeds and their ability to germinate in the dark (notably under trash blanket) are important characteristics of vine weeds which give them a competitive advantage over other species in the current agronomic context.

Moreover, generally weeds compete for light, mineral nutrients and water. Vine weeds can in addition exert mechanical stress on sugarcane growth and development when they creep, climb and twine on the cane plants. It has been observed in young canes that the twining effect around the leaf spindle impedes the unrolling of the leaf lamina, thus preventing the leaves to photosynthesise properly (Fig. 1.9). Vine weeds can also roll around existing cane leaves, tillers and stalks causing tensions on the different parts of the plants struggling for growth. This is further exacerbated when the vine weeds continue their development over the cane plants, producing important biomass which damages the cane leaves and leads to breakage of the stalks

near the growth points. Thus the developing cane plants are seriously and negatively affected, ultimately resulting in yield reduction.



Figure 1.9 The twining effect of *Ipomoea hederifolia* L. (left photo) and *I. triloba* L. (right photo) from the Convolvulaceae family around the spindle and leaves of sugarcane impeding an optimal exposure of the lamina for photosynthesis to take place properly, thus affecting development of the crop.

Resorting to herbicides in cropping systems is the fastest and cheapest means of managing vine weed infestations. Control is satisfactory in post-emergence, most species being susceptible to herbicide mixes used in different crops. The efficacy of pre-emergence products is on the other hand limited by the depth from which vine seeds emerge and by the trash blanket left by mechanized green cane harvesting. In 2002, Viator *et al.* have shown that the performance of pre-emergence herbicides in sugar cane was uneven and they attributed this to rainfall and soil factors. Their conclusion confirms the observation made by Zimdahl (2007) that the development of vine weed management systems must take into account the ecology of the species and the different interactions that exist between agro-environmental factors within agricultural production systems.

2 Chapter 2

ECOLOGY AND DISTRIBUTION OF VINE WEEDS IN SUGARCANE FIELDS

2.1 Introduction

Climate in Mauritius is characterized in the fields by three distinct agro-climatic zones which greatly influence the ecology and distribution of plants, hence weed, species (Rochecouste, 1967). The agro-climatic conditions also have significant effects on the weed population of cane fields where fluctuations in its floristic composition will depend mainly upon soil type and soil moisture content. In addition, the particular topography of the land creates specific micro-climates which favours the development of a flora characteristic of the three regions. This also applies to vine weed species growing in sugarcane fields found in the sub-humid (annual rainfall < 1500 mm), humid (1500 mm < annual rainfall < 2500 mm) and super humid (annual rainfall > 2500) zones of the island (Fig 1).

Every weed species has a range of habitat which may be wide or narrow. For example, *Cyperus rotundus* L. and *Cynodon dactylon* L. can grow in a varied set of climatic conditions and are consequently widespread species of sugarcane fields. On the other hand, *Clidemia hirta* L. and *Colocasia esculenta* L., owing to their high affinity for very humid environments, have a much more restricted occurrence.

Moreover, agronomic practices associated with the monocultural cropping system of sugarcane create open ecological niches that weeds occupy (Zimdahl 2007). These practices give rise to conditions of maximum soil disturbance which increase the adaptive mechanisms of weeds to become more competitive.

In Mauritius, sugarcane growers are categorized as miller-planters (including corporate planters, i.e. planters whose land is managed by miller-planters), large-planters (>42 ha), medium-planters (10-42 ha) and small-planters (<10 ha). These growers are grouped into five geographical sectors (MSIRI 2011), namely Northern, Eastern, Southern, Western and Central part of Mauritius (Fig 2.1). These categories of growers employ various techniques of sugarcane crop husbandry according to the availability of their means. These are influenced by the agro-climatic conditions in which their fields are found. For example, cultural practices on large estates which are owned by corporate planters, particularly herbicide application and

harvest, are more machine oriented whereas small growers always resort to manual operations. Furthermore, green cane trash blanketing (GCTB) (Seeruttun 1992 ; Mc Intyre 1996) are carried out in cane fields found in the sub-humid and humid areas compared to trash lining in the superhumid areas (Seeruttun *et al.* 1999).

The various environmental and agronomic conditions under which sugarcane is grown set up intricate agro-ecological situations which dictate the development of characteristic weed communities in the fields. Studies on the ecology and distribution of weeds in crop production systems are geared towards growth and adaptations. These two processes enable weeds to exploit niches in environments disturbed by man during agricultural activities. Understanding weed-crop ecology can lead to more effective weed prevention, management and control (Zimdahl 2007).

The problem of vine weeds in sugarcane fields started in the 1990s, a decade where major socio-economic and agronomic changes were brewing in the industry. It persisted and became worst in the 2000s when these changes evolved very rapidly, causing existing weed control practices to become ineffective to prevent vine infestations in the fields. Although actions are being taken to manage the problem, they are not efficient, and the emergence of new and more aggressive species is suspected. But information regarding the ecology and distribution of species responsible for the infestations is lacking.

Therefore the main objective of this work is to characterise the floristic composition, species richness and distribution of vine weeds posing problem in the sugarcane fields of Mauritius. The aim is to develop sound and effective management strategies through an optimisation of existing resources.

2.1 Materials and Methods

Vine weed surveys were carried out from January to May 2012 and 2013 in sugarcane fields in the three agro-climatic zones of Mauritius (Fig 1). A balanced sampling design (Deville 2005) was adopted where 360 plots were sampled, half of these were selected from small growers' fields (cultivating < 10 ha) while the rest was from large growers (cultivating > 1000 ha). These two categories of growers represent the upper and lower extremes of sugarcane planters in Mauritius and the way they carry out their cultural practices in their fields differ due to their respective level of organization and the availability of resources they have. The medium planters are closer to the large ones in terms of organization. The two extremes have been chosen in this study to better bring out the effect of sugarcane crop husbandry strategies on the ecological distribution and adaptation of vine weeds.

In each group, fields were randomly chosen based on the following main agronomic criteria:

- (1) trash management practices (Conventional trash lining v/s trash blanket)
- (2) crop cycle (plant cane, 2nd -3rd ratoon or 4th- 7th ratoon)
- (3) planting dates/harvest dates (small season/early harvest v/s long season/late harvest)

Vine weed surveys were carried out in these fields to identify the species present and to characterise their distribution.



Figure 2.1. Agro-climatic map of Mauritius. Source : MSIRI GIS Lab.

2.2 Sampling of survey plots

The number of fields to be surveyed in each of the two categories were calculated based on the area of land under sugarcane in the particular region (Table 2.1, 2.2 & 2.3). From these data, the different scenarios integrating the different agronomic criteria listed above were randomly attributed to the various estates or small planters' groupings in each factory area. As an example, for the large estate found in the region of Beau Plan, 7 fields were calculated to be surveyed having the following scenarios:

	Estate:	Beau Plan		No. of fields per agroclimatic zone		
		Trash management	Crop cycle	Date of planting/ Harvesting date	Sub-humid	Humid
1	Conventional.	Plant cane	Small season			
2	Conventional.	Plant cane	Long season		1	
3	Conventional.	Ratoon 2-3	Early			
4	Conventional.	Ratoon 2-3	Late	1	1	
5	Conventional.	Ratoon 4-7	Early	1		
6	Conventional.	Ratoon 4-7	Late			
7	GCTB	Plant cane	Small season			
8	GCTB	Plant cane	Long season			
9	GCTB	Ratoon 2-3	Early	2		
10	GCTB	Ratoon 2-3	Late			
11	GCTB	Ratoon 4-7	Early			
12	GCTB	Ratoon 4-7	Late	1		
			Total	5	2	0

A similar exercise was carried out for the sampling of small planters' fields.

Table 2.1. Percentage of land under sugarcane present in each agricultural estate in the three agro-climatic zones of Mauritius. Source : MSIRI land index database

<i>Sectors</i>	<i>Estates</i>	<i>Sub-humid</i>	<i>Humid</i>	<i>Superhumid</i>
<i>North</i>	Beau Plan	8.7	3.3	0.0
	Belle Vue	18.1	4.6	0.0
	Mon Choisy	9.2	0.0	0.0
	Mon Loisir	2.7	10.7	0.0
	Mount	0.0	6.5	2.3
	Mon Songe	0.0	0.8	0.0
	N. Industrie	0.3	3.3	0.2
	Saint Antoine	13.7	2.0	0.0
	Total	52.7	31.2	2.5
<i>East</i>	Beau Champ	0.0	7.1	12.6
	Constance	0.0	11.2	0.0
	FUEL	0.0	9.8	18.8
	Total	0.0	28.0	31.4
<i>Centre</i>	Highlands SE	0.0	0.0	0.8
	Highlands SIT	0.0	0.0	0.5
	Highlands SLDC	0.0	0.8	4.6
	MDA	0.0	1.9	12.0
	Total	0.0	2.8	17.8
<i>West</i>	Medine	46.9	5.3	2.3
	Total	46.9	5.3	2.3
<i>South</i>	Britannia SE	0.0	2.5	3.5
	Britannia SIT	0.0	0.0	4.4
	Bel Ombre	0.0	4.6	0.2
	La Fleche	0.4	0.4	0.2
	Mon Tresor SE	0.0	6.9	2.5
	Mon Tresor SIT	0.0	1.5	2.6
	Rose Belle	0.0	0.0	10.3
	R. E. Eau	0.0	4.8	7.9
	St Felix	0.0	1.3	0.9
	Savannah	0.0	6.8	6.0
	Cascade Ltee	0.0	0.4	4.7
	Union SE	0.0	3.6	2.9
	Total	0.4	32.7	46.1
Grand Total		100	100	100

Table 2.2. Number of plots attributed for vine weed surveys on large growers fields

<i>Sectors</i>	<i>Estates</i>	<i>Sub-humid</i>	<i>Humid</i>	<i>Super humid</i>	<i>Total</i>
<i>Nord</i>	Beau Plan	5	2	0	7
	Belle Vue	11	3	0	14
	Mon Choisy	5	0	0	5
	Mon Loisir	2	6	0	8
	Mount	0	4	1	5
	Mon Songe	0	1	0	1
	N. Industrie	0	2	0	2
	Saint Antoine	8	1	0	9
	<i>No. of fields per agro-climatic zone</i>		31	19	1
<i>East</i>	Beau Champ	0	4	8	12
	Constance	0	6	0	6
	FUEL	0	6	11	17
	<i>No. of fields per agro-climatic zone</i>	0	16	19	35
<i>Centre</i>	Highlands SE	0	0	0	0
	Highlands SIT	0	0	1	1
	Highlands SLDC	0	0	3	3
	MDA	0	2	6	8
	<i>No. of fields per agro-climatic zone</i>	0	2	10	12
<i>West</i>	Médine	28	3	2	33
<i>No. of fields per agro-climatic zone</i>	28	3	2	33	
<i>South</i>	Britannia SE	0	1	2	3
	Britannia SIT	0	0	3	3
	Bel Ombre	0	3	0	3
	La Fleche	1	0	0	1
	Mon Tresor SE	0	4	1	5
	Mon Tresor SIT	0	1	2	3
	Rose Belle	0	0	6	6
	R. E. Eau	0	3	4	7
	St Felix	0	1	1	2
	Savannah	0	4	4	8
	Cascade Ltee	0	1	3	4
	Union SE	0	2	2	4
	<i>No. of fields per agro-climatic zone</i>	1	20	28	49
	<i>Total</i>		60	60	60

Table 2.3. Number of fields attributed for vine weed surveys on small growers' fields

<i>Sector</i>	<i>Factory areas</i>	<i>Sub-humid</i>	<i>Humid</i>	<i>Superhumid</i>	<i>Total</i>	
<i>North</i>	Beau Plan	5	2	0	7	
	Belle Vue	17	9	2	28	
	Mon Loisir	10	7	0	17	
<i>No. of fields per agro-climatic zone</i>		32	18	2	52	
<i>Est</i>	Beau Champ	0	5	8	13	
	Constance	0	7	0	7	
	FUEL	0	6	11	17	
	<i>No. of fields per agro-climatic zone</i>		0	18	19	37
<i>Centre</i>	Highlands SE	0	1	4	5	
	MDA	0	1	7	8	
	<i>No. of fields per agro-climatic zone</i>		0	2	11	13
<i>Ouest</i>	Medine	28	3	1	32	
	<i>No. of fields per agro-climatic zone</i>		28	3	1	32
<i>South</i>	Britannia SE	0	2	4	6	
	Mon Tresor SE	0	4	3	7	
	Rose Belle	0	0	6	6	
	R. E. Eau	0	3	5	8	
	St Felix	0	1	1	2	
	Savannah	0	4	4	8	
	Union Saint Aubin	0	5	4	9	
	<i>No. of fields per agro-climatic zone</i>		0	19	27	46
<i>Total</i>		60	60	60	180	

2.3 Data collections

Each field selected was surveyed at four different places and represented 5-10 % of its area. The survey consisted in listing all the species present in the plot in an exhaustive manner until no more species were spotted (Chicouène 2000; Maillet 1981). All vine weed species encountered in the survey plot were attributed a rating of 0 to 3 as defined below:

0 – Absent

Vine species not found in this part of the field

1 – Present but not very important

Species rarely to very rarely present in this part of the field

2 – Present and quite important

Species encountered quiet frequently to frequently in this part of the field

3 – Present and very important

Species appeared very frequently in this part of the field causing infestations at places

These ratings corresponded respectively to 0, 1, 3 and 7 of those developed and elaborated by Rochecouste (1967) and Marnotte (1984).

In order to characterise the frequency-abundance of a species at the field level, a global rating was attributed to it based on that obtained from each of the four observations. All data was tabulated in a spreadsheet and was complemented with agronomic information contained in the MSIRI Land Index Database (MSIRI 1990; Jhoty et al. 1997). Information about rainfall, altitude and soil type was also obtained from the database for each field for which the global positioning system (GPS) coordinates were recorded during the surveys.

2.4 Data analysis

Two approaches were adopted in this research to analyse the data of the floristic surveys as detailed by Le Bourgeois (1993).

- In the first approach, the components of the vine weed flora were described. It was mostly descriptive (qualitative) and consisted in characterising the various vine species present in sugarcane fields.

- A phytoecological approach was adopted in the second analysis to provide quantitative explanations on species development and community formation as a function of the ecological environment and cultural practices. Two types of analyses were carried out :
 1. Diagrammatic representations of the number of species per survey were elaborated which allow an assessment of the floristic richness of vine species in sugarcane fields.
 2. 'Infestation diagrams' were used to graphically plot the species. The relative frequency of species in a set of surveys (x-axis co-ordinates) were plotted against mean of abundance and this enabled the differentiation of species groups according to their level of infestations.

2.5 Results

Sampling and distribution of survey plots

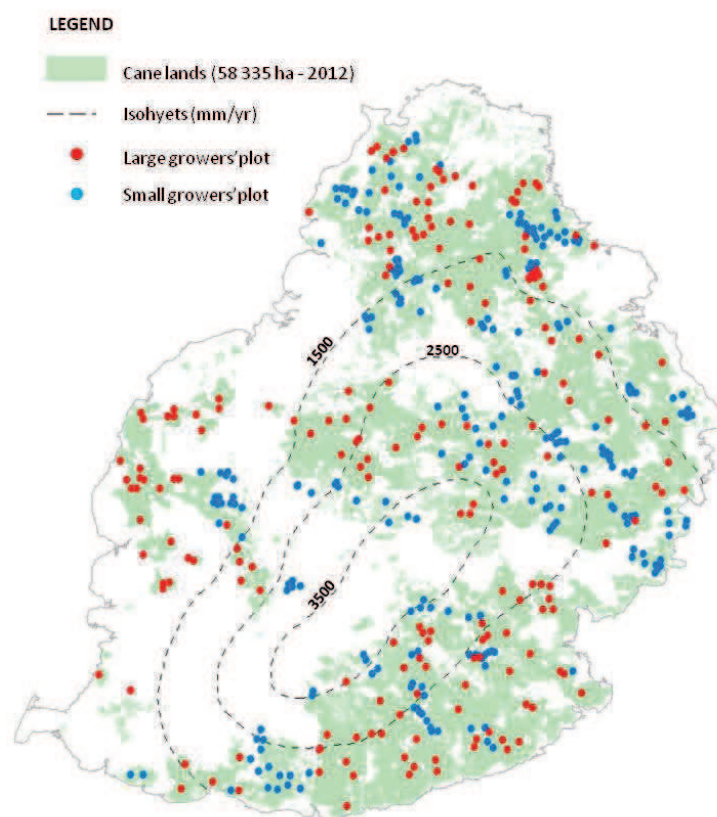


Figure 2.2 Distribution of survey plots in the sugarcane areas of Mauritius in order to identify and list the different vine weed species present therein. Courtesy: MSIRI GIS Lab.

The GPS coordinates recorded during the vine weed surveys for each field enabled the mapping of the latter's distribution onto the sugarcane areas through Geographical Information System (GIS) (Fig 2.2). The selected survey plots were well distributed in the three agro-climatic zones where they covered all the sugarcane areas. There was also a good balance in the representation of small and large growers plots in these areas.

Floristic composition of vine weeds

The 360 surveys had revealed the occurrence of 26 species of vine weeds in the sugarcane fields of Mauritius (Table 2.4). These species belonged to 9 botanical families with the Convolvulaceae having 10 individuals followed by 7 for the Fabaceae; at most one or two species occurred from each of the remaining families. The genus *Ipomoea* was the dominant taxon in the

Convolvulaceae family with 8 species whereas in the Fabaceae family a unique genus characterized every species except for *Rhynchosia* which had two.

One of the main biological characteristics of most of the vine weed species, particularly those from the Convolvulaceae family, is their twining ability. This helps them to effectively climb vertically in search of more optimal light conditions or to better establish them in their environment at the expense of other plants which are adversely affected. The presence of tendrils in *M. charantia* (Cucurbitaceae) and the two *Passiflora* spp. (Passifloraceae) are biological features that enable these species to climb in their environment.

Table 2.4. List and main characteristics of vine weed species present in sugarcane fields in Mauritius (*Source: *La Flore des Mascareignes*)

	EPPO code	Vine weed species	Family	*Main biological & ecological characteristics	*Geographical origins
1	THNAL	<i>Thunbergia alata</i> Bojer ex Sims	Acantaceae	A twining perennial species found naturalized in many places of the sub-humid zone where it behaves as a ruderal plant. It reproduces by seeds ($\varnothing = 3-4$ mm) enclosed in capsules.	It originates from East and South Africa.
2	THNFR	<i>Thunbergia laevis</i> Roxb	Acantaceae	A twining perennial species found naturalized in many places of the humid and sub-humid zone where it grows along roadsides, on hedges and on uncultivated land. It reproduces by seeds ($\varnothing = 4.5-5$ mm) enclosed in capsules.	It has an Asian origin.
3	CYNCA	<i>Cynanchum callialatum</i> Buch.-Ham.ex Wight	Asclepiadaceae	It is a twining perennial plant found naturalized on roadsides, hedges and uncultivated or unoccupied lands. It produces a toxic milky latex and the fruits are fusiform follicles enclosing oboval flattened seeds. The latter bears filamentous hair-like structures (papus) which help in their dissemination by wind.	It has an Asian origin.
4	MIKMI	<i>Mikania micrantha</i> Kunth	Asteraceae	It is a twining perennial species found mostly in the humid and superhumid areas where it can be seen developing on unoccupied land and riverbanks. It produces numerous achenes that are carried away by wind to infest new areas; it can also propagates by stems which root easily at the nodes when in contact with soil.	The species is indigenous to Mexico but it may have been introduced from African or Asian countries.
5	BADAL	<i>Basella alba</i> L.	Basellaceae	It is a twining perennial plant found mostly in inhabited areas where it is grown for its edible fleshy leaves and young shoots. It reproduces by seeds which are disseminated by birds after feeding on the berry-like fruits.	It probably originates from Sri Lanka, hence its common name Ceylon spinach.
6	AGJNE	<i>Argyrea nervosa</i> (Burm.f.) Bojer	Convolvulaceae	A large twining, perennial vine naturalized in areas found at low altitude. It reproduces by seeds.	It has been introduced from India.

Table 2.4. List and main characteristics of vine weed species present in sugarcane fields in Mauritius (*Continued*)

7	CLYAC	<i>Ipomoea alba</i> L.	Convolvulaceae	A twining annual to perennial vine developing mostly on hedges, unoccupied land and along riverbanks. It produces large white flowers which open at dusk and it reproduces by seeds.	It originates from tropical America.
8	IPOHF	<i>Ipomoea hederifolia</i> L.	Convolvulaceae	An aggressive twining annual species growing on roadsides, rotational and unoccupied lands. It reproduces by seeds produced in large numbers.	It originates from tropical America.
9	IPOAC	<i>Ipomoea indica</i> (Burm.) Merr.	Convolvulaceae	It is a moderately rapid twining annual to perennial species found on roadsides, unoccupied lands, hedges and riverbanks. It reproduces by seeds.	It originates most probably from tropical America.
10	IPONI	<i>Ipomoea nil</i> (L.) Roth	Convolvulaceae	An aggressive twining annual species found naturalized in some places, mostly in the humid areas. It reproduces by seeds produced in large numbers.	It originates from tropical regions of America.
11	IPOOB	<i>Ipomoea obscura</i> (L.) Ker Gawl	Convolvulaceae	A passive twining perennial plant that grows frequently on roadsides, hedges, rotational and unoccupied lands. It can propagate vegetatively from stems that can root easily but it also produces large number of seeds.	It has most probably been introduced from countries of tropical Africa or Asia.
12	PHBPU	<i>Ipomoea purpurea</i> (L.) Roth	Convolvulaceae	A moderately twining annual plant that has naturalized in some places where it occurs less frequently. It reproduces by seeds.	It originates from the tropical regions of America.
13	IPOQU	<i>Ipomoea quamoclit</i> L.	Convolvulaceae	A rapid twining annual species grown as ornamental plants in inhabited areas. It is rarely found naturalized and it reproduces by seeds produced in large numbers.	It is probably of American origin.
14	IPOTR	<i>Ipomoea triloba</i> L.	Convolvulaceae	An aggressive twining annual species found mostly in sugarcane fields and on rotational lands. It reproduces by seeds produced in large numbers.	It originates from tropical America.
15	MERAE	<i>Meremia aegyptia</i> (L.) Urb.	Convolvulaceae	It is a rapid twining annual plant that has occasionally naturalized in some places. It reproduces by seeds	It probably originates from tropical America.
16	MOMCH	<i>Momordica charantia</i> L.	Cucurbitaceae	It is a monoecious annual vine that is cultivated as vegetable for its bitter gourd. It is rarely found growing in the wild; it reproduces by seeds.	It could have been introduced from India.

Table 2.4. List and main characteristics of vine weed species present in sugarcane fields in Mauritius (*Continued*)

17	ATYSC	<i>Cajanus scarabaeoides</i> (L.) Thouars	Fabaceae	Generally a twining annual species but can also behave as a perennial one. It reproduces by seeds and is commonly encountered in the dry zones where it develops along roadsides and on abandon lands.	It originates from Asian countries.
18	COSPU	<i>Centrosema pubescens</i> Benth.	Fabaceae	It is a twining perennial species reproducing by seeds. Introduced as a fodder for cattle on experimental stations, it is now naturalized in some regions.	Origin unknown?
19	CLHET	<i>Clitoria heterophylla</i> Lam.	Fabaceae	It is a twining annual to perennial species propagating by seeds. It is naturalized in some regions where it is found growing along roadsides.	Origin unknown?
20	DOLLA	<i>Lablab purpureus</i> (L.) Sweet	Fabaceae	It is a twining perennial species multiplying by seeds and is sometimes grown as an annual crop. It is now naturalized in several regions.	Origin unknown?
21	MACAT	<i>Macroptillum atropurpureum</i> (DC.) Urban	Fabaceae	It is a twining perennial plant that forms adventitious roots at the nodes where a new plant can develop. It also multiplies by seeds and is found naturalized in some regions after it was introduced as a fodder for cattle.	Origin unknown?
22	RHYMI	<i>Rhynchosia minima</i> (L.) DC	Fabaceae	It is a twining perennial species and can reproduce by seeds. It was introduced as a fodder for cattle and is now naturalized in some regions.	It is of Indian origin.
23	RHNVI	<i>Rhynchosia viscosa</i> (Roth) DC.	Fabaceae	It is a twining perennial plant that reproduces by seeds. It is commonly found growing among thorny bush in the low and medium altitude.	It originates from tropical Africa and was introduced in Mauritius at the beginning of the nineteenth century.

Table 2.4. List and main characteristics of vine weed species present in sugarcane fields in Mauritius (*Continued*)

24	PAQFO	<i>Passiflora foetida</i> L.	Passifloraceae	It is an annual to biannual vine found naturalized in the low to medium altitude on rocky places, along roadsides and on unoccupied or rotational land. It has tendrils which enable it to climb and at maturity it produces many subglobular berries ($\varnothing = 2-3$ cm) containing long (4-5 mm) ovoid seeds. Birds feed on them when they are ripe and assist in their dissemination.	It originates from tropical America.
25	PAQSU	<i>Passiflora suberosa</i> L.	Passifloraceae	It is a perennial plant that can regenerate from the remains of the taproot system. But it propagates mainly from seeds that are produced in large quantities and enclosed in subglobular berries. Birds feed on these berries when they are ripe and thus helps in their disseminating the seeds. Apart from being a weed in sugarcane fields, it is also commonly found growing on unoccupied land or climbing on hedges, walls and rocky cliffs by the help of its tendrils.	It originates from the tropical regions of America.
26	PAEFO	<i>Paederia foetida</i> L.	Rubiaceae	A twining perennial species found on hedges, riverbanks and on uncultivated lands at all altitudes. It reproduces mainly by vegetative propagation through their stems which root easily at the nodes when in contact with soil.	It originates most probably from India.

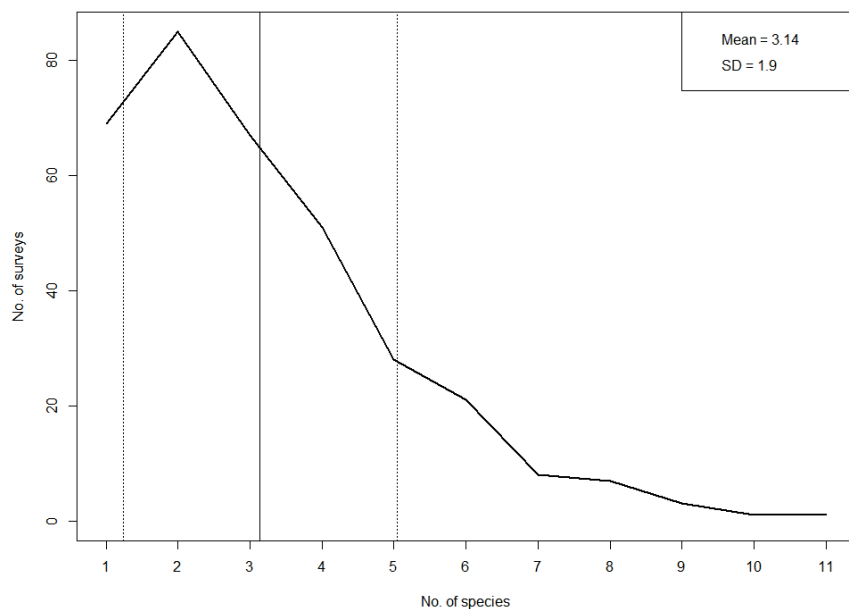
Floristic richness of vine weeds

Figure 2.3 Mean occurrence of vine weeds in sugarcane fields.

Analysis of the data showed that at least three vine weed species (3.14 ± 1.9) were generally present in any of the sugarcane fields surveyed (Fig 2.3). In a high proportion of them, however, at least two vine weeds were found whereas more than seven species occurred in very few cases. There was a contrast between the species richness in small growers fields compared to those of the large growers, the latter tended to have more vine weed species than the former (Fig 2.4 & 2.5).

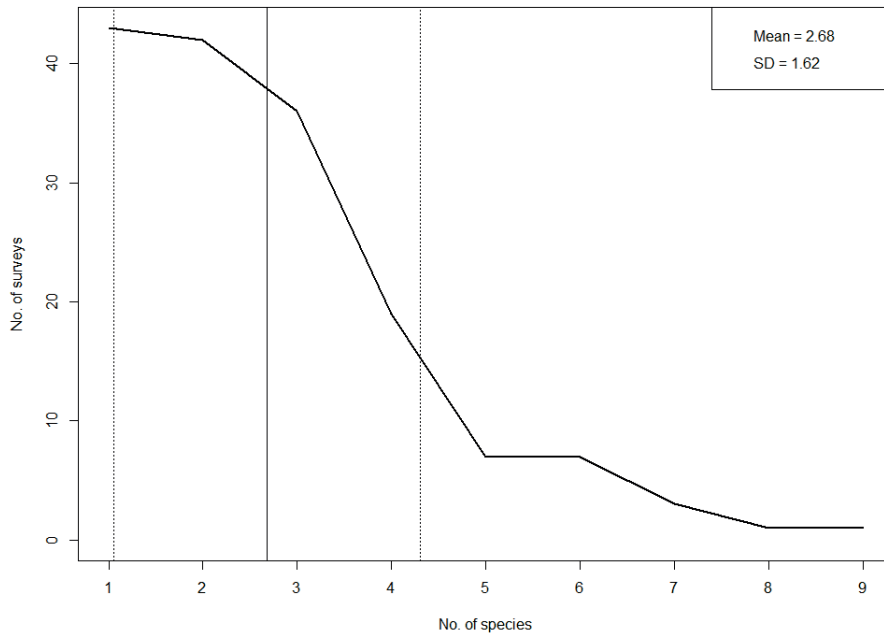


Figure 2.3 Mean occurrence of vine weed species on small grower's fields

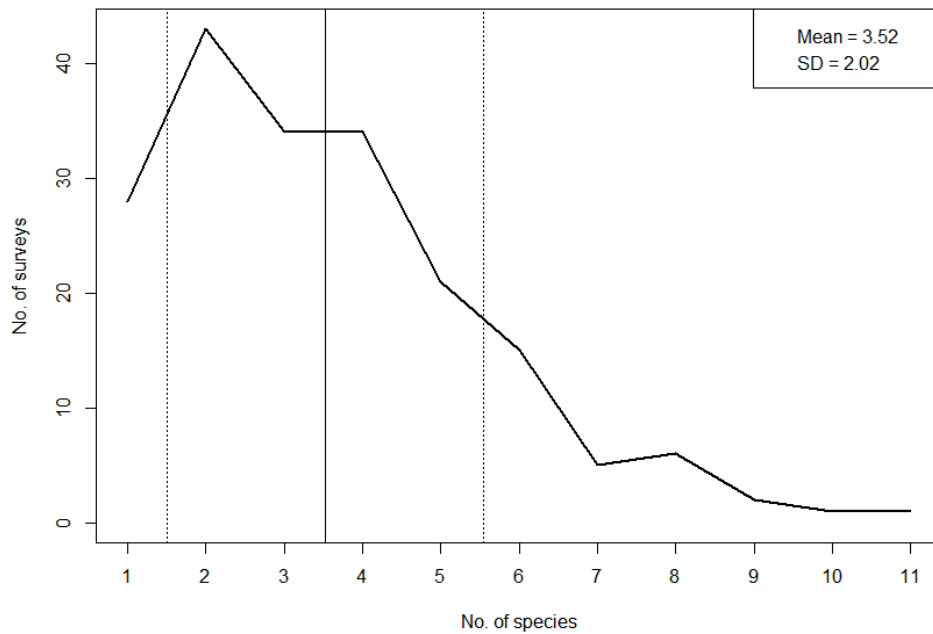


Figure 2.4 Mean occurrence of vine weed species on large grower's fields

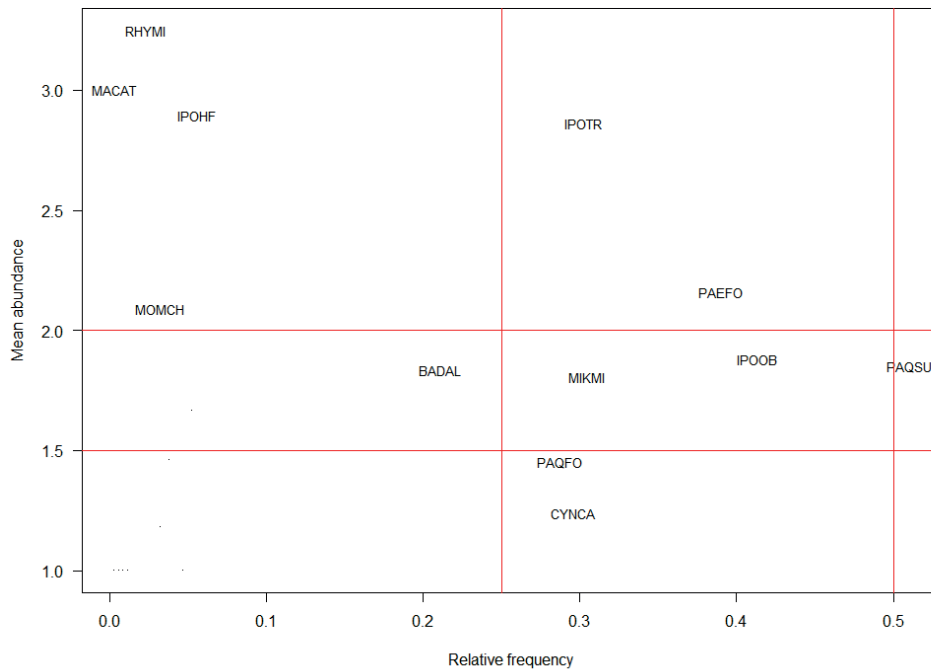
Infestations of vine weeds

Figure 2.5 Diagrammatic representation of the species groups differentiation of vine weeds according to their level of infestation in sugarcane fields.

The diagrammatic representations of the species groups differentiations according to their level of infestations revealed that *P. suberosa* was the most frequent species encountered in the sugarcane survey plots across the island (Fig 2.6). Although it had a relative frequency of around 50%, its mean abundance was less than 2. It was as abundant as *I. obscura*, *M. micrantha* and *B. alba* with each having lower relative frequency which was in the order of about 40%, 30% and 20% respectively. On the other hand, *I. triloba* was more abundant (mean abundance > 2.5) though it had a relative frequency of about 30% in the fields where vine weeds were observed. Moreover, the abundance of *Paederia foetida* was found to be intermediate between *P. suberosa* and the other species listed above, being greater than 2.0 but lower than 2.5. It was noted in nearly 40% of the fields that were surveyed, making it the second more frequent vine species at par with *I. obscura*. The analysis also revealed the existence of two contrasting groups of species. The first group was composed of *Cynanchum calliatum* and *Passiflora foetida*, and was characterised with a low mean abundance (< 1.5) and a relative frequency of 30%. The second group was in the other extreme with mean abundance ranging from 2.0 to 3.5 but with a relative frequency less than 5%. It consisted of *Momordica charantia*, *I. hederifolia*, *Macroptilium atropurpuream* and *Rhynchosia*

minima. The remaining species of Table 4 did not appear on the diagram due to their occasional occurrence in sugarcane fields, thus implying very low mean abundance and relative frequencies.

Further analysis highlighted some contrasting differences between species occurring in small growers' fields compared to those observed in large growers' fields (Fig 2.7 and 2.8). Firstly, the diagrams showed that the number of species having a mean abundance > 1.5 and a relative frequency $> 20\%$ in small grower' fields was nearly half than that present in large growers' fields. Secondly, the floristic composition of vine weeds in small growers' fields was different from that in large growers' fields. In the latter, *P. suberosa* and *I. triloba* were the most important species with the highest relative frequency and mean abundance respectively. They were followed by *I. obscura*, *B. alba* and *Paederia foetida*. The latter species, along with *I. obscura* and *M. micrantha* were the dominant species in small growers' fields. Thirdly, the main species present in large growers' fields occurred in greater abundance (mean abundance between 2.0 and 3.5) than those in small growers' fields where their mean abundance was less than 2.0. Although *I. hederifolia* was less frequent in large growers' fields and absent from those of small growers', it was abundant and troublesome in places where it occurred, unlike species having similar mean abundance and relative frequency.

Distribution of vine weeds

Mapping of the spatial distribution of vine weeds using ARCVIEW GIS software (ESRI, USA) was carried out for the main and important species onto the sugarcane areas (Fig 2.9). It was found that *P. suberosa* was distributed everywhere on the sugarcane areas and therefore appeared to be adapted to all the agro-climatic conditions. On the other hand, *P. foetida* was mostly present in the humid and superhumid regions of the Central and Southern sectors of the sugarcane areas. Similarly, *I. triloba* and *B. alba* were frequently encountered in the subhumid and humid regions of the Northern, Eastern, Western and Southern sectors of the island; they were practically absent from the Central sector. Finally, *I. hederifolia* had a more localised distribution, being mostly present in some part of the subhumid region of the Northern sector.

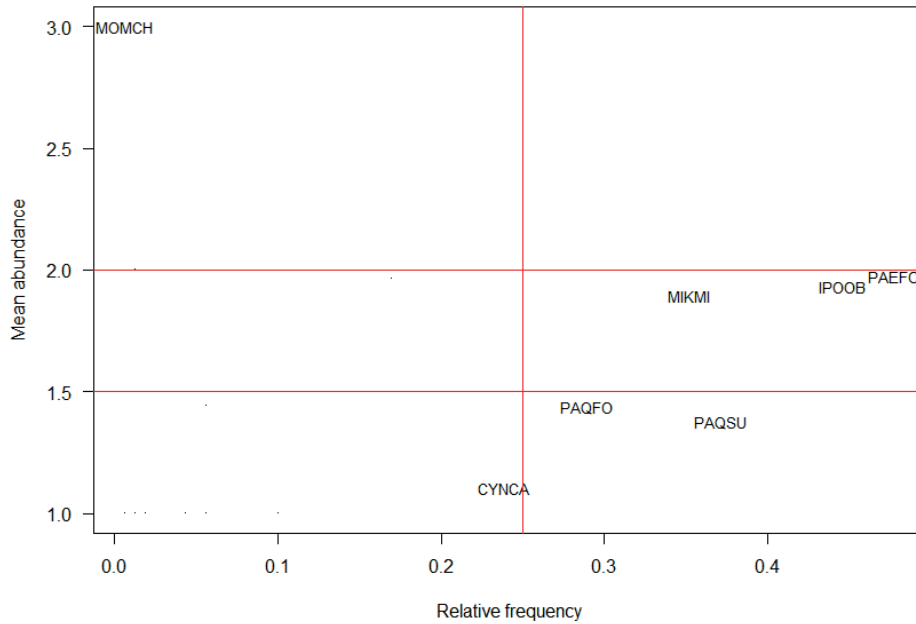


Figure 2.7 Diagrammatic representation of the species groups differentiation of vine weeds according to their level of infestation in small growers' sugarcane fields.

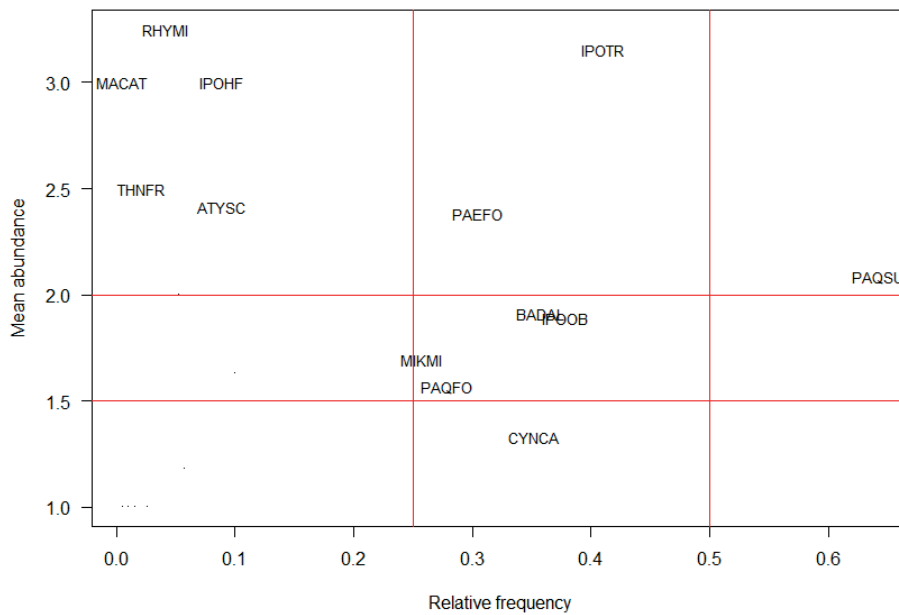


Figure 2.8 Diagrammatic representation of the species groups differentiation of vine weeds according to their level of infestation in large growers' sugarcane fields.

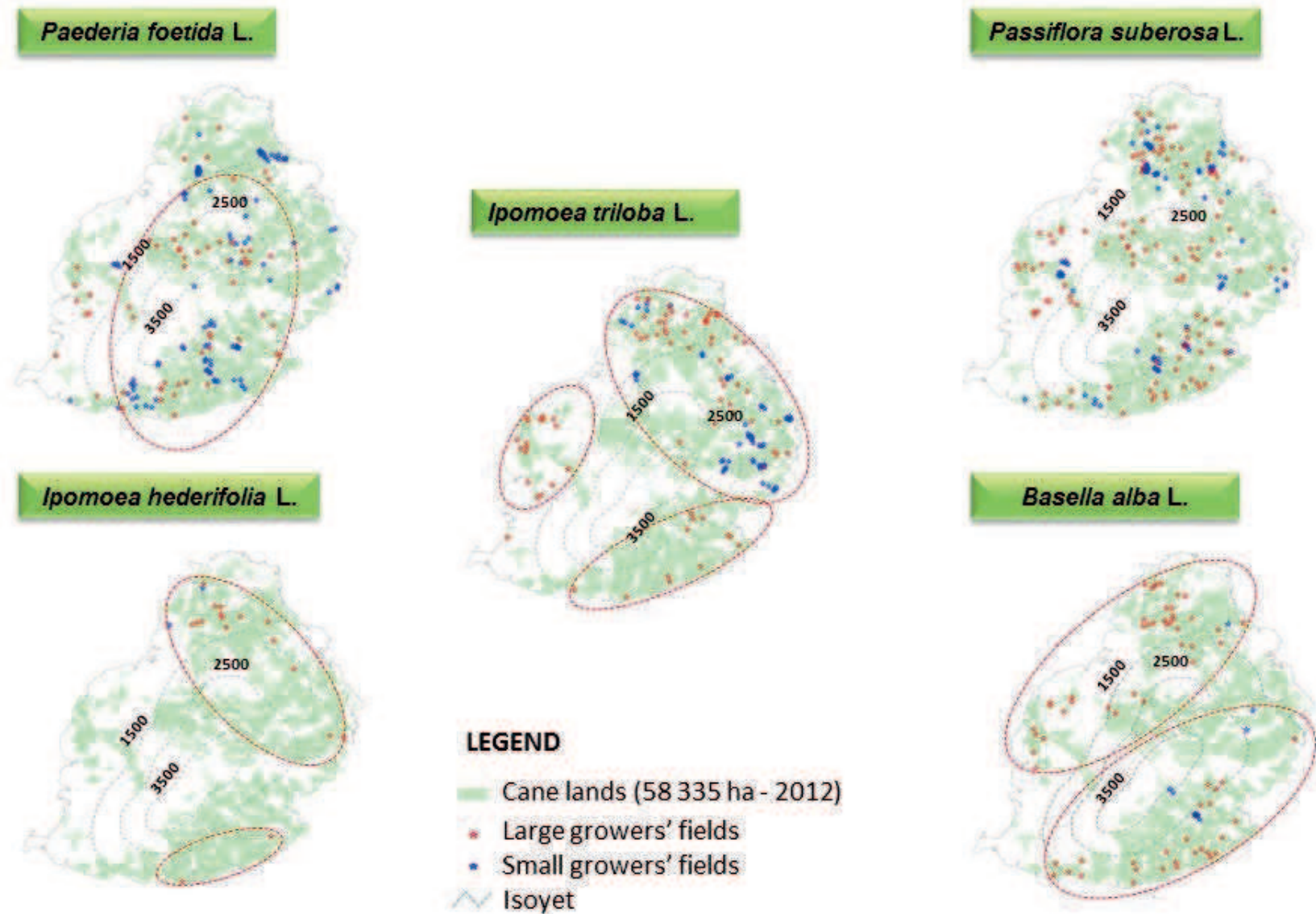


Figure 2.9 GIS mappings showing the spatial distribution of some important vine weeds in the different agro-climatic regions where sugarcane lands are found in Mauritius.

2.6 Discussions and Conclusions

This study had enabled to characterise the floristic composition and species richness of vine weeds in the sugarcane fields of Mauritius. The list of 26 species identified in this work comprise mostly of new species which had been occurring in sugarcane fields since 1990's. In fact, Rochecouste (1967) and Mc Intyre (1991) had mentioned only *Paederia foetida* as the important vine weed of sugarcane fields at the time they published their respective work. Also, *I. obscura*, *M. micrantha* and *P. suberosa* were seldom encountered in weed surveys in the 1980's (unpublished data) and therefore did not represent a major weed control issue. The results had shown that *P. suberosa* had become the most frequently encountered species (Fig 6) with an island wide distribution as shown with the GIS mappings (Fig 9).

These results had some parallel with the work undertaken in the cane fields in Réunion Island to study the effect of harvesting season on weed flora and growth dynamics (Lebreton *et al.* 2009). Results had shown that there also 26 vine species were indentified, *M. charantia*, *Coccinia grandis* (L.) Voigt, *Ipomoea* spp. and *Passiflora* spp. being the most frequent and most important in sugarcane. The ecological conditions present there and the cultural practices adopted by the sugarcane growers could explain why these species are more troublesome but we cannot explain why *M. charantia* is very abundant and frequent in Réunion Island while it is really not frequent nor (or rarely) abundant in Mauritius..

Moreover, based on field observations and from complaints noted from growers and agronomists in Mauritius, it had been possible to classify the vine weed species according to their importance in relation to their impact on cane development. Thus, the new species *I. triloba*, *I. hederifolia* and *B. alba* appeared to be more aggressive as infestations of these species might smother and kill young plant canes and cause lodging and cane breakage in tall canes. Such effect had never been observed with *Paederia foetida*, *P. suberosa*, *M. micrantha*, *C. callialatum*, *Passiflora foetida*, *I. obscura*, *I. nil* and *Cajanus scarabaeoides* even though when their infestations were high. Their network of flexible stem could, however, cause obstruction to other cultural practices like harvest. These species could be classified as being passive. These 11 species are illustrated in Appendix 2. The remaining of the 26 species was encountered occasionally or rarely in sugarcane fields and their sporadic infestations were not a cause of concern for the growers.

The GIS mappings of the main vine species onto the sugarcane areas (Fig 9) had further revealed the characteristic spatial distribution of each species. This could be related to the

biology of the species in addition to the influence of agronomic practices and environmental conditions. The island wide adaptation of *P. suberosa* could be due to the fact that this species propagate by seeds which are easily disseminated by birds that feed on the fruits. Their growth in the different agro-climatic conditions appeared to be favoured by humid conditions because it had been shown that it would be more likely to develop in super humid areas (Gaungoo *et al.* 2010). On the other hand, the occurrence of *P. foetida* in the humid and super humid environment mostly could be linked to its mode of propagation which is essentially vegetative. Moreover, the specific distribution *B. alba*, *I. hederifolia* and *I. triloba* were mostly associated with large growers' fields where mechanized green cane harvesting and GCTB were practiced.

On the other hand it has been reported that vine weeds, particularly *Ipomoea* spp., are also infesting sugarcane fields in India (Bhullar *et al.* 2012), Pakistan and some African countries like Ouganda, Zambia and Ivory Coast (Seeruttun, personal communication) where GCTB is not a current cultural operations. It is a fact that the planet is currently going through significant climate changes caused by the gradual increase in CO₂ levels in the atmosphere. Recent ecological studies on tropical vines suggest that climbers are more and more proliferating in tropical ecosystems because of these changes (Phillips *et al.* 2002). Experimental studies have shown that climbers have a faster growth rate than trees when atmospheric CO₂ levels are high (Condon *et al.* 1992; Granados *et al.* 2002; Hättenschwiller *et al.* 2003). It is therefore assumed that such a phenomenon could also explain why vine weeds have proliferated under agricultural conditions, particularly in sugarcane cropping where they find favorable environmental conditions.

In conclusion, this work has established the floristic composition of vine species that are present in the sugarcane fields of Mauritius and has shown the occurrence of new species. Changes in the weed species composition, or weed shifts, are a common occurrence in agricultural fields in response to natural or man-made environmental changes in agricultural systems. Weed shifts generally result in the emergence of species that are tolerant to existing weed management practices (Radosevich *et al.* 1997). The present vine weed flora appears to be the result of changes that occurred in the last two decades and some species, like *I. triloba*, have found suitable conditions for their growth and development. The differential aggressiveness of the various species could be related to their twining and climbing abilities.

2.7 References

- Chicouène D. 2000. Evaluation du peuplement de mauvaises herbes en végétation dans une parcelle : II - Protocoles rapides pour un usage courant. *Phytoma - Défense des cultures* 524: 18-23
- Gaungoo, A., Seeruttun, S., Barbe, C., Chummum, N. (2010). Development of *Ipomoea triloba*, *Mikania micrantha* and *Passiflora suberosa* in different agro-climatic conditions of Mauritius. 21ème conférence du COLUMA - Journées internationales sur la lutte contre les mauvaises herbes, 8 - 9 décembre 2010, Dijon, France.
- Jyoti, I., Govinden, N., Lim Shin Chong, J., Ramsamy, S. and Deville, J. 1997. Index of large-planters' cane lands. 25p.: 16 tbls, 7 figs, 4 appen.
- Le Bourgeois T. 1993. Les mauvaises herbes dans la rotation cotonnière au Nord-Cameroun (Afrique). Amplitude d'habitat - Degré d'infestation. Thèse de doctorat, Montpellier II, Montpellier, France, 250 p.
- Lebreton G., Le Bourgeois T. and Marnotte P. 2009. Effet de l'époque de coupe sur la dynamique de développement de l'enherbement de la canne à sucre à la Réunion. In: *XIIIème colloque international sur la biologie des mauvaises herbes*). Dijon (France).
- Maillet J., Evolution de la flore adventice dans le montpellierais sous la pression des techniques culturales. Thèse DDI, USTL, Montpellier, 200p. + annexes.
- Marnotte P., 1984. Influence des facteurs agroécologiques sur le développement des mauvaises herbes en climat tropical humide. *C. R. du 7ème Coll. Int. Ecol. Biol. et Syst. des mauvaises herbes, COLUMA-EWRS*, Paris: 183-189.
- Mauritius Sugar Industry Research Institute (MSIRI). 1990. The Land Index Project for Small Planters. 40p.: 17 tbls, 8 figs, 9 Annexes.
- Mauritius Sugar Industry Research Institute (MSIRI) 1991. *Rep. Maurit. Sug. Ind. Res. Inst.* 1990:.
- Mauritius Sugar Industry Research Institute (MSIRI) 2012. SUGAR CANE – Sectors / Soils / Planter categories. *Rep. Maurit. Sug. Ind. Res. Inst.* 2011: p. 3.
- Mc Intyre G. 1991. *Weeds of Sugar cane in Mauritius, their description and control*. Réduit: Mauritius Sugar Industry Research Institute.

- Mc Intyre G., Seeruttun, S. and Barbe, C. 1996. *Trash management in Mauritian sugar cane plantations. Proceedings of the XXII International Society of Sugar Cane Technologists 2, 213-216.*
- Radosevich, S. R., Holt, J. and Ghera, C. 1997. *Weed Ecology: Implications for Management* 2nd ed. New York: J. Wiley.
- Rocheouste E. 1967. *Weed Control in sugarcane*. Réduit: Mauritius Sugar Industry Research Institute.
- Seeruttun, S., Intyre, G. M. and Barbe, C. 1992. Agronomic and economic significance of trash blanketing in the sub-humid areas of Mauritius. *Revue agric. sucr. Ile Maurice* 71: 324-331.
- Seeruttun, S., Barbe, C. and Mc Intyre, G. 1999. "Le paillis complet dans la canne à sucre en zone à forte pluviosité". *Rev. agric. sucr. Ile Maurice* 77(2&3): 42-49
- Zindahl, R. I. 2007. *Fundamentals of weed science*, 3rd ed. New York: Academic Press, Inc.,

3 Chapter 3

BIOLOGY OF GERMINATION AND EMERGENCE OF VINE WEEDS

3.1 Introduction

Seedling emergence probably is the single most important phenological event that influences the success of an annual plant. Emergence represents the point in time when a seedling is weaned from dependence upon non-renewable seed reserves originally produced by its parent, and when photosynthetic autotrophism begins (Forcella *et al.* 2000). Timing of emergence often determines whether a plant competes successfully with its neighbours, is consumed by herbivores, infected with diseases, and whether it flowers, reproduces, and matures properly by the end of the growing season. Assuming seeds are non-dormant, germination is the key component of seedling emergence. Although germination is a continuous process commencing with various physiological activities within seeds, it is typically considered from a practical point of view. That is, germination is represented by the first visual appearance of the radicle from the outermost structure enveloping the embryo. Seed germination is perhaps the most thoroughly examined aspect of plant development. It has been studied extensively in controlled environments, but only rarely in natural soil environments. Nevertheless, the primary factors governing seed germination in arable soils are temperature, water potential, and air quality (Roberts 1988; Roberts *et al.* 1989).

The emergence of a seedling is a two-stage process (Grundy *et al.*, 1996). Firstly germination must be successful, then the seed must have sufficient food reserves to enable the seedling to reach the soil surface. The vertical position of weed seeds in the soil and the potential emergence from a given depth is therefore important in predicting the probability of a successful seedling emergence. Yet, differences exist in soil physical properties, moisture content, aeration, light availability and temperature within the soil profile which influence the two processes (Stoller & Wax, 1973). It has also been demonstrated that the depth at which weed seeds are buried affects their ability to germinate and emerge (Benvenuti *et al.* 2001). The magnitude of this effect varies between species, for example *Matricaria recutita* L. has a light requirement that precludes germination from depths of burial in excess of 1 cm from the soil surface. Conversely, species such as *Veronica hederifolia* L. have been found to emerge from depths of up to 13 cm in light sandy soils (Grundy *et al.*, 1996).

Vine weeds in agricultural crops, particularly dominated by *Ipomoea* genus, are large-seeded species, size being generally greater than 2 mm in diameter; they fall into the category of *V. hederifolia*. This characteristic imparts tolerance to many of the stresses encountered in emergence and early development which have to be reconciled in putting forward control strategies. The stored reserves can sustain the young plant while a photosynthetic capability is being established to enhance early growth of the vine weeds compared to the small-seeded species. This ability among large-seeded species is rapidly set up due to the presence of large green cotyledons at the time of emergence. This is particularly very typical among *Ipomoea* spp which have characteristic shapes, *Basella alba* L. and *Cajanus scarabaeoides* (L.) Thouars.; these vine weeds are important species of sugarcane fields. It is suspected that the inherent qualities that this category of weeds possesses regarding their germination and emergence abilities are at the root of their success in the sugarcane cropping system.

The weed control practices that have been adopted in the past decades, mainly based on the use of herbicides, have effectively managed the emergence of small-seeded weed species that exist in the sugarcane fields in Mauritius (Mc Intyre 1991). The easy availability of a low cost manual labour in the years before the 1990s (Fig 2.3) had also, directly or indirectly through other cultural practices, enabled the management of perennial and difficult weeds, namely vine weeds. However, the major socio-economic changes that the sugarcane industry experienced in the last two decades had greatly influenced agronomic practices (Ismael *et al.* 2008), leading to the creation of a new set of agro-ecological conditions. The gradual elimination of manual weeding during the inter-harvest season and the increasing adoption of mechanized green cane harvest with GCTB becoming more prevalent are two major changes that have affected cultural operations in the fields. They appeared to have established new favourable ecological situations for particularly vine weeds which germinate and emerge from large seeds.

Therefore the main objective of this chapter is to understand how biological or agro-ecological factors are influencing the germination and emergence of vine weeds in sugarcane fields. Four aspects focused on *Ipomoea* spp. and related to the two processes had been studied, namely influence of temperature, effects of burial depths, mulching of sugarcane trash residue and post-harvest trash management practices. The outcomes are reported in the form of publications, two of which have already been submitted. The aim is to contribute towards the setting up of sustainable management strategies for the control of vine weeds.

Reference

- Benvenuti S., Macchia M. and Miele S. 2001. Quantitative analysis of emergence of seedlings from buried weed seeds with increasing soil depth. *Weed Science* **49**, 528-535.
- Forcella F., Benech Arnold R.L., Sanchez R. and Ghera C.M. 2000. Modelling Seedling Emergence. *Annals of Botany* **67**, 123-139.
- Ismael F., Seeruttun S., Barbe C. and Gaungoo A. 2008. A review of changing cultural practices to improve productivity of sugar cane in Mauritius. In: *Proceedings South African Sugar Technologists Association*). Durban.
- Mc Intyre G. 1991. *Weeds of Sugar cane in Mauritius, their description and control*. Réduit.
- Roberts E.H. 1988. Temperature and seed germination. In: *Plants and Temperature* (ed. Long S. P., Woodward, F.I.). Society for Experimental Biology. Company of Biologists., Cambridge, 109-132.
- Roberts E.H. and Ellis R.H. 1989. Water and seed survival. *Annals of Botany* **63**, 39-52.

3.2 Influence of temperature on germination of vine weeds in sugarcane fields in Mauritius.

Introduction

Temperature is one of the primary factors governing seed germination in arable soils along with water potential and air quality (Roberts 1988, Roberts *et al.* 1989). It is directly related to the timing of weed emergence which has an important effect on crop-weed interactions and crop yield. Most of the studies carried out to improve knowledge of weed emergence in the field (Bradford 2002; Colbach N 2002; Forcella *et al.* 2000) aim to develop prediction models that can provide information to farmers to plan more effective weed control (Grundy 2003). Temperature is a central and important parameter in all these models, and knowledge about its influence on the growth and development of weeds, particularly germination, is crucial.

The weather in Mauritius is characterised by tropical conditions where hot and wet summer climate prevail during the months of November to May whereas the cooler and drier winter period extends from June to October. The mean daily temperature ranges from about 22 °C in the upland to 28 °C on the coast in summer and 16 °C to 22 °C in winter. The island receives a mean annual rainfall of 2,100 mm which ranges from 750 mm on the leeward coast to 4,350 mm on the highest grounds (Padya 1989; Willaime 1984).

These climatic conditions are favourable to the development of the weed species present in sugarcane fields throughout the year. More than a hundred weed species have been identified (Le Bourgeois *et al.* 2008) and (Rochecouste 1967) showed that their distribution depends mainly upon soil type and moisture. However, the competitive effect of some weed species also varies with the season; e.g. *C. rotundus* is more competitive during the summer months, and then particularly in the lowlands. Similarly, it is noted that vine weeds, especially *Ipomoea* spp., are more active in the period from November to April. Studies carried out on their life cycle (unpublished data) have revealed that they have high germination and emergence rates followed by rapid vegetative development during this period. This is especially enhanced by their creeping, climbing and twining abilities leading to an exponential growth. It is during this period also that the sugarcane crop completes its vegetative phase but is not able to compete with the very

aggressive vine weeds. Furthermore, the climbing and twining capacities of the latter enable them to pursue their development on tall canes making control even more difficult.

Most of the time field operations managers on large sugarcane estates (> 3000 ha) are not able to cope with the rapid establishment of vine weed infestations in the crop during the months of January to March. In this situation, a repositioning of the control strategies is required through a better knowledge of the timing of germination and emergence. This depends mainly on the minimal temperature requirement for these two processes to occur for the important vine weed species interfering with sugarcane development. As this information is not available, it warrants evaluations to be carried out. Therefore the objective of this work is to determine the minimal temperature requirement for the germination of the most important vine weeds infesting sugarcane fields in Mauritius with the aim of anticipating the timing of their emergence for a more effective control.

Materials and Methods

An experiment was held in November-December 2012 and consisted of laboratory germination tests on eight vine weed species in plant growth chambers at CIRAD Montpellier (France). Mature seeds of the different species were collected from vine weed development occurring in and outside sugarcane fields in different regions of Mauritius (Table 3.1). All the seeds were kept at 4°C before setting up the evaluations.

The seeds used in the experiment were afterward scarified with 98% sulphuric acid for one hour (Hardcastle 1978; Suwanketnikom *et al.* 2004) to ensure a homogeneous germination. After scarification, 20 seeds of each species were placed on a 10 cm diameter Watson filter paper in a petri dish of equal size to which 10 ml of distilled water was added. There were five such petri dishes for every species and they were all incubated for one week at the following constant temperatures in a plant growth chamber with the light set off: 5, 10, 15, 20, 25, 30, 35, 40 and 45°C.

Data collection and analysis

Germination counts were recorded daily over the period of incubation and were based on the appearance of the radicle; all germinated seeds were removed after every count. The mean cumulative germination counts of the replicates along with the standard errors were calculated for each vine species. In addition, a three parameter logistic model was fitted to the data and log-logistic regressions were carried out with the add-on package *drc* (ver 2.3-7), using the open source programme R version 3.0.3 (R *et al.* 2014).

Table 3.1: Details of vine weed species seeds used in germination tests at CIRAD Montpellier

Vine species	Family	Date and places of seed collections
<i>Cajanus scarabaeoides</i> (L.) Thouars	Fabaceae	July 2012, Riche en Eau
<i>Ipomoea hederifolia</i> L.	Convolvulaceae	August 2009, Solitude
<i>Ipomoea nil</i> (L.) Roth	Convolvulaceae	September 2009, Albion
<i>Ipomoea obscura</i> (L.) Ker Gawl.	Convolvulaceae	June 2008, Quatre Bornes
<i>Ipomoea quamoclit</i> L.	Convolvulaceae	May 2009, Phoenix
<i>Ipomoea triloba</i> L.	Convolvulaceae	May 2009, Albion
<i>Passiflora foetida</i> L.	Passifloraceae	July 2011, Albion
<i>Passiflora foetida</i> L.	Passifloraceae	September 2011, Pamplemousses

Results

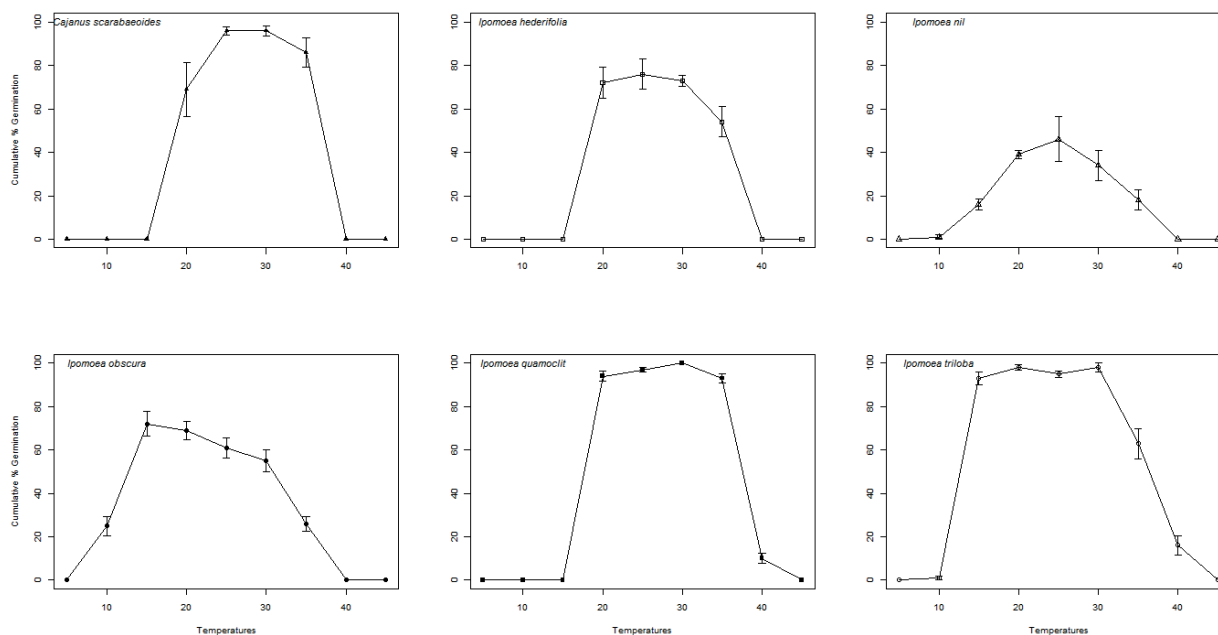


Figure 3.1 Influence of temperature on the germination of vine weed seeds from tests carried out in plant growth chamber. Error bars represent the standard error of five replicates.

The acid scarification treatment was very effective in removing the physical barrier due to the seed coat to allow seed germination of *C. scarabaeoides* and the *Ipomoea* spp. However, the two *Passiflora* spp. did not show any response to this treatment and hence no germination was recorded for any of the temperature tested. This would mean that the seed coat of these species would be chemically inert to the activity of the concentrated sulphuric acid.

Otherwise, the results showed that *C. scarabaeoides*, *I. hederifolia* and *I. quamoclit* required more than 15°C to initiate germination and they reached their maximum cumulative percentage after an additional 5°C (Fig 3.1). On the other hand, radicle emergence in *I. nil* and *I. obscura* was noted even when temperature was below 10°C though they took a further 10°C to attain their optimal germination. The response of *I. triloba* seeds to the influence of increasing temperature appeared to be intermediate between the two groups of vine weeds. In fact, germination in this species was triggered around 10°C and was already at the highest rate after 15°C. However, temperatures above 30°C negatively affected the rate of germination of all species, and this was even more drastic for *I. nil* and *I. obscura* where a reduction in the rate was

even noted above 25°C and 15°C respectively. Finally, very few or no germination was recorded for the six species beyond 40°C.

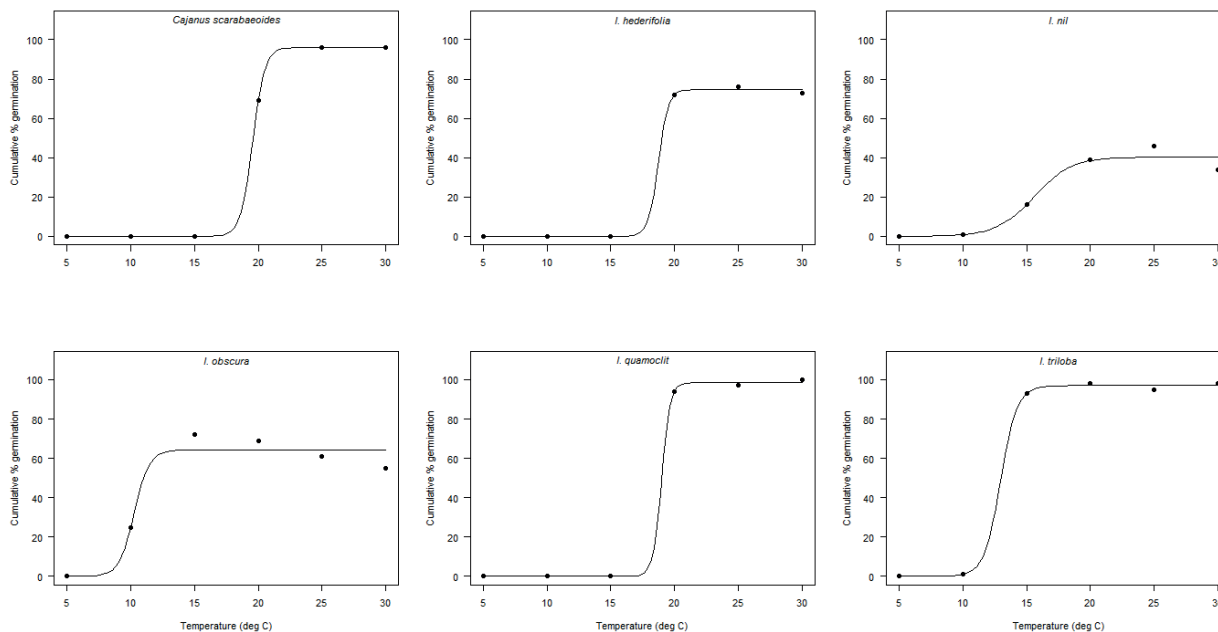


Figure 3.2 Log-logistic regression of the cumulative percentage germination of six vine weeds following tests carried out in growth chambers. The black dots represent the observations and the curves are the regressions.

Thus the log-logistic regression on the cumulative percentage germination of each vine species was performed on the temperature range of 5°C to 30°C using the three parameter logistic model (Fig. 3.2). The Neill's lack-of-fit tests were not significant in every case, confirming the goodness of the fits. The function $ED()$ of the add-on package *drc* from the open source programme R also enabled the estimations of the minimal effective temperature needed to initiate germination of the different vine weed species seeds (Ritz *et al.* 2005). This was based arbitrarily on a 0.5% cumulative germination rate in order to demonstrate the difference in their minimum temperature requirement for germination.

The results (Table 2) showed that this effective temperature ($ET_{0.5}$) was about 17°C for *C. scarabaeoides*, *I. hederifolia* and *I. quamoclit* whereas that of *I. nil* and *I. obscura* was around 7.5°C. The $ET_{0.5}$ of *I. triloba* was more or less 9.5°C. These estimations provided a quantitative

comparison of the minimal temperature needed to initiate germination among the six vine weed species and confirmed the existence of three distinct groups.

Table 3.2: Estimations of the effective temperatures for vine species using the function $ED()$ of the add-on package *drc* from the open source programme R.

Vine species	Effective temperature for 0.5% germination	
	°C	se (\pm)
<i>C. scarabaeoides</i>	17.02	1.54
<i>I. hederifolia</i>	16.67	1.63
<i>I. nil</i>	7.79	0.90
<i>I. obscura</i>	7.16	1.45
<i>I. quamoclit</i>	17.22	3.27
<i>I. triloba</i>	9.53	0.33

Discussions and Conclusions

The laboratory tests had shown that the effective range of temperatures for initiating germination among the six vine weeds occurring in sugarcane fields in Mauritius is situated between 7 °C and 17 °C, depending upon the species. This range of temperature implies that these vine species have the potential to germinate all round the year anywhere on the island provided that other factors necessary for germination to take place are not limiting. This is because the minimum winter temperatures, based on a long term average for the period 1961-1990, are found between 14°C and 20°C, respective of the regions (Fig 1.1). In these conditions, the germination and emergence of the six vine weed species studied in this work can be expected to take place in any sugarcane fields in the three agro-climatic zones (Chapter 2). But from studies carried out on the emergence dynamics of *I. triloba* in the field (results not presented in this thesis), it had been found that germination was slow at the end of winter and the beginning of summer (September to November). Eventually, it increased exponentially in the full summer months where optimal humid and temperature conditions were also present for rapid growth and development. (Fig. 4.1, Chapter 4).

However, studies carried out on their ecology and distribution (Chapter 2) had revealed that some species are more prevalent in the sub-humid and humid areas where the average long term minimum and maximum winter temperatures are 15°C and 27°C (Fig 1.1), compared to others that are better adapted to the superhumid zone characterised by cooler temperatures. Hence, development of *C. scarabaeoides*, *I. hederifolia* and *I. quamoclit*, with higher $ET_{0.5}$, would be more prone to occur in fields present in the humid and subhumid regions. Although the other *Ipomoea* spp. had lower $ET_{0.5}$, they were rarely found in the superhumid zone. This could be related to biotic (species development abilities) and abiotic (management practices and agronomic conditions) factors present in the fields.

The lower $ET_{0.5}$ of *I. nil*, *I. obscura* and *I. triloba* would also mean that they may have the ability to germinate and emerge earlier than the other species after fields had gone through the winter period from June to December following sugarcane harvest. The early development of particularly *I. triloba* due to its lower $ET_{0.5}$ means that it is at a phenological advantage compared to the sugarcane crop. The latter has been shown to be associated with a base temperature of 16°C which characterises the phases of vegetative growth of the cane plants (Singels *et al.* 2005). Moreover, the inefficacy of pre-emergence herbicides to control large-seeded weeds compared to the small-seeded ones have been discussed in the studies on the effect of burial depth on the germination and emergence of *Ipomoea* spp. (Gaungoo *et al.* 2014). These two conditions create favourable growth and development opportunities for *I. triloba* to out-compete the sugarcane crop. Thus, this, in addition to its greater intrinsic biological and phenological capacities, may explain the very aggressive nature of this *Ipomoea* species which is the most troublesome vine weed present in sugarcane fields in Mauritius.

Therefore, information generated in this work concerning the minimum temperature requirement for germination and emergence of the six vine weed species would allow the setting up of more effective management strategies for their control. These would be geared towards an early treatment of seedling emergence through a better knowledge of the influence of temperature on the germination of their non-dormant seeds. Hence, the timing of control of vine weeds appears to be an important aspect for the effective control of vine weeds in sugarcane fields in Mauritius.

References

- Bradford K. 2002. Applications of hydrothermal time to quantifying and modelling seed germination and dormancy. *Weed Sci.* **50**, 248–260.
- Colbach N.C.B., Du'rr C. & Richard G. 2002. Effects of environmental conditions on *Alopecurus myosuroides* germination. II. Effect of moisture conditions and storage length. *Weed Res.* **42**, 222–230.
- Forcella F., Benech Arnold R.L., Sanchez R. and Ghersa C.M. 2000. Modelling Seedling Emergence. *Ann. Bot.* **67**, 123-139.
- Gaungoo A., Seeruttun S. and Le Bourgeois T. 2014. Effect of burial depth on germination and emergence of *Ipomoea* spp. in sugarcane fields: Implications for the development of vine weed management strategies. *Article to be submitted*.
- Grundy A. 2003. Predicting weed emergence: a review of approaches and future challenges. *Weed Res.* **43**, 1-11.
- Hardcastle W.S. 1978. Influence of Temperature and Acid Scarification Duration on Scarlet Morningglory (*Ipomoea coccinea*) Seed Germination. *Weed Sci.* **26**, 261-263.
- Le Bourgeois T., Carrara A., Dodet M., Dogley W., Gaungoo A., Grard P., Ibrahim Y., Jeuffault E., Lebreton G., Poilecot P., Prospero J., Randriamampianina J.A., Andrianaivo A.P. and Théveny F. 2008. Advent-OI : Principales adventices des îles du sud-ouest de l'Océan Indien. V.1.0. In: *Software*). Cirad Montpellier, France.
- Padya B.M. 1989. Weather and climate of Mauritius. MGI, Moka, Mauritius.
- R, Core and Team 2014. R: A language and environment for statistical computing. (ed. Computing R. F. f. S.). Vienna, Austria. URL
- Ritz C. and Streibig J.C. 2005. Bioassay analysis using R. *Journal of Statistical Software* **12**, 1-22.
- Roberts E.H. 1988. Temperature and seed germination. In: *Plants and Temperature* (ed. Long S. P., Woodward, F.I.). Society for Experimental Biology. Company of Biologists., Cambridge, 109-132.

- Roberts E.H. and Ellis R.H. 1989. Water and seed survival. *Ann. Bot.* **63**, 39-52.
- Rochecouste E. 1967. *Weed Control in sugarcane*. Adlard & Son Ltd, Bartholomew Press, Dorking, England.
- Singels A., Smit M.A., Redshaw K.A. and Donaldson R.A. 2005. The effect of crop start date, crop class and cultivar on sugarcane canopy development and radiation interception. *Field Crops Res.* **92**, 249-260.
- Suwanketnikom R. and Julakasewee A. 2004. Hardseededness and germination of small white flower morningglory. *Kasetsart-Journal,-Natural-Sciences.* **38**, 425-433.
- Willaime P. 1984. Carte pédologique de l'Ile Maurice. Office de la Recherche Scientifique et Technique Outre-mer.). France and Mauritius Sugar Industry Research Institute Mauritius.

3.3 Effect of burial depth on germination and emergence of *Ipomoea* spp. in sugarcane fields: Implications for the development of vine weed management strategies

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Abstract

Vine weed infestations mainly caused by *Ipomoea* species are more frequent in sugarcane fields in Mauritius; current weed management practices are not effective in providing adequate control of these weeds. The germination and emergence abilities of *Ipomoea* spp. were investigated with the objective of improving the vine weed management strategies. Laboratory tests were conducted to characterise the seed size and weight traits of *I. hederifolia*, *I. nil*, *I. obscura*, *I. quamoclit* and *I. triloba*. Acid scarified seeds of these species were buried at soil depths of 0, 4, 8 and 12 cm under controlled conditions in five trials in 2008 and 2010. Data of germination counts and measurements of hypocotyl length were analysed using generalised linear mixed models with quadratic effect of burial depth. The five *Ipomoea* spp. seeds, which individually weighed between 10 mg to 21 mg with a size of 2-3 mm, had the capacity to germinate and emerge beyond 8 cm underground. However, emergence success was found to peak at an optimal soil depth, located in between 4 cm and 8 cm for *I. nil*, *I. quamoclit* and *I. triloba* and between 0 cm and 4 cm for *I. hederifolia* and *I. obscura*. Hypocotyl lengths were highly and positively correlated to burial depths. These results, in the light of available knowledge on the pre-emergence activity of herbicides, demonstrate the greater capacities of the *Ipomoea* spp. than small-seeded weeds to infest sugarcane fields. This implies that the present control practices would need innovative approaches to find effective solutions to the problem of vine weeds.

Keywords: large-seeded weeds, vine infestations, soil depth, hypocotyl length, pre-emergence herbicides

Introduction

Many *Ipomoea* spp. are troublesome vine weeds affecting sugarcane and other crops worldwide (Azania *et al.* 2002; Bhullar *et al.* 2012; BSES 1989; Chauhan *et al.* 2012; Christoffoleti *et al.* 2006; Jones 2006; Lancaster *et al.* 2005; Lebreton *et al.* 2009; Norsworthy 2004). Unlike other broad-leaved weeds, grasses and sedges growing along sugarcane crop, vine weeds, particularly *Ipomoea* spp., have the ability to develop late in the season and spread long distances both horizontally and vertically making their control difficult. In Mauritius the problem started in the 1990s following changes in sugarcane husbandry practices with respect to green cane harvesting and post-harvest trash management. Since then, vine-weed infestation, particularly those by *Ipomoea* spp. has become a common feature in sugarcane fields where a few species of this genus are currently being encountered. *Ipomoea* species reproduce mostly through the production of large-sized seeds (Crowley *et al.* 1982; Gomes *et al.* 1978). Seeds of *Ipomoea* spp. have hard envelope which may allow them to survive in the soil for more than 35 years (Toole *et al.* 1946). After an initial phase of vertical growth up to the five-leaf stage following germination and emergence, they creep on the ground until they get into contact with the crop whence they start twining rapidly all over. The vine weed development can afterward sprawl into a larger area, severely compete with the crop and eventually lead to yield losses unless timely control measures are undertaken.

All *Ipomoea* spp. infest agricultural fields through the germination and emergence of their soil-born seeds. Several studies (Chauhan *et al.* 2012; Cole *et al.* 1973; Gomes, *et al.* 1978; Oliveira *et al.* 2006; Singh *et al.* 2012; Sobrero *et al.* 2003) have focused on the various factors that influence the establishment of an *Ipomoea* sp. population in a crop. Burial depth and temperature appear to be the two most important conditions that determine the germination and emergence of scarified *Ipomoea* seeds. Studies have also revealed that soil moisture, salt stress, pH and flooding play a significant role in the process. On the other hand, though light is a crucial element for the germination of small-seeded weeds mostly present on the surface or shallow depths (< 3 cm) (Benvenuti *et al.* 2001) of soil, it does not contribute significantly to increase the germination success of *Ipomoea* seeds (Singh *et al.* 2012).

Seedling survival is generally higher in large-seeded species than in small-seeded ones (Moles *et al.* 2004). This applies to natural conditions (Bakker 1989; Dalling *et al.* 2002), as well as to a wide range of experimentally-controlled constraints including shade (Grime *et al.* 1965; Leishman *et al.* 1994a), drought for early-stage seedlings (Leishman *et al.* 1994b),

competition from other seedlings (Leishman 2001; Turnbull *et al.* 1999), defoliation (Armstrong *et al.* 1993; Harms *et al.* 1997) and competition with established plants (Burke *et al.* 1996; Gross 1984). In any case, seed size thereby confers an advantage for establishment. It has also been demonstrated that emergence from the weed seed bank occurs mostly in the uppermost 10 cm of soil but bigger seeds (> 10 mg) can emerge from deeper depths (Benvenuti *et al.* 2001). As large-seeded weeds, *Ipomoea* spp. can also possess these abilities. In addition, around 10% of the sugarcane fields in Mauritius undergo profound soil preparation every 7 to 8 years when establishing a new crop cycle. During this operation, major changes occur in the seedbank and seeds are redistributed along the soil profile. Thus, large seeds that are buried deep in the ground may emerge in several flushes. However, the effects of soil depths on the emergence of their seedlings in the agronomic systems of sugarcane are not well documented.

Weed control is one of the main cultural practices associated with sugarcane production in Mauritius. The tropical climatic conditions allow weeds to grow all throughout the year and their control is achieved mainly through the application of cost-effective pre- and post-emergence herbicide tank-mixes (Appendix 1). Green cane trash blanketing (GCTB) is also another practice which is contributing to suppress weed emergence in sugarcane fields (McIntyre *et al.* 1996; Morandini *et al.* 2005; Seeruttun *et al.* 1992). This practice was adopted in the 1990s and though it effectively impedes the development of small-seeded weeds, it has been reported to be ineffective against the large-seeded ones, especially *Ipomoea* spp. (Manechini *et al.* 2005). In fact, field observations are attributing the increase of vine weed infestation to this practice. Both trash blanketing and herbicides are targeting weeds that are germinating close to the soil surface and do not tolerate burial. The issue addressed here is whether the success of *Ipomoea* species in sugarcane fields can be attributed to their ability of germinating deeper in the soil and escaping the effect of these management practices.

Therefore, the objective of this work is to understand the germination and emergence abilities of *Ipomoea* spp. seeds infesting sugarcane fields in Mauritius, so that this knowledge can be used in order to develop effective vine weed management strategies. This work is a component of a more global study where the capacities of the seeds were evaluated with regards to burial depths and mulching of sugarcane trash. This publication reports the outcome of an experiment undertaken with five *Ipomoea* spp. buried at different depths.

Materials and methods

The experiment was carried out in the year 2008 and 2010 under controlled conditions at the Réduit Experimental Station of the Mauritius Sugarcane Industry Research Institute (20 14' 06'' S, 57 29' 42'' E). Five germination and emergence trials were setup with *I. hederifolia* L., *I. nil* (L.) Roth, *I. obscura* (L.) Ker Gawl., *I. quamoclit* L and *I. triloba* L. Although *I. quamoclit* is very rarely found in the fields, it represents a potential threat to sugarcane cultivation as it is an important vine weed in Brazil and Australia (BSES 1989; Correia *et al.* 2004). Laboratory tests were also carried out to characterise seed size and weight of the different species. Mature seeds of *Ipomoea* spp. were collected from vine weed development occurring in and outside sugarcane fields in different parts of the island (Table 1). All the seeds were stored at 4°C before setting up the trial.

Mean weight and size of vine weed seeds

For each of these five species, ten batches of one hundred seeds each were weighed on an electronic balance; the mean weight of one hundred seeds (WHS) and the respective standard deviations were calculated for comparison between species.

As the seeds of the *Ipomoea* spp. were not spherical, we also investigated the largest dimension of each species by allowing every batch of one hundred seeds to go through a 4 mm followed by 2 mm Retsch sieves. The seeds were grouped into 3 categories of sizes:

> 4 mm – seeds retained by the 4 mm sieve

2-4 mm – seeds that went through the 4 mm sieve but retained by the 2 mm sieve

< 2 mm – seeds that went through the 2 mm sieve

The number of seeds obtained in each category was recorded for every batch of one hundred seeds and the averages were computed for the species under test.

Vine species x burial depths trials

The experiments were conducted in 2008 (Trial I and II) and 2010 (Trial III, IV and V) (Table 1). The seeds of all the *Ipomoea* spp. were sorted out to choose the ones with a regular hard body, and all seeds were scarified with 98% sulphuric acid for one hour to ensure homogeneous germination (Hardcastle 1978; Suwanketnikom *et al.* 2004). The germination

tests were conducted in fiberglass tanks having dimensions 0.60 m x 0.30 m x 0.16 m (Trial I) and 0.90 m x 0.45 m x 0.25 m (Trial II, III, IV and V), and all tanks had holes pierced at the bottom to allow drainage of excess water after irrigation. The tanks were filled with soil collected from the same experimental station where the soil group is Oxisol, containing some 80% clay and 4.7% organic matter (Parish *et al.* 1965; Soil *et al.* 1999). On the station, *Ipomoea* spp. were not present in the fields, and hence the possibility of having *Ipomoea* seeds in the soil could be waived out. Each soil-filled fiberglass tank was divided into four compartments corresponding to soil depths of 0 (surface), 4, 8 and 12 cm. Ten acid-scarified seeds were buried at each soil depth. All the fiberglass tanks were laid outside and were irrigated when required. The statistical design adopted for all the trials was a split-plot with vine species as the main plot and burial depth as the sub-plot. Trial I, III and IV consisted of four replicated blocks whereas the treatments in Trial II and V were replicated eight and six times respectively. Table 3.3 summarizes the experimental design of the five germination and emergence trials.

Data collection and analysis

In each trial, the number of emerged seedlings was accounted for when their cotyledons became visible above the soil surface. This was carried out on a three-day basis for a period of 3 weeks, resulting in 7 series of counts for each trial. The emerged seedlings were, however, not uprooted after every count since their hypocotyl lengths were measured at the end of the trial. This was carried out for Trials I, III, IV and V at the four sowing depths but not for Trial II as the trial was mistakenly stopped before any measurement could be taken. The readings of hypocotyl length for each seedling was partitioned into underground (UG) and above ground (AG) components, such that the whole plant hypocotyl length (WP) was defined as $WP = AG + UG$.

All the statistical analyses were performed using the R software version 3.0.3 (R Core Team 2014). The cumulative count of emerged seeds was analyzed through time by fitting a three-parameter (b, d, e) logistic function:

$$f(x, (b, d, e)) = \frac{d}{1 + \exp\{b(\log(x) - \log(e))\}}$$

where d is the asymptotic count of emerged seeds and e represents the time to mid-emergence. The parameter b denotes the relative slope around e.

We further calculated the time to reach 10%, 50%, 90% and 99% emergence of the five *Ipomoea* spp. at each burial depth. We also analyzed the variation of the upper limit d as a function of burial depths for each *Ipomoea* sp.

We then analyzed how the emergence success for each of the five *Ipomoea* spp. at the end of the three-week study varied depending on soil depth and species. We investigated the issue by using binomial generalised linear mixed models (GLMM) (Bolker *et al.* 2009) including the relative number of emerged/non-emerged seeds per tank as the binomial response variable, soil depth as fixed effect, and the nested split-plot block as random effect within Trials. We also included the square of soil depth as a fixed effect, to acknowledge any quadratic effect of burial depth on seedling emergence. Our hypothesis was that there is an optimal depth for germination and emergence success yielding such quadratic relationship. The ANOVAs of the GLMM results were performed to test the effect of each variable alone or in addition to the others. The variation in hypocotyl lengths was likewise analyzed by performing GLMM models including the same fixed and random effects, but with a gaussian response variable. We used the `lmer` function of R package `lme4` for GLMM analyses (family parameter set to “binomial” or “gaussian” for the germination counts and hypocotyl lengths, respectively).

Table 3.3: Details of trials to test the germination and emergence of *Ipomoea* spp. at the MSIRI experimental station at Réduit.

Trial no.	Period of study	<i>Ipomoea</i> spp. tested	Date and places of seed collections	Average Temperature °C		Total Rainfall (mm)
				Min	Max	
I	3.03.2008 – 24.03.2008	<i>I. nil</i>	Feb 2008, Réduit	20	27	154
		<i>I. obscura</i>	Feb 2008, Bonne Terre			
		<i>I. triloba</i>	Feb 2008, Constance			
II	31.03.2008 – 25.04.2008	<i>I. nil</i>	Feb 2008, Réduit	19	28	67
		<i>I. obscura</i>	Feb 2008, Bonne Terre			
		<i>I. triloba</i>	Feb 2008, Constance			
III	4.03.2010 – 25.03.2010	<i>I. hederifolia</i>	Aug 2009, Solitude	22	29	183
		<i>I. nil</i>	Sep 2009, Albion			
		<i>I. triloba</i>	May, 2009, Bon Espoir			
IV	10.03.2010 – 1.04.2010	<i>I. hederifolia</i>	Aug 2009, Solitude	21	28	137
		<i>I. nil</i>	Sep 2009, Albion			
		<i>I. triloba</i>	May, 2009, Bon Espoir			
V	21.05.2010 – 11.06.2010	<i>I. hederifolia</i>	Aug 2009, Solitude	17	26	39
		<i>I. nil</i>	Sep 2009, Albion			
		<i>I. obscura</i>	Jun 2008, Quatre Bornes			
		<i>I. quamoclit</i>	May 2009, Phoenix			
		<i>I. triloba</i>	May, 2009, Bon Espoir			

Results

Mean weight and size of vine weed seeds

The mean WHS of the five *Ipomoea* spp. ranged from 1.00 g to 2.10 g. *I. triloba* seeds were lightest ($1.0344\text{g} \pm 0.0059$) whereas that of *I. obscura* were heaviest ($2.0618\text{g} \pm 0.0146$). *I. nil* ($1.3112\text{g} \pm 0.0091$) and *I. quamoclit* ($1.3048\text{g} \pm 0.0055$) had comparable mean WHS and that of *I. hederifolia* was slightly less than them ($1.2552\text{g} \pm 0.0111$). The standard error for the mean WHS of each species was very low, implying that the variance among the different batches of 100 seeds for the split-plot experiment was also very low for the respective *Ipomoea* sp. This would in turn mean a more or less regular individual seed mass for the five *Ipomoea* spp.

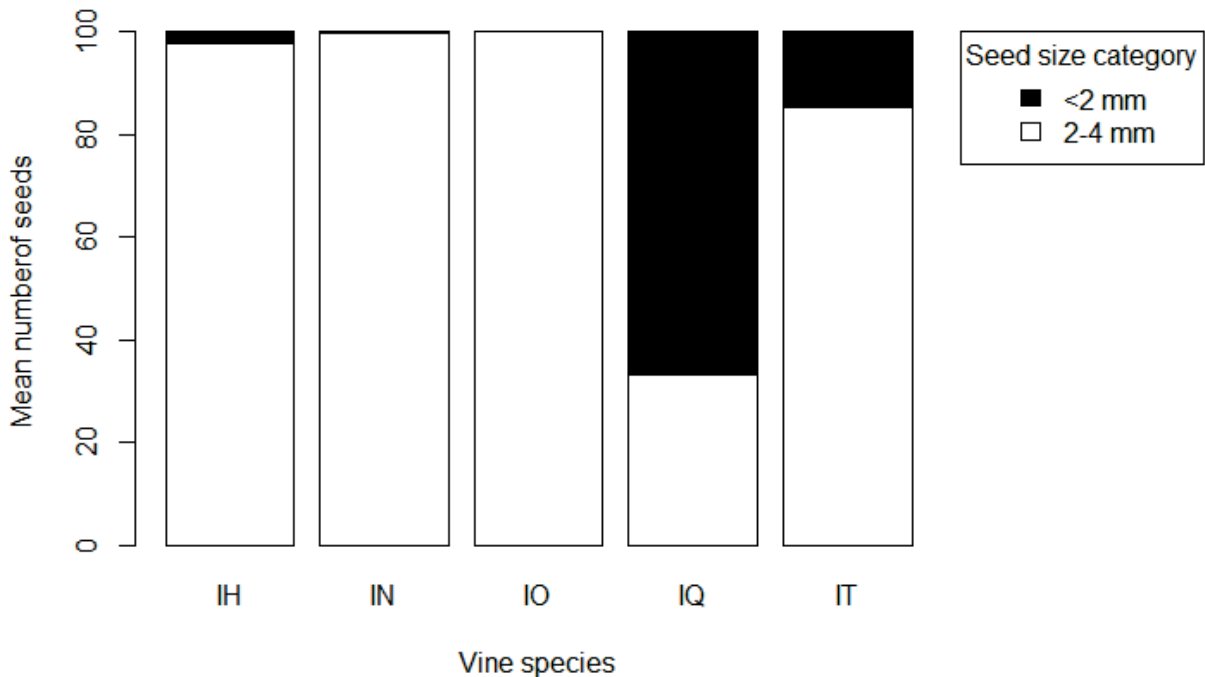


Figure 3.3: Size categories of *Ipomoea* spp. IH - *I. hederifolia*, IN - *I. nil*, IO – *I. obscura*, IQ – *I. quamoclit*, IT - *I. triloba*.

The average counts from the seed size investigations showed that all the seeds of *I. obscura* were between 2 and 4 mm (Fig. 3.3). Similarly, nearly all the seeds of *I. hederifolia* and *I. nil* (97.7% and 99.7% respectively) belonged to this category. Conversely, 15% of *I. triloba* seeds and two-third of the *I. quamoclit* seeds fell into the <2 mm category. The size of *I. quamoclit* seeds contrasted sharply with its WHS which was comparable to that of *I. hederifolia* and *I. nil*. Actually this was due to the shape of the seeds which in the case of *I. quamoclit* were smaller but more elongated whereas it was slightly rounder for the other species. Anyhow, these results would mean that seeds of the five *Ipomoea* spp. are quite large compared to the other types of weeds (Le Bourgeois *et al.* 2008) that generally grow along sugarcane in Mauritius. The size of their seeds varies between 1 mm to 2 mm with an average mass of less than 1 mg in most cases.

Effect of burial depth on germination and emergence

We modelled the emergence dynamics of the five *Ipomoea* spp. for the four burial depths (Fig. 3.4) using logistic curves. The Neill's lack-of-fit tests were not significant in every case, confirming the goodness of the fits. The curves showed that each species had a characteristic pattern of emergence at the different burial depths. Analysis of values giving the number of days to 10%, 50%, 90% and 99% emergence respectively (Fig. 3.5) showed that *I. hederifolia*, *I. nil* and *I. triloba* attained their maximum level (99%) more rapidly than *I. obscura* and *I. quamoclit*. This result could explain the rapid development of *I. hederifolia*, *I. nil* and *I. triloba* in places where they occur in sugarcane fields compared to *I. obscura*.

The results in Figure 3.5 also showed that nearly all emergences (99%) for all the *Ipomoea* spp. was reached around 21 days, and this corresponded to the last emergence count after the trials were established. The GLMM analyses carried out on these sets of data for all the trials established that burial depth had a highly significant ($P < 0.001$) effect on the germination and emergence of almost all the *Ipomoea* spp. except for *I. hederifolia* where the difference was only significant at 0.05 (Table 3.4). Moreover, these differences had a highly significant ($P < 0.001$) quadratic effect for *I. triloba*, *I. nil* and *I. quamoclit*. On the other hand, *I. hederifolia* and *I. obscura* demonstrated a significant ($P < 0.05$) and highly significant ($P < 0.001$) linear effects respectively (Fig. 4). The biologically plausible interpretation of the

data would suggest that there is some intermediate soil depth that was optimal for the germination and emergence of *I. triloba*, *I. nil* and *I. quamoclit*. The linear effect of *I. hederifolia* and *I. obscura* on the other hand would imply a better germination near the soil surface than deeper down in the soil.

Table 3.4: Effect (ANOVA P-value) of burial depth on emergence counts of *Ipomoea* spp sown in fiberglass tanks.

Species	Overall effect	Linear component	Quadratic component
<i>I. hederifolia</i>	<0.05	<0.05	ns
<i>I. nil</i>	<0.001	ns	<0.001
<i>I. obscura</i>	<0.001	<0.001	<0.01
<i>I. quamoclit</i>	<0.001	ns	<0.001
<i>I. triloba</i>	<0.001	ns	<0.001

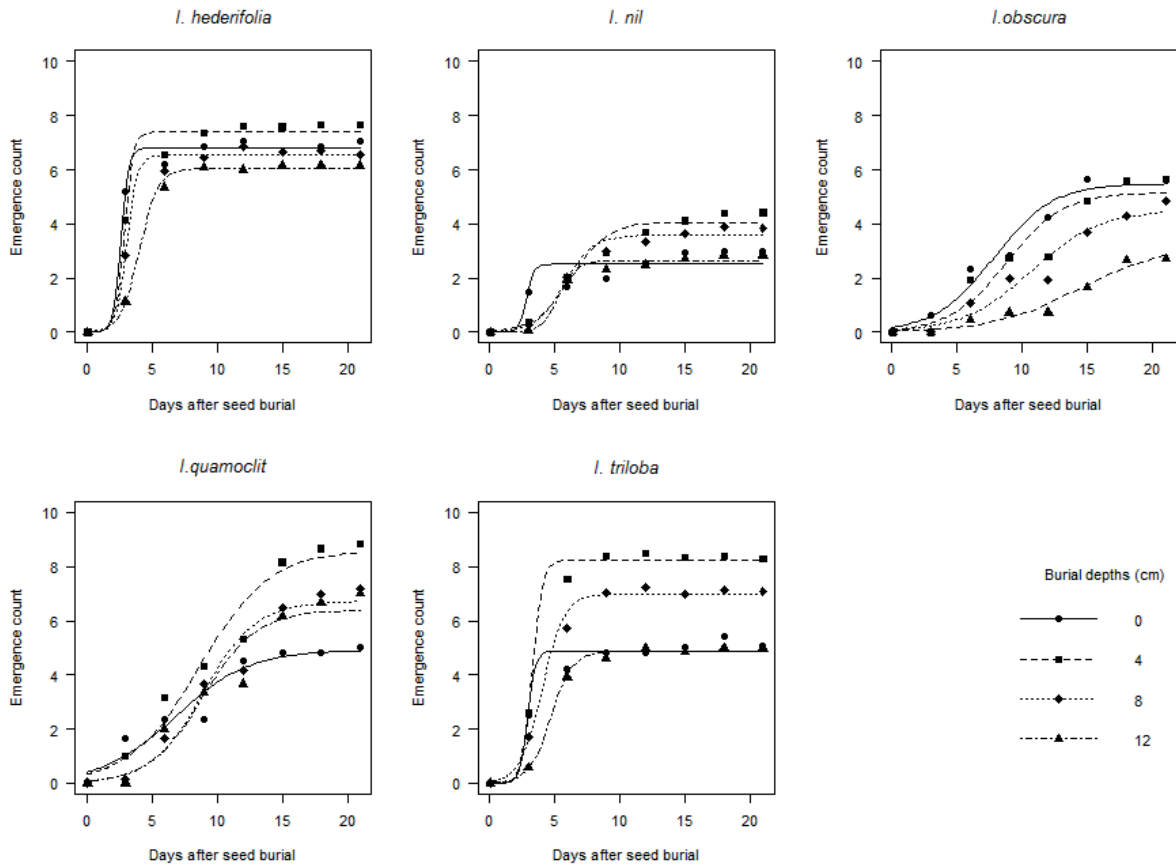


Figure 3.4: Fitted logistic curves and observed counts (dots) modeling the emergence of *Ipomoea* spp. in relation to the number of days that their seeds were buried at soil depths of 0 (surface), 4, 8 and 12 cm.

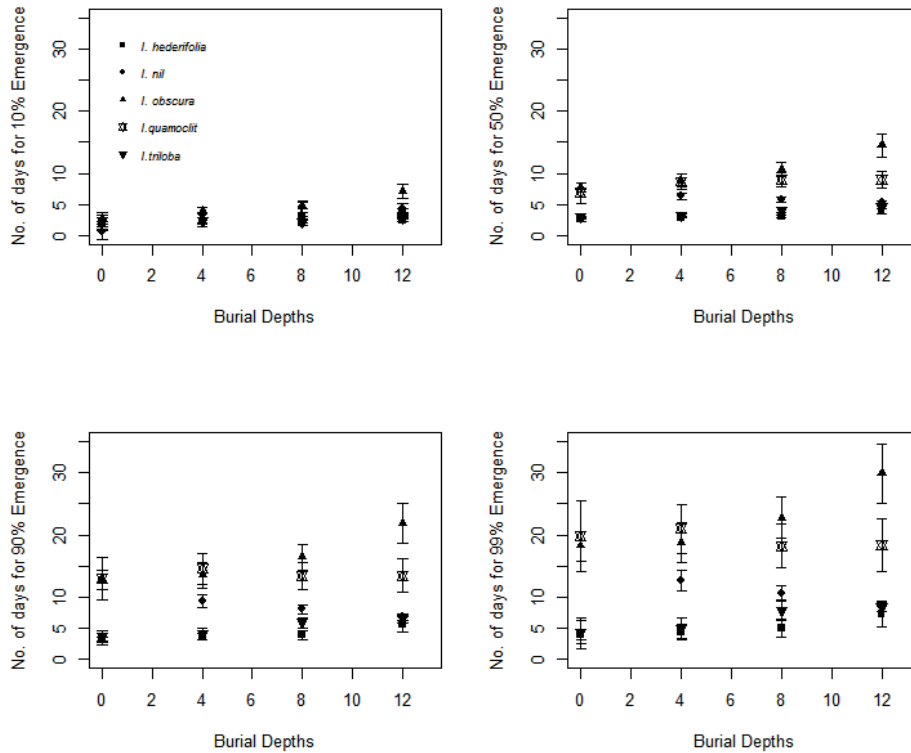


Figure 3.5: Effects of burial depths on the number of days taken for 10%, 50%, 90% and 99% of *I. hederifolia*, *I. nil*, *I. obscura*, *I. quamoclit*, and *I. triloba* seedlings to emerge. Values (dots) and standard error (error bars) were calculated after modelling through a three parameter logistic function. The legend in the first graphic applies to the other three plots also.

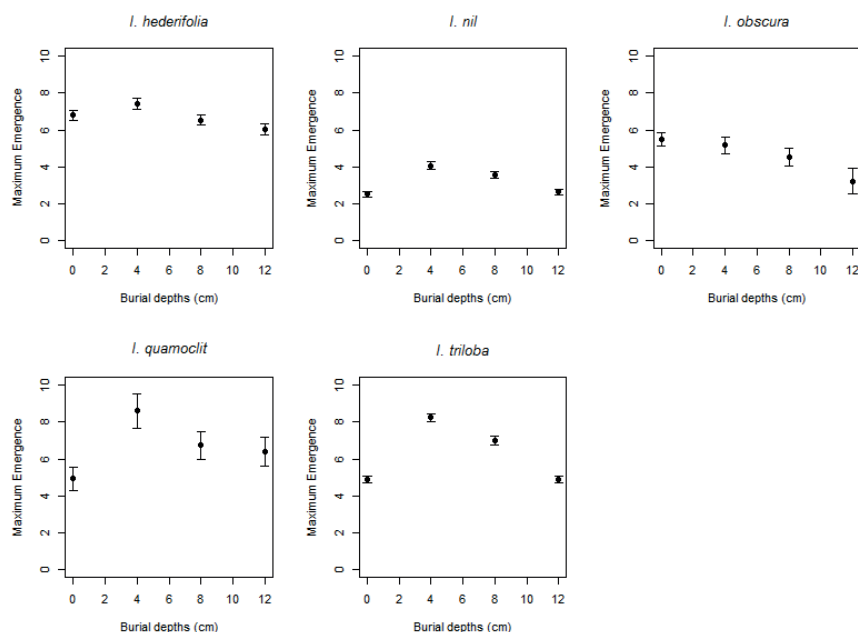


Figure 3.6: Values (dots) of the maximum emergence and standard errors (error bars) after 21 days obtained from a three parameter logistic fits of emerged *Ipomoea* spp. seedlings counts at burial depths of 0 (surface), 4, 8 and 12 cm.

In fact, the scatter-plots in Figure 3.6 indicated that the optimal soil depth for emergence was located in between 4 cm and 8 cm for *I. triloba*, *I. nil* and *I. quamoclit*. There was, however, a better emergence for *I. hederifolia* and *I. obscura* between 0 cm and 4 cm and which decreased linearly afterward. This ability to germinate and emerge beyond a soil depth of 4 cm is an important biological trait of these *Ipomoea* species.

Effect of burial depth on hypocotyl length

The effect of burial depth on underground (UG) hypocotyl length was found to be highly significant ($P < 0.001$) for the five *Ipomoea* spp. (Table 3.5 and Figure 3.7), based on the quadratic GLMM models. These biological characteristics could explain the greater emergence ability at deep of *Ipomoea* spp. It was further noted that the effect of sowing depth is less significant on the extension of the above ground (AG) hypocotyl compared to the UG (Table 3.5). Generally, either the AG hypocotyl length of the seedlings at the different burial depths followed a decreasing trend or they were comparable (Fig. 3.8). This would mean that once the

developing cotyledons were above ground level, there was a decrease in the hypocotyl extension. Moreover, the highly significant ($P < 0.001$) (Table 3.5) linear effect of the whole plant (WP) hypocotyl length would suggest that the development of the underground part played a vital role in the emergence of the *Ipomoea* seedlings beyond depths of 4 cm in the soil.

Table 3.5: Effects (P-value) of burial depths on the hypocotyl length of *Ipomoea* spp. seedlings sown in trays. Hypocotyl parts: AG – Above Ground, UG – Under Ground, WP – Whole Plant

Species	Hypocotyl parts	Burial Depths	Linear effects	Quadratic effects
<i>I. hederifolia</i>	AG	<0.05	<0.01	<0.05
<i>I. nil</i>	AG	ns	ns	ns
<i>I. obscura</i>	AG	<0.05	<0.05	ns
<i>I. quamoclit</i>	AG	<0.01	<0.05	<0.05
<i>I. triloba</i>	AG	<0.01	<0.05	<0.01
<i>I. hederifolia</i>	UG	<0.001	<0.001	ns
<i>I. nil</i>	UG	<0.001	<0.001	ns
<i>I. obscura</i>	UG	<0.001	<0.001	ns
<i>I. quamoclit</i>	UG	<0.001	<0.001	<0.1
<i>I. triloba</i>	UG	<0.001	<0.001	ns
<i>I. hederifolia</i>	WP	<0.001	<0.001	<0.01
<i>I. nil</i>	WP	<0.001	<0.001	ns
<i>I. obscura</i>	WP	<0.001	<0.001	<0.05
<i>I. quamoclit</i>	WP	<0.001	<0.001	ns
<i>I. triloba</i>	WP	<0.001	<0.001	ns

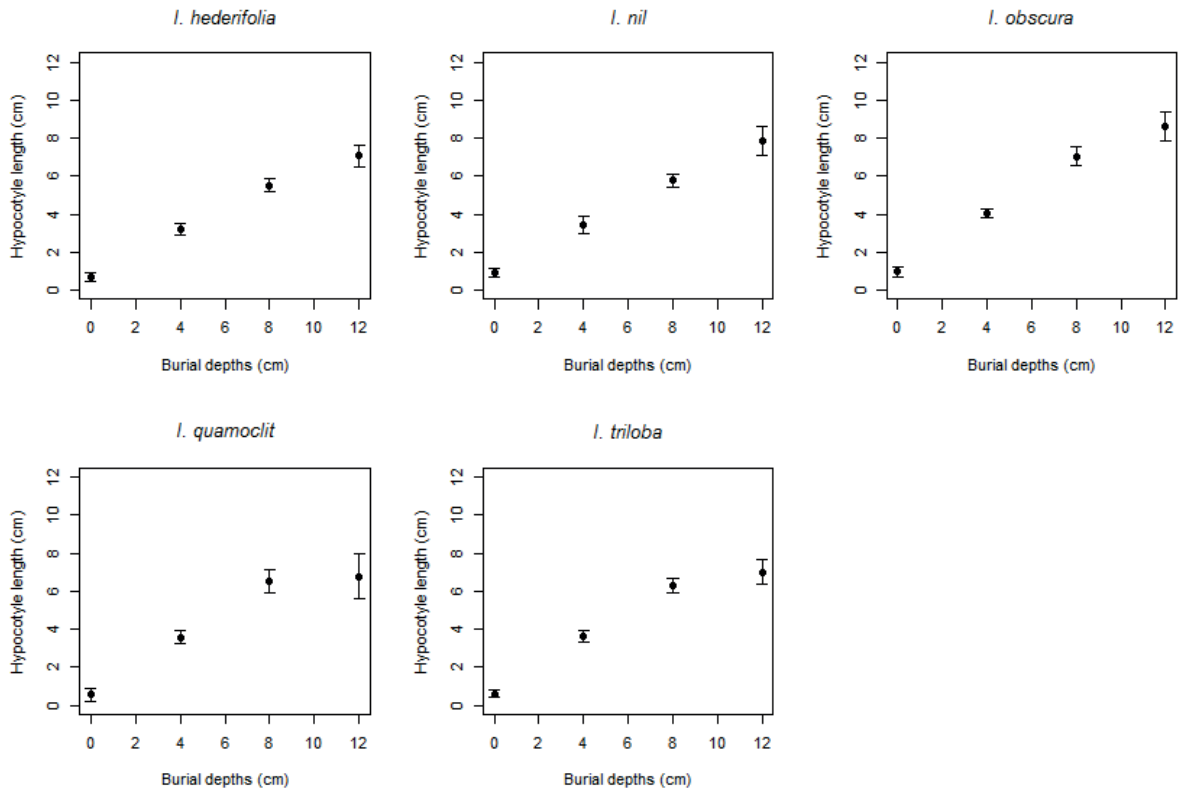


Figure 3.7 Effects of burial depths on the actual measurements of the underground hypocotyl lengths of *Ipomoea* spp. Values (dots) are means \pm standard error (error bars)

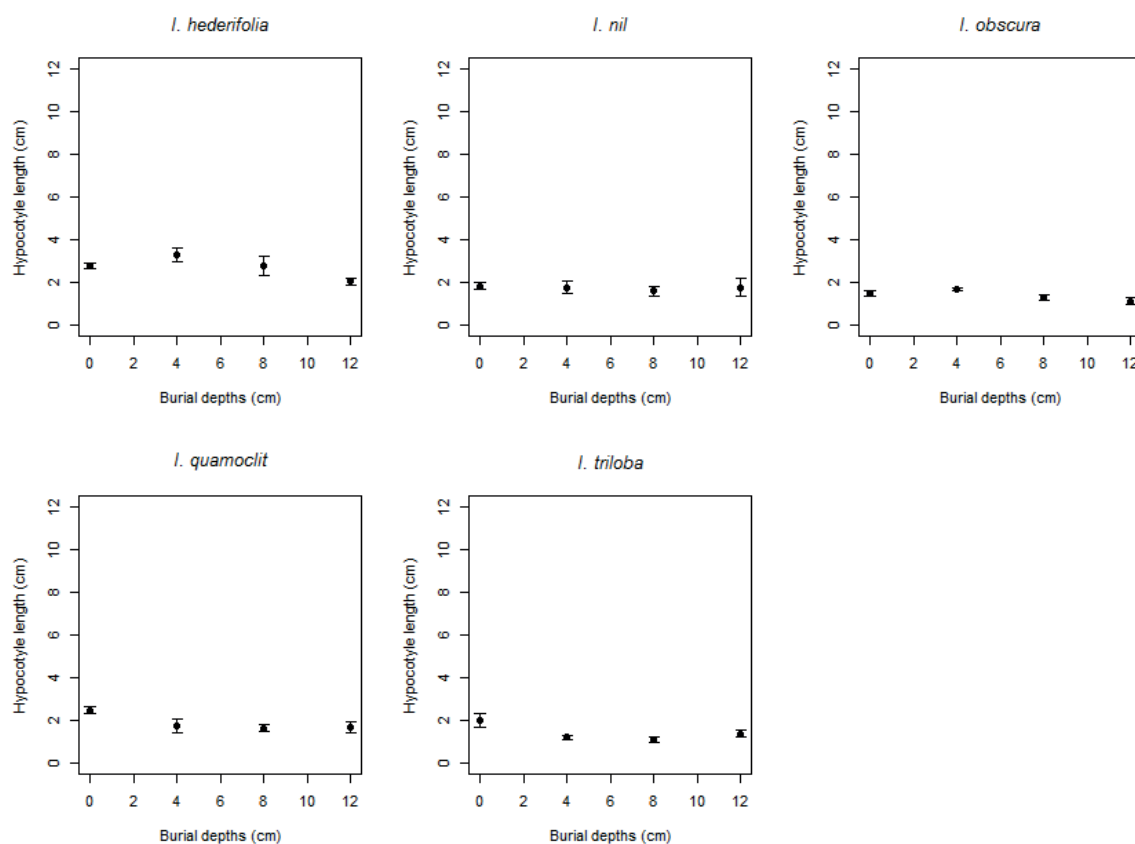


Figure 3.8: Effect of burial depths on the actual measurement of the above ground hypocotyl lengths of *Ipomoea* spp. Values (dots) are means \pm standard error (error bars)

Discussions

This study has revealed important biological characteristics of the five *Ipomoea* spp. seeds that can improve germination and emergence in the context of sugarcane fields. The basic hypothesis was that the larger seed sizes (2-3 mm) and higher WHS (1.0 – 2.1 g) would provide sufficient food reserve enabling the seeds to germinate and emerge from deeper than 4 cm underground compared to smaller-seeded weeds. Our results confirm that large-seed *Ipomoea* are indeed available to germinate even at high burial depth, sometimes even at a depth of 12 cm in the soil. In fact, (Roberts 1982) reported that most annual weeds, with seed weights between 0.1 and 5.0 mg, usually emerge from depths of less than 5 cm although seedlings of larger-seeded species such as *Polygonum convolvulus* L. may do so from 10 cm or more (Fig. 3.9). Similarly, (Benvenuti *et al.* 2001) found a correlation ($P < 0.05$) between the 1000-seed

weight of 20 weed species and their depth of 50% emergence according to a second-degree equation. His work showed that, generally, the depth of 50% emergence of weeds having 1000-seed weight less than 1.0 g did not exceed 4.0 cm in the soil whereas those with 1000-seed weight greater than 8.0 g could emerge from 6.5 to 7.0 cm (Fig. 3.10). Thus there seems to be an allometric relationship between seed size and maximum emergence depth for weed species occurring in agricultural situations. Such a relationship was found to exist among wild plant species present in fire-prone fynbos shrublands of South Africa (Bond *et al.* 1999).

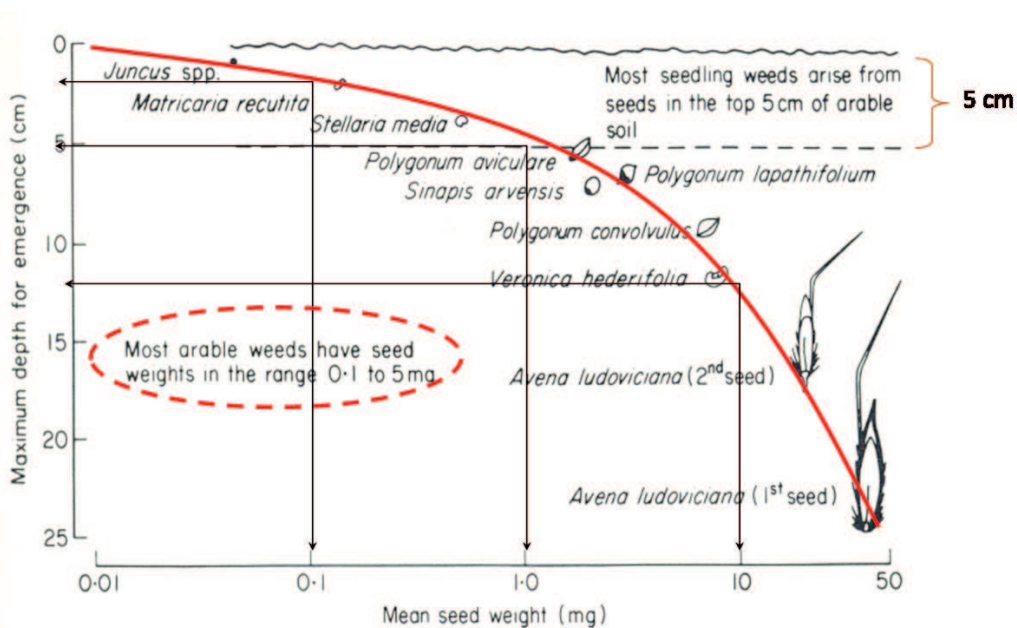


Figure 3.9: Relationship between seed size and the maximum depth of germination from which seedling emergence can occur, (Source: adapted from Roberts, 1982). The average seed mass of *Ipomoea* spp. tested ranges from 10 to 21 mg and can therefore emerge at a maximum depth varying between 12 to 15 cm (see text).

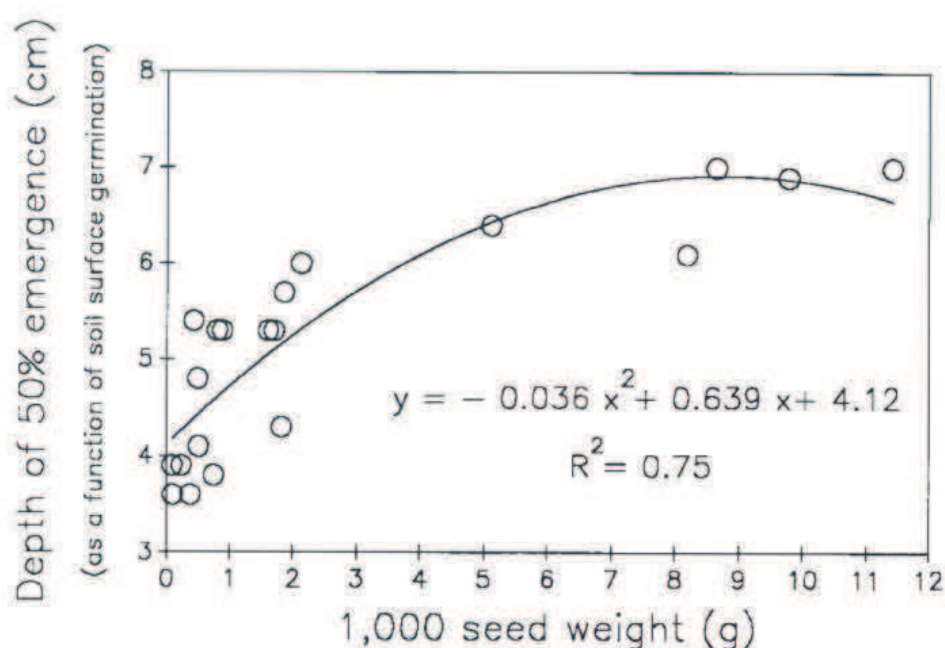


Figure 3.10: Regression between burial depth necessary to reduce emergence of the 20 weed species tested to 50% and corresponding 1,000-seed weight. The equation (significant for $P > 0.05$) and the corresponding R^2 value are shown (Source: Benvenuti *et al.*, 2001). The maximum emergence in the soil of *Ipomoea* spp. tested ranges between 4 and 8 cm (*see text*).

Our results, however, suggest that other factors among the five *Ipomoea* spp. studied should mitigate the effect of burial depth on emergence efficiency. The germination and emergence trials had shown that *I. nil*, *I. quamoclit*, and *I. triloba* with average weight of 10.0, 13.0 and 13.0 mg per seed respectively had maximum emergence in the soil between 4 and 8 cm. However, *I. hederifolia* and *I. obscura* seeds with average seed weight of 12.5 and 21.0 mg could optimally emerge in the range between 0 to 4 cm. This would imply that germination and emergence were more favourable near the soil surface for them. Emergence from different soil depths has been found to be proportional to seed energy reserves (Lafond *et al.* 1986). However, it may also be influenced by the nature of such reserves, depending on the amount of oxygen required for their utilization (Raymond *et al.* 1985). Energy reserves are vital for seedling growth prior to emergence, because given the absence of light, growth takes place completely autotrophically. Furthermore, independent of the physiological aspects characterizing this agronomically important stage, weed species may differ in their ability to emerge from the

various soil layers (Benvenuti *et al.* 2001). This could explain the results for *I. hederifolia* and *I. obscura* which field observations had shown to behave similarly as small-seeded weeds as regard to their control with classical pre-emergence herbicide treatments. In fact, *I. obscura* has always been present in sugarcane fields prior to the 1990s, but it has never raised management problems in situation where classical pre-emergent herbicides are applied. On the other hand, the herbicide sulfentrazone had been found to be more effective on *I. hederifolia* than on *I. triloba* (MSIRI 2012).

In addition, previous studies (Elmore *et al.* 1990) in diverse agricultural contexts showed that *Ipomoea* species can emerge from a broad range of soil depths varying from just beneath the soil surface to a maximum depth of 16 cm. Seeds of *I. obscura* in pineapple fields in Thailand, for example, did not germinate on the soil surface though over 85% emergence was recorded at sowing depths of 1 and 2 cm (Suwanketnikom *et al.* 2004). Some seedlings of *I. pandurata* (L.) G. Mey. were able to emerge even from a depth of 16 cm (Horak *et al.* 1991). On the other hand, the burial depth required for 50% inhibition of maximum emergence of *I. triloba* in rainfed rice fields in Philippines was 2.8 cm, no seedlings emerged further down to 6 cm or deeper (Chauhan *et al.* 2012). Similarly, in the agricultural systems of Florida, germination of *I. purpurea* (L.) Roth were maximum when found on the soil surface or 2 cm underground, but decreased significantly at a depth of 4 cm or deeper (Singh *et al.* 2012). Other large-seeded species like *Cardiospermum halicacabum* L. (Johnston *et al.* 1979) and *Rottboellia cochinchinensis* (Lour.) Clayton (Bolfrey-Arku *et al.* 2011) were found to have emergence capacities akin to the *Ipomoea* spp. Weed species, seed size, soil compaction, soil texture, and soil moisture may possibly account for the differences among the various *Ipomoea* species and among agricultural contexts. The type of crop being cultivated and the associated cultural practices can create conditions that may influence the depth of emergence. Thus the results obtained in this work for the sugarcane crop are in line with the outcome of work carried out previously. The reduced emergence at the soil surface was most likely due to fluctuating moisture conditions. Similar results were reported by Krueger *et al.* (1982) and Baird *et al.* (1991) with *Euphorbia supina* Raf. and *Diodia virginiana* L. weed respectively

Epigeal germination characterises the five *Ipomoea* spp. studied here, where the developing hypocotyl pushes the cotyledons above the ground during the process of emergence. The germinating seedling, through the development of the hypocotyl, has to maximise tissue column width in order to force its way to the soil surface (Bond *et al.* 1999). The growth of the hypocotyl is characterised by its speed and final length. It respectively determines the time of emergence and corresponds to the maximum depth of emergence (Bond *et al.* 1999; Gardarin *et al.* 2010). The positive correlation found here between burial depth and underground hypocotyl extension (Fig 5) clearly establishes the relationship between final length and maximum depth of emergence for the five *Ipomoea* spp. The growth and development of hypocotyl of these species therefore represent another important biological trait which explains their greater emergence capacities. This is directly related to the elongation of the hypocotyl during pre-emergent growth. Once above ground level, the large cotyledons typical of *Ipomoea* spp. start photosynthesis to sustain the ongoing development of the seedlings. This may explain the generalised reduced extension of the above-ground hypocotyls. The large surface area of the cotyledons could in addition allow the young seedlings to optimize light interception in shaded environments as usually present when a crop is growing.

In summary, our results highlight that the germination and emergence abilities of the five *Ipomoea* spp. tested in this study are closely related to their large-seed properties. These results should help adapt weed management strategies in the context of sugarcane fields, especially regarding the use of herbicides. We have underlined that the ability of the *Ipomoea* spp. to germinate and emerge from deep burial is at the root of the serious challenges for their effective pre-emergence management in sugar cane fields in Mauritius. Here, weed control just after harvests in fields without GCTB and in newly planted ones are mainly achieved through the application of pre-emergence herbicide tank-mixes which are effective in suppressing weed development for 10 to 16 weeks after spraying (McIntyre *et al.* 1995; Seeruttun *et al.* 2007). These tank-mixes have been evaluated and recommended for the management of small-seeded weeds which are the most predominant in sugarcane fields. They germinate and emerge from the superficial zone of the soil profile down to a maximum depth of 3 cm since most of them are less than 1 mm in diameter with a mean seed weight of less than 1 mg. Pre-emergence

herbicides are most active on this zone of the soil, they are taken up by the radicles and may have a contact action on the plumules of germinating seeds to eradicate them.

Furthermore, sugarcane is grown on various soil types characterised by levels of organic matter content (OMC) ranging from 2% to 10% and pH of 4.5 to 7.0 (Ng Cheong *et al.* 2008; Ng Cheong *et al.* 2009; Parish, *et al.* 1965). Studies had shown that such levels of OMC negatively interfere with the pre-emergence activity of herbicide molecules. It is also known that OMC tends to retain herbicide applied to the soil in the upper zone of the profile, limiting their mobility downward. Furthermore, the slightly acidic nature of the soils in sugarcane fields can have similar effects on pre-emergence herbicides, which are mostly weak acids. The OMC also provides a habitat for soil micro-organisms which have been reported to accelerate the degradation of pre-emergence herbicides, particularly in tropical conditions, thus affecting their efficacy. This work has shown that the five *Ipomoea* spp. have the capacity to germinate and emerge at depth beyond 5 cm in the soil. It is suspected that at this depth, the radicles of the *Ipomoea* spp. seedlings are outside the zone of the soil profile containing lethal doses of the pre-emergence herbicides. It has further been reported that the uptake and translocation of pesticides by the hypocotyls of intact radish (*Raphanus sativus*, L., cv. Black Spanish) seedlings appear to be largely passive processes and seem to be unaffected by humidity (Shone *et al.* 1976). The seedlings of the *Ipomoea* spp. may be behaving in a similar manner to account for the unsatisfactory control obtained with most pre-emergence herbicides. Moreover, the physical dormancy due to the hard seed-coat could play a role in retarding germination, allowing most of the pre-emergence herbicides to have undergone dissipation so that the seeds can germinate unaffected when conditions are conducive.

The soil-herbicide interaction is not the only mechanism influencing the pre-emergence management of *Ipomoea* spp. in sugarcane fields in Mauritius. Some cultural practices, particularly tillage before planting (every 7 years) and GCTB (each year) after mechanical green cane harvesting can have similar effects. Numerous studies have demonstrated the significant impact of tillage on seedbank dynamics. It strongly influences the vertical distribution in soil and the longevity of weed seeds (Cousens *et al.* 1990; Roberts *et al.* 1973). It has been reported that the fraction of seeds found in the upper 5 cm soil layer is 70 to

85% in no-till cultivation and approximately 30% in chisel-till farming (Pareja *et al.* 1985; Yenish *et al.* 1992). Generally, seeds lying on or near the soil surface, as is common in a no-tillage system, germinate or emerge less than those in a tilled system for large-seed species (Bararpour *et al.* 1998). (Lovelace *et al.* 2001) found that *I. lacunosa* L. emergence increased more than twofold following tillage compared with the absence of tillage over a single growing season. In the sugarcane cultural system, tillage and soil preparations are carried out only at the time of the establishment of a new crop, the field remaining undisturbed over the seven year cycle. Any *Ipomoea* sp. seeds buried beyond 15 cm in the soil at the time of planting would still be viable at the next planting season. This is due to the tough seed-coat enabling the seeds to remain persistent in the seedbank for very long period when conditions are not favourable to germination (Toole *et al.* 1946). Seeds present in the upper 15 cm layer can progressively emerge during a crop cycle depending on the soil structure and texture. However, information on the longevity of *Ipomoea* spp seeds in relation to their size and mass is lacking in the literature.

The mulching effect of GCTB is yet another important cultural practice which greatly influences weed population dynamics, thus altering weed control practices. Whereas GCTB can effectively suppress the germination and emergence of small-seeded weeds, large-seeded species can better tolerate cover crop residue-mediated stress (Kruidhof *et al.* 2011; Manechini *et al.* 2005). This is particularly true for *Ipomoea* spp. growing in GCTB fields where these species are able to germinate and emerge even with a residue level of 15 t/ha of dry matter (equivalent to a trash thickness of 6 to 7 cm) (Azania *et al.* 2002). The trash cover also hinders the pre-emergence activity of herbicides, creating better agro-ecological conditions for the development of the *Ipomoea* spp. seedlings. Research dealing with the mulching effect of sugarcane trash on these species tends to show improved weed control with increasing residue level. The occurrence of large-seeded species in GCTB fields nevertheless represents a big management challenge requiring further investigations.

Conclusions

This study has provided a better insight into the mechanism of germination and emergence of *Ipomoea* spp. in sugarcane fields in Mauritius and the limitations of pre-

emergence herbicide treatments to provide effective control have been discussed. In this work, the use of scarified *Ipomoea* seeds has enabled a good level of germination in order to test only the effect of the burial depth on the emergence which has provided the interesting results. Although this is not representative of what occurs naturally in the fields, it nevertheless becomes apparent from this work that the large-seed property of *Ipomoea* spp. compared to classical weeds would confer greater advantages to avoid herbicide effects in order to thrive in field conditions. It also establishes a link between the allometry of seed size and the maximum emergence depth of these species. An understanding of this allometric relationship can have useful applications in the development of weed management strategies, particularly putting forward innovative approaches for the sustainable control of vine weeds.

References

- Armstrong D.P. and Westoby M. 1993. Seedlings from large seeds tolerate defoliation better - a test using phylogenetically independent contrasts. *Ecology* **74**, 1092-1100.
- Azania A.A.P.M., Azania C.A.M., Gravena R., Pavani M.C.M.D. and Pitelli R.A. 2002. Sugar cane (*Saccharum spp.*) straw interference in emergence of weed species of the Convolvulaceae family. *Planta Daninha* **20**, 207-212.
- Baird J.H. and Dickens R. 1991. Germination and emergence of virginia buttonweed (*Diodia virginiana*). *Weed Sci.* **39**, 37-41.
- Bakker J.P. 1989. *Nature management by grazing and cutting: on the ecological significance of grazing and cutting regimes applied to restore former species-rich grassland communities in the Netherlands*. Academic Publishers., Kluwer.
- Bararpour M.T. and Oliver L.R. 1998. Effect of tillage and interference on common cocklebur (*Xanthium strumarium*) and sicklepod (*Senna obtusifolia*) population, seed production, and seedbank. *Weed Sci.* **46**, 424-431.
- Benvenuti S., Macchia M. and Miele S. 2001. Quantitative analysis of emergence of seedlings from buried weed seeds with increasing soil depth. *Weed Sci.* **49**, 528-535.
- Bhullar M.S., Walia U.S., Singh S., Singh M. and Jhala A.J. 2012. Control of morningglories (*Ipomoea spp.*) in sugarcane (*Saccharum spp.*). *Weed Technol.* **26**, 77-82.
- Bolfrey-Arku G.E.K., Chauhan B.S. and Johnson D.E. 2011. Seed germination ecology of itchgrass (*Rottboellia cochinchinensis*). *Weed Sci.* **59**, 182-187.
- Bolker B.M., Brooks M.E., Clark C.J., Geange S.W., Poulsen J.R., Stevens M.H.H. and White J.-S.S. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecol. Evol.* **24**, 127-135.

- Bond W.J., Honig M. and Maze K.E. 1999. Seed size and seedling emergence: an allometric relationship and some ecological implications. *Oecologia* **120**, 132-136.
- BSES 1989. Weeds of Australia. In: *Bses Bulletin*. 33-43.
- Burke M.J.W. and Grime J.P. 1996. An experimental study of plant community invasibility. *Ecology* **77**, 776-790.
- Chauhan B.S. and Abugho S.B. 2012. Threelobe morningglory (*Ipomoea triloba*) germination and response to herbicides. *Weed Sci.* **60**, 199-204.
- Christoffoleti P.J., Borges A., Nicolai M., Carvalho S.J.P., Lopez-Ovejero R.F. and Monquero P.A. 2006. Carfentrazone-ethyl applied in post-emergence to control *Ipomoea* spp. and *Commelina benghalensis* in sugarcane crop. *Planta Daninha* **24**, 83-90.
- Cole A.W. and Coats G.E. 1973. Tall morningglory germination response to herbicides and temperature. *Weed Sci.* **21**, 443-446.
- Correia N.M. and Durigan J.C. 2004. Weed emergence in soil covered with sugarcane harvest straw residue. *Planta Daninha* **22**, 11-17.
- Cousens R. and Moss S.R. 1990. A model of the effects of cultivation on the vertical distribution of weed seeds within the soil. *Weed Res.* **30**, 61-70.
- Crowley R.H. and Buchanan G.A. 1982. Variations in seed production and the response to pests of morningglory (*Ipomoea*) species and smallflower morningglory (*Jacquemontia tamnifolia*). *Weed Sci.* **30**, 187-190.
- Dalling J.W. and Hubbell S.P. 2002. Seed size, growth rate and gap microsite conditions as determinants of recruitment success for pioneer species. *J. Ecol.* **90**, 557-568.
- Elmore C.D., Hurst H.R. and Austin D.F. 1990. Biology and control of morningglories (*Ipomoea* spp.). *Rev Weed Sci* **5**, 83-114.

- Gardarin A., Dürr C. and Colbach N. 2010. Effects of seed depth and soil aggregates on the emergence of weeds with contrasting seed traits. *Weed Res.* **50**, 91-101.
- Gomes L.F., Chandler J.M. and Vaughan C.E. 1978. Aspects of germination, emergence and seed production of three *Ipomoea* taxa. *Weed Sci.* **26**, 245-248.
- Grime J.P. and Jeffrey D.W. 1965. Seedling establishment in vertical gradients of sunlight. *J. Ecol.* **53**, 621-642.
- Gross K.L. 1984. Effects of seed size and growth form on seedling establishment of 6 monocarpic perennial plants. *J. Ecol.* **72**, 369-387.
- Hardcastle W.S. 1978. Influence of temperature and acid scarification duration on scarlet morningglory (*Ipomoea coccinea*) seed germination. *Weed Sci.* **26**, 261-263.
- Harms K.E. and Dalling J.W. 1997. Damage and herbivory tolerance through resprouting as an advantage of large seed size in tropical trees and lianas. *J. Trop. Ecol.* **13**, 617-621.
- Horak M.J. and Wax L.M. 1991. Germination and seedling development of bigroot morningglory (*Ipomoea pandurata*). *Weed Sci.* **39**, 390-396.
- Johnston S.K., Murray D.S. and Williams J.C. 1979. Germination and emergence of balloonvine (*Cardiospermum halicacabum*). *Weed Sci.* **27**, 73-76.
- Jones C.A. 2006. Red morningglory (*Ipomoea coccinea* L.) biology and management in sugarcane. In: *The Department of Agronomy and Environmental Management*). B.S Texas A & M University, 69.
- Krueger R.R. and Shaner D.L. 1982. Germination and establishment of prostrate spurge (*Euphorbia supina*). *Weed Sci.* **30**, 286-290.
- Kruidhof M., Gallandt E.R., Haramoto E.R. and Bastiaans L. 2011. Selective weed suppression by cover crop residues: Effects of seed mass and timing of species' sensitivity. *Weed Res.* **51**, 177-186.

- Lafond G.P. and Baker R.J. 1986. Effects of genotype and seed size on speed of emergence and seedling vigor in nine Spring wheat cultivars. *Crop Sci.* **26**, 341-346.
- Lancaster S.H., Jordan D.L., York A.C., Wilcut J.W., Brandenburg R.L. and Monks D.W. 2005. Interactions of late-season morningglory(*Ipomoea* spp.) management practices in peanut(*Arachis hypogaea*). *Weed Technol.* **19**, 803-808.
- Le Bourgeois T., Carrara A., Dodet M., Dogley W., Gaungoo A., Grand P., Ibrahim Y., Jeuffrault E., Lebreton G., Poilecot P., Prosperi J., Randriamampianina J.A., Andrianaivo A.P. and Théveny F. 2008. Advent-OI : Principales adventices des îles du sud-ouest de l'Océan Indien.V.1.0. In: *Software*). Cirad Montpellier, France.
- Lebreton G., Le Bourgeois T. and Marnotte P. 2009. Effet de l'époque de coupe sur la dynamique de développement de
L'enherbement de la canne à sucre à la Réunion. In: *XIIIème colloque international sur la biologie des mauvaises herbes*). Dijon (France).
- Leishman M.R. 2001. Does the seed size/number trade-off model determine plant community structure? An assessment of the model mechanisms and their generality. *Oikos* **93**, 294-302.
- Leishman M.R. and Westoby M. 1994a. The role of large seed size in shaded conditions - experimental evidence. *Funct. Ecol.* **8**, 205-214.
- Leishman M.R. and Westoby M. 1994b. The role of seed size in seedling establishment in dry soil-conditions - experimental-evidence from semiarid species. *J. Ecol.* **82**, 249-258.
- Lovelace M.L. and Oliver L.R. 2001. Effects of interference and tillage on hemp sesbania and pitted morningglory emergence, growth, and seed production. In: *Proc. South. Weed Sci. Soc.*). 202.

- Manechini C., Ricci-Junior A. and Donzelli J.L. 2005. An overview of controlled and non-controlled weeds as influenced by sugarcane trash blankets. *Sugar Cane International UK*. **23**, 11-14.
- McIntyre G. and Barbe C. 1995. Oxyfluorfen, acetochlor and metazachlor, new long residual herbicides for sugar cane. In: *Proceedings of the ISSCT Congress*). 1-10.
- McIntyre G., Seeruttun S. and Barbe C. 1996. Trash management in Mauritian sugar cane plantations. In: *Proceedings of the XXII ISSCT Congress*). 213-216.
- Moles A.T. and Westoby M. 2004. Seedling survival and seed size: a synthesis of the literature. *J. Ecol.* **92**, 372-383.
- Morandini M., Figueroa R., Zamora F.P. and Scandaliaris J. 2005. The effects of green-cane trash blanket on soil temperature, soil moisture and sugar cane growth. In: *Proceedings of the XXV ISSCT Congress* (ed. Hogarth D. M.). The XXV ISSCT Congress Organising Committee, Atagua, Guatemala City (Guatemala), 231-237.
- MSIRI 2012. Control of vine weeds. In: *2011 Annual Report*). Mauritius Sugar Industry Research Institute., 33.
- Ng Cheong L.R., Ng Kee Kwong K.F. and Du Preez C.C. 2008. Soil organic matter and microbial biomass as influenced by sugar cane (*Saccharum* hybrid sp.) production practices in Mauritius. *South African Journal of Plant Soil* **25**.
- Ng Cheong L.R., Ng Kee Kwong K.F. and Du Preez C.C. 2009. Effects of sugar cane (*Saccharum* hybrid sp.) cropping on soil acidity and exchangeable base status in Mauritius. *South African Journal of Plant Soil* **26**.
- Norsworthy J.K. 2004. Soybean canopy formation effects on pitted morningglory(*Ipomoea lacunosa*), common cocklebur (*Xanthium strumarium*), and sicklepod (*Senna obtusifolia*) emergence. *Weed Sci.* **52**, 954-960.

- Oliveira M.J. and Norsworthy J.K. 2006. Pitted morningglory (*Ipomoea lacunosa*) germination and emergence as affected by environmental factors and seeding depth. *Weed Sci.* **54**, 910-916.
- Pareja M.R., Staniforth D.W. and Pareja G.P. 1985. Distribution of weed seed among soil structural units. *Weed Sci.* **33**, 182-189.
- Parish D.H. and Feillafé S.M. 1965. Notes on the 1:100,000 Soil Map of Mauritius. In: *Occasional Paper No 22*). MSIRI, Mauritius.
- R Core Team 2014. R: A language and environment for statistical computing. . In: *Software*). R Foundation for Statistical Computing, Vienna, Austria. .
- Raymond P., Al-Ani A. and Pradet A. 1985. ATP production by respiration and fermentation, and energy charge during aerobiosis and anaerobiosis in twelve fatty and starchy germinating seeds. *Plant Physiol.* **79**, 879-884.
- Roberts H.A. 1982. *Weed Control Handbook: Principles*. Blackwell Scientific Publications, Oxford.
- Roberts H.A. and Feast P.M. 1973. Emergence and longevity of seeds of annual weeds in cultivated and undisturbed soil. *J. Appl. Ecol.* **10**, 133-143.
- Seeruttun S., Barbe C. and Gaungoo A. 2007. New herbicide tank-mix, Krismat® + Dinamic® : a cost-effective broad-spectrum pre-& post-emergence treatment for managing weeds in sugar cane. *Sugar Cane International* **26**, 18-21,25.
- Seeruttun S., G Mc Intyre G. and C Barbe C. 1992. Agronomic and economic significance of trash blanketing in the sub-humid areas of Mauritius. *Révue agricole et sucrière de l'île Maurice* **71**, 324-331.
- Shone M.G.T. and Wood A.V. 1976. Uptake and translocation of some pesticides by hypocotyls of radish seedlings. *Weed Res.* **16**, 229-238.

- Singh M., Ramirez A.H.M., Sharma S.D. and Jhala A.J. 2012. Factors affecting the germination of tall morningglory (*Ipomoea purpurea*). *Weed Sci.* **60**, 64-68.
- Sobrero M.T., Fioretti M.N., Chaila S., Avila O.B. and Ochoa M.d.C. 2003. Factors that influence the germination of *Ipomoea nil* (L.) Roth. *Agro-Sur.* **31**, 60-68.
- Soil, Survey and Staff 1999 *Keys to soil taxonomy, 8th edn.* Blacksburg, Virginia.
- Suwanketnikom R. and Julakasewee A. 2004. Hardseededness and germination of small white flower morningglory. *Kasetsart Journal: Natural Sciences* **38**, 425-433.
- Toole E.H. and Brown E. 1946. Final results of the Duvel buried seed experiment. *Journal of Agricultural Research* **72**, 201-210.
- Turnbull L.A., Rees M. and Crawley M.J. 1999. Seed mass and the competition/colonization trade-off: a sowing experiment. *J. Ecol.* **87**, 899-912.
- Yenish J.P., Doll J.D. and Buhler D.D. 1992. Effects of tillage on vertical distribution and viability of weed seed in soil. *Weed Sci.* **40**, 429-433.

3.4 Mulching effects of post-harvest sugarcane trash on germination and emergence of *Ipomoea* spp

Introduction

Vine weed seeds, particularly those of *Ipomoea* spp. have been shown to possess strong germination and emergence capacities even when buried at soil depths of 8-12 cm (Gaungoo *et al.* 2014b). This partly explains the increasing vine weed infestations that are reported in sugarcane fields. Unlike other broad-leaved weeds, grasses and sedges normally present in sugarcane cropping systems, vines have the ability to develop late in the season and spread long distances both horizontally and vertically making their control difficult. The growing vine infestations in the recent years have often been associated with green cane trash blanketing (GCTB) in both mechanized and manually harvested fields. The development of vine weeds is becoming a serious drawback to the adoption of GCTB, which is an economically and ecologically sustainable cultural operation in sugarcane (Morandini *et al.* 2005; Seeruttun *et al.* 1992).

The practice of GCTB in sugarcane cropping system is a typical example of the use of organic non-living mulches for weed control purposes and other agronomic benefits. The application of a certain thickness of non-living mulches on soil surface can suppress weed seed germination by exclusion of light or by acting as a physical barrier (Bond *et al.* 2001). Mulches also make it difficult for biennial and perennial weeds to establish early and compete with the crops due to a delayed emergence time (Rask *et al.* 2007). Mulching reduces water evaporation from the soil surface, maintains higher soil moisture content, promotes the structural stability and fertility of soils and prevents erosion (Jordan *et al.* 2010; Mulumba *et al.* 2007). Organic mulches can decrease soil temperature fluctuations, whereas it can also add to the organic matter of the soil and the soil water retention ability (Havlin *et al.* 1990; Jordan, *et al.* 2010).

Non-living organic mulching can also influence the agro-ecological conditions of the fields leading to other interactions. Hence, Gill *et al.* (2011) found that ants, which tend to feed on small plant feeders, were fairly abundant in organic mulch, as were predatory beetles. On the other hand, the practice of GCTB in sugarcane cropping system has created ecological conditions for the proliferation of army worms in the fields; they feed on the leaves of the young developing shoots (Ganeshan 2005). Organic mulch may also have an allelopathic effect which

Lorenzi (1984) and Quintela *et al.* (2002) linked to the suppression of weeds by sugarcane straw.

In the sugarcane cropping system, trash residue after harvest remains in the fields and may act as a non-living mulch depending upon the practices. This results mostly from the mechanical harvesting of green cane and acts as a thick and fairly uniform layer of leaves, tops, and stalk chips. The amount of dry matter just after harvest ranges from 10 to 15 t.ha⁻¹ depending on variety and cut stage (Correia *et al.* 2004; Manechini *et al.* 2005). The mulching effect due to this amount of organic matter has greatly influenced weed population dynamics, thus altering weed control practices. Whereas GCTB can effectively suppress the germination and emergence of small-seeded weeds, large-seeded species can better tolerate cover crop residue-mediated stress (Kruidhof *et al.* 2011; Manechini, *et al.* 2005). This is particularly true for *Ipomoea* spp. which is believed to have been the consequence of a species population shift owing to the repeated practice of GCTB. Their germination and emergence are not completely inhibited even with a residue level of 15 to 20 t.ha⁻¹ of dry matter (Azania *et al.* 2002).

Similarly, the increasing problem of vine weeds in Mauritius, dominated mainly by a few *Ipomoea* spp., is related to the ineffectiveness of the GCTB mulch to prevent their germination and emergence. This practice had been recommended in the early 1990s for the sub-humid zone (< 1500 mm of annual rainfall) after studies showed its cost-effectiveness and agronomic benefits in conserving soil moisture in addition to suppressing weed development. In that time, infestations caused by *Ipomoea* spp. were not found in sugarcane fields and there was a rapid adoption of GCTB. This was further enhanced with mechanized green cane harvesting which started off in the mid 1990s (MSIRI 2012). The uniform trash cover remaining in the fields after this operation provided an economical way of managing post-harvest sugarcane residue in addition to its agronomic advantages. The mulching effect of the trash cover, however, created agro-ecological conditions that influenced the germination and emergence of weeds. The weed flora of sugarcane fields in Mauritius is mostly dominated by small-seeded annual species (Le Bourgeois *et al.* 2008) that are relatively well managed by the trash cover in GCTB situations. But the regular practice of GCTB during the last two decades has caused a shift in species whereby the control of vines has become more challenging.

Vine weeds like *Paederia foetida* L. and *Passiflora suberosa* L. have always been found as localized infestations in sugar cane fields; these perennial species are effectively controlled by the recommended post-emergence herbicide tank-mixes (Seeruttun *et al.* 2005).

The emergence of the more invasive *Ipomoea* and other vine species observed in the recent years are partly attributed to changes in some cultural practices including trash management (Ismael *et al.* 2008). It is suspected that these new species have been favoured by more conducive ecological conditions of the sugarcane trash cover and include mainly *I. hederifolia* L., *I. nil* (L.) Roth, *I. obscura* (L.) Ker Gawl. and *I. triloba* L. These vines are annuals and reproduce exclusively through the production of large amounts of large seeds as it is the characteristics of many *Ipomoea* spp. (Crowley *et al.* 1982).

The most commonly found species is *I. triloba* which occur mainly in the humid and subhumid regions of the island; *I. nil* and *I. hederifolia* can also be encountered there. Earlier, it was thought that the rapid expansion of these vines was due to the non-use of a pre-emergence herbicide treatment under GCTB conditions. However, it is observed that even in cases where pre-emergence herbicide treatments are applied several weeks after harvest when the trash has decayed, the vines are still ineffectively controlled. As several of the currently used pre-emergence herbicides are known to be effective on vines, the poor control remains unexplained. Furthermore, the use of post-emergence herbicides for the control of vines is not very practical as several flushes can emerge and application in well-developed or tall cane is not easy.

Therefore, the objective of this work is to understand how the mulching effects of post-harvest sugarcane trash have influenced the germination and emergence abilities of *Ipomoea* spp. seeds with the aim of developing effectively appropriate vine weed management strategies. This work reports on the outcome of trials undertaken with seeds of four *Ipomoea* spp. buried at different depths in the presence of various levels of sugarcane trash mulch from two commercial varieties.

Materials and methods

Four germination and emergence trials were carried out in the year 2008 (Trial I and II) and 2010 (Trial III and IV) in controlled conditions at the Réduit Experimental Station of the Mauritius Sugarcane Industry Research Institute (20 14' 06'' S, 57 29' 42'' E) (Table 1). The trials were setup with *I. hederifolia*, *I. nil*, *I. obscura* and *I. triloba* in the presence of different levels of trash cover of the commercial sugarcane varieties M 1176/77 and R 570. The two varieties differed in the width of their leaf lamina, the latter are medium sized whereas those of the former are narrower (Fig. 3.11) (MSIRI 1985; MSIRI 1986). Consequently, a relatively more compact and thinner trash layer is obtained in the field following harvest of the

variety M 1176/77. The variety R 570, on the other hand, results in a more voluminous and thicker mulch.

The trash of both varieties was obtained from fields which had undergone mechanized green cane harvesting with a chopper harvester. It was stored in a dry place until the trials were setup. Mature seeds of the *Ipomoea* spp. were collected from vine weed development occurring in and outside sugarcane fields in different regions of the island (Table 3.6). All the seeds were kept at 4°C before setting up the trial. They were eventually sorted out to choose the ones with a regular hard body, and to ensure a homogeneous germination, all seeds used were scarified with 98% sulphuric acid for one hour (Hardcastle 1978; Suwanketnikom *et al.* 2004). The germination tests were conducted in fibreglass tanks (0.90 m x 0.45 m x 0.25 m) and all of them had holes pierced at the bottom to allow drainage of excess water after irrigation. The tanks were filled with soil collected from the same experimental station and the soil was Oxisol-type, containing some 80% clay and 4.7% organic matter (Parish *et al.* 1965.; Soil *et al.* 1999). On the station, *Ipomoea* spp. are not present in the fields, and hence the possibility of having *Ipomoea* seeds in the soil can be waived out.

The tanks were placed outdoor in a split-split plot design with vine species as the main plots, trash cover as the sub-plots and burial depths as the sub-sub-plots. Each tank was divided into two compartments along the length with iron sheets and each compartment was further sub-divided into four equal sections corresponding to the soil depths of 0 (surface), 4, 8 and 12 cm. All the fibre glass tanks were irrigated when required after the seeds were buried.

In the experiment of 2008, two such tanks represented the main plot where 10 seeds of *I. nil*, *I. obscura* and *I. triloba* were buried at the different depths. Three of the four compartments were afterwards covered with 5, 10 and 15 cm layers of dry trash from the variety R 570 in Trial I and M 1176/77 in Trial II. The height of each compartment was extended with iron sheets in order to accommodate the various trash layers. Samples of trash were also oven-dried to determine the dry matter equivalents for each layer. The fourth compartment did not receive any trash cover and represented the control. Each treatment in both trials was replicated four times.

The experiment was repeated in 2010 with six levels of trash mulching which were expressed as the mass of dry matter required for each cover treatment; this was equivalent to 0 (control), 10, 20, 30, 40 and 50 t.ha⁻¹. The main plot consequently consisted of three fibre glass

tanks and seeds of *I. hederifolia* were used instead of *I. obscura*; Trial III was established with trash of cane variety R 570 whereas in Trial IV it was with that of M 1176/77. In both trials, measurements of trash thickness were taken for the different levels of trash cover for correlation analyses with the respective masses per unit hectare. This was carried out in order to establish the relationship between the two varieties due to the difference in the leaf size.

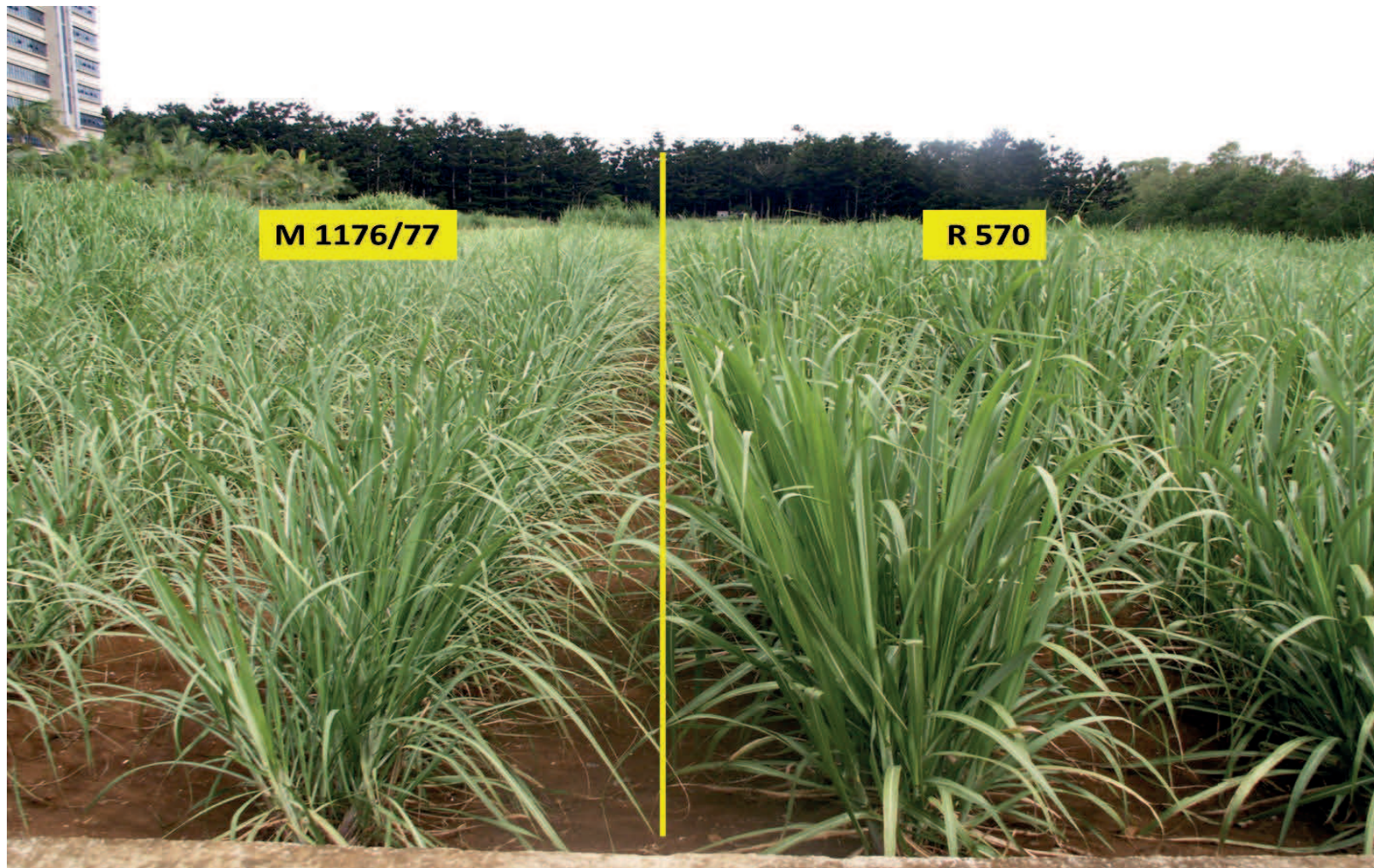


Figure 3.11 Sugarcane varieties M 1176/77 and R 570 grown side by side and showing differences in the size of their leaves. The slender leaves of the former results in a more compact and thinner trash mulch after mechanical harvest whereas a more voluminous and thicker layer is formed with the cut pieces of the larger leaf lamina of the latter.

Data collection and analysis

In each trial, the number of emergence was accounted for when the cotyledons of the developing seedling had grown above the soil surface or trash cover. This was carried out on a three-day basis for a period of 3 weeks, resulting in 7 series of counts for each trial. Seedlings were not uprooted after each observation resulting in the count being cumulated over the period of assessment.

All the data in this work were processed using the open source programme R version 3.0.3 (R Core Team 2014). The emergence counts for each of the four trials were analysed at the end of the three-week study, using binomial generalised linear mixed models (GLMM) (Bolker *et al.* 2009) including the relative number of emerged/non-emerged seeds per tank as the binomial response variable including soil depth, species and trash cover as fixed effects, and the nested split-split-plot block random effect within Trials. We used the *lmer* function of R, package *lme4* for GLMM analyses where the various interactions were examined.

The cumulative counts of emerged seeds through time in each trial were further modelled by fitting a three-parameter (b, d, e) logistic function:

$$f(x, (b, d, e)) = \frac{d}{1 + \exp\{b(\log(x) - \log(e))\}}$$

where d is the asymptotic count of emerged seeds, e represents the time to mid-emergence and b denotes the relative slope around e . This enabled us to calculate the time to reach 90% emergence of the *Ipomoea* spp. Using the above function, we also carried out log-logistic dose response modelling to determine the level of trash cover required to effectively suppress the emergence of the *Ipomoea* spp. seedlings for seeds buried at the four soil depths (Ritz 2010). Regressions were carried out with the add-on package *drc* (ver 2.3-7) (Ritz *et al.* 2005) which enabled calculations of the ED50 and ED90 values. These are defined as the level of trash thickness (cm) or dry mass ($t\cdot ha^{-1}$) which reduced the emergence counts by 50% or 90% respectively. Comparisons between the trash varieties were carried out by t-test based on differences of ED50 and ED90 values and their associated standard errors.

Table 3.6. Trial details for experiments carried out on the effects of different levels of trash cover on the emergence of *Ipomoea* spp. seeds buried at various soil depths.

Trial no.	Period of study	Variety of cane trash	Variety of <i>Ipomoea</i> spp. tested	Date and places of seed collections	Average	Temperature	Total Rainfall (mm)
					°C		
					Min	Max	
I	31.03.2008 21.04.2008	R 570	<i>I. nil</i>	Feb 2008, Réduit	19	28	67
			<i>I. obscura</i>	Feb 2008, Bonne Terre			
			<i>I. triloba</i>	Feb 2008, Constance			
II	31.03.2008 21.04.2008	M 1176/77	<i>I. nil</i>	Feb 2008, Réduit	19	28	67
			<i>I. obscura</i>	Feb 2008, Bonne Terre			
			<i>I. triloba</i>	Feb 2008, Constance			
III	4.03.2010 25.03.2010	R 570	<i>I. hederifolia</i>	Aug 2009, Solitude	22	29	183
			<i>I. nil</i>	Sep 2009, Albion			
			<i>I. triloba</i>	May, 2009, Bon Espoir			
IV	10.03.2010 1.04.2010	M 1176/77	<i>I. hederifolia</i>	Aug 2009, Solitude	22	29	183
			<i>I. nil</i>	Sep 2009, Albion			
			<i>I. triloba</i>	May, 2009, Bon Espoir			

Results

GLMM analysis of the effects of Vine species x Trash layer x burial depths on emergence

Main effects of Species

The analysis (Table 3.7) showed that there was a highly significant ($P < 0.001$) difference for the species factor meaning that the *Ipomoea* spp. tested differed in their abilities to emerge through the sugarcane mulch in the four trials (Fig 3.12). Emergence of *I. triloba* were significantly higher than *I. nil* and was comparable to *I. hederifolia* in Trials III and IV. In Trials I and II, the emergence of *I. obscura* was also significantly lower than *I. triloba* but higher than that of *I. nil*. The variety of the trash did not affect the emergence of the *Ipomoea* spp. except for *I. nil* in the trial of 2010 where its emergence was significantly lower with a mulch of R 570 than with M 1176/77. Otherwise, it was possible to categorise the emergence capacities of the four vine weed species $I. nil < I. obscura < I. hederifolia \leq I. triloba$. This classification is in line with field observations where it is noted that *I. triloba* is the most aggressive vine weed often causing severe infestations in sugarcane. This has not been observed with *I. obscura* although the species has been present in sugarcane well before the other *Ipomoea* spp. started interfering with the crop. Similarly, *I. hederifolia* which is of recent occurrence is more troublesome whereas *I. nil*, found localised in some places, can be more easily managed.

Main effects of Trash Cover

The trash cover significantly ($P < 0.001$) reduced the emergence counts (Fig 3.13). The reduction was particularly important when trash thickness was equal to or greater than 10 cm (equivalent to 21 (± 2.0) and 30 (± 2.7) t.ha⁻¹ of dry mass for varieties R 570 and M 1176/77 respectively) or when the dry mass was equal to or greater than 20 t.ha⁻¹ (equivalent to 8.9 (± 2.7) and 7.9 (± 1.7) cm thickness for varieties R 570 and M 1176/77 respectively). On the other hand, a trash thickness less than 5 cm (equivalent to 10.5 (± 2.0) and 15.1 (± 2.7) t.ha⁻¹ of dry mass for varieties R 570 and M 1176/77 respectively) or a dry mass less than 10 t.ha⁻¹ (equivalent to 4.5 (± 2.7) and 3.9 (± 1.7) cm thickness for varieties R 570 and M 1176/77 respectively) had no effect on the emergence of the *Ipomoea* spp seedlings compared to the no trash control. In field conditions, a trash mulch of 10 cm or more is never present for a long enough period in GCTB fields after mechanised green cane harvests to cause a prolonged

suppression of the vine weed emergence. The most often persistent post-harvest trash layer in mechanically harvested ratoon canes ranges from 4 to 6 cm.

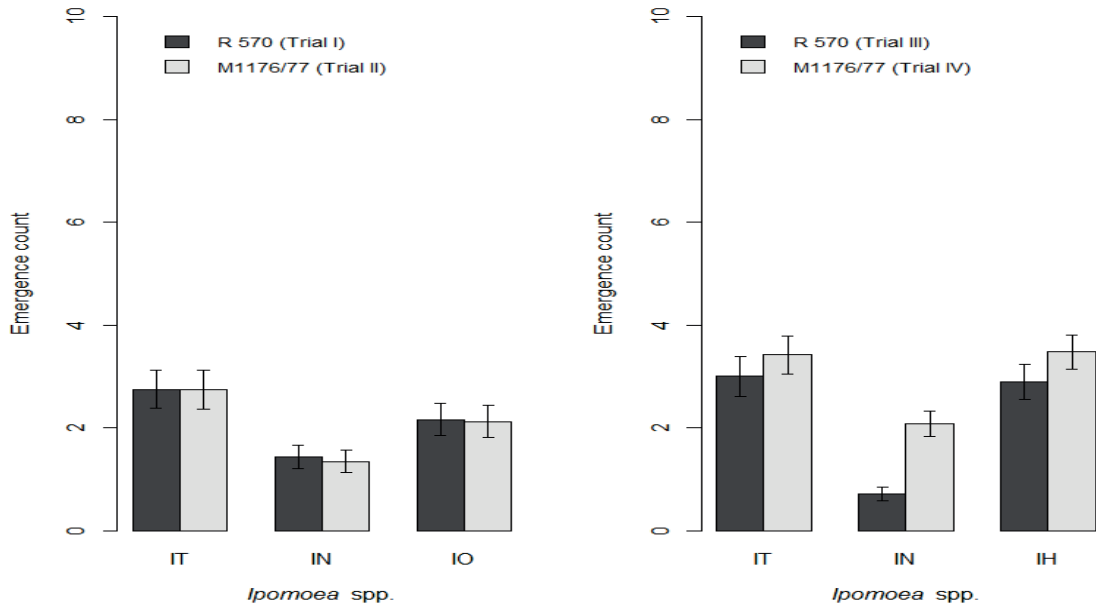


Figure 3.12 Mulching effects of sugarcane trash from the variety R 570 and M 1176/77 on the emergence of *Ipomoea* spp. seedlings. Error bars represent the standard error of four replicates.

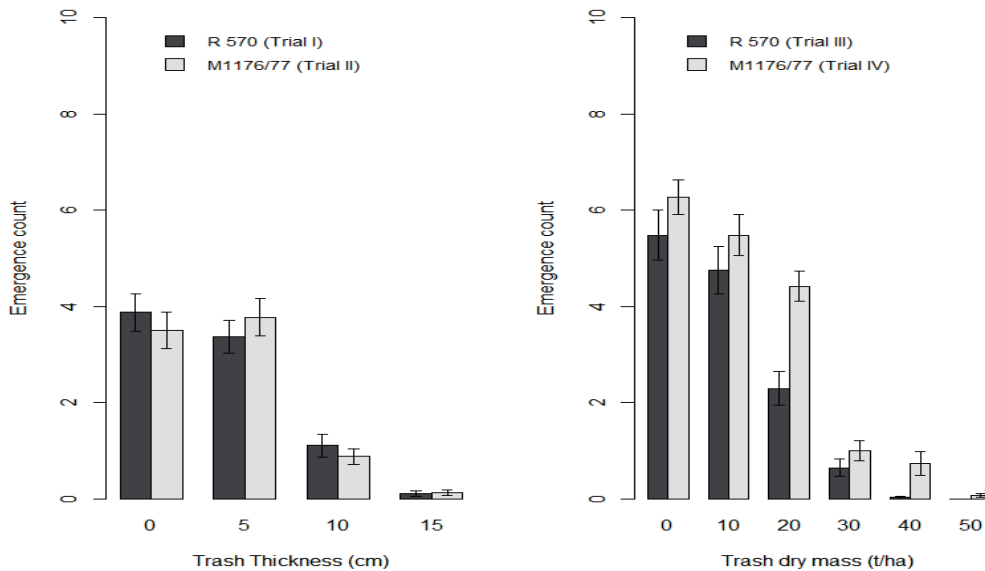


Figure 3.13 Effects of different levels of trash thickness (cm) and dry mass ($t \cdot ha^{-1}$) of sugarcane varieties R 570 and M 1176/77 on the emergence of *Ipomoea* spp. Error bars represent the standard error of four replicates.

Table 3.7 Anova output of the generalised linear mixed model analysis of the emergence count of *Ipomoea* species seeds buried at four soil depths and covered with different levels of post-harvest trash from the sugarcane varieties R 570 and M 1176/77.

Factors analysed	Trial I 2008 – R 570	Trial II 2008 – M 1176/77	Trial III 2010 – R 570	Trial IV 2010 – M 1176/77
1 + (1 Block)	-	-	-	-
Species + (1 Block)	***	***	***	***
Cover + (1 Block)	***	***	***	***
Depth + (1 Block)	ns	ns	ns	ns
Species*Cover + (1 Block/Depth)	***	***	***	***
Species*Depth + (1 Block/Cover)	ns	ns	***	***
Cover*Depth + (1 Block/Species)	***	***	ns	ns
Species*Cover*Depth + (1 Block)	***	**	***	***

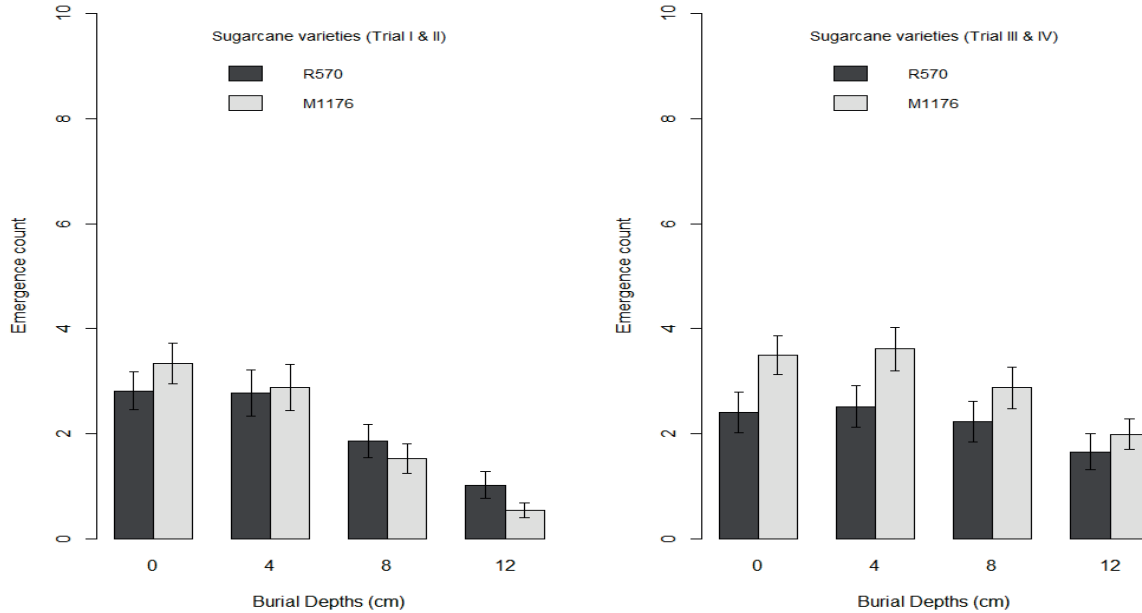


Figure 3.14 Effects of burial depths on the emergence of *Ipomoea* spp. seedlings in the presence of a mulch of sugarcane trash from varieties R 570 and M 1176/77. Error bars represent the standard error of four replicates.

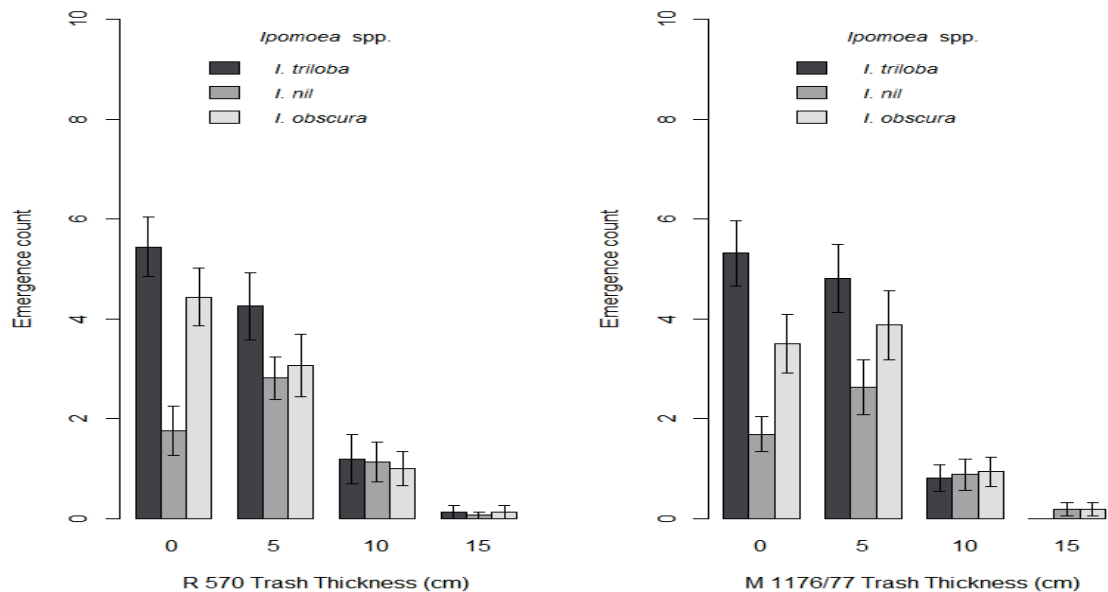


Figure 3.15 Interactions of *Ipomoea* spp. and thickness (cm) of trash cover of sugarcane varieties R 570 and M 1176/77 on seedling emergence. Error bars represent the standard error of four replicates.

Main effects of Burial Depths

In all four trials, though burial depths did not significantly affect the final emergence counts, there was a sensible reduction when seeds were found deeper than 4 cm in Trials I and II, and 8 cm in Trials III and IV (Fig 3.14). A difference was also found in Trial IV about the effect of the trash varieties on the emergence counts which were sensibly lower for R 570. The reduction was more pronounced when seeds were located on the surface and at 4 cm in the soil profile. In the fields, *Ipomoea* seeds produced during a vine weed development fall on the ground surface and is covered by the GCTB during harvest. Since interrow cultivation is not a common practice in Mauritius, these seeds can be embedded only a few millimetres in the soil when there are machine or other human activities. Seeds found deeper down constitute the existing seedbank reserve from where they can germinate and emerge, and may get depleted during the crop cycle.

The results of the main effects on emergence counts presented above were mostly dependent upon vine weed species and levels of trash cover. Burial depth was a significant factor when seeds were found at 8 cm or deeper. The interactions of these factors further influenced the emergence of the *Ipomoea* spp. seedlings.

Species and Trash Cover interactions

The interaction between *Ipomoea* spp. and trash cover was highly significant ($P < 0.001$) in the four trials. The vine weed species tested responded differentially to the trash cover treatments. In trials I and II, *I. triloba* and *I. obscura* had significantly higher emergence counts than *I. nil* on bare soil (Fig 3.15). In the presence of a trash layer of 5 cm, the emergence of the latter was significantly improved whereas that of the other two species got a decrease. However, the three vines behaved in the same way when the trash layer was doubled and tripled.

A similar effect was found in trial III except that the emergence of *I. nil* did not improve with the increasing dry mass of R 570 trash (Fig 3.16). The same response was noted with M 1176/77 trash in trial IV, the only difference being that the emergence of the three species was comparable beyond a dry mass cover of 10 t.ha⁻¹. In practical situations, such differential development of the *Ipomoea* spp. in sugarcane fields after harvest would not allow a specific control operation, hence complicating management strategies.

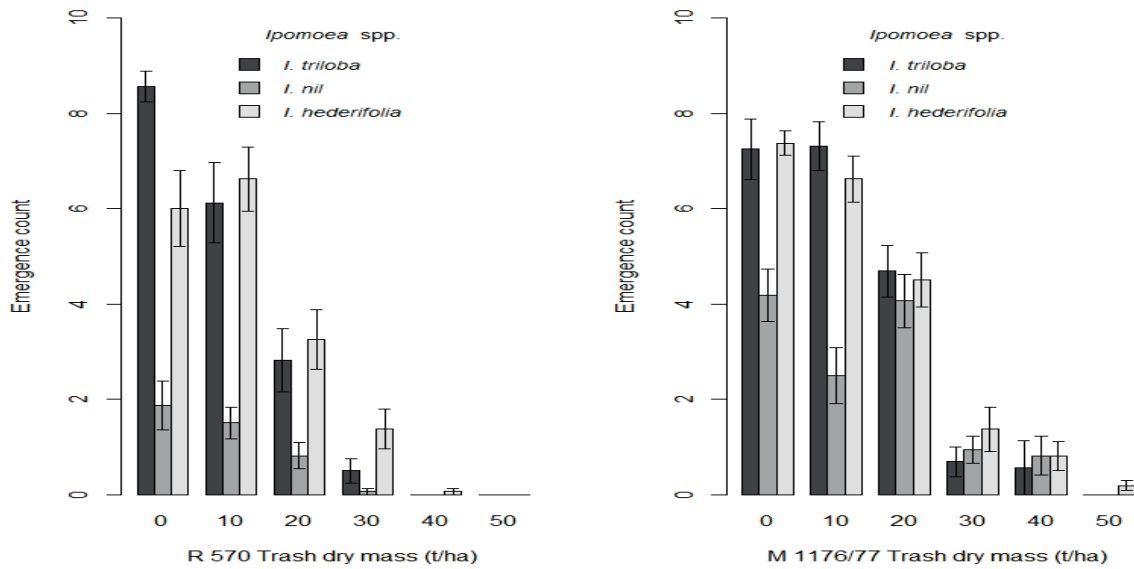


Figure 3.16 Interactions of *Ipomoea* spp. and dry mass ($t \cdot ha^{-1}$) of trash cover of sugarcane varieties R 570 and M 1176/77 on seedling emergence. Error bars represent the standard error of four replicates.

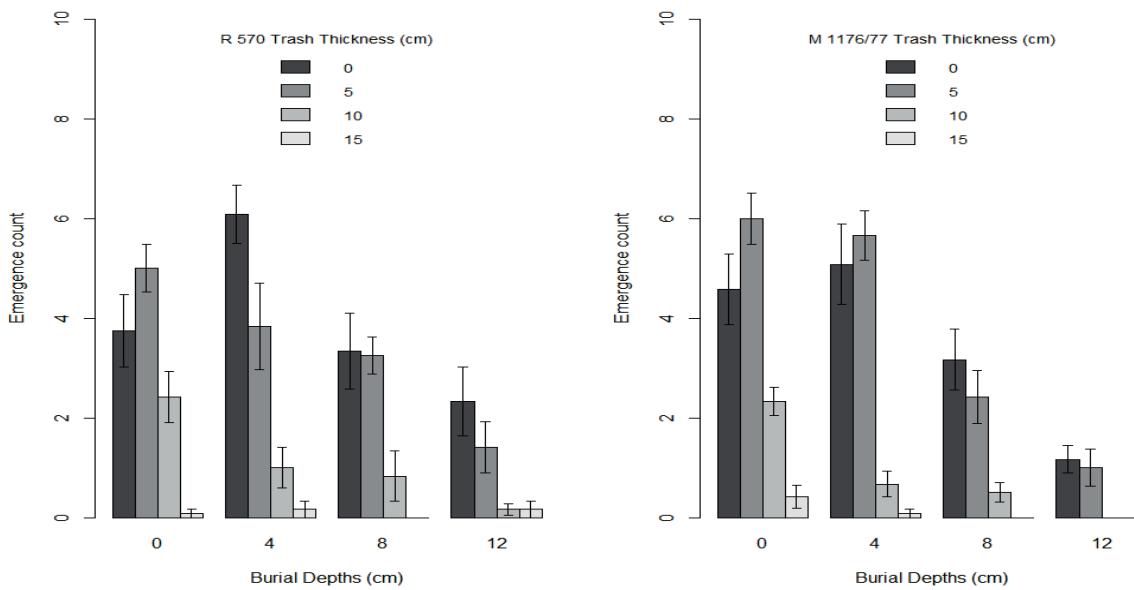


Figure 3.17 Interaction of trash thickness (cm) of sugarcane varieties R 570 and M 1176/77, and burial depths on the emergence of *Ipomoea* spp. Error bars represent the standard error of four replicates.

Trash cover and burial depths interactions

There was a highly significant ($P < 0.001$) interaction between the different thickness of trash cover of the two sugarcane varieties and burial depths of *Ipomoea* spp. seeds in Trials I and II (Fig 3.17). This implied that emergence of *Ipomoea* spp seedlings was influenced by the amount of trash present on the soil surface and the location of the seeds in the soil profile. When seeds were found on the soil surface, a 5 cm trash cover (equivalent to $10.5 (\pm 2.0) \text{ t ha}^{-1}$ and $15.1 (\pm 2.7) \text{ t ha}^{-1}$ of dry matter of trash from variety R 570 and M 1176/77 respectively) caused a significant increase in the emergence count of the vine weed seedlings compared to the uncovered control. There was, however, an opposite effect when the mulch layer was doubled, the trash from the two sugarcane varieties reducing the number of seedlings by more than 50%. There was no such response when seeds were found at 4 cm or deeper down in the soil profile, the reduction in emergence count being directly due to the hindrance provided by the thicker trash layers and effect of burial depths.

The positive interaction found in the trials of 2008 between trash cover and burial depths did not happen again when the experiment was repeated in 2010 with trash cover levels expressed on a dry mass basis (Fig 3.18). It could be that the trash increments used in the two trials did not allow the occurrence of the interaction, meaning that significant germination and emergence of *Ipomoea* seedlings could be enhanced by an optimal amount of trash cover. The corresponding thickness of the different trash dry mass was calculated from the regression analysis in Fig 3.21 (Table 3.8) and it was found that this optimal trash thickness which was located between 10 and 20 t ha^{-1} of dry mass was not expressed in Trial III and IV. The regression analysis also revealed that the cane variety M 1176/77 had higher dry weight values compared to those of R 570 for the same trash thickness (left graph), implying a difference in the level of compactness in their trash layer. The same trend was noted in the investigation carried out on data collected in the trials of 2010.

Table 3.8 Calculated equivalent trash thickness for the various levels of dry mass used in Trial III and IV

		Trash dry mass (t.ha ⁻¹)					se
		10	20	30	40	50	
Trash thickness (cm)	<i>R 570</i>	4.5	8.9	13.4	17.9	22.3	±2.7
	<i>M 1176/77</i>	3.9	7.9	11.8	15.8	19.7	±1.7

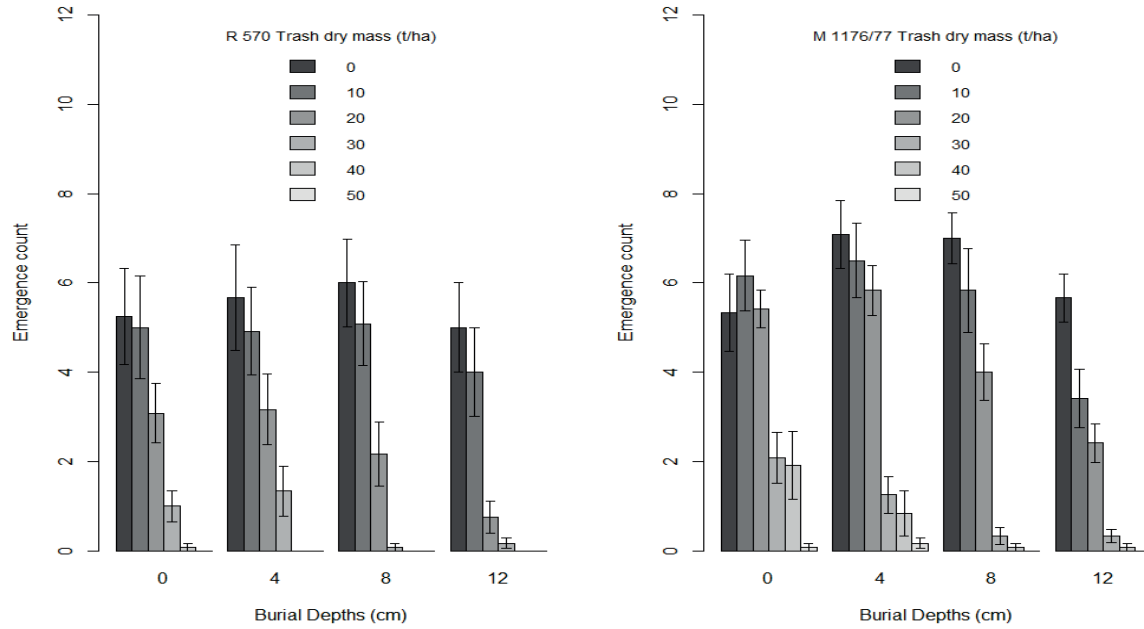


Figure 3.18 Interaction of trash dry mass ($t \cdot ha^{-1}$) of sugarcane varieties R 570 and M 1176/77, and burial depths on the emergence of *Ipomoea* spp seedlings. Error bars represent the standard error of four replicates.

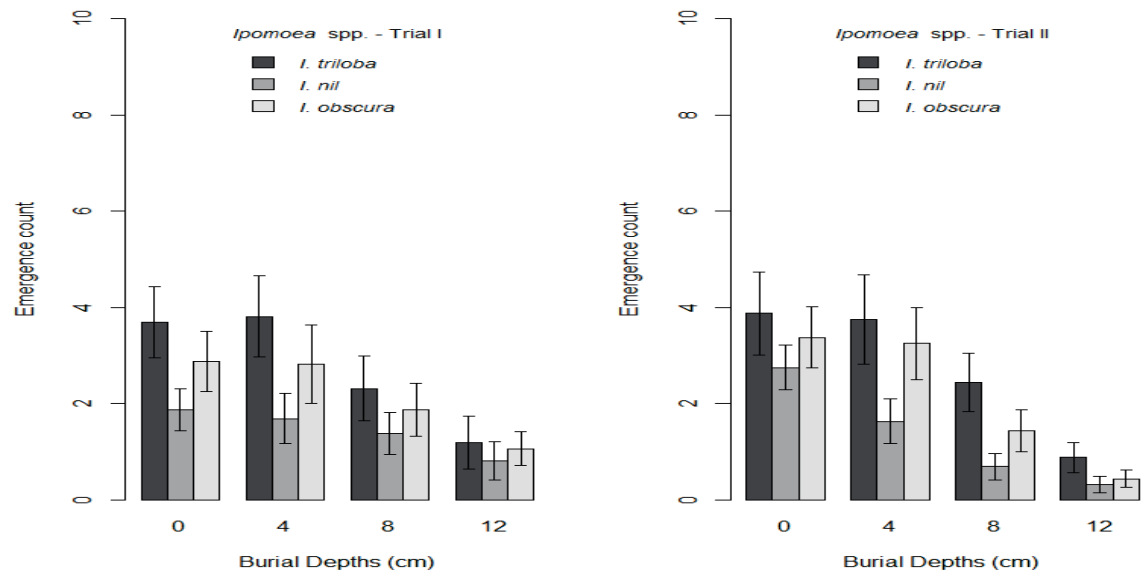


Figure 3.19 Interactions of *Ipomoea* spp. and burial depths in 2008 on the emergence of *Ipomoea* spp seedlings. Error bars represent the standard error of four replicates.

Species and Burial Depths interactions

Interaction between species and burial depths was not significant in Trials I and II, but this was highly significant in Trials III and IV. Actually in the latter, emergence counts for *I. triloba* and *I. hederifolia* were comparable, but these were significantly higher for both species compared to those of *I. nil* (Fig 3.19 & 3.20). It was also found that the emergence counts of *I. nil* was sensibly lower with the trash of R 570 than that with M 1176/77. These differences may be attributed to the ability of the species to respond to the trash dry mass.

Species, trash cover and burial depths interactions

The overall interaction of species, trash cover and burial depths was significant in Trial II and highly significant for the other trials. This would mean that species and trash cover were dominant factors that influenced the interactions though burial depths were not significant in all the trials.

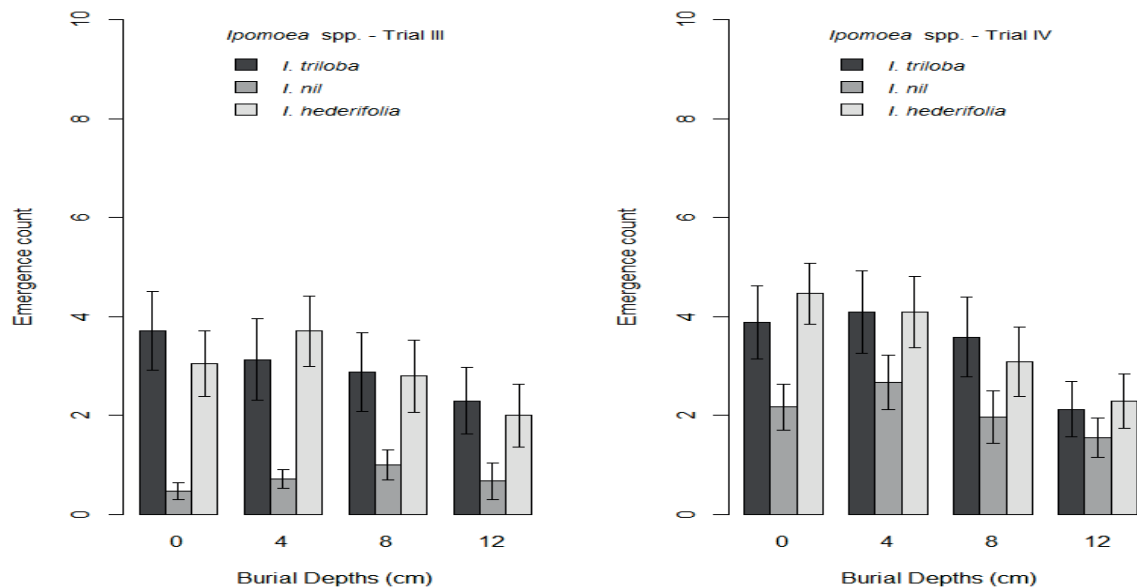


Figure 3.20 Interactions of *Ipomoea* spp. and burial depths in 2010 on the emergence of *Ipomoea* spp seedlings. Error bars represent the standard error of four replicates.

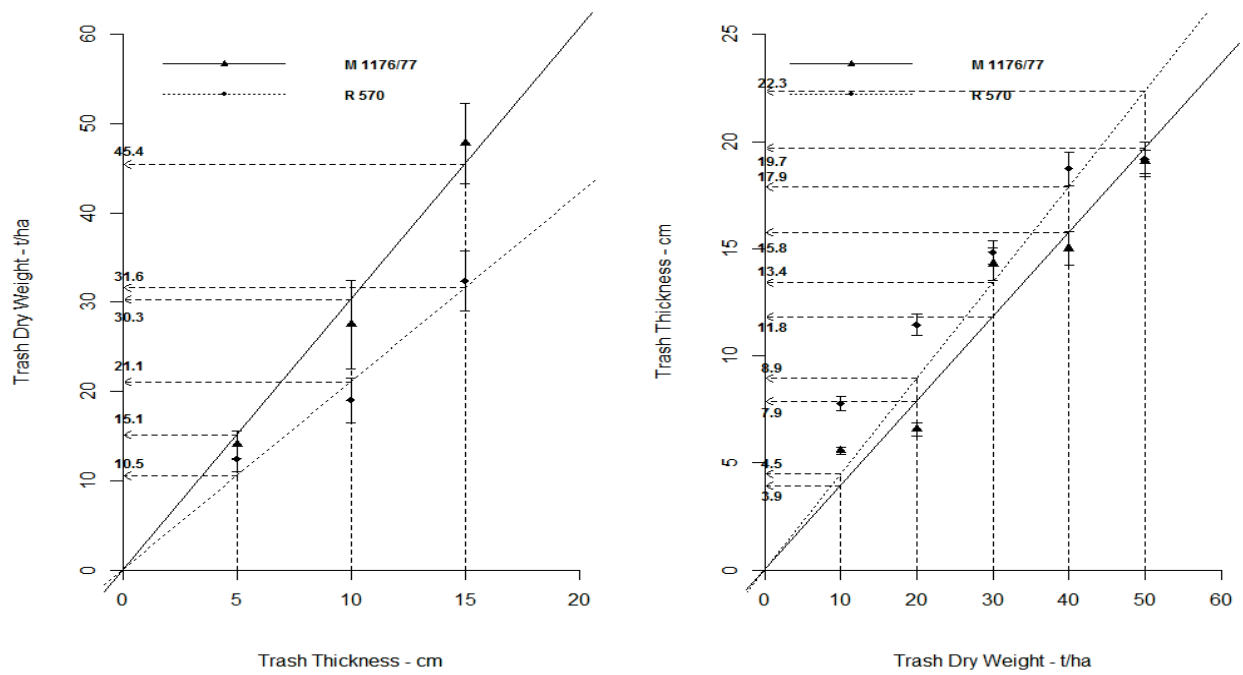


Figure 3.21 Correlation of trash thickness and dry mass of sugarcane varieties R 570 and M 1176/77 in the trials of 2008 (left graph) and 2010 (right graph). Error bars represent the standard error of data analysed.

Logistic analysis of the emergence dynamics of Vine species x Trash layer x burial depths

Emergence dynamics

The present study also provided information about the emergence dynamics of the *Ipomoea* spp. in the given conditions of the experiments. The logistic model fitted to the data of each of the four trials showed that *I. hederifolia*, *I. nil*, *I. obscura* and *I. triloba* demonstrated characteristic pattern of emergence for the respective mulch treatment at a particular burial depth, in line with the results of the GLMM analysis. The Neill's lack-of-fit tests were not significant in every case, confirming the goodness of the fits. Inspection of the time taken to attain 90% emergence or more revealed that it ranged from 5 to 15 days for the trials in 2008 whereas this range was between 5 to 10 days in 2010. It was also found that *I. triloba* seedlings emerged more rapidly, taking 5-7 and 3-5 days in 2008 and 2010 respectively. In all the trials, the influence of sugarcane varieties in the delay of the time of emergence was comparable.

ED50 and ED90 calculations of trash cover using dose-response analysis

The dose response curves established for the trash thickness and dry mass of the two sugarcane varieties were characterised by specific patterns for each *Ipomoea* species at a given burial depth (Fig 3.22 & 3.23). Generally seeds buried at 8 and 12 cm soil depth produced lower regression curves than those found in the upper soil profile. This was particularly important in the experiment of 2008 where the GLMM analysis showed a highly significant interaction between trash cover and burial depths.

The ED50 and ED90 values of trash cover were calculated for seeds located on the soil surface or buried at 4 cm underground since most of the emergence occurred from these two burial depths (Table 3.9). These values indicated the threshold level of trash thickness (2008 experiments) and dry mass (2010 experiments) required to cause a 50% (ED50) and 90% (ED90) reduction in the emergence of the *Ipomoea* species.

It was found that the ED50 of trash thickness for R 570 was significantly higher when seeds were located at the surface than when they were buried at 4 cm in the soil (Table 3.9). A similar trend was observed for M 1176/77 with a slight significant difference. However, the level

of trash thickness calculated to reduce 90% of the emergence (ED90) was comparable for both sugarcane varieties at the two burial depths. The response of the *Ipomoea* species to the different threshold level of trash thickness was also practically comparable for the respective burial depths.

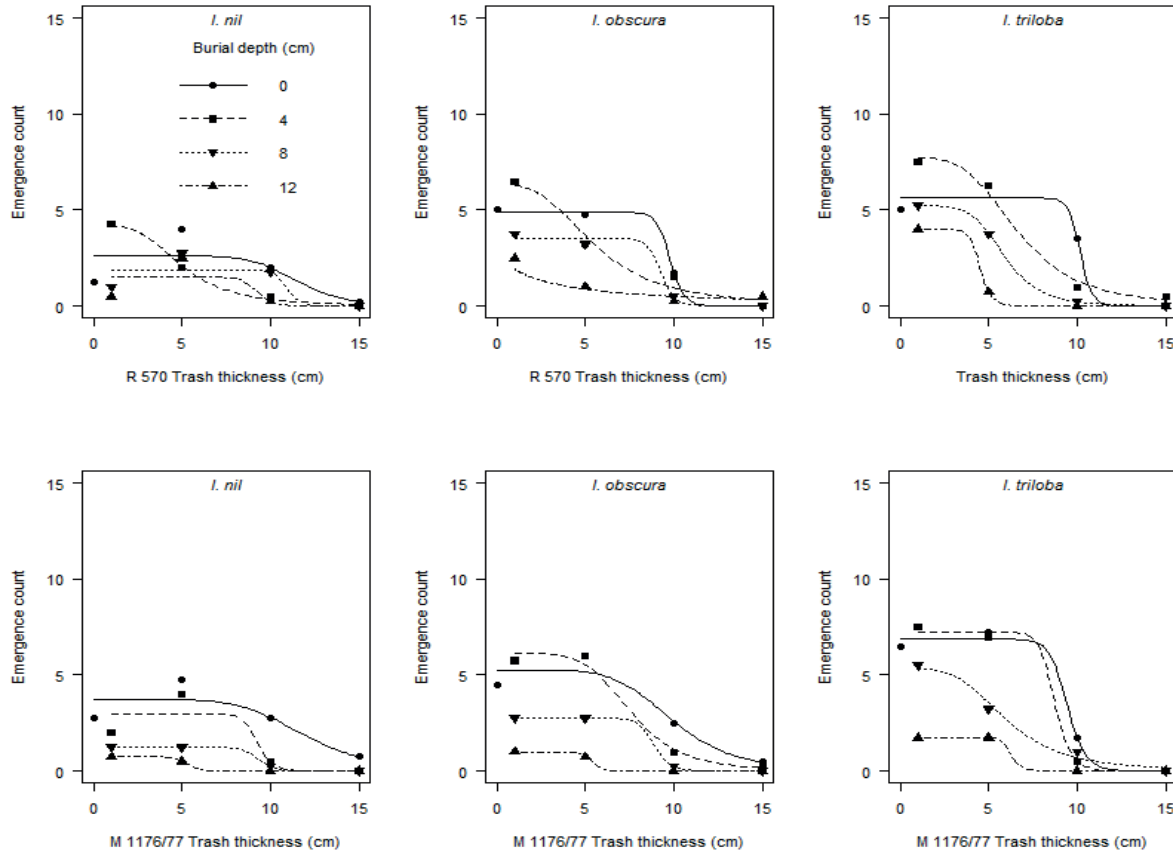


Figure 3.22 Dose response curves plotted from log-logistic fits to the emergence counts of *Ipomoea* spp. buried at four soil depths and subjected to different trash cover treatments from sugarcane varieties R 570 and M 1176/77. The legend in the first plot of the first row applies to the other graphics also.

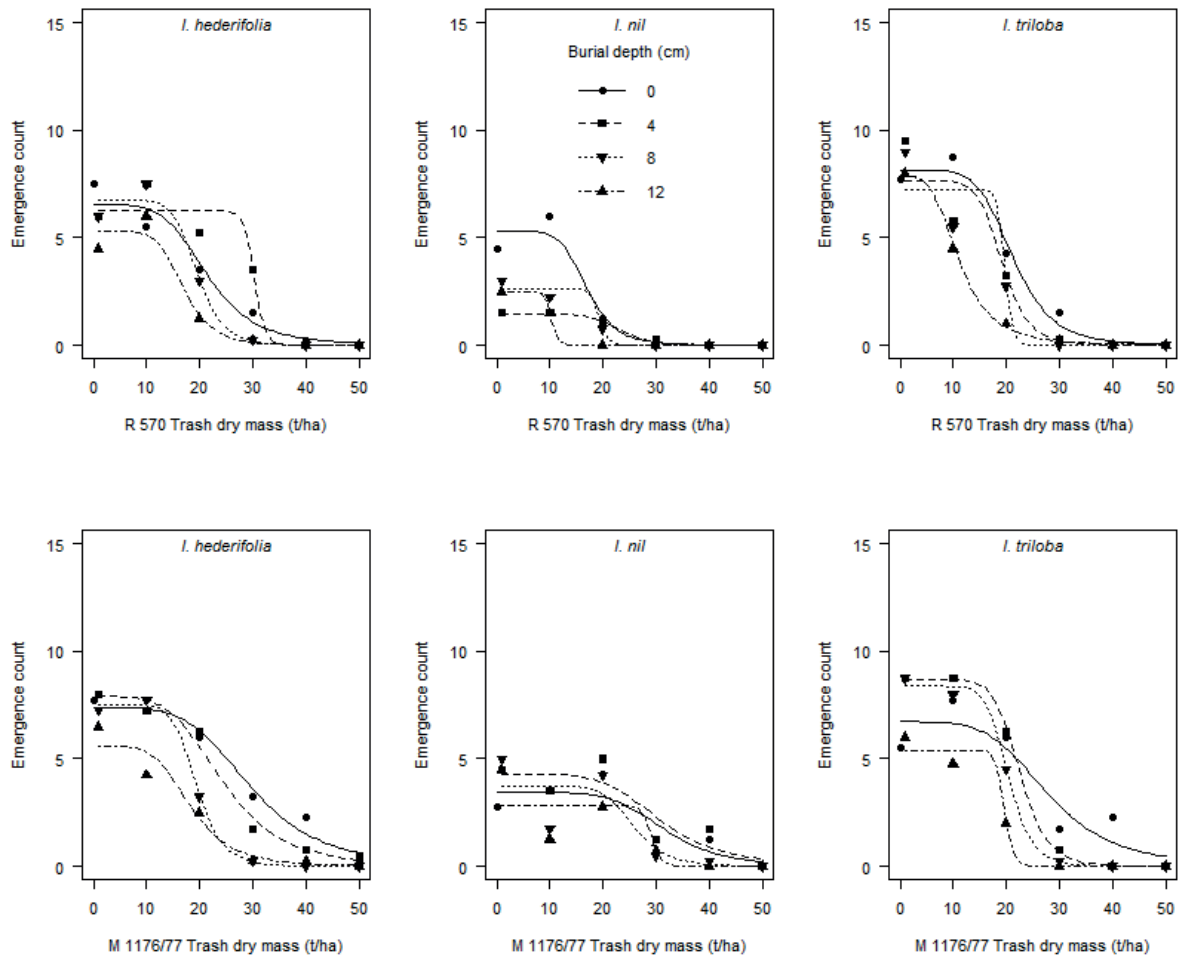


Figure 3.23 Dose response curves plotted from log-logistic fits to the emergence counts of *Ipomoea* spp. buried at four soil depths and subjected to different trash cover treatments from sugarcane varieties R 570 and M 1176/77. The legend in the second plot of the first row applies to the other graphics also.

Table 3.9 ED50 and ED90 values of trash thickness and dry mass from sugarcane varieties

Species	Depth (cm)	Trash thickness (cm)				Trash dry mass (t.ha ⁻¹)				
		ED50	se(±)	ED90	se(±)	ED50	se(±)	ED90	se(±)	
R 570	<i>I. hederifolia</i>	0	-	-	-	21.4	3.3	34.0	3.4	
	<i>I. hederifolia</i>	4	-	-	-	30.2	0.7	32.4	4.6	
	<i>I. nil</i>	0	11.5	1.7	14.9	1.9	17.0	2.1	24.1	2.4
	<i>I. nil</i>	4	5.0	1.2	9.4	2.0	23.1	5.6	31.2	5.1
	<i>I. obscura</i>	0	9.8	1.2	10.7	3.5	-	-	-	-
	<i>I. obscura</i>	4	5.6	1.4	11.7	2.2	-	-	-	-
	<i>I. triloba</i>	0	10.2	1.1	10.9	6.1	21.3	2.2	31.0	2.5
	<i>I. triloba</i>	4	6.7	1.1	11.7	1.6	19.2	1.5	25.4	2.0
	Mean	0	10.5	0.5	12.2	1.4	19.9	1.4	29.7	2.9
	Mean	4	5.8	0.5	10.9	0.8	24.2	3.2	29.7	2.2
M 1176/77	<i>I. hederifolia</i>	0	-	-	-	29.6	4.0	48.4	5.3	
	<i>I. hederifolia</i>	4	-	-	-	24.2	2.8	40.0	3.9	
	<i>I. nil</i>	0	11.9	1.7	17.1	2.7	31.6	4.1	45.9	5.4
	<i>I. nil</i>	4	9.3	3.8	10.3	1.6	30.8	4.0	47.2	5.7
	<i>I. obscura</i>	0	9.9	1.2	14.7	1.9	-	-	-	-
	<i>I. obscura</i>	4	7.6	1.2	11.5	1.3	-	-	-	-
	<i>I. triloba</i>	0	9.4	1.0	10.6	1.2	27.9	3.4	45.6	4.8
	<i>I. triloba</i>	4	8.7	4.9	9.8	1.0	22.5	1.8	28.8	1.9
	Mean	0	10.4	0.8	14.1	1.9	29.7	1.1	46.3	0.9
	Mean	4	8.5	0.5	10.5	0.5	25.8	2.5	38.7	5.3

In the experiment of 2010, 19.9 t.ha⁻¹ (±1.4) of dry trash from the variety R 570 were calculated to cause a 50% reduction in emergence of seeds placed on the soil surface. This value was not statistically different to that obtained for suppressing seedling emergence from a soil depth of 4 cm (Table 3.9). Similarly, there was no difference in the amount of trash that impeded 90% emergence from seeds located on the soil surface (29.7 t.ha⁻¹ ±2.9) or buried at 4 cm (29.7 t.ha⁻¹ ±2.2) in the soil.

The values of ED50 and ED90 calculated for the dry trash of the variety M 1176/77 were higher than those of R 570, indicating a difference between the two varieties in their effectiveness to suppress emergence. A significantly lower amount of dry trash from the variety R 570 was

required to cause a 50% or 90% reduction of *Ipomoea* spp. seedling emergence at a particular burial depth. Otherwise, the variety M 1176/77 required significantly higher masses of dry trash to suppress emergence from seeds found on the soil surface than those buried 4 cm underground. Moreover, just as with trash thickness, the *Ipomoea* spp. reacted in practically the same way for each effective dose at the respective burial depths. It was, however, noted that significantly higher dry masses of trash of each sugarcane variety were required to reduce emergence by 90% compared to 50%.

Discussions and conclusions

The log-logistic analysis of the cumulative emergence counts of *Ipomoea* spp. seedlings in this study had provided some estimates of the effective doses of trash cover necessary to suppress their appearance in the fields by 50% and 90%. The results showed that at least 10 cm of trash layer from each of the two sugarcane varieties would be required to hinder emergence by half when seeds were located on the surface. But for seeds at 4 cm in the soil profile, this layer ranged from 6 cm (R 570) to 8 cm (M 1176/77). On the other hand, a 90% suppression of seedlings emerging from the soil surface would be obtained with a minimum of 12 cm and 14 cm of trash thickness from R 570 and M 1176/77 respectively. Such effect would be caused by a comparatively similar trash layer (about 11 cm) from both varieties when seeds were located at 4 cm deeper.

In practice, the mulch of trash produced just after mechanized green cane harvesting turns around a thickness of 10 cm. A study (Gaungoo *et al.* 2014a) reported recently found that the initial trash thickness of the sugarcane variety M 695/69 with an average cane yield of 110 t.ha⁻¹ decreased to less than 5 cm four weeks after harvest. This would imply that the GCTB mulch, though very effective in controlling small-seeded weeds, would provide a limited and ineffective control of *Ipomoea* spp. and other weeds having comparable seed sizes as them. In fact, it has been demonstrated in Brazil (Manechini *et al.* 2005) that a trash cover equivalent to 5 cm was ineffective in controlling *I. quamoclit*, *I. purpurea*, *I. grandifolia*, *I. hederifolia*, and *I. nil*. The present study had in addition shown that a 5 cm trash layer would on the contrary favour the germination and emergence of *Ipomoea* spp. seeds found just under the mulch (Fig 6). In a study to assess the effect on weed emergence of soil covered with sugarcane harvest straw residue, (Correia *et al.* 2004) obtained a similar result on *I. quamoclit* with a mulch of 5-15 t.ha⁻¹. Moreover, the trash cover

represents a major obstruction for the activity of pre-emergence herbicides and this provides further conditions for the development of the *Ipomoea* seedlings by avoiding chemical control.

When expressed on a dry matter basis, the mass of trash necessary to reduce seedling emergence by 50% for *Ipomoea* spp. seeds placed in the 0-4 cm soil profile ranged from 20-24 t.ha⁻¹ for R 570 whereas this necessitated 26-30 t.ha⁻¹ for M 1176/77. These values increased to 30 t.ha⁻¹ and 39-46 t.ha⁻¹ for the two sugarcane varieties respectively in order to induce a 90% reduction of seedling emergence. A comparative result was obtained in Sao Paulo (Brazil) in an experiment conducted to study the effect of different amounts of sugarcane straw from two cultivars on the emergence of *Ipomoea* spp. (Azania *et al.* 2002) At least 20 t.ha⁻¹ of trash was required to reduce emergence of *I. grandifolia*, *I. hederifolia* and *I. nil* by 62%, 70% and 60% respectively compared to the control. Furthermore, the calculated ED values also showed that less amount of trash from the variety R 570 was needed to suppress *Ipomoea* spp. seedlings than M 1176/77. The better efficiency of the trash cover of R 570 may be attributed to its larger leaves, causing the mulch to be more voluminous and therefore thicker compared to that of M 1176/77 for a specific dry weight (Fig 3.21). This would in turn mean that the suppressive property of a mulch of sugarcane trash would be more dependent upon its thickness rather than on the amount of dry matter per unit area.

This study had also revealed important interactions involving trash cover, the most important agronomically being between burial depths. It appeared that a mulch around 5 cm thick tends to favour the development of *Ipomoea* spp. seedlings from seeds that are near the soil surface. But this trash thickness negatively affected emergence from seeds that were deeper down in the soil (Fig 3.17). The effect was even more drastic when the layer was doubled or tripled. In real field conditions, distribution of *Ipomoea* spp. seeds in the soil profile is mainly influenced by tillage operations at planting of a new sugarcane crop as interrow cultivation is not practiced in Mauritius. Tillage and field preparations occur after each crop cycle which takes around seven years. Therefore, seeds produced from any *Ipomoea* species infestation during the ratoon crop remain near the soil surface and are covered by the trash residue coming from mechanised green cane harvesting.

It is possible, on the other hand, to manage this layer of GCTB appropriately to suppress emergence of *Ipomoea* spp. seedlings. It appeared from this study that very effective control of vines may be achieved by uniform trash thickness greater than 10 cm. This can be achieved if trash from two interrows is windrowed onto one and weed emergence on the cleared interrows can be managed with herbicides (Gaungoo *et al.* 2014a). In fact, this was a common practice in Mauritius where trash was raked and aligned manually on alternate interrows in layers reaching 20 cm or more after green cane harvesting. This may explain partly the good control of vines obtained previously in Mauritius.

It appears from the experiments carried out in 2008 and 2010 that the mulching effect of post-harvest sugarcane trash is a determinant factor that influences the emergence of *Ipomoea* species in the fields. This work has shown that GCTB creates better agro-ecological conditions for the development of these vine weeds, thus confirming the general hypothesis that this practice is in part responsible for their proliferation in the sugarcane crop. Although the findings of this study need to be confirmed at the field level, there is an indication that the thickness of the trash layer is an important parameter that should be taken into consideration in the development of strategies to control vines in sugar cane.

Reference

- Azania A.A.P.M., Azania C.A.M., Gravena R., Pavani M.C.M.D. and Pitelli R.A. 2002. Sugar cane (*Saccharum spp.*) straw interference in emergence of weed species of the Convolvulaceae family. *Planta Daninha*. **20**, 207-212.
- Bolker B.M., Brooks M.E., Clark C.J., Geange S.W., Poulsen J.R., Stevens M.H.H. and White J.-S.S. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecol. Evol.* **24**, 127-135.
- Bond B. and Grundy A.C. 2001. Non-chemical weed management in organic farming systems. *Weed Res.* **41**, 383-405.
- Correia N.M. and Durigan J.C. 2004. Weed emergence in soil covered with sugarcane harvest straw residue. *Planta Daninha* **22**, 11-17.
- Crowley R.H. and Buchanan G.A. 1982. Variations in Seed Production and the Response to Pests of Morningglory (*Ipomoea*) Species and Smallflower Morningglory (*Jacquemontia tammifolia*). *Weed Science* **30**, 187-190.
- Ganeshan S. 2005. The effect of armyworms *Mythimna* spp. (Lepidoptera: Noctuidae) on cane growth in Mauritius. In: *Proceedings XXV Congress International Society of Sugar Cane Technologists* (ed. Hogarth M.). Cengicana, Guatemala, 730-734.
- Gaungoo A. and Seeruttun S. 2014a. Influence of Post-harvest Trash Management Practices on Control of Vine Weeds in Sugarcane.).
- Gaungoo A., Seeruttun S. and Le Bourgeois T. 2014b. Effect of burial depth on germination and emergence of *Ipomoea* spp. in sugarcane fields: Implications for the development of vine weed management strategies. *Weed Biol. Manage.*
- Gill H.K., Mc Sorley R. and Branham M. 2011. Effect of organic mulches on soil surface insects and other arthropods. *Fla. Entomol.* **94**, 226-232.

- Hardcastle W.S. 1978. Influence of Temperature and Acid Scarification Duration on Scarlet Morningglory (*Ipomoea coccinea*) Seed Germination. *Weed Science* **26**, 261-263.
- Havlin J.L., Kissel D.E., Maddus L.D., Claasen M.M. and Long J.H. 1990. Crop rotation and tillage effects on soil organic carbon and nitrogen. *Soil Sci. Soc. Am. J.* **54**, 448-452.
- Ismael F., Seeruttun S., Barbe C. and Gaungoo A. 2008. A review of changing cultural practices to improve productivity of sugar cane in Mauritius. In: *Proceedings South African Sugar Technologists Association*). Durban.
- Jordan A., Zavala L.M. and Gil J. 2010. Mulching effects on soil physical properties and runoff under semi-arid conditions in southern Spain. *Catena* **81**, 77-85.
- Kruidhof M., Gallandt E.R., Haramoto E.R. and Bastiaans L. 2011. Selective weed suppression by cover crop residues: Effects of seed mass and timing of species' sensitivity. *Weed Res.* **51**, 177-186.
- Le Bourgeois T., Carrara A., Dodet M., Dogley W., Gaungoo A., Grard P., Ibrahim Y., Jeuffrault E., Lebreton G., Poilecot P., Prospero J., Randriamampianina J.A., Andrianaivo A.P. and Théveny F. 2008. Advent-OI : Principales adventices des îles du sud-ouest de l'Océan Indien.V.1.0. In: *Software*). Cirad Montpellier, France.
- Lorenzi H. 1984. Consideracoes sobre plantas daninhas no plantio direto. In: *Plantio direto no Brasil*). Fundacao Cargill, 13-46.
- Manechini C., Ricci-Junior A. and Donzelli J.L. 2005. An overview of controlled and non-controlled weeds as influenced by sugarcane trash blankets. *Sugar Cane International UK.* **23**, 11-14.
- Morandini M., Figueroa R., Zamora F.P. and Scandaliaris J. 2005. The effects of green-cane trash blanket on soil temperature, soil moisture and sugar cane growth. In: *Proceedings of the XXV Congress* (ed. Hogarth D. M.). The XXV ISSCT Congress Organising Committee, Atagua, Guatemala City, Guatemala, 231-237.

- MSIRI 1985. Breeding of varieties. In: *1984 Annual Report*). Mauritius Sugar Industry Research Institute., 33.
- MSIRI 1986. Breeding of varieties. In: *1985 Annual Report*). Mauritius Sugar Industry Research Institute., 33.
- MSIRI 2012. Mechanized green cane harvesting. In: *2011 Annual Report*). Mauritius Sugar Industry Research Institute., 33.
- Mulumba L.N. and Lal R. 2007. Mulching effects on selected soil physical properties. *Soil & Tillage Research* **98**, 106-111.
- Parish D.H. and Feillafé S.M. 1965. Notes on the 1:100,000 Soil Map of Mauritius. . In: *Occasional Paper No. 22*). MSIRI Mauritius.
- Quintela A.C.R., Andrade L.A.B., Carvalho G.J., Figueiredo P.A.M. and Anjos I.A. 2002. Controle físico e alopatóico de plantas daninhas pelo palhamento de duas variedades de cana-de-açúcar, em condições de casa de vegetação. . In: *Anais do 8 Congresso Nacional da STAB*). 190-194.
- R Core Team 2014. R: A language and environment for statistical computing. . In: *Software*). R Foundation for Statistical Computing, Vienna, Austria. .
- Rask M. and Andreasen C. 2007. Influence of rhizome cutting, rhizome drying and burial at different developmental stages on the regrowth of *Calystegia sepium*. *Weed Res.* **47**, 84-93.
- Ritz C. 2010. Toward a unified approach to dose response modelling in ecotoxicology. *Environ. Toxicol. Chem.* **29**, 220-229.
- Ritz C. and Streibig J.C. 2005. Bioassay analysis using R. *Journal of Statistical Software* **12**, 1-22.

- Seeruttun S., Barbe C. and Gaungoo A. 2005. Vine weeds in sugarcane: fluroxypyr provides cost-effective post-emergence control in Mauritius. *Sugar Cane International*. **23**, 3-5.
- Seeruttun S., G Mc Intyre G. and C Barbe C. 1992. Agronomic and economic significance of trash blanketing in the sub-humid areas of Mauritius. *Révue agricole et sucrière de l'île Maurice* **71**, 324-331.
- Soil, Survey and Staff 1999 Keys to soil taxonomy, 8th edn. (ed. Pocahontas Press I.). Blacksburg, Virginia.
- Suwanketnikom R. and Julakasewee A. 2004. Hardseededness and germination of small white flower morningglory. *Kasetsart-Journal,-Natural-Sciences*. **38**, 425-433.

3.5 Influence of Post-harvest Trash Management Practices on Control of Vine Weeds in Sugarcane

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Abstract

Vine weeds are more frequent in sugarcane fields, particularly with the increasing adoption of green cane trash blanketing (GCTB). As current control measures are not completely effective in controlling vine weeds emerging through the trash cover, two trials have been conducted to understand the interaction between trash management practices (GCTB v/s trash lining) and early post-emergence herbicide treatments for the control of *Ipomoea nil* and *I. hederifolia*. The herbicide treatments consisted of tank-mixes including herbicides amicarbazone, diclosulam and sulfentrazone. Weed surveys were carried out prior to spraying and three, six and 12 weeks after spraying. The GCTB complemented with a herbicide treatment was found to be superior or as good as the practice of windrowing trash from three interrows into one without receiving any herbicide application. Among the herbicide treatments applied on the trash cover and which provided a good residual activity following a knock-down of young vine weeds emerged at spraying time, the tank-mix diclosulam + sulfentrazone was found to be the most effective. Tank-mixes with amicarbazone also showed some potential. Trash decomposition was also assessed with respect to thickness of GCTB. Further trials are required to confirm these combinations as well as those studying the trash decomposition and movement of herbicides through the mulch.

Keywords: early post-emergence application, GCTB, sulfentrazone, diclosulam, amicarbazone

Introduction

Vine weeds are troublesome plants affecting sugarcane and other crops worldwide (Azania *et al.* 2002; Bhullar *et al.* 2012; BSES 1989; Chauhan *et al.* 2012; Christoffoleti *et al.* 2006; Jones 2006; Lancaster *et al.* 2005; Lebreton *et al.* 2009; Norsworthy 2004). Unlike other broad-leaved weeds, grasses and sedges usually present in sugarcane fields, vine weeds (particularly *Ipomoea* spp.) have the ability to develop late in the season and grow both horizontally and vertically making their control more difficult. In Mauritius, the problem started in the 1990s following changes in sugarcane husbandry practices with increasing adoption of green cane harvesting and trash blanketing (GCTB).

Trash residue left on the surface after harvest may act as non-living mulch depending upon the practices; this may result from both manual and mechanized harvesting of green cane. The amount of dry matter just after harvest ranges from 10 to 15 t.ha⁻¹ depending on variety and cut stage (Manechini *et al.* 2005; Correia *et al.* 2004);). While green cane trash blanketing (GCTB) can effectively suppress the germination and emergence of small-seeded weeds, large-seeded species can better tolerate cover crop residue-mediated stress (Kruidhof *et al.* 2011; Manechini, *et al.* 2005). This is particularly true for vine weeds which are believed to have been the consequence of a species population shift owing to the repeated practice of GCTB; their germination and emergence are not completely inhibited even with a residue level of 15 to 20 t.ha⁻¹ of dry matter (Azania *et al.* 2002).

The increasing problem of vine weeds in Mauritius, dominated mainly by four *Ipomoea* spp., is related to the ineffectiveness of the GCTB mulch in preventing their germination and emergence. The mulching effect of the trash cover creates agro-ecological conditions that influence the germination and emergence of weeds. The weed flora of sugarcane fields in Mauritius is mostly dominated by small-seeded species (Le Bourgeois *et al.* 2008) and are relatively well managed by the trash cover in GCTB situations. GCTB, during the last two decades, has caused a shift in species with control of vines becoming more challenging.

In Mauritius, weed control is mainly achieved through the application of cost-effective pre- and post-emergence herbicide tank-mixes, handweeding being restricted for removing leftovers such as tall plants and semi-woody species. The standard practice of weed control in ratoon cane has been the application of a pre-emergence herbicide in the weeks following harvest, depending on the level of weed infestation. Growers tend to delay the first spraying until there are

enough weeds present before they can apply the required herbicide mixtures that will provide maximum post-emergence and pre-emergence control, based on the philosophy of weed management (Seeruttun, 2008). Eventually a second herbicide application is carried out some 10 to 12 weeks after the initial spraying, and the sugarcane crop afterward completes its canopy formation, thus suppressing further weed development.

Weed management in sugarcane in the second half of the decade of 2000 has been achieved by either applying herbicides in pre-emergence or in early post-emergence of the weeds, with treatments having both a knockdown and a residual effect. The research objectives underlying the evaluation of residual herbicides for sugarcane in Mauritius are mainly being geared towards the screening of treatments providing a broader-spectrum of control, together with a longer residual activity. The post-emergence treatments are also being tested for their ability to knockdown a wide range of weed species and offering a relatively long residual action (MSIRI 2009). It is with these objectives that the herbicide treatments listed in Appendix 1 have been recommended to sugarcane growers in Mauritius. These recommendations provide them with more flexibility in choosing the most cost-effective tank-mix required under specific field conditions.

However, in the recent years, the conventional pre-emergence herbicide treatments have been found to be ineffective on the new vine weeds. Previously, vine weeds like *Paederia foetida* L. and *Passiflora suberosa* L. were always found as localized infestations in sugarcane fields and these perennial species were effectively controlled by the recommended post-emergence herbicide tank-mixes (Seeruttun *et al.* 2005). Several new and more invasive vine species have been observed in the recent years; these are partly attributed to changes in some cultural practices including trash management (Ismael *et al.* 2008). These vine weeds, which include *Ipomoea triloba* L., *I. nil* (L.) Roth, *I. hederifolia* L., *Basella alba* L. and *I. obscura* (L.) Ker Gawl., are annuals and reproduce exclusively through the production of large amounts of large seeds (Crowley *et al.* 1982). The most commonly found species is *I. triloba* which occur mainly in the humid and sub-humid regions of the island; *I. nil* and *I. hederifolia* can also be encountered there.

It is suspected that these new species have been favoured by the more conducive conditions offered by the sugarcane trash cover (Gaungoo *et al.* 2010). It also appears that both trash blanketing and the existing pre-emergence herbicides are targeting weeds that are germinating close to the soil surface. Furthermore, GCTB is acting as a hindrance to the effective

applications of pre-emergence treatments for the control of vine weeds. Therefore, the objective of this work has been to study the interaction between two post-harvest trash management practices and different herbicide treatments for a more efficient control of vine weeds in sugarcane.

Materials and Methods

(a) Trial setup

Two field trials were established in 2009 at two sites (Table 3.10) where sugarcane (variety M 695/69) was harvested in green with a chopper harvester. A split-plot design with four replicates was used with main plot treatments consisting of two levels of trash management practices and the sub-plots of ten herbicide treatments (Table 3.11). In both trials, the plot size consisted of 8 cane rows of 15 m long with a row spacing of 1.62 m. For the main-plot, GCTB (T1 plots) was compared to a treatment where trash from three cane interrows, were windrowed into one (T2 plots) with the purpose of increasing the thickness of the mulch for further hindering the emergence of vine weeds (Fig 3.24). Herbicide treatments were then applied only on the cleared interrows of the T2 plots and on the trash of the GCTB plots to assess their effectiveness to control vine weeds in these situations. Application was carried out using knapsack sprayers delivering a volume of 350 L.ha⁻¹ at a pressure of 2.5 bars.

The mode of action and effect on plant of the active ingredients consisting the ten herbicide mixtures are listed in Table 3.12. The herbicides 2,4-D amine salt and fluroxypyr are characteristically foliar translocated herbicides and they have been included in some of the mixtures for a more effective post-emergence knockdown; all the other molecules, particularly diclosulam and amcarbazone, are either absorbed by roots or shoots. The list of treatments in this trial (Table 3.11) has been inspired with the objective of providing a broader-spectrum of control, together with a longer residual activity. The tank-mix trifloxysulfuron + ametryn + amicarbazone provides such an effect and has been recommended in 2005 as a new herbicide treatment for weed management strategies in sugarcane (Recommendation Sheet No. 153, Appendix 3). This tank-mix is used as a standard in this experiment along with the herbicide sulfentrazone and the mixture tebuthiuron + atrazine + 2,4-D amine salt. The latter has been recommended as a treatment for general weed control whereas sulfentrazone is used as a pre-emergence herbicide and can have a residual action of up to 4 months, effective on broad-leaved species, grasses and sedges. It has been shown to have a good early post-emergence effect on *I. hederifolia* in addition to its pre-emergence effectiveness in suppressing development from their seeds (Jones 2006).

The first trial was laid out in the third week of September 2009 at Trois Ilots where *I. nil* was the main vine weed infesting the field. Herbicide application was carried out four days after trash lining was completed in the T2 plots. The trial was repeated in the second week of October 2009 at Beau Plan where *I. hederifolia* was the predominating vine weed, and most of them were at the 5-6 leaf stage.

Table 3.10 Agro-climatic characteristics of trial sites

Site	Soil Group*	% OMC	Annual Rainfall (mm)	Rainfall during trial (mm)	Date of harvest	Date of trash lining	Date of spraying
Trois Ilots	L2N	4.7	1750	367	25.07.2009	14.09.2009	16.09.2009
Beau Plan	D1S	4.9	1200	560	8.09.2009	1.10.2009	12.10.2009

*Parish and Feillafé (1965).

Table 3.11 Herbicide treatments applied at Trois Ilots and Beau Plan.

Treatment no.	Herbicides	Rate kg ae or ai/ha
1	amicarbazone + fluroxypyr	1.05 + 0.36
2	amicarbazone + S- metolachlor + fluroxypyr	1.05 + 1.44 + 0.36
3	amicarbazone + S- metolachlor + 2,4-D amine salt	1.05 + 1.44 + 2.2
4	amicarbazone + diclosulam	0.875 + 0.059
5	diclosulam + sulfentrazone	0.059 + 1.00
6	diclosulam + S- metolachlor + 2,4-D amine salt	0.076 + 1.44 + 2.2
7	sulfentrazone (standard 1)	1.5
8	tebuthiuron + atrazine + 2,4-D amine salt (standard 2)	1.25 + 2.4 + 2.2
9	trifloxysulfuron + ametryn + amicarbazone (standard 3)	0.375 + 1.125 + 1.05
10	2,4-D amine salt**	2.2

** At Trois Ilots, asulam @ 3.0 kg ai.ha⁻¹ was added to treatment 10 to control grass weeds present in the plots.

Table 3.12 Mode of action and effect on plant of herbicide used in tank-mixes at Trois Ilots and Beau Plan.

Chemical Name	Mode of action and effect on plant
2,4-D Amine	Selective, translocated and absorbed mainly through leaves, increasing biosynthesis and production of ethylene causing uncontrolled cell division and so damages vascular tissue
Ametryn	Inhibits photosynthesis and other enzymatic processes. It is a selective systemic herbicide, absorbed by the leaves and roots, with translocation acropetally in the xylem, and accumulation in the apical meristems.
Amicarbazone	Residual and translocated action, absorbed by foliage, photosynthesis inhibition
Atrazine	Selective, systemic action with residual and foliar activity; inhibits photosynthesis
Diclosulam	Inhibits acetolactate synthesis, taken up by roots and foliage and translocated to growing points
Fluroxypyr	Selective, foliar uptake causing auxin-type response
S-Metolachlor	Selective, absorbed through roots and shoots
Sulfentrazone	Absorbed by roots and foliage and translocated; cell membrane disruption and protoporphyrinogen oxidase inhibitor
Tebuthiuron	Systemic, low selectivity, absorbed by roots and translocated; inhibits photosynthesis
Trifloxysulfuron Sodium	Inhibitor of acetolactate synthase, absorbed by shoots and roots and translocated

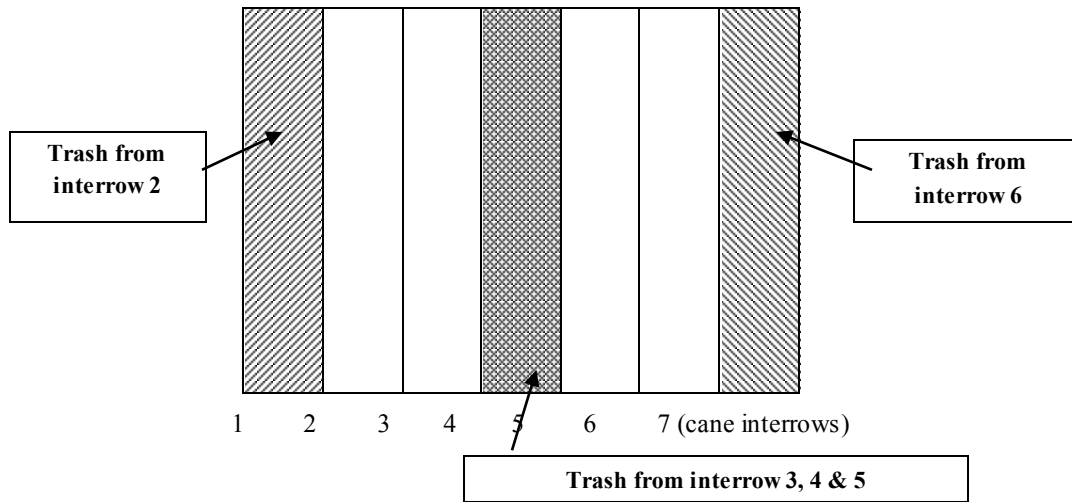


Figure 3.24. Schematic drawing of T2 plots showing trash placement after cane interrows 2, 3, 5, and 6 were cleared. The trash from interrows 3 and 5 was repositioned onto the trash that was already present in interrow 4 in order to increase the thickness of the mulch.

(b) Data collection and analysis

At Trois Ilots, *I. nil* plants were already creeping on the interrows and hence the technique of percentage cover assessment was used to estimate the infestations in the sub-plots before spraying. In the T1 sub-plots, vine weed infestations on each of the seven interrows were visually estimated (Roche couste 1967; Marnotte 1984) and then a mean was calculated for the herbicide treatment; this was done for the four cleared interrows of T2 plots. The same evaluation was carried six weeks after spraying (WAS) in order to assess the efficacy of the herbicide treatments. The vine weed infestations in all sub-plots were afterward eradicated with fluroxypyr @ 0.36 kg ai.ha⁻¹ and the pre-emergence effect of the various herbicide treatments was assessed 12 weeks after the initial spraying (WAS). A weed count of the new emerging *I. nil* plants on every treated interrows was carried out using a 0.5 m x 0.5 m quadrat at three places and then a mean was calculated for each sub-plot.

The same weed count procedure was used at Beau Plan to quantify the infestations of *I. hederifolia* before spraying since the plants were at a young growth stage. Another weed count was carried out at 6 WAS and the vine weed infestation was suppressed with fluroxypyr @ 0.36 kg ai.ha⁻¹ so that the pre-emergence effects of the herbicide treatments could be assessed six weeks later (12 WAS of herbicide treatments).

The decomposition of the trash cover in the main plots at both sites were also monitored over a period of five months by measuring the thickness and estimating the dry weight every 5 weeks at Trois Ilots and every 6 weeks at Beau Plan. Five replicates of trash samples on a 0.5 m x 0.5 m quadrat were collected for dry weight analysis at each monitoring time. Also, fifteen random trash thickness measurements were taken with a pointed metal ruler at five places in the T1 and T2 plots

All the statistical analyses were performed using the R software version 3.0.3 (R *et al.* 2014). The mean weed cover data were analysed using generalised linear mixed models (GLMM) (Bolker *et al.* 2009) including the relative proportion of weed covered/weed free area per sub-plot, trash management practices and herbicide treatments as fixed effects, and the nested split-plot block as random effect.

Results

(a) *Trois Ilots Trial*

The initial infestation of *I. nil* in the T1 plots were significantly ($P < 0.001$) higher than in the T2 plots, indicating that the mechanical operations involved in the repositioning of the trash could have caused some kill of the existing vine weeds (Fig. 3.25). At three weeks after spraying, the vine weed cover in all the herbicide treated sub-plots was eradicated except for those sprayed with diclosulam + s-metolachlor and trifloxysulfuron + ametryn + amicarbazone. However, regrowths were noted on the well-developed parts of the vine weed. At this stage, no difference was observed between the two trash management practices; there was also no emergence from the trash lined interrow in the T2 plot.



Figure 3.25 Percentage cover of *Ipomoea nil* before spraying in GCTB (T1) compared to trash lined (T2) plots at Trois Ilots. Error bars are the standard error of four replicates

Table 3.13: Effect (ANOVA P-value) of trash management practices, herbicide treatments and their interactions on the weed cover of *Ipomoea nil* before spraying (BS) and 6 weeks after spraying (WAS) at Trois Ilots. The effect at 12 WAS for this site and that for the three assessment time at Beau Plan for *I. hederifolia* was expressed on the values of weed count.

Trial sites	Target vine weeds	Factor analysed	BS	6 WAS	12 WAS
Trois Ilots	<i>I. nil</i>	Trash management (F1)	<0.001	<0.001	<0.001
		Herbicide treatments (F2)	<0.001	ns	<0.001
		Interaction F1 * F2	ns	<0.001	ns
Beau Plan	<i>I. hederifolia</i>	Trash management (F1)	<0.05	<0.001	<0.001
		Herbicide treatments (F2)	ns	ns	ns
		Interaction F1 * F2	ns	ns	< 0.05

The above observations on the knock-down of *I. nil* infestations were confirmed in the weed cover assessment at 6 WAS. The % kill of the herbicide treatments in the T2 plots ranged from 80% to 100%, indicating that they were all very effective (Fig 3.26). In the T1 plots, however, only amicarbazone + S-metolachlor + 2, 4-D amine salt, tebuthiuron + atrazine + 2, 4-D amine salt and trifloxysulfuron + ametryn + amicarbazone gave such level of control, the efficacy of the other herbicide treatments varied between 33% and 73%. This result implies a significant interaction between trash management practices and herbicide treatments (Table 3.13), some mixtures of the latter not having the same ability to perform in presence or absence of trash.

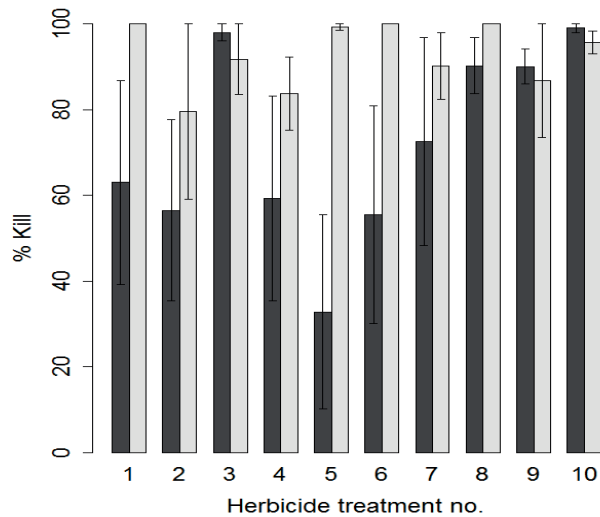


Figure 3.26 Percentage kill of *Ipomoea nil* at 6 weeks after spraying (WAS) comparing GCTB (darker columns) to trash lined plots (lighter columns) at Trois Ilots. Error bars are the standard error of four replicates

The weed count carried out at 12 WAS showed that only a few herbicide treatments provided better pre-emergence effect as compared to the control (treated with 2,4-D amine salt + asulam only). The tank-mix diclosulam + sulfentrazone were the only treatment which differed significantly to the latter, being more effective on the cleared interrows of the T2 plot (Fig 3.27).

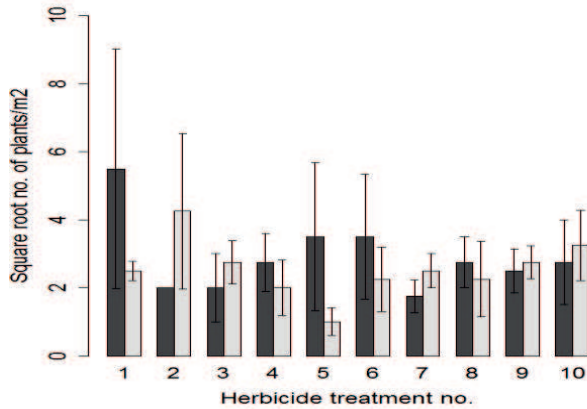


Figure 3.27 Weed count 12 weeks after spraying at Trois Ilots showing the pre-emergence effect of the herbicide treatments in GCTB (darker columns) and trash lined plots (lighter columns). Error bars are the standard error of four replicates

Furthermore, in the diclosulam + sulfentrazone plot, very few seedlings were also observed on the interrow where trash thickness was increased by the lining operation and which also did not receive any herbicide application. Analysis of the data from the follow up carried out on trash degradation in T1 and T2 plots showed that $11.3 \text{ t ha}^{-1} (\pm 4.8)$ of dry mass was present in the field eight weeks after harvest (just before spraying) compared to $47.0 \text{ t ha}^{-1} (\pm 19.9)$ on the interrow with the increased trash thickness (Fig. 3.28). At the time of the weed count (12 WAS), these values were $6.0 \text{ t ha}^{-1} (\pm 2.0)$ and $21.0 \text{ t ha}^{-1} (\pm 4.1)$ for the trash in the T1 and T2 plots respectively. The combined efficacy of diclosulam + sulfentrazone and a thicker trash cover seemed to be possibilities for a more effective vine weed management strategies.

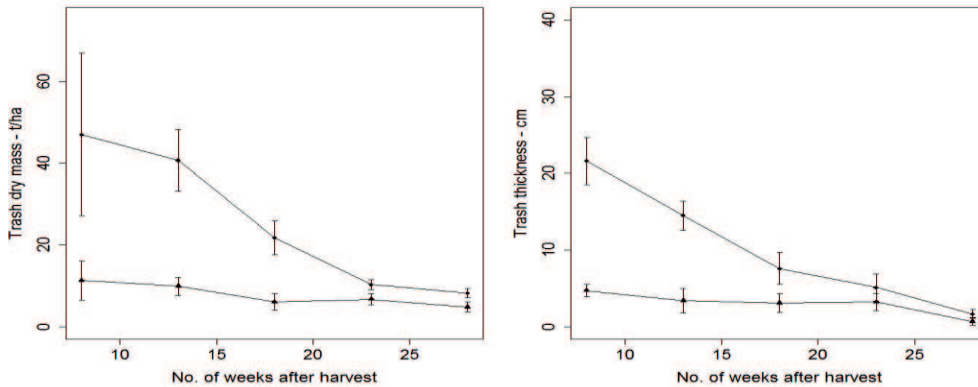


Figure 3.28 Evolution in the trash dry mass ($t \cdot ha^{-1}$) and thickness (cm) characterizing the decomposition of postharvest sugarcane trash at Trois Ilots in GCTB (triangle marker) and in trash lined plots (diamond marker). Error bars represent the standard deviations from the means

(b) Beau Plan Trial

The weed count carried out before spraying showed that there was slightly more ($P < 0.05$) *I. hederifolia* plants in T2 than T1 plots. However, at 3 WAS it was observed that this initial flush of vine weeds was effectively controlled by the various herbicide treatments, but new seedlings were also observed emerging at the same time in the different treated plots.

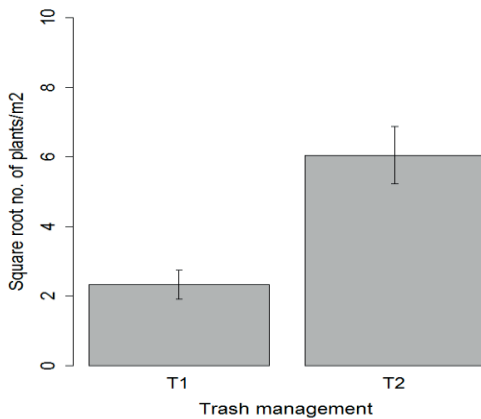


Figure 3.29 Weed count 6 weeks after spraying at Beau Plan showing the square root of the number of plants of *Ipomoea hederifolia* to be significantly ($P < 0.001$) lower in the GCTB (T1) than in the trash lined (T2) plots. Error bars represent the standard error of four replicates and were calculated on the square root transformed data.

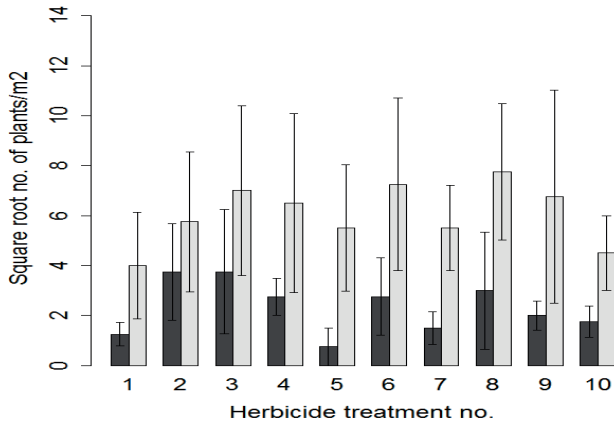


Figure 3.30 Weed count 6 weeks after spraying at Beau Plan showing the control obtained with the various herbicide treatments in GCTB (darker columns) compared to trash lined plots (lighter columns). Error bars are the standard error of four replicates

At 6 WAS, the number of vine weeds was significantly lower ($P < 0.001$) in the GCTB plots compared to the cleared interrows (Fig 3.29). Although the effect of the herbicide treatments (subplot treatments) was not statistically different, the tank-mix diclosulam + sulfentrazone provided the lowest count in the GCTB plot (Fig 3.30). This trend was maintained at 12 WAS when the pre-emergence effect was assessed (Fig 3.31), thus confirming the efficacy of the above herbicide mixture to control *I. hederifolia*. The trash management effect of GCTB contributed significantly ($P < 0.001$) in lowering the emergence of the vine weed at Beau Plan, striking a positive interaction with the herbicide treatments ($P < 0.05$). This implied that the latter were more effective in the presence of the sugarcane trash residue which contributed in suppressing new emergence of *I. hederifolia*, unlike the conditions that existed in the cleared interrows of the T2 plots where growth was superior. However, the increased mulch cover on the trash lined interrow provided some hindrance to the development of *Ipomoea* seedlings. It was noted that trash decomposition was rapid, thickness reducing to only one third of its initial height in only 6 weeks (Fig 3.32) compared to nearly 12 weeks at Trois Ilots (Fig 3.28); dry mass reduction was also quicker.

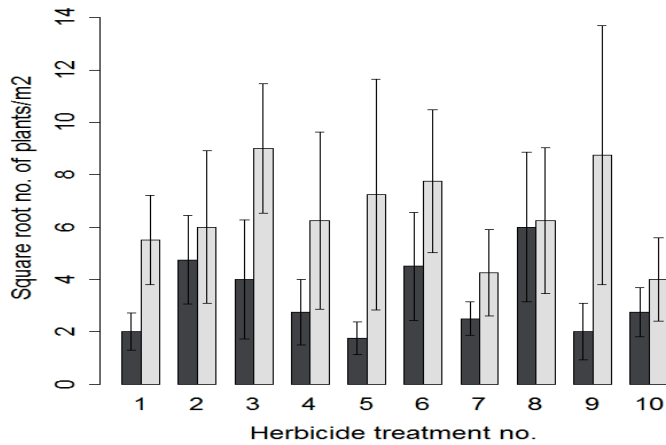


Figure 3.31 Weed count 12 weeks after spraying at Beau Plan showing the control obtained with the various herbicide treatments in GCTB (darker columns) compared to trash lined plots (lighter columns). Error bars are the standard error of four replicates.

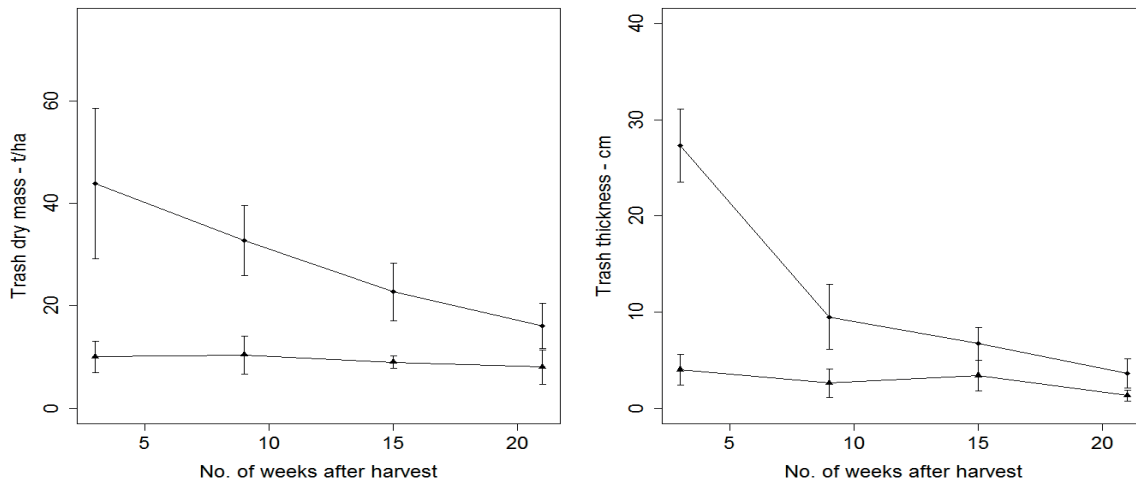


Figure 3.32 Evolution in the trash dry mass (t.ha⁻¹) and thickness (cm) characterizing the degradation of postharvest sugarcane trash at Beau Plan in GCTB (triangle marker) and in trash lined plots (diamond marker). Error bars represent the standard deviations from the means.

Discussions

A comparison of the weed counts at 12 WAS for Trois Ilots and the three assessments at Beau Plan revealed the relatively good performance of the increased trash thickness in suppressing vine weed emergence (Table 3.14). At Trois Ilots, suppression of vine weed development caused by the thicker trash cover was comparable to the treated cleared interrows and the GCTB even though herbicides were sprayed on the latter. Despite the rapid trash decomposition at Beau Plan, the GCTB

treated plots were significantly the best combination at 6 and 12 WAS. The density of *I. hederifolia* plants was even slightly higher in the cleared interrow of the T2 plots at 6 WAS.

Table 3.14: Effect of the different trash management practices on the emergence expressed as the number of plants m² of *Ipomoea nil* and *I. hederifolia* at Trois Ilots and Beau Plan respectively.

Trial Site	Trash management	BS*	6 WAS**	12 WAS
Trois Ilots	Interrows cleared	-	-	10.0±2.1
	Interrows with increased trash	-	-	11.1±2.9
	GCTB	-	-	16.8±2.9
Beau Plan	Interrows cleared	53.5±8.6	64.2±8.8	73.1±11.5
	Interrows with increased trash	16.1±4.0	46.6±12.7	72.5±20.7
	GCTB	36.5±4.7	12.8±2.2	19.9±3.2

*BS – Before spraying, **WAS – Weeks after spraying

The herbicide mixtures tested in the two trials had provided some level of post-emergence and pre-emergence control of the two *Ipomoea* spp. The tank-mix amicarbazone + S-metolachlor + 2,4-D amine salt showed some potential in the post-emergence control of *I. nil* whereas sulfentrazone + diclosulam was more effective in providing longer residual activity to suppress emergence of *I. hederifolia* and *I. nil*.

The standard practice of weed control in Mauritius has been the application of a pre-emergence herbicide just after planting or harvesting (in ratoon crops), followed by one or two post-emergence applications until canopy closure. The residual action of the first herbicide treatment usually lasts between 10-14 weeks, thus necessitating a second application consisting of one or two pre-emergence herbicides tank-mixed with a post-emergence one to control emerged weeds and, at the same time, to prevent others from emerging. Under certain circumstances, when canopy closure is retarded for reasons such as climate, cane variety and row spacing, a third herbicide application may be necessary usually as a full or spot treatment. This application is sometimes replaced by manual weeding depending on the availability of labour (especially during the intercrop period). Manual weeding is also resorted to when certain weed species are not controlled by the standard treatments. In sugar cane fields, the presence of more than 15 weed species consisting of broad-leaved weeds, including vine weeds, grasses and sedges is quite common. For this reason, tank-mixing of two or more herbicides to achieve a broader spectrum of control is a common practice in sugar cane production. This could be one reason why after over 60 years of herbicide use in

sugarcane no major indications of herbicide resistance were observed on weeds although a systematic scientific research has not yet been carried out.

These results provide interesting possibilities for developing effective and sustainable vine weed management strategies based on an optimised use of herbicides. It seems that in fields where a relatively thick blanket (> 10 cm) is available after harvest, early post-emergence herbicides (treatment offering a knock-down effect as well as a residual effect thereafter) may be applied directly on the trash when *Ipomoea* spp. seedlings appear at the surface. However, the appropriate herbicide treatment should be used; the tank-mix diclosulam + sulfentrazone or some containing amicarbazone were found to be more effective. Furthermore, the effect of trash decomposition should also be considered in decision taking as the thickness of the blanket and amount of rainfall/irrigation water may have an influence on the mobility of the herbicide treatments. Therefore, further studies are required to understand better the mechanisms of trash decomposition and movement of active ingredients applied through the trash layers.

Conclusions

The two field trials have revealed that there is an interaction between trash management practice and herbicide treatment for the control of *Ipomoea* species emerging in sugarcane fields. The trash cover enhanced control of vine weeds following a knock-down of the seedlings or young plants (up to 5-6 leaves growth stage) present a few weeks after harvest and assuring an effective pre-emergence effect thereafter. The tank-mix diclosulam + sulfentrazone is among the best treatments for use in such situation; some potential with tank-mixes containing amicarbazone was also shown. Further studies are required to confirm the above approach while studying the trash decomposition and movement of herbicides to the soil surface.

References

- Azania A.A.P.M., Azania C.A.M., Gravena R., Pavani M.C.M.D. and Pitelli R.A. 2002a. Sugar cane (*Saccharum* spp.) straw interference in emergence of weed species of the Convolvulaceae family. *Planta Daninha* 20, 207-212.
- Bhullar M.S., Walia U.S., Singh S., Singh M. and Jhala A.J. 2012. Control of morningglories (*Ipomoea* spp.) in sugarcane (*Saccharum* spp.). *Weed Technol.* 26, 77-82.
- Bolker B.M., Brooks M.E., Clark C.J., Geange S.W., Poulsen J.R., Stevens M.H.H. and White J.-S.S. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecol. Evol.* 24, 127-135.
- BSES 1989. Weeds of Australia. In: *Bses Bulletin*). 33-43.
- Chauhan B.S. and Abugho S.B. 2012. Threelobe morningglory (*Ipomoea triloba*) germination and response to herbicides. *Weed Sci.* 60, 199-204.
- Christoffoleti P.J., Borges A., Nicolai M., Carvalho S.J.P., Lopez-Ovejero R.F. and Monquero P.A. 2006. Carfentrazone-ethyl applied in post-emergence to control *Ipomoea* spp. and *Commelina benghalensis* in sugarcane crop. *Planta Daninha* 24, 83-90.
- Correia N.M. and Durigan J.C. 2004. Weed emergence in soil covered with sugarcane harvest straw residue. *Planta Daninha* 22, 11-17.
- Crowley R.H. and Buchanan G.A. 1982. Variations in Seed Production and the Response to Pests of Morningglory (*Ipomoea*) Species and Smallflower Morningglory (*Jacquemontia tamnifolia*). *Weed Science* 30, 187-190.
- Gaungoo A., Seeruttun, S. and Barbe, C. Proc. int. Soc. Sug. Cane Technol. 27: 11 p. 2010. Interactions between seed depth, thickness of trash blanket and herbicide treatments on emergence of vine weeds in sugar cane. In: *Proceedings of the ... ISSCT Congress*). Brazil.
- Ismael F., Seeruttun S., Barbe C. and Gaungoo A. 2008. A review of changing cultural practices to improve productivity of sugar cane in Mauritius. In: *Proceedings South African Sugar Technologists Association*). Durban.
- Jones C.A. 2006. Red morningglory (*Ipomoea coccinea* L.) biology and management in sugarcane. In: *The Department of Agronomy and Environmental Management*). B.S Texas A & M University, 69.

- Kruidhof M., Gallandt E.R., Haramoto E.R. and Bastiaans L. 2011. Selective weed suppression by cover crop residues: Effects of seed mass and timing of species' sensitivity. *Weed Research* 51, 177-186.
- Lancaster S.H., Jordan D.L., York A.C., Wilcut J.W., Brandenburg R.L. and Monks D.W. 2005. Interactions of late- season morningglory(*Ipomoea* spp.) management practices in peanut(*Arachis hypogaea*). *Weed Technol.* 19, 803-808.
- Le Bourgeois T., Carrara A., Dodet M., Dogley W., Gaungoo A., Grard P., Ibrahim Y., Jeuffrault E., Lebreton G., Poilecot P., Prosperi J., Randriamampianina J.A., Andrianaivo A.P. and Théveny F. 2008. Advent-OI : Principales adventices des îles du sud-ouest de l'Océan Indien.V.1.0. In: In Cirad [ed.], Cirad). , Montpellier, France.
- Lebreton G., Le Bourgeois T. and Marnotte P. 2009. Effet de l'époque de coupe sur la dynamique de développement de L'enherbement de la canne a sucre a la Réunion. In: XIIIème colloque international sur la biologie des mauvaises herbes). Dijon (France).
- Manechini C., Ricci-Junior A. and Donzelli J.L. 2005. An overview of controlled and non-controlled weeds as influenced by sugarcane trash blankets. *Sugar Cane International* UK. 23, 11-14.
- Norsworthy J.K. 2004. Soybean canopy formation effects on pitted morningglory(*Ipomoea lacunosa*), common cocklebur (*Xanthium strumarium*), and sicklepod (*Senna obtusifolia*) emergence. *Weed Sci.* 52, 954-960.
- R, Core and Team 2014. R: A language and environment for statistical computing. . In: Software). R Foundation for Statistical Computing, Vienna, Austria. .
- Rocheouste E. 1967. Weed Control in sugarcane. Adlard & Son Ltd, Bartholomew Press, Dorking, England.
- Seeruttun S., Barbe C. and Gaungoo A. 2005. Vine weeds in sugarcane: fluroxypyr provides cost-effective post-emergence control in Mauritius. *Sugar Cane International.* 23, 3-5.

4 Chapter 4

GENERAL DISCUSSION AND AGRONOMIC CONSIDERATIONS

4.1 Floristic composition, species richness and distribution of vine weeds

As shown by the work of Rochecouste (1967) and Mc Intyre (1991), vine weeds in sugarcane fields in Mauritius were not a major issue in the years before the 1990s. In that time, *Paederia foetida* was the main species occurring in the fields where *P. suberosa*, *I. obscura* and *M. micrantha* were occasionally encountered. The work of Le Bourgeois *et al.* (2008) described 13 of the 26 species found in this study and *I. triloba* was characterised as being very competitive even causing yield reduction. This work also revealed that the *Ipomoea* genus is the most important group where *I. hederifolia*, *I. nil* and *I. quamoclit* were also present in addition to *I. triloba*. These three species had been reported to be troublesome vines in sugarcane and in other crops as well (Azania *et al.* 2002 ; Sobrero *et al.* 2003 ; Manechini *et al.* 2005 ; Jones 2006). They have the potential to produce large amounts of seeds just like *I. triloba* and as any other *Ipomoea* species (Crowley & Buchanan 1982), and they are vigorous twiners. Although they had been found in localised places in sugarcane fields in Mauritius, they might become problematic once conditions for their expansion would be favourable.

Results from data analysis on the species richness had in addition shown that on average more than 3 species were present in a sugarcane field, indicating the greater importance that such plants are occupying in the weed flora. The growing importance of vine weeds in sugarcane fields was also found in a work carried out in Réunion Island (Lebreton *et al.* 2009) where 25 species were identified. The difference that was found between small growers and large ones also implied that other factors were responsible for their presence in these fields, mostly related to the cultural practices.

Moreover, the spatial distribution of the various species appeared to be greatly influenced by their biological propensity and adaptability to withstand the cultural practices present in the different agro-climatic regions. Thus, *I. triloba* were mostly distributed in the humid regions where mechanised green cane harvests were practiced and where the resulting GCTB provided favourable environment for the germination of their seeds. On the other hand, *Paederia foetida* was

particularly more adapted to the superhumid zone where the high humid conditions were particularly more conducive to its vegetative propagation. Any progress in the distribution of the different vine weed species would be directly related to their biological characteristics and the associated cultural practices. The increasing trend towards mechanized green cane harvesting (Fig. 1.7, Chapter 1) may increase the extent where favourable agro-ecological conditions can be present for the proliferation of vine weed infestations in areas where this operation can be practiced.

The evolution in the floristic composition of vine weeds in the last two decades is an indication of the changes that occurred in the sugarcane industry. This had resulted in the emergence of species that were tolerant to the existing weed management practices. It appeared that the species from the *Ipomoea* genus were the more adapted to exploit the new agro-ecological conditions.

4.2 Growth and development of Vine Weeds: Germination and Emergence

Germination and emergence are two important processes in the establishment of a species during its growth and development cycle. This work, centered on the biology of these two processes and focused on the *Ipomoea* spp. found in sugarcane fields, had in fact demonstrated their exceptional abilities to thrive in the present agronomic conditions of sugarcane cropping. The germination and emergence phases are also vulnerable stages in the life cycle of the vine weed species and where management strategies can be easily deployed for their control.

Germination and emergence of vines, particularly *Ipomoea* spp., can take place over a wide spectrum of temperatures (Egley 1990; Gomes *et al.* 1978). Results from the laboratory tests had been able to show that the minimal temperature requirements for their seeds to germinate ranged from 7°C to 17°C. Therefore under the tropical climate of Mauritius these species can germinate all throughout the year although a reduction in the rate could be expected during the cooler winter period. This could specifically apply to species having higher minimal temperature requirement, like *I. hederifolia* and *C. scarabaeoides*, which would encounter greater difficulties to develop in the superhumid areas where the average long term winter minimum and maximum temperatures are 14°C and 19°C. In fact, none of these species were encountered in fields found in these regions during surveys carried out to study their distribution (Chapter 2). On the other hand, species having lower values of minimal temperature requirement, like *I. nil*, *I. obscura* and

I. triloba, might be expected to emerge earlier in harvested sugarcane fields during the cooler days of the winter period. This was shown in studies (work not presented in this thesis) carried out on the life cycle of *I. triloba* at five sites where it was found that the increase in the cumulative emergence of the number of seedlings started to rise at the beginning of October (Fig. 4.1). A rapid increase was eventually noted in the month of November when summer temperature conditions started prevailing.

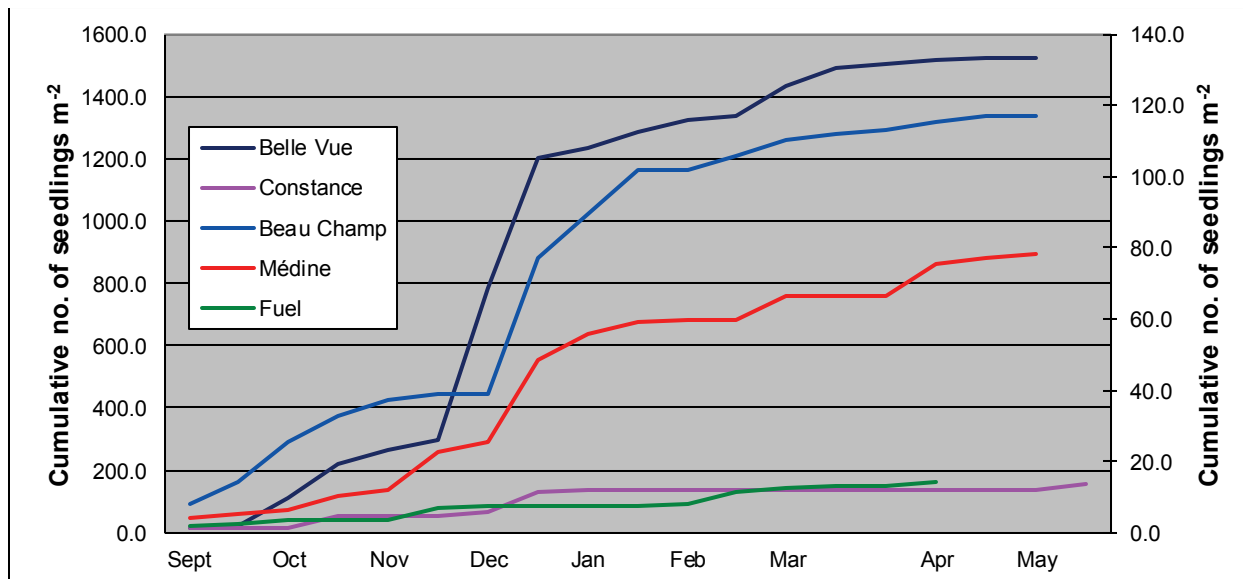


Figure 4.1. Seedling emergence dynamics of *Ipomoea triloba* L in ratoon sugarcane fields after harvest at five sites. The values on the primary axis refers to the site of Belle Vue whereas those of the other sites are represented on the secondary axis.

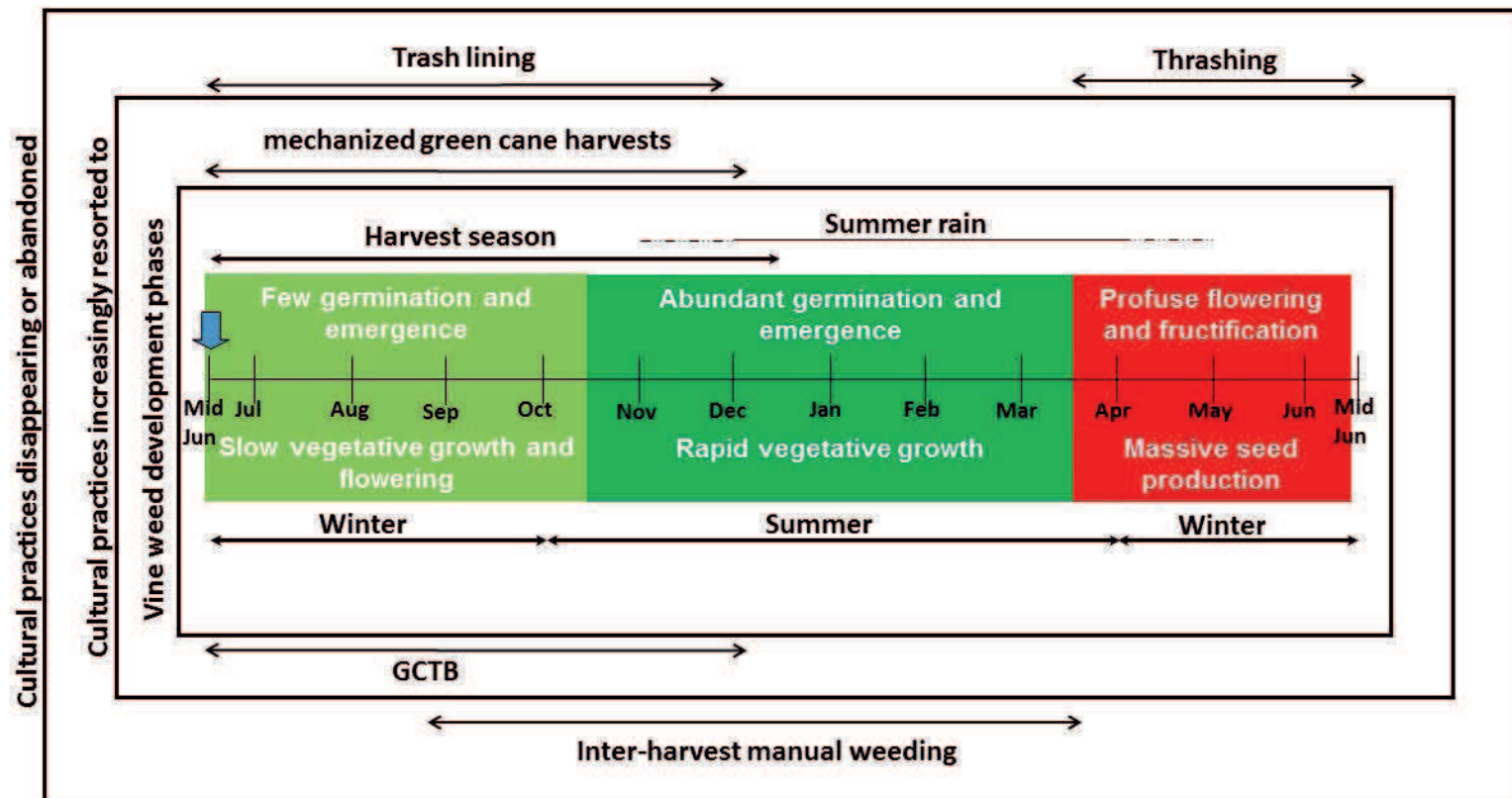
Moreover, interactions of vine weeds with other components of the agricultural production system (Norris 1992) can further influence germination and emergence through various agronomic practices. Tillage and post-harvest management of sugarcane trash residue appear to have the greatest direct impact on the germination and emergence of vine weeds. In the first place, tillage affects the distribution of vine seeds in the soil profile as has been demonstrated in numerous studies (Cousens & Moss 1990; Grundy *et al.* 1996). The effect is particularly significant after each sugarcane crop cycle of 7 to 8 years when a field is replanted following land preparation; however, tillage or interrow cultivation is generally not practiced in ratoon crops in Mauritius. It had become apparent from the studies carried out on the effect of burial depths that the large-seed

property of *Ipomoea* spp. and other vine weeds compared to classical weeds would confer greater advantages to avoid the activity of pre-emergence herbicides in order to thrive in field conditions.

Furthermore, it appears from the experiments carried out in 2008 and 2010 that the mulching effect of post-harvest sugarcane trash is a determinant factor that influences the emergence of *Ipomoea* species in the fields. The mulch or GCTB results from the trash residue left in the field after mechanized green cane harvest. In addition to creating better agro-ecological conditions for the germination and emergence of vine weeds, the mulch impedes the effect of pre-emergence herbicides. The amount of sugarcane trash residue that remains in the field after harvest represents one third of the cane yield which averages to 80 tha^{-1} on large estates where mechanised green cane harvest is mostly practised. Thus the fresh mass of trash that constitutes the GCTB turns around 25 to 30 tha^{-1} , equivalent to 15 to 20 tha^{-1} on a dry mass basis which has been shown to represent a layer of 7 cm to 10 cm of mulch in the field just after harvest. The rapid reduction in the trash thickness due to decomposition brings the layer to less than 5 cm which favours the emergence of *Ipomoea* spp. seedlings instead of suppressing them.

Studies, not reported in this thesis, have also been carried out on the life cycle of vine weeds in the sugarcane cropping situation in order to understand their growth and development habits. These studies has been conducted with *I. triloba* and have shown that vine weed seedlings adopt an upright growth habits after germination and emergence up to the five leaf stage. The young plants afterward develop flexible stems which allow them to creep, climb or twine around surrounding objects, but in the field it is mostly on the leaves and stems of young sugarcane plants. The developing vine weed then intensifies its vegetative growth stage, severely competing with the crop. This growth phase, which takes a longer period in the life cycle, eventually culminates into the flowering, fruiting and seed production stages.

The different development phases have been represented schematically in Figure 4.2 where they are positioned along the sugarcane crop cycle and the associated cultural practices. The figure also shows the positioning of some agronomic practices that are disappearing or abandoned together with other practices that are more resorted to. These cultural operations have greatly influenced the development of vine weeds over last two decades by creating more favourable agro-ecological conditions.



- (2) The time scale starts at mid-June and coincides with the beginning of sugarcane harvest (blue arrow). (2) The scale completes one calendar year and ends in June of the succeeding year. (3) The Winter and Summer seasons along with the Summer rain are positioned onto the scale according to the period they occur during the year. (4) The different phases of vine weed development are shown in three colours (pale green, green and red) along the scale. (5) The cultural practices outside the vine weed development phases box are also related to the time scale and they are positioned according to the period that they are practiced. (6) GCTB: Green Cane Trash Blanketing

Figure 4.2. Schematic representation of the different development phases of *Ipomoea triloba* to generalize the life cycle of vine weed in sugarcane cropping situation.

4.3 Agronomic considerations

The sugarcane crop

The sugarcane crop is a more or less upright plant that reaches 2 to 3 metres at maturity; they grow on rows spaced at 1.5-1.6 m apart. The critical periods of weed control (CPWC) have been found to be 12 to 28 weeks after harvest. In plant cane, the CPWC starts earlier and is longer than those in ratoon cane (Seeruttun 2008). Canopy formation follows afterward where leaf development of the tall canes from adjacent rows prevents light from reaching the interrows, hence drastically reducing weed growth. Studies on the life cycle of vine weeds, especially *Ipomoea* spp., have shown that though vines can germinate and emerge in the reduced light condition of the interrow, they cannot sustain a normal development afterward due to limited photosynthetic processes. On the other hand, the upright growth habit of sugarcane provides a tutor-like support for the rapid development of vine weeds, namely heavy twiners like the *Ipomoea* spp., that have escaped control. Tall canes that adopt a lodged position at maturity can also favour the growth of vine weeds due to greater exposure to sunlight.

Past and present weed control practices

Sugarcane crop husbandry in Mauritius has known many changes during the last century. In the early years of the 1900s, nearly all cultural operations in the fields were conducted manually, particularly weed control. This practice has known a major development in the late 1940s when hormone based herbicides were being evaluated for weed control in sugarcane fields. Rapid progress was achieved and already in the 1950s and 1960s chemical weed control was an adopted practice in sugarcane fields where post-emergence and pre-emergence treatments were applied. Research and evaluations for more effective molecules were reinforced in the 1970s and 1980s. Better performing post-emergence and pre-emergence herbicides were made available, the latter were more geared towards the control of small-seeded weeds mostly present in the first 3 cm layer of the soil profile. Large-seeded weeds and other difficult weeds that were not controlled were removed manually due to the easy availability of a cheap source of labour in that time. This manual force was specifically more active during the inter-harvest season from January to April when there is rapid vegetative growth of weeds (Fig 4.2).

Cane trashing and trash lining are also two cultural operations that indirectly contribute to reduce weed development in sugarcane fields. Cane trashing involves the removal of dry leaves

manually from the stem of mature canes, and lining them on alternate interrows (Seeruttun *et al.* 1998). This operation helps the cane-cutters to locate more precisely the base of the stalks and reduces the amount of extraneous matter sent to the mill. It is performed every year as from the end of April and coincides with the flowering phase of vine weeds (Fig 4.2). Hence, any vine weed development that may occur in a field where trashing is carried out can be eliminated

Trash lining consists of clearing the trash found on an interrow and repositioning it onto the adjacent one. This results in a thicker trash layer on alternate interrows and it helps to control small-seeded as well as large-seeded weeds, namely vines that reproduce by seeds; the cleared interrows are treated with herbicides. This operation is still practiced in the superhumid areas where excess water in the field during rainy period is a problem (Seeruttun *et al.* 1999).

Nowadays, the practice of trashing has practically disappeared on large estates (cultivating > 1000 ha) but is still carried out by many small growers (cultivating < 10 ha). Similarly, trash lining is no more practiced on large estates where mechanised green cane harvest is practiced whereas inter-harvest manual weeding has been reduced to a minimum, pending the availability of labour and the amount it costs.

The scarcity and high costs of labour in the sugarcane industry is pushing cane growers, particularly large estates, towards increasing mechanized cultural operations, the most important ones being herbicide application and cane harvest. The reduction in manual weeding may have influenced the development of weeds not controlled by herbicides and which stay in the fields, thus allowing them to continue their growth cycle. The increasing area under GCTB resulting from mechanized green cane harvest have also led to new situations that have been favouring large seeded species, particularly vine weeds because their germination and emergence are better adapted to this new ecological situation.

The reduction or disappearance of some cultural practices and the adoption of others which are more appropriate to the present context of the sugarcane industry have created new agro-ecological conditions that have resulted into the vine weed problem in sugarcane fields. Over the years, there appear to have been a build up of their seeds in the fields and these seeds possess specific biological properties that enable them to prosper in the present agronomic conditions of

sugarcane cropping. This has been demonstrated through the biology of their germination and emergence.

Socio-economic impact

Labour shortage and its resulting high costs are among the main reasons behind the major changes that have influenced the various cultural practices over the last two decades. Growers have tried to adapt to this situation by altering their field operations so as to keep their sugarcane cropping activity economically viable. In most cases, particularly on large estate, this has been achieved at the expense of efficient agricultural management, an example of it being weed control. Formerly, the latter was closely monitored in the field by a team of workers headed by a gang-man who ensured that sprayings were effectively carried out or handweeding of uncontrolled weeds, creepers being one of them, were properly performed afterward. Several such teams were present on a large estate and they were responsible for maintaining small sections of fields not exceeding 600 ha. Nowadays, in a logic of cost reduction, these sections have been reorganized into larger ones with a reduced labour force but with increased mechanized operations. In order to facilitate the mechanization process, a new farm planning philosophy has been adopted where larger field plots (10 to 20 ha each, sometimes reaching 30-40 ha) are designed. The required level of weed free conditions in the fields is therefore not attained, hence creating niches for the propagation of tough or invasive species.

Moreover, profitability of sugarcane growing activity has suffered a harsh blow with the elimination of the preferential access to our traditional export markets for sugar, and the challenges imposed by the trade liberalization process (Van Berkum 2005). One of the ways in which large estates have been coping with this situation is through the cessation of cane production in fields considered to be marginal due to their low yield capacity and inadaptability to mechanization. Many small growers have had no other options than to stop cane cultivation as their production costs have been outweighing their revenue. The actions of the two categories of growers have resulted in an increased number of fields which have been left unoccupied or abandoned for a long time, causing the proliferation of unwanted plants, namely vine weeds (SIFB 2011).

Strategies for the management of vine weeds

Even when vine weeds were not a major issue in sugarcane fields in the 1980s, post-emergence herbicide treatments were available to manage localized outbreak of *Paederia foetida* and occasionally *P. suberosa*. The rising vine weed problem afterward, with the appearance of more competitive species, necessitated the evaluation of more cost-effective herbicides (Seeruttun *et al.* 2005). The outcome was the publication of another MSIRI Recommendation Sheet (No. 139) where the molecule fluroxypyr, alone or tank-mixed with other herbicides provided effective post-emergence control of vines (MSIRI 2003).

However, since most of the new species, namely *Ipomoea* spp., reproduce by seeds of bigger sizes than those of classical weeds, and which are produced in large amounts, pre-emergence herbicide treatments have to be used to suppress them at the germination stage. Yet, it appears from the studies on the effect of burial depths (chapter 3) that the existing pre-emergence treatments applied in sugarcane fields provide unsatisfactory and limited control of such vine weeds. They provide only 5-6 weeks control compared to at least 10-12 weeks obtained for classical weeds. The new flush of seedlings that can emerge from depth beyond 4 cm in the soil have to be treated afterward to prevent eventual infestation and interference with the crop. In this way, growers may have to act a few more times during the critical period of cane development to curtail the recurring emergence of vine seedlings. Some hope exists with the molecule sulfentrazone (Recommendation Sheet No. 136 and MSIRI 2003) which can provide up to 10 weeks control. Trials in Mauritius (MSIRI 2010) and studies in Florida (Jones 2006) have even shown it to be very effective for controlling *I. hederifolia*. Scope for using it as an early post-emergence treatment followed by pre-emergence effect is possible and is being investigated further.

Pre-emergence control of vine weeds in GCTB fields is further complicated due to the cover of sugarcane trash residue. It is a fact from the work carried out on the mulching effect in chapter 3 that GCTB provides better agro-ecological conditions for the proliferation of vine weeds in sugarcane fields. Presence of the trash cover is a major hindrance to the efficacy of pre-emergence herbicides. Thus, strategies for controlling vine weeds in GCTB situations must be directed towards post-harvest trash management as has been presented in Chapter 3, though trash decomposition is a factor that must be dealt with in regions having frequent rainfall. This is because

the presence of moisture accelerates the degradation process, causing the increased trash cover obtained from the two adjacent interrows and relocated onto the middle one to lose its efficacy to repress vine weed emergence. But otherwise, this strategy offers the possibility of reducing herbicide application by 25% to 30% as the interrow with the increased trash layer would not require herbicide sprayings. This can have positive economic impact on the cost of production of sugarcane growers. In addition, though environmental problem due to herbicide applications in sugarcane fields is not an issue in Mauritius, the strategy can further help to reinforce the good management practices associated with the cropping system.

In Chapter 2, information obtained on the spatial distribution of vine weeds through GIS mapping has provided a clearer insight into the occurrence of the different species in the various agro-climatic regions. This information, coupled with a better knowledge on the biology and phenology of vine weeds (Fig 4.2) can be useful to decide on the timing of vine weed control. This strategy can lead to a rational utilization of herbicide products and a better optimization of resources.

CONCLUSIONS

The characteristic growth and development habits of vine weeds have enabled them to occupy the new ecological niches caused by changes in the cultural practices that the sugarcane cropping system has experienced over the last two decades in Mauritius. Their peculiar life form has altered the agricultural environment in many sugarcane fields and the initially unobserved interactions that they have created have led to complex and complicated weed problems difficult to manage. Since the goal of every grower is to increase production per unit area while minimizing costs, the understanding of the important interactions through a holistic approach was necessary to develop management strategies for the control of vine weeds (Fig 5.1 & 5.2).

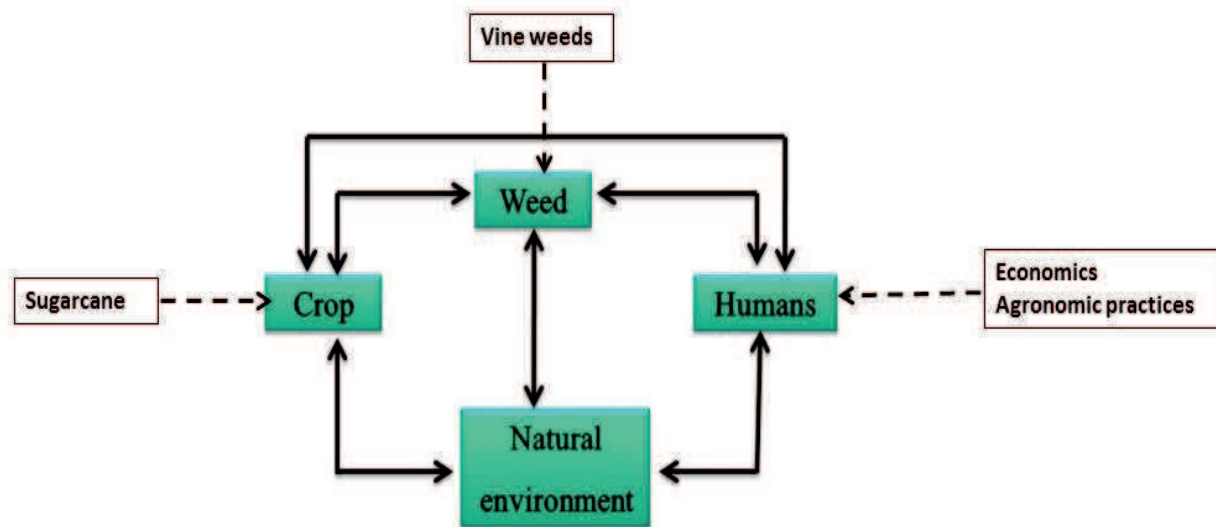


Figure 5.1. The weed-crop system (Aldrich 1984) adapted to provide a conceptual framework to analyse the vine weed problem in sugarcane fields in Mauritius. It appears that the economics and agronomic practices of sugarcane cropping have influenced human activities in the system, resulting in the creation of agro-ecological conditions for the development of vine weeds.

The weed-crop ecosystem model (Aldrich 1984) has allowed the setting up of a conceptual framework to logically analyse the problem and formulate the appropriate hypotheses which have guided this research. Human is one component of this model through whom all the disturbances influencing the weed, crop and natural environment are mediated. In the case of the vine weed problem in sugarcane fields in Mauritius, the economics and agronomic practices of the cropping system are the main driving forces that have caused a reaction in the growers' agricultural

activities (Fig 5.1). This has in turn influenced the crop and weed environments resulting in vine weed infestations in sugarcane fields.

The weed crop model is a product of interactions and Norris (1992) has stated that no level of the weeds and other components of the agricultural production system can exist independent of another (Fig 5.2). In the case of the vine weed problem, factors that are related to changes in the socio-economics and cultural operations have indirectly, through the crop, or directly interacted with the weed control practices. This has created new agro-ecological conditions which have favoured the development of vines. Weeds are found in the environment they prefer, and weed control or weed management often may be aided by changing the environment (Zimdahl 2007). Hence, this study has unveiled some important knowledge about the biology and ecology of vines that would be useful in the development of new and innovative approaches to restrain their expansion in sugarcane fields.

The approach used in this research has also made it possible to verify the hypotheses put forward initially and to meet the objectives that have been set. It has been established that the floristic composition of vine weeds has been enriched with various new species and the main ones causing troubles in sugarcane fields have been identified. Hence, *I. triloba*, *I. hederifolia* and *B. alba* are the more important among large growers (cultivating > 1000 ha) whereas *Paederia foetida* occurs frequently in small growers' (cultivating < 10 ha) fields. Although *P. suberosa* is the most frequent species island wide, it has not been observed to worry cane growers much. GIS mapping has shown that these species are present in distinct agro-climatic zones. It has also been found that small growers tend to have fewer vine weeds in their fields than those of the large estates.

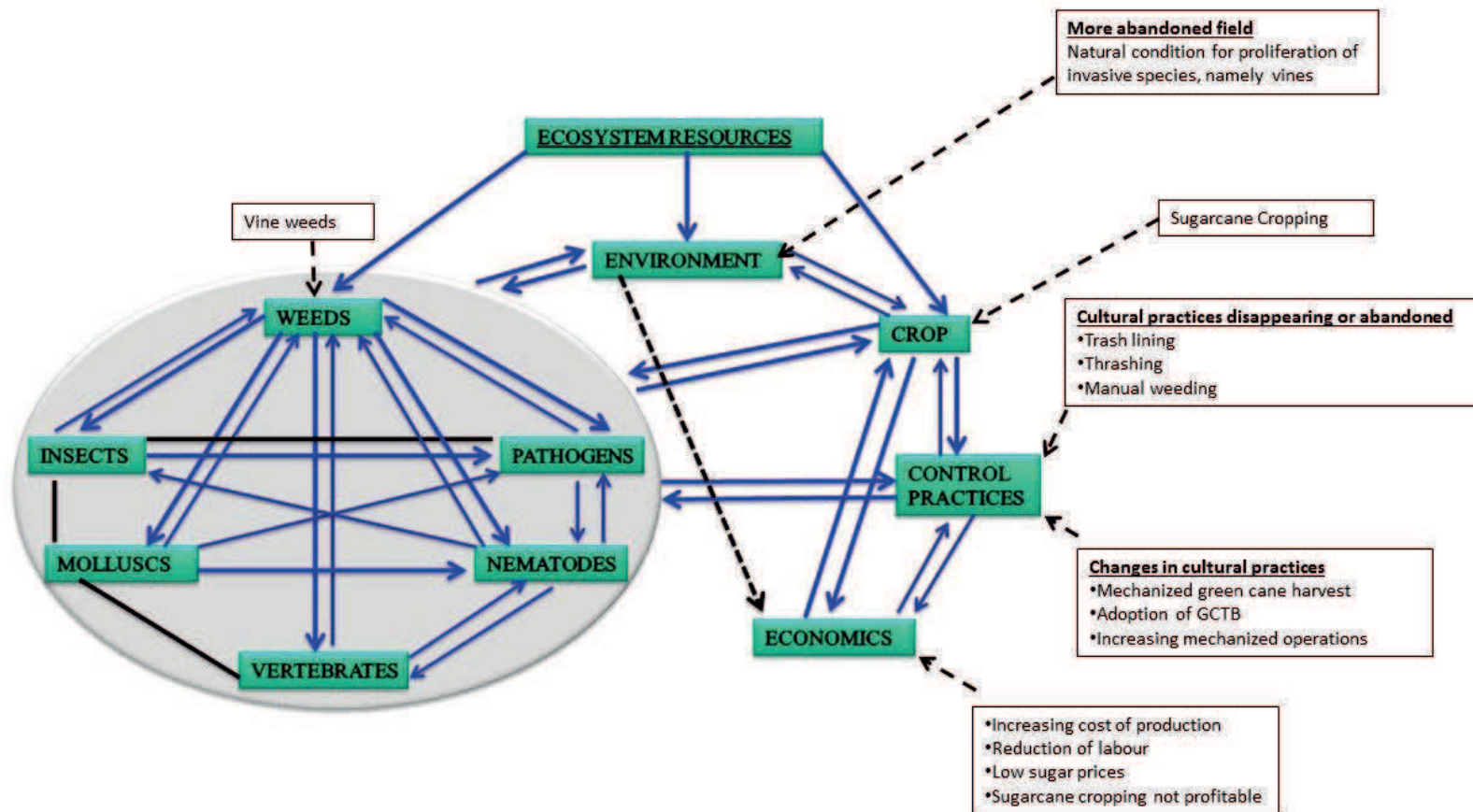


Figure 5.2. The interaction of weeds and other components of the agricultural production system (Norris 1992) as adapted to the problem of vine weeds in sugarcane fields in Mauritius.

The important vine weeds, dominated by the *Ipomoea* spp., propagate by seeds produced in large amounts. It has been shown that their large-seeded property confers to them the abilities to emerge from depths < 4 cm in the soil profile and through a trash mulch of 5 cm. This layer of trash was also conducive to the germination and emergence of *Ipomoea* spp. seeds whereas thicker trash cover (> 10 cm) suppressed them. Moreover, laboratory investigations have established the minimum temperatures required to initiate seed germination in six vine weed species. These ranged from 7°C for *I. nil* and *I. obscura* to 17°C for *Cajanus scarabaeoides*, *I. hederifolia* and *I. quamoclit*; that for *I. triloba* was around 9.5°C. Finally, field trials had shown that control of vine weed emergence in GCTB fields would either require application of specific herbicide combinations or appropriate trash management practices involving increased mulch on some interrows whereas cleared ones would be treated with pre-emergence tank-mixes.

The findings of this PhD thesis have enabled a better understanding of the biological, ecological and agronomic interactions of the factors which influence the growth and development habits of vine weeds in sugarcane. These interactions are grounded on agro-ecological conditions which are at the root of the favourable environment that has benefitted the proliferation of these species. This better insight into the problem will create new synergies for the formulation of sustainable management practices for their control.

Additionally, the unravelling of the complexities behind the vine weed problem that started in the 1990s in the sugarcane fields of Mauritius has opened out new research opportunities to further enhance our understanding of the vine weeds problem in order to limit their negative impact on sugarcane cropping. In the first place, since growers rely a lot on chemical weed control for its cost-effectiveness, new, environment-friendly herbicide molecules will have to be looked for that can act on vine seeds found deeper than 4 cm in the soil. Such herbicides will also have to be evaluated in GCTB conditions to study their movement through the trash cover in order to control seeds found beneath. Also, since most of the germination and emergence occur during the rainy period, herbicides molecule that are activated in the presence of water after a dry spell must be evaluated. The molecule isoxaflutole possesses this property and its potential can be explored in the context of vine weed control.

Moreover, the volume of water that is used for herbicide applications ranges from 180 Lha⁻¹ for mechanical sprayings to 450 Lha⁻¹ with knapsack sprayers. Recent work on the application of herbicides through the pivot irrigation system in a GCTB field has shown an improvement in the control of large-seeded weeds. This has been associated with a better movement of the herbicides through the trash and soil profile where the large volume of water has acted as a carrier to bring the molecules near the seeds. Hence a 'drenching effect' is suspected and research will have to be undertaken in this direction in order to open up the underlying mechanism so that it can have agronomic applications for the control of vine weeds.

Studies on the biology and ecology of vine weeds with regards to their relative competitiveness to the sugarcane crop are other aspects of the growth and development habits of vine weeds that need to be explored. This is because competition of vine weeds appears to be more related to the mechanics of creeping and twining, causing physical damages which result in yield reduction. This will warrant a biomechanical approach to understand the various processes that are involved.

It has also been noted during this study that the 26 vine species do not have the same competitive capacities and it is suspected that this can be related to the twining abilities. In fact, the majority of vines climb by various means (Putz and Mooney, 1991) but some species like *I. triloba*, *B. alba* and *M. Micrantha* do so by twining, as for *P. suberosa* this is achieved with the aid of tendrils. For these species, twining is triggered when the developing shoots or tendrils come into physical contact with a solid object. This directional response of the plant organs is known as thigmotropism which is caused by the induction of some pattern of differential growth (Jaffé et al., 2002). This aspect need to be further explored in relation to light and shade.

The recurring emergence of vine weed seedlings in the field is closely related to the seedbank dynamics and their position in the soil, particularly when they can emerge deeper underground compared to small-seeded species. Research in this direction will therefore enhance our understanding of the emergence patterns of vine weeds, thus making it possible to formulate appropriate control strategies.

Also, the distribution of the various species will be further investigated by performing multivariate analyses with potentially important factors like soil type, agro-climatic conditions and

cultural practices, namely trash management (trash lining versus GCTB). This would enable to establish the appropriate ecological conditions that vine weeds would require to further their invasive development. In addition, more investigations would have to be carried out to monitor the evolution in the spatial distribution of species already present in sugarcane fields in Mauritius and to control any new introduction that can be harmful to the crop.

Finally, global climate change and the rising level of CO₂ in the atmosphere are realities that need not be neglected. Their influence on life processes has been confirmed, so their effect on the development of vine weeds in sugarcane fields and their impact on the crop will have to be assessed.

REFERENCES

- Aldrich R.J. 1984. *Weed-Crop Ecology: Principles in Weed Management*. Brenton Publishers, N. Scituate, MA.
- Alexander A.G. 1973. *Sugar cane physiology: a comprehensive study of the Saccharum source-to-sink system*. Elsevier, Amsterdam.
- Alif A.F.M. 1992. Comparison of three weeding methods in rubber cultivation. *Planters Bulletin Malaysia* (212-213), 99-101
- Azania A.A.P.M., Azania C.A.M., Gravena R., Pavani M.C.M.D. and Pitelli R.A. 2002. Sugar cane (*Saccharum spp.*) straw interference in emergence of weed species of the Convolvulaceae family. *Planta Daninha*. **20**, 207-212.
- Barbe C., Seeruttun S., McIntyre G. and Gaungoo A. 1997. Halosulfuron: a new herbicide for *Cyperus rotundus* control in sugar cane. *Revue Agricole et sucrière de l'île Maurice* **76**, 9-13.
- Barker M., Thompsom L.J. and Godley F.M. 1984. Control of annual morningglories (*Ipomoea spp.*) in soybeans (*Glycine max*). *Weed Science* **32**, 813-818.
- Bhattacharya S.P., Banerjee H., Ranjani T.S. and Bera P. 2001. Bio-efficacy of Mon-77569 on tea (*Camellia sinensis* L.). *Environment and Ecology* **19**, 826-828.
- Bhullar M.S., Walia U.S., Singh S., Singh M. and Jhala A.J. 2012. Control of morningglories (*Ipomoea spp.*) in sugarcane (*Saccharum spp.*). *Weed Technology* **26**, 77-82.
- BSES 1989. Weeds of Australia. *Bses Bulletin* **28**, 33-43.
- Buchanan G.A. and Burns E.R. 1971. Weed Competition in Cotton. I. Sicklepod and Tall Morninglory. *Weed Science* **19**, 576-579.
- Calcino D. 1986. NQ variety use with changed farm practices. *Bses Bulletin* **13**, 16-17.

- Chee Y.K., Ahmad F.M.A. and Yang Z.N. 1993. Weed management in rubber. 2. Control of noxious weeds with herbicides. *Planters' Bulletin Malaysia* **216**, 80-86
- Chiang M.Y., Hsu L.M. and Chen F.Y. 2002a. Confirmation on the presence of *Mikania micrantha* Kouth in Taiwan. *Plant-Protection-Bulletin-Taipei*. **44**, 61-65.
- Chiu S.B., Chan S.M. and Siow A. 2002. Biological control of *Mikania micrantha* - a preliminary finding. *Planter* **78**, 715-718.
- Chiu S.B. and Shen H. 2004. Growth studies of *Cuscuta* spp. (Dodder parasitic plant) on *Mikania micrantha* and *Asystasia intrusa*. *Planter* **80**, 31-36.
- Condon M.A., Sasek T.W. and Strain B.R. 1992. Allocation patterns in two tropical vines in response to increased atmospheric CO₂. *Funct. Ecol.* **6**, 680-685.
- Coussens R. and Moss S.R. 1990. A model of the effects of cultivation on the vertical distribution of weed seeds within the soil. *Weed Res.* **30**, 61-70.
- Cordes R.C. and Beauman T.T. 1984. Field competition between ivyleaf morningglory (*Ipomoea hederacea*) and soybeans (*Glycine max*). *Weed Science* **32**, 364-370.
- Correia N.M. and Durigan J.C. 2004. Weed emergence in soil covered with sugarcane harvest straw residue. *Planta-Daninha* **22**, 11-17.
- Crowley R.H. and Buchanan G.A. 1982. Variations in seed production and the response to pests of morningglory (*Ipomoea*) species and smallflower morningglory (*Jacquemontia tamnifolia*). *Weed Sci.* **30**, 187-190.
- De Sornay P. 1936. *Manuel de la canne à sucre à l'usage des chargés des cours et des élèves des grandes écoles coloniales*. General Printing & Stationery Co Ltd, Port Louis.
- Dutta A.C. 1977. Biology and control of *Mikania*. *Two and a Bud India*. **24**, 17-20
- Feng H.L., Cao H.L., Liang X.D., Zhou-Xia and Ye W.H. 2002a. The distribution and harmful effect of *Mikania micrantha* in Guangdong. *Journal-of-Tropical-and-Subtropical-Botany*. **10**, 263-270.

- Feng H.L., Cao H.L., Liang X.D., Zhou-Xia and Ye W.H. 2002b. The distribution and harmful effect of *Mikania micrantha* in Guangdong. *Journal of Tropical and Subtropical Botany*. **10**, 263-270.
- Gaungoo A., Seeruttun, S. and Barbe, C. Proc. int. Soc. Sug. Cane Technol. 27: 11 p. 2010. Interactions between seed depth, thickness of trash blanket and herbicide treatments on emergence of vine weeds in sugar cane. In: *Proceedings of the ... ISSCT Congress*). Brazil.
- Gealy D. 1998. Differential Response of Palmleaf Morningglory (*Ipomoea wrightii*) and Pitted Morningglory (*Ipomoea lacunosa*) to Flooding. *Weed Science* **46**, 217-224.
- Gentry A.H. 1985. An ecotaxonomic survey of Panamanian lianas. In: *The Biology of Vines* eds. Putz F. E. and Mooney H. A.). Cambridge University Press, Cambridge, 3-42.
- Gerwing J.J., Schitzer S.A., Burnham R.J., Bongers F., Chave J., Dewalt S.J., Ewango C.E.N., Foster R., Kenfack D., Ramos M.M., Parren M., Parthasarathy N., Perez-Salicip P.R., Putz F.E. and Thomas D.W. 2006. A standard protocol for Liana Censuses. *Biotropica* **38**, 256-261.
- Gomes L.F., Chandler J.M. and Vaughan C.E. 1978. Aspects of Germination, Emergence, and Seed Production of Three *Ipomoea* Taxa. *Weed Science* **26**, 245-248.
- Granados J. and Körner C. 2002. In deep shade, elevated CO₂ increases the vigour of tropical climbing plants. *Global Change Biology* **8**, 1109-1117.
- Grundy A.C., Mead A. and Bond W. 1996. Modelling the effect of weed-seed distribution in the soil profile on seedling emergence. *Weed Res.* **36**, 375-384.
- Hardcastle W.S. 1978. Influence of Temperature and Acid Scarification Duration on Scarlet Morningglory (*Ipomoea coccinea*) Seed Germination. *Weed Science* **26**, 261-263.
- Hättenschwiler S. and Körner C. 2003. Does elevated CO₂ facilitate naturalization of the non-indigenous *Prunus laurocerasus* in Swiss temperate forests? *Funct. Ecol.* **17**, 778-785.

- Hsu L.M. and Chiang M.Y. 2003. Comparison of seed germination and vegetative growth of two *Mikania* species. *Plant Protection Bulletin Taipei* **45**, 321-328.
- Huang Z.L., Cao H.L., Liang X.D., Ye W., Feng H.L. and Cai C.X. 2000. The growth and damaging effect of *Mikania micrantha* in different habitats. *Journal-of-Tropical-and-Subtropical-Botany* **8**, 131-138
- Ismael F., Seeruttun S., Barbe C. and Gaungoo A. 2008. A review of changing cultural practices to improve productivity of sugar cane in Mauritius. In: *Proceedings South African Sugar Technologists Association*). Durban.
- Jones C.A. 2006. Red Morningglory (*Ipomoea coccinea* L.) Biology and Management in Sugarcane. In: *The Department of Agronomy and Environmental Management*). B.S Texas A&M University, 69.
- Koenig J. 1988. Mauritius and Sugar.). Mauritius Sugar Industry Research Institute (MSIRI).
- Lamusse R. 2011. *The Supremacy & Twilight of the Mauritius Sugar Industry*. Osman Publishing.
- Lancaster S.H., Jordan D.L., York A.C., Wilcut J.W., Brandenburg R.L. and Monks D.W. 2005. Interactions of Late- Season Morningglory(*Ipomoea* spp.) Management Practices in Peanut(*Arachis hypogaea*). *Weed Technology* **19**, 803-808.
- Le Bourgeois T., Carrara A., Dodet M., Dogley W., Gaungoo A., Grard P., Ibrahim Y., Jeuffrault E., Lebreton G., Poilecot P., Prosperi J., Randriamampianina J.A., Andrianaivo A.P. and Théveny F. 2008. Advent-OI : Principales adventices des îles du sud-ouest de l'Océan Indien.V.1.0. In: *In Cirad [ed.], Cirad*). , Montpellier, France.
- Lebreton G. 2010. Effet de l'époque de coupe de la canne à sucre sur l'enherbement et le cycle biologique des adventices à La Réunion. In: *Sciences de la Vie et de la Terre*). École Pratique des Hautes Études Paris, 87.
- Lebreton G., Le Bourgeois T. and Marnotte P. 2009. Effet de l'époque de coupe sur la dynamique de développement de l'enherbement de la canne a sucre a la Réunion. In: *XIIIème colloque international sur la biologie des mauvaises herbes*). Dijon (France).

- Lian J., Ye W.H., Cao H.L., Lai Z.M. and Liu S.P. 2006. Effects of periodic cutting on the structure of the *Mikania micrantha* community. *Botanical-Studies* **47**.
- Manechini C., Ricci-Junior A. and Donzelli J.L. 2005. An overview of controlled and non-controlled weeds as influenced by sugarcane trash blankets. *Sugar Cane International* UK. 23, 11-14.
- Mc Intyre G. and Barbe C. 1995. Oxyfluorfen, acetochlor and metazachlor, new long residual herbicides for sugar cane. In: Proc. int. Soc. Sug. Cane Technol). 1-10.
- Mc Intyre G. 1991. *Weeds of Sugar cane in Mauritius, their description and control*. Réduit.
- Mc Intyre G. and Barbe C. 1988. Le controle de *Cynodon dactylon* L. Pers à l'Ile Maurice. In: *Third. Congr. Ass. Reunionnaise Dev. technol. agric. Sucre*). La Réunion, 380-388 (Also published in *Revue agric. sucre Ile Maurice* 67: 71-76)
- Mc Intyre G., Barbe C., Pitchen J. and Yerriah M. 1980a. The control of *Cyperus rotundus* in sugar cane fields and in fallow land. *Proc. int. Soc. Sug. Cane Technol* **17**, 76-84.
- Mc Intyre G., Pitchen J., Barbe C. and Yerriah M. 1980b. The effect of various herbicidal treatments on *Digitaria horizontalis* growing in plant cane. In: *Proc. int. Soc. Sug. Cane Technol*). 93-98.
- MC Intyre G., Pitchen J., Barbe C. and Yerriah M. 1983. Use of Roundup (Glyphosate) for the control of problem weeds in sugar cane fields. *Proc. int. Soc. Sug. Cane Technol* **18**, 273-276.
- Messersmith D.T., Curran W.S., Hartwig N.L., Orzolek M.D. and Roth G.W. 1999. Evaluation of several herbicides for Burcucumber (*Sicyos angulatus*) control in corn (*Zea mays*). *Weed Technology* **13**, 520-524.
- Millhollon R.W. 1988. Control of morningglory (*Ipomoea coccinea*) in sugar cane with layby herbicide treatments. *Journal of American Society of sugar cane technologists* **8**, 62-66.

- Ministry of Agriculture Food Technology and Natural Resources 2001. The Sugar Sector Strategic Plan, 2001-2005.). Ministry of Agriculture, Food Technology and Natural Resources, Port-Louis.
- Ministry of Agro-Industries and Fisheries 2006. Multi-Annual Adaptation Strategy Action plan 2006-2015: Safeguarding the future through consensus.). Ministry of Agro-Industry and Fisheries, Port Louis, 96.
- Morandini M., Figueroa R., Zamora F.P. and Scandaliaris J. 2005a. The effects of green-cane trash blanket on soil temperature, soil moisture and sugar cane growth. In: *Proceedings of the XXV Congress* (ed. Hogarth D. M.). The XXV ISSCT Congress Organising Committee, Atagua, Guatemala City, Guatemala, 231-237.
- MSIRI 2012a. Control of vine weeds. In: *2011 Annual Report*. Mauritius Sugar Industry Research Institute.,
- MSIRI 2004. *2003 Annual Report*. Mauritius Sugar Industry Research Institute., 33.
- MSIRI 2012b. Mechanized green cane harvesting. In: *2011 Annual Report*). Mauritius Sugar Industry Research Institute.
- Norris R.F. 2005. Ecological bases of interactions between weeds and organisms in other pest categories. *Weed Science* **53**, 909-913.
- Norris R.F. and Kogan M. 2000. Interactions between weeds, arthropods pests, and their natural enemies in managed ecosystems. *Weed Science* **48**, 94-158.
- Norsworthy J.K. 2004. Soybean Canopy Formation Effects on Pitted Morningglory(*Ipomoea lacunosa*), Common Cocklebur (*Xanthium strumarium*),and Sicklepod (*Senna obtusifolia*) Emergence. *Weed Science* **52**, 954-960.
- Norsworthy J.K. and Oliver L.R. 2002. Pitted morningglory interference in drill-seeded glyphosate-resistant soybean. *Weed Science* **50**, 26-33.

- North Coombes A. 1993. *A history of sugar production in Mauritius*. Mauritius Printing Specialists (Pte.) Ltd, Mauritius.
- Padya B.M. 1989. *Weather and climate of Mauritius*. MGI, Moka, Mauritius.
- Parish D.H. and Feillafé S.M. 1965. Notes on the 1:100,000 Soil Map of Mauritius. In: *Occasional Paper No 22*). MSIRI, Mauritius.
- Phillips O.L., Martínez R.V., Arroyo L., Baker T.R., Killeen T., Lewis S.L., Malhi Y., Mendoza A.M., Neill D., Vargas P.N., Alexiades M., Cerón C., Di Fiore A., Erwin T., Jardim A., Palacios W., Saldias M. and Vinceti B. 2002. Increasing dominance of large lianas in amazonian forests. *Nature* **418**, 770-774.
- Roach B. and Daniels J. 1987. A review of the origin and improvement of sugar cane. In: *Copersucar International Sugarcane Breeding workshop*).
- Rochecouste E. 1967. *Weed Control in sugarcane*. Adlard & Son Ltd, Bartholomew Press, Dorking, England.
- Rouillard and Guého 1999. *Les Plantes et Leur Histoire a L'Ile Maurice* MSM Limited.
- Rouillard G. 1989. *Historique de la canne à sucre à l'île Maurice, 1639-1989*. Mauritius Chamber of Agriculture, Port Louis.
- Schnitzer S.A., Dewalt S.J. and Chave J. 2006. Censusing and Measuring Lianas: A quantitative Comparison of the common methods. *Biotropica* **38**, 581-591.
- Schnitzer S.A., Rutishauser S. and Aguilar S. 2008. Supplemental protocol for liana censuses. *Forest Ecology and Management* **255**, 1044-1049.
- Seeruttun S., Intyre G.M. and Barbe C. 1992. Agronomic and economic significance of trash blanketing in the sub-humid areas of Mauritius. *Révue agricole et sucrière de l'île Maurice* **71**, 324-331.
- Seeruttun, S., Barbe, C. and Mc Intyre, G. 1999. "Le paillis complet dans la canne à sucre en zone à forte pluviosité". *Rev. agric. sucr. Ile Maurice* 77(2&3): 42-49

- Seeruttun, S., Mangar, M., Barbe, C. and Gaungoo, A. 1999. Effect of date of trashing on cane yield. (Paper presented at the Annual Meeting of Agricultural Scientists, 17th-18th November 1998, Réduit, Mauritius)
- Seeruttun S., Barbe C. and Gaungoo A. 2005. Vine weeds in sugarcane: fluroxypyr provides cost-effective post-emergence control in Mauritius. *Sugar Cane International*. **23**, 3-5.
- Seeruttun S., Barbe C. and Gaungoo A. 2008. New herbicide tank-mix, Krismat® + Dinamic®: a cost-effective broad-spectrum pre-& post-emergence treatment for managing weeds in sugar cane. *Sugar Cane International* **26**, 18-21,25.
- Seeruttun S. 2008. Weed Management in sugar cane: critical periods of weed competition and mechanisms of interference from *Paspalum paniculatum* and *P. urvillei*. Thesis, PhD; Department of Plant Production and Soil Science, faculty of Natural Sciences, University of Pretoria, South Africa. 205 p.: 69 figs, 69 tpls, 1 ppen
- Shannon R. 1999. Vine Control. *BSES BULLETIN* **66**, 8.
- SIFB. 2011. Survey report on abandonment of cane lands 2001-2010. Port louis: Sugar Insurance Fund Board, p 30.
- Sobrero M.T., Fioretti M.N., Chaila S., Avila O.B. and Ochoa M.d.C. 2003. Factors that influence the germination of *Ipomoea nil* (L.) Roth. *Agro-Sur*. **31**, 60-68.
- STASM 1990. *Manual of sugar cane agronomy*. Réduit, Mauritius.
- STASM 2003. *Manual of sugar cane agronomy*. Réduit, Mauritius.
- Stone A.E., Peeper T.F. and Kelley J.P. 2005. Efficacy and Acceptance of Herbicides Applied for field Bindweed(*Convolvulus arvensis*) Control. *Weed Technology* **19**, 148-153.
- Suwanketnikom R. and Julakasewee A. 2004. Hardseededness and germination of small white flower morningglory. *Kasetsart-Journal,-Natural-Sciences*. **38**, 425-433.

- Suwanketnikom R. and Julakasewee A. 2005. Development of small white flower morningglory seeds and influence of storage on their germination and viability. *Kasetsart-Journal,- Natural-Sciences*. **39**, 329-337.
- Thakar C. and Singh H.N. 1954. Nilkalamine (*Ipomoea hederacea*), a menace to sugar cane. *Horticultural Abstract* **24**, 530.
- Van Dillewijn J. 1952. *Botany of Sugar Cane*. MA, USA.
- Viator B.J., Griffin J.L. and Ellis J.M. 2002. Red Morningglory *Ipomoea Coccinea* Control with Sulfentrazone and Azafeniden applied at layby in Sugarcane(*saccharum* spp.). *Weed Technology* **16**, 142-148.
- Willaime P. 1984. Carte pédologique de l'Ile Maurice. Office de la Recherche Scientifique et Technique Outre-mer.). France and Mauritius Sugar Industry Research Institute Mauritius
- Zimdahl R.I. 2007. *Fundamentals of weed science*. Academic Press, Inc., New York.

Appendix 1

HERBICIDE RECOMMENDATIONS USED IN SUGARCANE CROPPING IN MAURITIUS

List of herbicides

	Herbicides	Common Names	g a.e. or a.i. per L or kg
1	2,4-D Amine salt	2,4-D amine salt	720
2	Ametryn	Ametryn	500
3	Arsenal Gen 2 SL	Imazapyr	240
4	Asulox	Asulam	400
5	Atrazine	Atrazine	500
6	Authority	Sulfentrazone	750
7	Basta	Glufosinate-ammonium	140
8	DCMU	Diuron	800
9	Dinamic	Amicarbazone	700
10	Dinamic Ace	Amicarbazone + acetochlor	200 + 686
11	Dinamic Extra L 1.2	amicarbazone + ametryn + MCPA	210 + 240 + 280
12	Dinamic Extra H 1.6	amicarbazone + ametryn + MCPA	190 + 229 + 255
13	Escort	Metsulfuron-Methyl	600
14	Falcon Gold	S-metolachlor	960
15	Garlon	Triclopyr	480
16	Gesaprim	Atrazine	900
17	Goal	Oxyfluorfen	236
18	Harness	Acetochlor	900
19	Integrity EC	Saflufenacil + dimethenamid-P	62.4 + 550.4
20	Krismat	Trifloxysulfuron + ametryn	18.5 + 731.5
21	Lumax	Mesotrione + s-metolachlor + terbuthylazine	37.5 + 375 + 125
22	MCPA	Methyl chlorophenoxyacetic acid	400
23	Merlin	Isoxaflutole	750
24	Paraquat	Paraquat dichloride	276
25	Roundup	Glyphosate	360
26	Roundup Energy	Glyphosate	679
27	Servian	Halosulfuron	750
28	Starane, Tomahawk	Fluroxypyr	200
29	Strongarm	Diclosulam	840
30	Tebusan	Tebuthiuron	500
31	Terbo	Terbuthylazine + bromoxynil	333 + 150
32	Tordon 101	Picloram + 2,4-D amine salt	304
33	Touchdown Forte	Glyphosate	500
34	Velpar L	Hexazinone	250
35	Velpar WG	Hexazinone	750

PLANT CANE - 1st Application

TMT	MIXTURES	RATES(L or kg) /ha		CONTROL (weeks)
1	Authority	1.6		14 - 16
2	Authority	2		14 - 16
3	DCMU	4.8		10 - 12
4	Dinamic + Krismat	1.25	2	14 - 16
5	Dinamic + Krismat	1.5	2	14 - 16
6	Dinamic Ace	5.25		14 - 16
7	Falcon Gold + atrazine	1.6	4.8	10 - 12
8	Falcon Gold + DCMU	1.6	2.4	10 - 12
9	Falcon Gold + Gesaprim	1.6	2.7	10 - 12
10	Goal + atrazine (50%)	2.4	4.8	16 - 18
11	Goal + DCMU	2.4	2.4	16 - 20
12	Goal + Gesaprim (90%)	2.4	2.7	16 - 18
13	Harness + atrazine	2.4	4.8	10 - 12
14	Harness + DCMU	2.4	2.4	10 - 12
15	Harness + Gesaprim	2.4	2.7	10 - 12
16	Integrity EC	1.5		12 - 14
17	Integrity EC	2		12 - 14
18	Krismat	2.4		14 - 16
19	Lumax	4		12 - 14
20	Lumax	4.5		12 - 14
21	Strongarm + Falcon Gold	0.07	1.6	12 - 14
22	Strongarm + Falcon Gold	0.09	1.6	12 - 14
23	Strongarm + Goal	0.07	2.4	16 - 20
24	Strongarm + Goal	0.09	2.4	16 - 20
25	Strongarm + Harness	0.07	2.4	12 - 14
26	Strongarm + Harness	0.09	2.4	12 - 14
27	Strongarm + Tebusan	0.07	3.2	14 - 16
28	Strongarm + Tebusan	0.09	3.2	14 - 16
29	Tebusan + atrazine	3.2	4.8	12 - 14
30	Tebusan + DCMU	3.2	2.4	12 - 14
31	Tebusan + Gesaprim	3.2	2.7	12 - 14

NOTE:

1. If weeds are present add paraquat @ 0.5 - 1.0 L/ha or Basta @ 0.6 L/ha + WETTING AGENT
2. Mixtures with DCMU should be preferred in humid areas and where grasses are predominant.
3. Atrazine should be preferred where broad-leaved weeds are predominant and in dry areas.
4. Goal or mixtures should be used in fields where *Panicum subalbidum* (fataque rouge) is expected.
5. Goal + DCMU or DCMU alone would be used where foodcrops are grown in interline.

PLANT CANE - 2nd Application

TMT	MIXTURES	RATES(L or kg)/ha		CONTROL (Wks)	Add (See Note)	
					2,4-D @ 3.0 L/ha	Terbo @ 1.8 L/ha
1	Atrazine	4.8		10 - 12	✓	✓
2	DCMU	3.0		10 - 12	✓	✓
3	Dinamic + Krismat	1.25	2	14 - 16		
4	Dinamic + Krismat	1.5	2	14 - 16		
5	Dinamic Extra L 1.2	5.0		12 - 14		
6	Dinamic Extra H 1.6	5.5		12 - 14		
7	Falcon Gold + Gesaprim	1.6	2.7	10 - 12	✓	✓
8	Falcon Gold + atrazine	1.6	4.8	10 - 12	✓	✓
9	Gesaprim	2.7		10 - 12	✓	✓
10	Harness + atrazine	2.4	4.8	10 - 12	✓	✓
11	Harness + Gesaprim	2.4	2.7	10 - 12	✓	✓
18	Lumax	4		12 - 14	✓	✓
19	Lumax	4.5		12 - 14	✓	✓
22	Strongarm + Falcon Gold	0.07	1.6	12 - 14	✓	✓
23	Strongarm + Falcon Gold	0.09	1.6	12 - 14	✓	✓
24	Strongarm + Harness	0.07	2.4	12 - 14	✓	✓
25	Strongarm + Harness	0.09	2.4	12 - 14	✓	✓
28	Strongarm + Tebusan	0.07	3.2	14 - 16	✓	✓
29	Strongarm + Tebusan	0.09	3.2	14 - 16	✓	✓
30	Tebusan + atrazine	2.6	4.8	10 - 14	✓	✓
31	Tebusan + Gesaprim	2.6	2.7	10 - 14	✓	✓

NOTE:

- Mixtures with DCMU should be used only in tolerant varieties.
- Terbo must be used instead of 2,4-D amine salt in sugarcane fields nearby to those with vegetables to avoid phytotoxicity caused by drift.
- A wetting agent should be added where 2,4-D amine salt is used.
- Mixtures with atrazine should be preferred if broad-leaved weeds are present.
- Dinamic Extra H 1.6 - in tolerant varieties only
- Dinamic Extra L 1.2 - in tolerant varieties and susceptible varie

**RATOON CANE 1st Application
STUBBLE SHAVING
PRE EMERGENCE OF CANE & WEEDS**

TMT	MIXTURES	RATES(L or kg)/ha		CONTROL(WKS)
1	Authority	1.6		14 - 16
2	Authority	2		14 - 16
3	DCMU	4.8		10 - 12
4	Dinamic Ace	5.25		14 - 16
5	Falcon Gold + atrazine	1.6	4.8	10 - 12
6	Falcon Gold + DCMU	1.6	2.4	10 - 12
7	Falcon Gold + Gesaprim	1.6	2.7	10 - 12
8	Goal + atrazine (50%)	2.4	4.8	16 - 18
9	Goal + DCMU	2.4	2.4	16 - 20
10	Goal + Gesaprim (90%)	2.4	2.7	16 - 18
11	Harness + atrazine	2.4	4.8	10 - 12
12	Harness + DCMU	2.4	2.4	10 - 12
13	Harness + Gesaprim	2.4	2.7	10 - 12
14	Integrity EC	1.5		12 - 14
15	Integrity EC	2		12 - 14
16	Krismat	2.4		14 - 16
17	Lumax	4		12 - 14
18	Lumax	4.5		12 - 14
19	Merlin + Tebusan	0.15	2.5	14 - 16
20	Merlin + Tebusan	0.2	2.5	14 - 16
21	Strongarm + Falcon Gold	0.07	1.6	12 - 14
22	Strongarm + Falcon Gold	0.09	1.6	12 - 14
23	Strongarm + Goal	0.07	2.4	16 - 20
24	Strongarm + Goal	0.09	2.4	16 - 20
25	Strongarm + Harness	0.07	2.4	12 - 14
26	Strongarm + Harness	0.09	2.4	12 - 14
27	Strongarm + Tebusan	0.07	3.2	14 - 16
28	Strongarm + Tebusan	0.09	3.2	14 - 16
29	Strongarm + Velpar	0.07	2.3	12 - 14
30	Strongarm + Velpar	0.09	2.3	12 - 14
31	Tebusan + atrazine	3.2	4.8	10 - 14
32	Tebusan + DCMU	3.2	2.4	10 - 14
33	Tebusan + Gesaprim	3.2	2.7	10 - 14
34	Velpar L + atrazine	2.3	4.8	10 - 12
35	Velpar L + Gesaprim	2.3	2.7	10 - 12
36	Velpar L+ DCMU	2.3	2.4	10 - 12
37	Velpar WG + atrazine	0.8	4.8	10 - 12
38	Velpar WG + Gesaprim	0.8	2.7	10 - 12
39	Velpar WG + DCMU	0.8	2.4	10 - 12

NOTE:

1. If weeds are present add paraquat @ 0.5 - 1.0 L/ha or Basta @ 0.6 L/ha in all treatments
2. Mixtures with DCMU should be preferred in humid areas and where grasses are predominant.
3. Atrazine should be preferred where broad-leaved weeds are predominant and in dry areas.
4. Goal or mixtures should be used in fields where *Panicum subalbidum* (fataque rouge) is expected.

RATOON CANE 1st Application SELECTIVE HARVEST

TMT	MIXTURES	RATES(L or kg)/ha		CONTROL(WKS)	Add (See note)	
					2,4-D @ 3.0 L/ha	Terbo @ 1.8 L/ha
1	DCMU	4.8		10 - 12	✓	✓
2	Dinamic Ace	5.25		14 - 16	✓	✓
3	Dinamic Extra L 1.2	5		12 - 14		
4	Dinamic Extra H 1.6	5.5		12 - 14		
5	Falcon Gold + atrazine	1.6	4.8	10 - 12	✓	✓
6	Falcon Gold + DCMU	1.6	2.4	10 - 12	✓	✓
7	Falcon Gold + Gesaprim	1.6	2.7	10 - 12	✓	✓
8	Harness + atrazine	2.4	4.8	10 - 12	✓	✓
9	Harness + DCMU	2.4	2.4	10 - 12	✓	✓
10	Harness + Gesaprim	2.4	2.7	10 - 12	✓	✓
11	Integrity EC	1.5		12 - 14		
12	Integrity EC	2		12 - 14		
13	Lumax	4		12 - 14	✓	✓
14	Lumax	4.5		12 - 14	✓	✓
15	Strongarm + Falcon Gold	0.07	1.6	12 - 14	✓	✓
16	Strongarm + Falcon Gold	0.09	1.6	12 - 14	✓	✓
17	Strongarm + Goal	0.07	2.4	16 - 20	✓	✓
18	Strongarm + Goal	0.09	2.4	16 - 20	✓	✓
19	Strongarm + Harness	0.07	2.4	12 - 14	✓	✓
20	Strongarm + Harness	0.09	2.4	12 - 14	✓	✓
21	Strongarm + Tebusan	0.07	3.2	14 - 16	✓	✓
22	Strongarm + Tebusan	0.09	3.2	14 - 16	✓	✓
23	Strongarm + Velpar	0.07	2.3	12 - 14	✓	✓
24	Strongarm + Velpar	0.09	2.3	12 - 14	✓	✓
25	Tebusan + atrazine	3.2	4.8	10 - 14	✓	✓
26	Tebusan + DCMU	3.2	2.4	10 - 14	✓	✓
27	Tebusan + Gesaprim	3.2	2.7	10 - 14	✓	✓
28	Velpar L+ atrazine	2.3	4.8	10 - 12	✓	✓
29	Velpar L+ DCMU	2.3	2.4	10 - 12	✓	✓
30	Velpar L+ Gesaprim	2.3	2.7	10 - 12	✓	✓
31	Velpar WG + atrazine	0.8	4.8	10 - 12	✓	✓
32	Velpar WG + DCMU	0.8	2.4	10 - 12	✓	✓
33	Velpar WG + Gesaprim	0.8	2.7	10 - 12	✓	✓

NOTE:

1. Mixtures with DCMU should be preferred on tolerant varieties in humid areas and where grasses are predominant.
2. Terbo must be used instead of 2,4-D amine salt in sugarcane fields nearby to those with vegetables to avoid phytotoxicity caused by drift.
3. Atrazine should be preferred on susceptible varieties where broad-leaved weeds are predominant and in dry areas.
4. 2,4 D amine salt or Terbo should be added where applicable to above mixtures if weeds are present at time of application.
5. Dinamic Extra H 1.6 - in tolerant varieties only
6. Dinamic Extra L 1.2 - in tolerant varieties and susceptible varieties

Ratoon Cane - 2nd Application

TMT	MIXTURES	RATES(L or kg)/Ha		CONTROL(WKS)	Add	
					2,4-D @ 3.0 L/ha	Terbo @ 1.8 L/ha
1	Atrazine	4.8		10 - 12	✓	✓
2	DCMU	3.0		10 - 12	✓	✓
3	Dinamic + Krismat	1.25	2	14 - 16		
4	Dinamic + Krismat	1.5	2	14 - 16		
5	Dinamic Extra L 1.2	5		12 - 14		
6	Dinamic Extra H 1.6	5.5		12 - 14		
7	Falcon Gold +atrazine	1.6	4.8	10 - 12	✓	✓
8	Falcon Gold +Gesaprim	1.6	2.7	10 - 12	✓	✓
9	Gesaprim	2.7		10 - 12	✓	✓
10	Harness + atrazine	2.4	4.8	10 - 12	✓	✓
11	Harness + Gesaprim	2.4	2.7	10 - 12	✓	✓
12	Krismat + Velpar WG	2.0	0.8	10 - 14	✓	✓
13	Integrity EC	1.5		12 - 14		
14	Integrity EC	2		12 - 14		
15	Lumax	4.0		10 - 14	✓	✓
16	Lumax	4.5		10 - 14	✓	✓
17	Strongarm + Falcon Gold	0.07	1.6	12 - 14	✓	✓
18	Strongarm + Falcon Gold	0.09	1.6	12 - 14	✓	✓
19	Strongarm + Goal	0.07	2.4	16 - 20	✓	✓
20	Strongarm + Goal	0.09	2.4	16 - 20	✓	✓
21	Strongarm + Harness	0.07	2.4	12 - 14	✓	✓
22	Strongarm + Harness	0.09	2.4	12 - 14	✓	✓
23	Strongarm + Tebusan	0.07	3.2	14 - 16	✓	✓
24	Strongarm + Tebusan	0.09	3.2	14 - 16	✓	✓
25	Strongarm + Velpar	0.07	2.3	12 - 14	✓	✓
26	Strongarm + Velpar	0.09	2.3	12 - 14	✓	✓
27	Tebusan + atrazine	2.6	4.8	10 - 14	✓	✓
28	Tebusan + DCMU	2.6	2.4	10 - 14	✓	✓
29	Tebusan + Gesaprim	2.6	2.7	10 - 14	✓	✓
30	Velpar L+ atrazine	2.3	4.8	10 - 12	✓	✓
31	Velpar L+ DCMU	2.3	2.4	10 - 12	✓	✓
32	Velpar L+ Gesaprim	2.3	2.7	10 - 12	✓	✓
33	Velpar WG + atrazine	0.8	4.8	10 - 12	✓	✓
34	Velpar WG + DCMU	0.8	2.4	10 - 12	✓	✓
35	Velpar WG + Gesaprim	0.8	2.7	10 - 12	✓	✓

NOTE

- Mixtures with DCMU should be used only in tolerant varieties.
- Terbo must be used instead of 2,4-D amine salt in sugarcane fields nearby to those with vegetables to avoid phytotoxicity caused by drift.
- A wetting agent should be added where 2,4-D amine salt is used.
- Dinamic Extra H 1.6 - in tolerant varieties only
- Dinamic Extra L 1.2 - applicable to all varieties

Herbicide Recommendation for problem weeds

Common name	Botanical name	Mixture	Rates (commercial products/ha)	Remarks
Chiendent	<i>Cynodon dactylon</i>	Roundup	10 - 12 litres	
Songe	<i>Colocasia esculenta</i>	Escort + Wet Agent	0.05 kg + 0.25 5 v/v	
Herbe sifflette	<i>Paspalidium geminatum</i>	Roundup	10 - 12 litres	
Herbe à oignon	<i>Cyperus rotundus</i>	Servian + Complement Super	0.055 kg + 0.2 litre	for susceptible vars e.g.M 2593/92, M1246/86 & R 570,
		Servian + Complement Super	0.10 kg + 0.2 litre	for tolerant vars e.g M 1400/86, M 52/78, M 3035/66, etc...
		2,4-D + Wet Agent Roundup	3.0 + 0.025 % v/v 3.0 litres	
Herbe duvet	<i>Paspalum paniculatum</i>	2,4-D + Asulox	3.0 + 7.5 litres	
Hebe cheval	<i>Paspalum urvillei</i>	2,4-D + Asulox	3.0 + 7.5 litres	
Petit mota	<i>Kyllinga bulbosa</i>	Roundup	3.0 litres	
		Velpar + 2,4 - D	2.3 + 3.0 litres	
Fataque Rouge	<i>Panicum subalbidum</i>	Velpar + atrazine + Terbo	2.3 + 4.0 + 1.8 litres	
		Velpar + atrazine + 2,4-D	2.3 + 4.0 + 3.0 litres	
		2,4-D + Asulox	3.0 + 7.5 litres	
Gros meinki	<i>Digitaria horinzontalis</i>	2,4-D + Asulox	3.0 + 7.5 litres	
Herbe Mackaye	<i>Phalaris arundinacea</i>	Roundup	10 - 12 litres	
Herbe créole	<i>Paspalum conjugatum</i>	Roundup	5 - 6 litres	
Herbe bol	<i>Hydrocotyle bonariensis</i>	Escort + Wet Agent	0.05 kg + 0.25 % v/v	
Herbe panier	<i>Sida acuta</i>	Escort + Wet Agent	0.05 kg + 0.25 % v/v	
Liseron	<i>Ipomoea nil</i>	Fluroxypyr	1.5 - 2.0 l/ha	An adjuvant should be added to Tomahawk. In tank mixes with atrazine lower rates may be used
Liane lastique	<i>Ipomoea obscura</i>			
Pistache marrone	<i>Cajanus scaeabaeoides</i>			
Liane lingue	<i>Paederia foetida</i>			
Liane poc poc	<i>Passiflora suberosa</i>			
For problem weeds on field roads and fallow/abandoned land		Arsenal Gen 2	3.5 - 4.5 l/ha	An adjuvant should be added

Appendix 2

THE MAIN VINE WEEDS SPECIES OF SUGARCANE FIELDS IN MAURITIUS

The 11 species have been listed as per their historical occurrence in the fields.

Paederia foetida L. (Rubiaceae)



Passiflora suberosa L. (Passifloraceae)



Ipomoea obscura (L.) Ker Gawl.



***Mikania micrantha* Kunth (Asteraceae)**



***Cynanchum callialatum* Buch.**



***Cajanus scarabeoides* (L.) Thouars**



***Passiflora foetida* L. (Passifloraceae)**



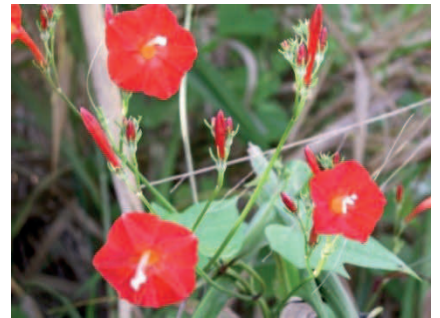
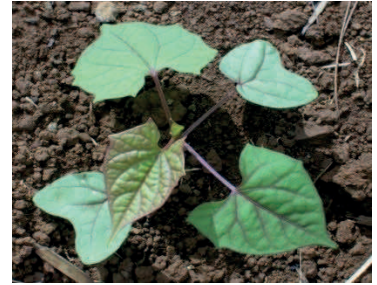
***Basella alba* L. (Basellaceae)**



***Ipomoea triloba* L. (Convolvulaceae)**



Ipomoea hederifolia L. (Convolvulaceae)



Ipomoea nil (L.) Roth (Convolvulaceae)



Appendix 3

RECOMMENDATION SHEET No: 153



MAURITIUS SUGAR INDUSTRY RESEARCH INSTITUTE Recommendation Sheet

November 2005, No. 153

Dinamic + Krismat: a new herbicide treatment for weed management strategies in sugar cane

MSIRI has been developing different weed management strategies to reduce costs of weed control in sugar cane. Studies based on critical periods of weed competition in sugar cane have shown that the first herbicide treatment after harvest could be delayed a few weeks until the emergence of the first flush of weeds. However, this approach can be implemented only if the herbicide treatment used controls all emerged weeds, provides a good residual activity and is tolerated by young cane shoots.

In this context, MSIRI has evaluated herbicides **Dinamic** and **Krismat**, which are both formulated as water-dispersible granules (WG). **Dinamic** contains 700 g of amicarbazone, whereas **Krismat** contains 18.5 g of trifloxysulfuron and 731.5 g of ametryn per kg of product.

Trial have shown that:

- both herbicides provides good pre- and post-emergence control of most broad-leaved weeds
- **Krismat** is effective against grasses such as *Paspalum* spp. (e.g. herbe cheval, herbe duvet) and sedges such as *Cyperus rotundus* (herbe à oignons) and *Kyllinga* spp. (e.g. gros and petit mota)
- **Dinamic** is particularly effective against some grasses, including *Digitaria horizontalis* (gros meinki)
- tank-mixing **Dinamic** and **Krismat** improves the spectrum of control
- both herbicides are non-volatile and are well tolerated by sugar cane at the recommended rates.

Recommendation

- The two herbicides are recommended as a tank-mix as follows:

Herbicides	Recommended rates	
	kg / ha	kg / arp
Dinamic	1.25 - 1.5	0.53 - 0.63
+	+	+
Krismat	2.0	0.84

- An adjuvant should be added to the above tank-mix
- Spraying should be carried out when weeds are relatively young
- Higher rates of **Dinamic** should be used when a longer residual activity is required.

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