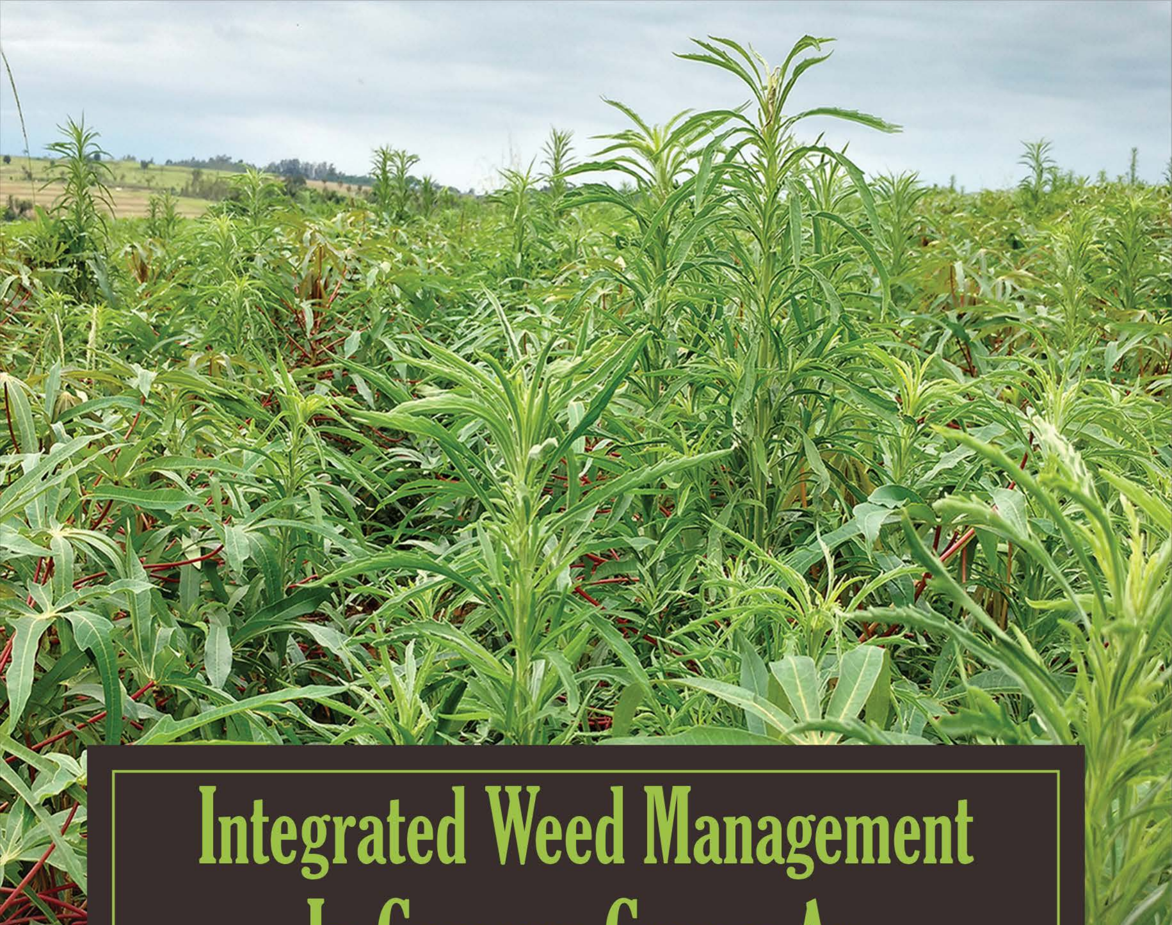

Integrated Weed Management In Cassava Crops: An Environmentally Correct Challenge

Valdemir Antonio PERESSIN
Neumárcio Vilanova da COSTA
José Eduardo Borges de CARVALHO
José Carlos FELTRAN

Agronomic Institute
Campinas (SP), 2022

São Paulo State Government
Secretariat of Agriculture and Supply
São Paulo Agribusiness Technology Agency
Agronomic Institute

Governor of São Paulo
Rodrigo Garcia

Secretary of Agriculture and Supply
Francisco Matturro

Undersecretary of Agriculture
Orlando Melo de Castro

Exective Secretary of Agriculture and Supply
Adriano Quércia Soares

São Paulo Agribusiness Technology Agency Coordinator
Sergio Luiz dos Santos Tutui

Department Technical Director of the Agronomic Institute
Marcos Guimarães de Andrade Landell

Integrated Weed Management in Cassava Crops: An Environmentally Correct Challenge

Valdemir Antonio **PERESSIN**
Neumárcio Vilanova da **COSTA**
José Eduardo Borges de **CARVALHO**
José Carlos **FELTRAN**

Agronomic Institute
Campinas (SP) 2022

File prepared by the Scientific Documentation Center of the Agronomic Institute

I61 Integrated Weed Management in Cassava Crops: An Environmentally Correct Challenge / Valdemir Antonio Peressin, Neumárcio Vilanova da Costa, José Eduardo Borges de Carvalho, et al. Campinas: Instituto Agronômico, 2022. 65p. (online)

ISBN 978-65-88414-10-1

1. Cassava. 2. Integrated Management. 3. Weeds. I. Peressin, Valdemir Antonio. II. Costa, Neumárcio Vilanova da. III. Carvalho, José Eduardo Borges de. IV. Feltran, José Carlos. V. Título.

CDD 633.495

The Authors of This Text Are Solely Responsible for its Content.

Team involved in this publication

Publishing Coordenation: Silvana Aparecida Barbosa

Desktop Publishing and Cover: Quebra-Cabeça

qcartesgraficas@terra.com.br / +55 19 99729-2463

English Translation: Giuliana Almada

Agronomic Institute

Caixa Postal 28

13012-970 Campinas (SP) - Brasil

www.iac.sp.gov.br

Table of Contents

List of Figures

List of Tables

Page

Authors

Valdemir Antonio Peressin, PhD

Scientific Researcher at the Horticulture Research Center of the Agronomic Institute (IAC) of the São Paulo's Agency of Agribusiness Technology (APTA), of the Department of Agriculture and Supply of the State of São Paulo. Dr. Peressin holds a bachelor's degree in Agronomy from São Paulo State University "Júlio de Mesquita Filho" (1984), a master's degree in Plant Science from the University of São Paulo (1991), and a doctorate in Agronomy (Plant Production) from São Paulo State University "Júlio de Mesquita Filho" (1997).

Dr. Peressin joined the IAC in 1988, where he began to devote himself to research on the integrated management of weeds in cassava crops, with emphasis on weed competition and efficiency of herbicides applied in weeds and cassava crop pre and postemergence. He also develops other research work with cassava and sweet potato crops in the areas of physiology, plant science, management and cultural treatments and fertilization. He coordinates the Sweet Potato Improvement Program which has the goal of sweet potato biofortification and collaborates in the Improvement Programs for table stock and industrial cassava at IAC.

Neumárcio Vilanova da Costa, PhD

Associate Professor at Western Paraná State University (Unioeste), Marechal Cândido Rondon campus, Paraná, Brazil. He has a bachelor's degree in Agronomy from the Federal University of Tocantins (2002), a master's and a doctorate degree in Agronomy (Agriculture) from the São

Paulo State University "Júlio de Mesquita Filho". Dr. Costa has experience in the field of Agronomy, working mainly on the following topics of Weed Science: ecology and biology, weed interference, sustainable weed management systems in areas of conventional and organic no-tillage planting, herbicide resistance, herbicide selectivity and efficiency, and pesticide application technology. He is the leader of the Western Paraná Study Group on Weed Science at Unioeste (GEMOP), and a member of the Brazilian Society of Weed Science and the Brazilian Cassava Society. He is currently a coordinator of the Agronomy Graduate Program (PPGA) of Unioeste.

José Eduardo Borges de Carvalho, PhD

Researcher at the Embrapa Cassava and Fruits.

Dr. Carvalho holds a bachelor's degree in Agronomic Engineering from the School of Agronomy of the Federal University of Bahia (1971), a master's degree in Plant Science from the Luiz de Queiroz College of Agriculture of the University of São Paulo (1976) and a PhD in Soil and Plant Nutrition from the Luiz de Queiroz College of Agriculture of the University of São Paulo (1986).

For over thirty years, he has been dedicated to research, development and innovation in soil, mulch and integrated weed management in citrus, papaya and cassava crops.

José Carlos Feltran, PhD

Scientific Researcher at the Horticulture Research Center of the Agronomic Institute (IAC) of the São Paulo's Agency of Agribusiness Technology (APTA), of the Department of Agriculture and Supply of the State of São Paulo.

Dr. Feltran holds a bachelor's degree in Agronomy from São Paulo State University "Júlio de Mesquita Filho" (1997), a master's in Agronomy (Agriculture) from São Paulo State University "Júlio de Mesquita Filho" (2002) and a PhD in Agronomy (Agriculture) from São Paulo State University "Júlio de Mesquita Filho" (2005). Since 2005 he has been a Scientific Researcher at Agronomic Institute (IAC), based in Campinas (SP). He conducts research on cassava, potato and sweet potato, in the areas of physiology, plant science, crop management and fertilization. He participates in the Program for Improvement of Potato, Sweet Potato and Cassava for table stock and industry at IAC.

ACKNOWLEDGEMENTS

The authors wish to express their most sincere acknowledgement to the following Institutions:

➢ The Horticulture Research Center of the Agronomic Institute (IAC) of the São Paulo's Agency of Agribusiness Technology (APTA), of the Department of Agriculture and Supply of the State of São Paulo and to Halotek-Fadel Industrial Ltda. for the technical-economical support, promptness and trust in our research activities;

➢ Embrapa Cassava and Fruits for their support in generating the technological assets that make up this work;

➢ Western Paraná State University (UNIOESTE) and the Technical Association of the Cassava Industries of Paraná (ATIMOP) for supporting the studies that generated these results, as well as the Coordination for the Improvement of Higher Education Personnel (CAPES)–Financing Code 001, and the National Council for Scientific and Technological Development (CNPq) for granting scholarships to the students involved in cassava crop projects;

➢ UPL Brazil for their technical-economic support, which enabled the printing of this book;

➢ APMESP–Association of Producers of Cassava and Derivatives of the State of São Paulo, for their promptness and trust in our research activities.

Foreword

Cassava (*Manihot esculenta* Crantz) is a perennial, shrubby plant that belongs to the *Euphorbiaceae* family; it is highly tolerant to drought and widely adapted to a variety of soil and climate conditions. It is native to the American continent, probably the Brazilian Amazon, where its wild varieties are found to this day. The most important part of the plant is its tuberous roots, rich in starch, used for human and animal consumption or as raw material for several industries. The potential use of the above-ground part, extremely rich in protein, is almost unlimited, which makes cassava a source of energy and protein for monogastric and ruminants.

2019 global production was 303.57 million tons, spanning approximately 27.52 million hectares, with an average yield of 11.03 tha^{-1}, quite low when compared with the average yield of the State of São Paulo—30.30 tha^{-1}. Conversely, between 1970 and 2019, global cassava production grew substantially from 98.60 to 303.57 million tons, highlighting the social and economic importance of this crop, which provides sustainable development to tropical countries.

Among the factors that can negatively affect cassava yield in fields, the presence of weeds (competition) that reflects on the agricultural economy on a permanent basis should be highlighted. Weeds cause significant damage by competing with the plant for the same water, light and nutrients, in addition to other forms of negative interference (allelopathies).

Nevertheless, many advances in integrated weed management in cassava have already been published in Brazil. This, along with the need to disseminate other research results generated by IAC, Embrapa Cassava and Fruits and UNIOESTE motivated the authors to produce this new book.

We hope that these results, most of which have been illustrated with photos, can assist in decision making for the adoption of this method of cultural treatments of cassava in the State of São Paulo, Brazil and the world. It should be noted that such information is purely technical and, in cases involving the use of pesticides, current legislation must be followed.

Besides being an important vehicle of scientific and technological education for the new generation of students in this strategic field of human knowledge, this invaluable book will also be, thanks to its easily accessible information, a powerful instrument of cultural practices for producers of cassava, the most Brazilian of foods.

José Reynaldo Bastos da Silva, PhD
APMESP–Association of Producers of Cassava
and Derivatives of the State of São Paulo

Integrated Weed Management in Cassava Crops: An Environmentally Correct Challenge

Valdemir Antonio **PERESSIN** ([1])

Neumárcio Vilanova da **COSTA** ([2])

José Eduardo Borges de **CARVALHO** ([3])

José Carlos **FELTRAN** ([1])

Introduction

Cassava is grown in many countries and across a wide swathe of the globe that spans 30 degrees of latitude North to South. In 20.19, its global production output was 303.57 million tons, covering approximately 27.52 million hectares. Brazil is the fifth largest producer in the world with 17.50 million tons of cassava roots cultivated on about 1.19 million hectares, placing it among the country's main agricultural holdings. The top five cassava producing

---

([1]) Agronomic Institute (IAC), Horticulture Research Center, Campinas (SP). valdemir.peressin@sp.gov.br

([2]) Western Paraná State University (Unioeste), Marechal Cândido Rondon (PR).

([3]) Embrapa Cassava and Fruits, Cruz das Almas (BA).

countries in the world are: Nigeria, Democratic Republic of Congo, Thailand, Republic of Ghana and Brazil, which together represent 56.11% of world production.

Cassava is a key energy food for more than 800 million people worldwide and is also the raw material for several products, such as table flour and starch. Cassava starch can be used in the food industry to make gumdrops, spreads, pies, jams, fruit preserves, sausages, bologna, sausages, canned meats, ice cream, baking powder, and even baby food. Other uses include the manufacturing of fabrics, paper, glues, paints, and even oil well drill bits, while biodegradable packaging is yet another item in the list. The starch is also used in the pharmaceutical industry.

The cassava crop is slow growing initially and has little shade capacity, which means it has a low competitive capacity against weeds, thus increasing the production cost. This is easily confirmed by the share of labor allocated to manual and mechanical hoeing for weed control, about 45% of the total cultivation cost (LORENZI & DIAS, 1993). Moreover, cassava is predominantly grown in sandy soils where erosion is more pronounced.

Thus, research into the ecology of invasive plant communities in cassava crops should be intensified, aimed at studying rational weed management systems that are efficient, economical, and have lower environmental impact. Invasive plants should be managed as companion plants, important for soil protection, managing pests and diseases, and in nutrient cycling. This would ensure environmental and even economic sustainability, given the reduction in weeding it can also provide (CARVALHO et al., 2006).

It should be noted that the issues addressed in this book intend to guide invasive plant management and control in cassava crops, aiming to lower costs without negatively affecting yields and avoiding unnecessary invasive plant control measures often applied at a greater environmental cost.

WEED INTERFERENCE IN CASSAVA CROPS

From the moment humankind began to select species and modify the environment to produce its own food in a period that marked the birth of agriculture, the need to avoid the presence of unwanted plants in coexistence with those of interest already existed. Practices adopted before initiating the exploration of an area for agricultural purposes and sowing the plant species of interest, such as removal of the original forest and soil management (soil revolving) cause a series of disturbances in the environment and stimulate the emergence of plants called "pioneers" or "colonizers" which are responsible for reestablishing environmental balance during the ecological succession process.

In general, pioneer plants are highly aggressive, characterized by a great and prolonged capacity to produce seeds that may remain viable in the soil for extended periods of time. These seeds germinate discontinuously in many environments and have special adaptations for short and long-distance dissemination. Pioneer plants tend to have rapid vegetative growth and flowering, and are self-compatible but not completely autogamous or apomictic. When allogamous, they use non-specific pollination agents or the wind; when perennial, besides vigorous vegetative reproduction and fragment regeneration, the plants should be very fragile, so as not to be easily uprooted from the ground (PITELLI, 1987). Nevertheless, since they negatively interfere with the development of crops of economic interest these plants are commonly classified as weeds.

The term “weed” should be adopted to designate any superior plant that interferes with humankind’s interests and with the environment (PITELLI, 1985). In the case of cassava crop weeds can drastically reduce plant growth and root productivity from 89% to 100% (COSTA et al., 2013; JOHANNS; CONTIERO, 2006), thus requiring the adoption of control measures.

Weed control decision-making should be based on the potential to cause damage as well as data on interference periods for optimal timing to carry it out. This information can support the development of rational weed management systems that are efficient, economical, and cause less environmental impact.

Weed Competition in Cassava Crops

Several weed species can interfere with crop development, but some are observed in greater numbers and with greater frequency in certain regions, thus being considered the most significant.

The following weed species are considered as having the highest occurrence in cassava cultivation in Brazil (Table 1).

Table 1. Weeds considered the most common in cassava crops in Brazil

a) Broadleaves – Dicotyledons (Magnoliopsidas)			b) Narrow leaves – Monocotyledons (Liliopsida)		
Code EPPO ([1])	Common name	Scientific name	Code EPPO ([1])	Common name	Scientific name
SIDSS	Sida	Sida sp.	BRADC	*Signal grass*	Urochloa decumbens
ACOSA	Marcela	*Achyrocline satureioides*	CCHEC	Southern sandbur	*Cenchrus echinatus*
AGECO	Billy goat weed	*Ageratum conyzoides*	DIGHO	Jamaican crabgrass	*Digitaria horizontalis*
RCHBR	Tropical Mexican clover	*Richardia brasiliensis*	ELEIN	Goose grass	*Eleusine indica*
GASPA	Gallant soldier	*Galinsoga parviflora*	TRCIN	Sourgrass	*Digitaria insularis*
EMISO	Red tasselflower	*Emilia sonchifolia*	PANMA	Guinea grass	*Panicum maximum*
BIDPI	Blackjack	*Bidens pilosa*	RHYRE	Rose natalgrass	*Rhynchelytrum roseum*
AMASS	Spiny amaranth	*Amaranthus sp.*	BRAPL	Creeping signalgrass	*Urochloa plantaginea*
EPHHL	Wild poinsettia	*Euphorbia heterophylla*	SORHA	Johnson grass	*Sorghum halepense*
ERIBO	Hairy fleabane	*Conyza bonariensis*	CYNDA	Bermuda grass	*Cynodon dactylon*
ACNHI	Bristly starbur	*Acanthospermum hispidum*	CYPRO	Purple nutsedge	*Cyperus rotundus*
ACNAU	Spiny-bur	*Acanthospermum australe*	CYPES	Yellow nutsedge	*Cyperus esculentus*
IPOSS	Morning glory	*Ipomoea sp.*	COMBE	Wandering jew	*Commelina benghalensis*
LEPRU	Narrow-leaf pepperwort	*Lepidium ruderale*	BRARU	Congo grass	*Urochloa ruziziensis*
RAPRA	Wild radish	*Raphanus raphanistrum*	-	-	-
PYLTE	Long-stalked phyllanthus	*Phyllanthus corcovadensis*	-	-	-

([1]) EPPO Code: European and Mediterranean Plant Protection Organization (EPPO). https://gd.eppo.int/rppo/EPPO. Accessed on 14 Sept. 2021.

The most problematic weeds for cassava cultivation are broadleaf varieties, particularly the tall morning-glory (*Ipomoea purpura*) and the wild poinsettia (*Euphorbia heterophylla*), especially in areas of more fertile soil where cassava is included in a production system with soybeans and corn being grown in rotation. In areas of pasture reform, the *Urochloa* genus is also quite problematic.

With the introduction of genetically modified soy and corn resistant to glyphosate herbicide, the various products or product combinations that were used in conventional soy and corn crops have been replaced by a single active ingredient, glyphosate. As a result, other invasive species such as wandering jew (*Commelina benghalensis*), hairy fleabane (*Conyza bonariensis*), and sourgrass (*Digitaria insularis*) have become more significant in cassava crops.

The main damages caused by these weeds can be highlighted as follows:

a) Reduction in crop yield: the coexistence of weeds and the cassava crops during the entire first vegetative cycle of the crop can lead to a production reduction of up to 98% in root weight (PERESSIN, 1997; PERESSIN et al., 1998; PERESSIN, 2013);

b) Increase in production cost: weed control in cassava crops accounts for approximately 40% of production cost;

c) Difficulty in harvesting: this difficulty is easily understood by harvest yield. When the crop is free of weeds, the yield will usually be around 1,000 to 1,500 kg/worker/day; if the crop is infested with weeds, especially *Urochloa decumbens*, the yield will hardly exceed 500 kg/worker/day;

d) Qualitative reduction of the harvested product: effects on root quality, essential mainly in table stock cassava cultivation, range from average root diameter and length reduction to perforation by purple nutsedge rhizomes (*Cyperus rotundus*), causing them not to be well-accepted in the market (Fig. 1);

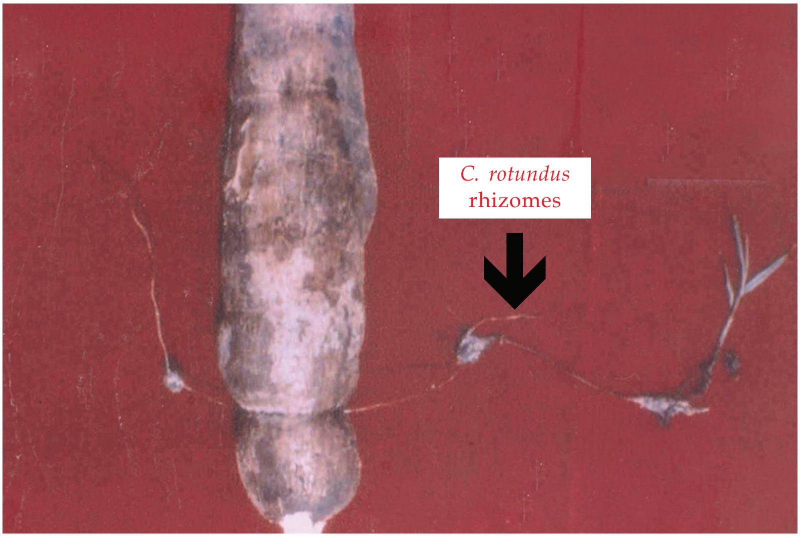

Figure 1. Qualitative reduction of the harvested product.
Source: CIAT (1982).

e) Reduction in appearance and shelf life of the harvested product: when harvesting table stock cassava, the obstruction effects caused by weed roots range from skinning of the suberous layer of cassava roots (Fig. 2) to their breakage. Such effects invariably result in a shorter shelf life of the harvested product. This damage accelerates the process of root pulp deterioration, whether microbial or physiological (Fig. 3);

f) Damage to the planting material (stem cuttings): in areas heavily infested with purple nutsedge (*Cyperus rotundus*), cassava stem cuttings may get punctured by the weed's rhizomes (Fig. 4);

Figure 2. Reduction in appearance and shelf life of the harvested product (skinning of roots' suberous layers in areas with high weed infestation at harvest time).
Photo: Peressin, V. A.

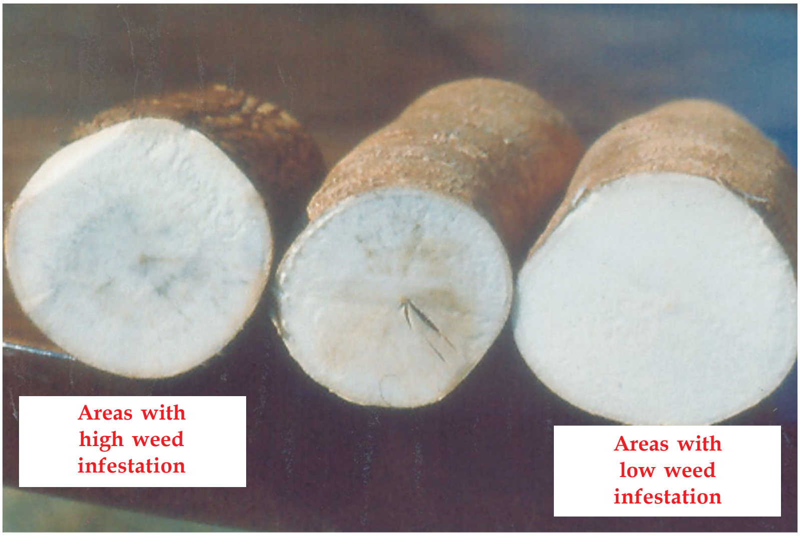

Figure 3. Reduction in appearance and shelf life of the harvested product due to the acceleration of root pulp deterioration processes in areas with high weed infestation at harvest time.
Photo: Peressin, V. A.

g) Pest and disease hosting: some weed species may serve as food for major cassava pests such as ello sphinx and mealybugs (Fig. 5, A and B), and also as inoculum for diseases (Fig. 6).

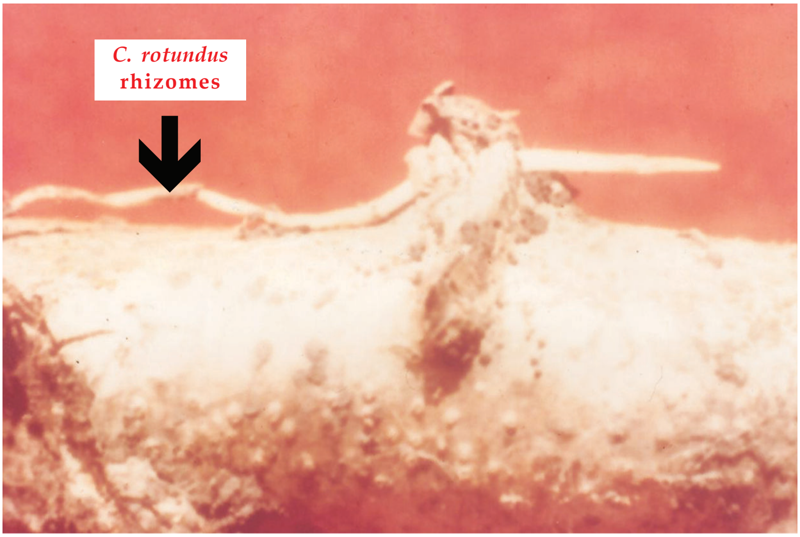

Figure 4. Damage to the planting material.
Source: CIAT (1982).

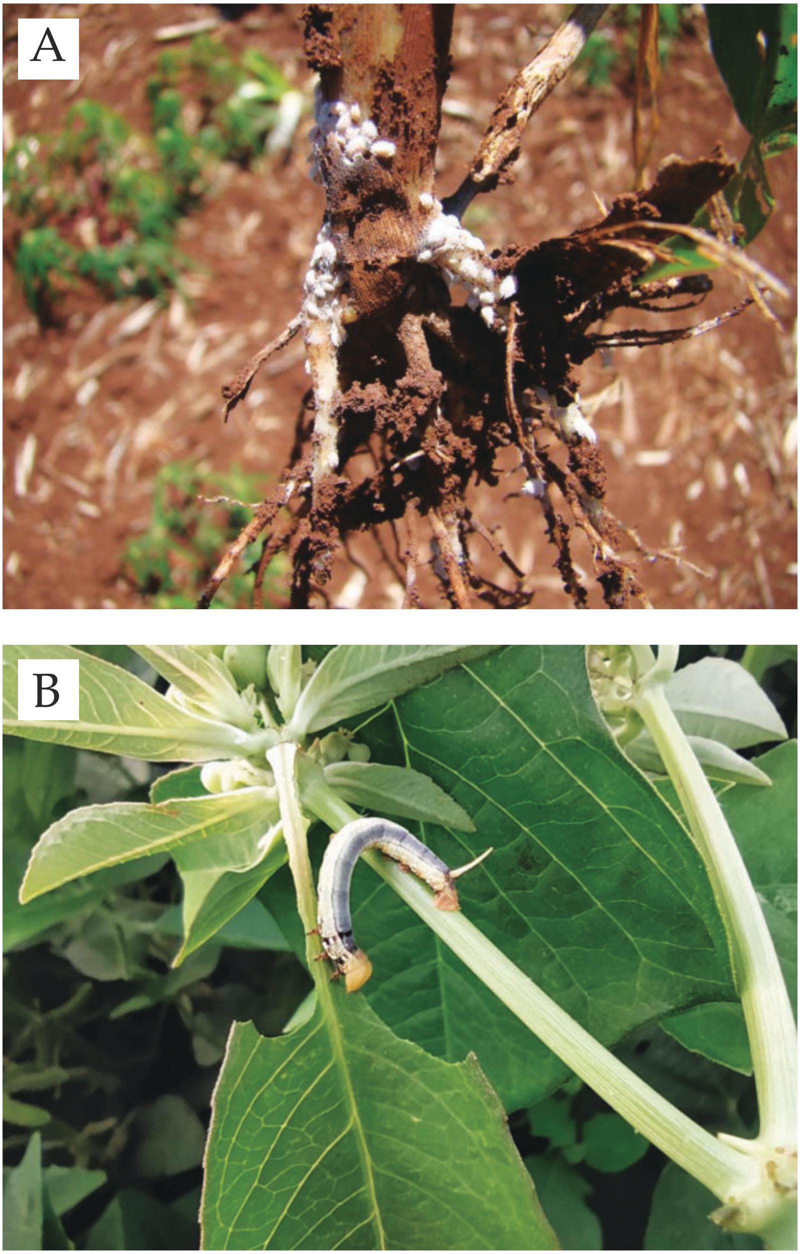

Figure 5. Weed pest host plants. Mealybug (*Dysmicoccus sp.*) on Johnson grass (*Sorghum halepense*) plants (A). Ello sphinx (*Erinnyis ello*) on wild poinsettia (*Euphorbia heterophylla*) plants (B).
Photo: Pietrowski, V.

Figure 6. Wild poinsettia (*Euphorbia heterophylla*) plants with symptoms of Cassava Common Mosaic Virus-CsCMV in cassava production areas in the presence of the viral disease vector (silverleaf whitefly) (A). Symptoms of the viral disease in cassava plants (B).
Photo: Costa, N. V.

Periods of control and crop coexistence with weeds

The degree of competition between crop and weed communities can be influenced by factors linked to the weed community (species, density and distribution), factors linked to the crop itself (spacing, density, cultivar and cycle length), and the timing and period length in which both coexist in their common environment. In addition, edaphoclimatic conditions and the cultural treatments that are employed can alter the degree of interference.

These negative effects are easily observed in studies of control periods and crop/invasive community coexistence. There are in fact three periods of weed control and coexistence with crops.

Among research on biotic interactions between invasive communities and crops, studies concerning the prevention period of invasive community interference on crop yield are of particular interest. The most frequently conducted research is in the time period following emergence or planting (or sowing) in which the crop should be kept clear of the invasive community to prevent invasive plants that germinate thereafter from interfering with the cultivated plant, as this could significantly reduce its economic yield. In practice, this is the period in which manual and/or mechanical hoeing or the residual power of herbicides should be employed. Pitelli and Durigan (1984) refer to this period as the total interference prevention period (PTPI).

The second type of period studied essentially aims to determine the time, from planting or emergence, during which the crop can coexist with the invasive community before interference occurs causing damage to the cultivated species' yield. This type of study aims to provide guidance on the appropriate time for the beginning of invasive plant control operations in postemergence. This period is designated by Pitelli and Durigan (1984) as the pre-interference period (PAI), whose length also depends on the manifestation of the various factors mentioned above.

However, we will focus on just one of the periods—the critical weed interference prevention period (CPWC) in cassava crops, which basically means controlling the invasive community immediately before resource competition ensues and extending control up to a point when later emerging weeds no longer compete with crops.

A typical case, although it can be more comprehensive, is that which occurs in the State of São Paulo where cassava can be harvested in one or two vegetative cycles. In turn, the second vegetative cycle can be carried out with or without drastic pruning during the physiological dormancy period that follows the end of the first vegetative cycle. Conversely, the planting period is very long (May to October) and can be divided in two: from May to August (the dry and cold planting period), and from September to October (the rainy and hot planting period).

When the crop is grown for two vegetative cycles (18-24 months), which is more common throughout the South-Central of Brazil, it enters physiological dormancy in between the two cycles. This phase is characterized by leaf fall and reduced plant metabolic activity, and its duration depends mainly on environmental conditions (Fig. 7). It is during this period that weed infestation begins in the second cycle (Fig. 8).

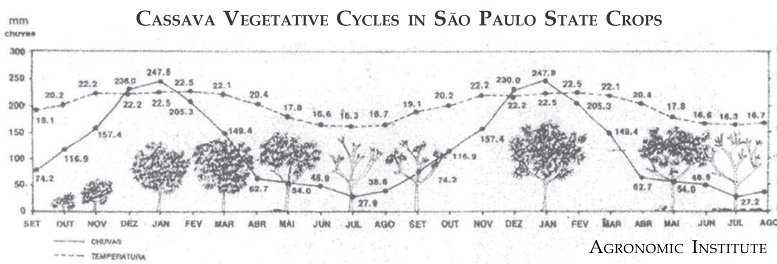

Figure 7. Schematic representation of the two vegetative crop cycles in the State of São Paulo.
Source: Lorenzi, J. O. e Dias, C. A. C. (1993).

Figure 8. Beginning period of weed infestation in the second cycle.
Photo: Lorenzi, J. O.

Drastic plant pruning has been the artifice used by most growers to facilitate weed control in the second vegetative cycle (Fig. 9). Invasive plant control in the second cycle is necessary not only due to the probable damage they may cause to the crop, but also to facilitate other cultural practices and harvesting. Without the aid of pruning, it is very difficult and costly to carry out the hoeing or chemical weed control, given the difficulty in penetrating the crop.

Figure 9. Drastic plant pruning.
Photo: Lorenzi, J. O.

CRITICAL PERIOD OF WEED CONTROL IN THE FIRST CASSAVA CROP CYCLE

Studies carried out in the State of São Paulo show that the degree of interference can be altered by weather conditions. Figure 10 shows the effects of increasing periods without weed control (Days with Weeds) and with weed control (Days without Weeds) on cassava yield in the two main planting periods: May to August (early planting or planting in the dry and cold period) and September to October (planting at the beginning of the hot and rainy period).

Under these conditions, plant behavior is totally different: in the dry and cold planting period (Fig. 10A), emergence of the cassava plants occurs slowly, with the establishment of the stand from 45 to 60 days after planting; in the rainy and hot planting period (Fig. 10B), sprouting and emergence of the cassava plants occurs faster, as the stand is established from 15 to 30 days after planting.

There are several advantages to planting in the dry and cold period, particularly the lower invasive plant incidence and growth rates when compared to planting in the hot and rainy period. The critical period for weed control in cassava in the dry and cold planting period is between 70 and 160 days after planting (Fig. 10A).

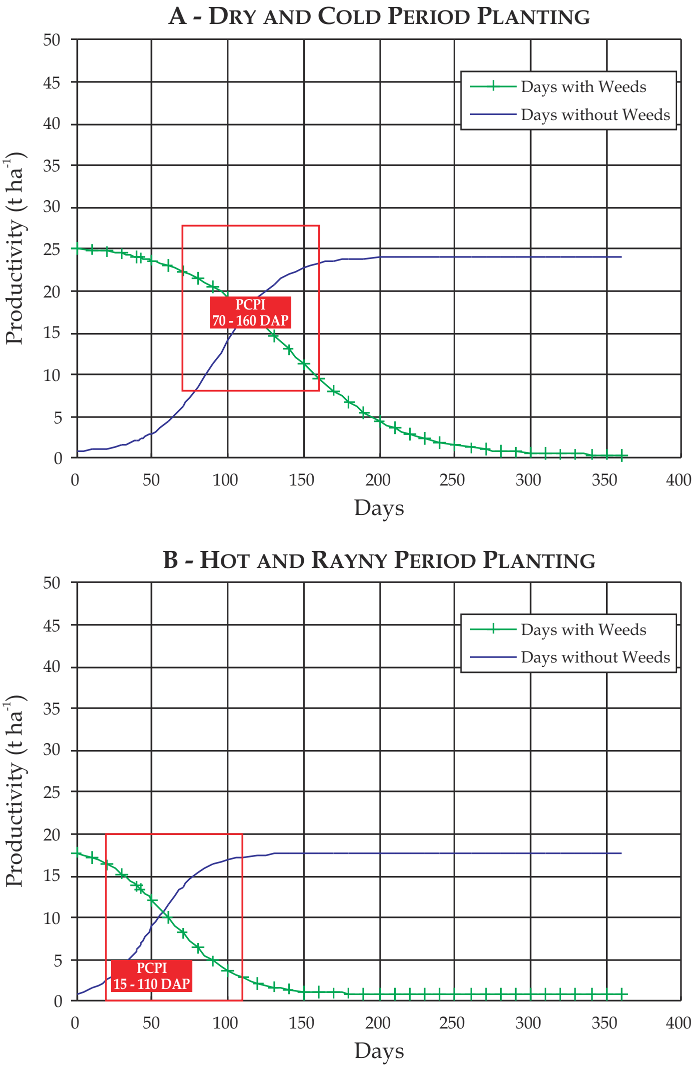

Figure 10. Weed competition in the first cassava crop cycle. Source: Adapted from Peressin, V. A. (2013).

Weather conditions in the rainy and hot period are more favorable for the sprouting of cassava stem cuttings/seeds than in the dry and cold period. It is worth noting that favorable conditions for the emergence of cassava plants are also favorable for the emergence of invasive plants. Therefore, generally speaking, the emergence of the crop and the invasive communities occur simultaneously at that time, which suggests greater weed aggressiveness in competition with the crop.

The data from these studies suggest that the critical period for cassava crop weed control in the rainy and hot planting season is between 15 and 110 days after planting (Fig. 10B).

Other research has also determined the different periods of coexistence and culture control with the invasive community (Table 2).

Table 2. Pre-interference Period (PAI), Total Interference Prevention Periods (PTPI), and Critical Weed Interference Prevention Period (CPWC) of weeds in the first cassava crop cycle

Author	Days after planting or cassava plants emergence		
	PAI	PTPI	CPWC
Alcântara et al. (1982)	0 - 60	0 - 120	60 - 120
Albuquerque et al. (2008, 2012)	0 - 25	0 - 75	25 - 75
Carvalho et al. (1993, 2004 e 2006)	0 - 30	0 – 150	30 - 150
Bife et al. (2010)	0 - 18	0 - 100	18 - 100
Costa et al. (2013)	0 - 87	0 - 80	-
Peressin (2013)	0 - 15	0 - 110	15 - 110
Peressin (2013)	0 - 70	0 - 160	70 - 160

This knowledge allows producers better use of available resources, consequently reducing production costs and avoiding expenses with unnecessary hoeing.

Critical period of weed control in the second cassava crop cycle

When the crop is grown for two vegetative cycles (18-24 months), which is more common, it enters physiological dormancy in between the two cycles. This phase is characterized by leaf fall and reduced plant metabolic activity, and its duration depends mainly on environmental conditions. In the conditions of the State of São Paulo, the leaves may fall off completely during the coldest and driest period of the year (Fig. 7 and 8).

At the beginning of the second vegetative cycle the cassava plants begin to sprout. This sprouting occurs with the utilization of the reserves accumulated in the stems and roots. Conversely, between the first and second cycle, from nine to twelve months of age (depending on the planting period), traditional drastic pruning is often carried out (Fig. 9) either to facilitate crop care, especially invasive plant control, or when there is a wish to use the aboveground portion for further planting. There are, however, producers who believe that pruning increases root production. This subject is still contentious in the scientific field, as there have been controversial findings on the practice of pruning in root production. At times research results show an increase although at others the results show a decrease in root production due to pruning.

Other authors also believe that pruning can be used to prevent frost damage and reduce the inoculum source of pests and diseases (ANDRADE et al., 2011;

TAKAHASHI, 1998). An unpublished work entitled "Aspectos agronômicos da cultura da cassava" [Agronomic aspects of cassava crops], published by Agronomic Institute (IAC) in 1950, summarized 15 years of research presenting the most diverse aspects of cassava production technology (NORMANHA & PEREIRA, 1950). Thus, following the pruning of cassava plant branches (Fig. 9), weed interference can hinder the new cycle of crop development. Although cassava has two crop cycles, there is little information about the periods of weed interference in the second cycle of crop development.

Peressin's (1997) studies in this area found that it was not possible to establish a critical period for weed control in the second cassava vegetative cycle, but it was possible to determine two other periods: 1) Pre-Interference Periods (PAI); 2) Total Interference Prevention Periods (PTPI).

The Pre-Interference Periods (PAI) in the second cassava crop cycle are those that follow the drastic pruning, or the leaf fall and metabolic activity reduction phase (Fig. 8), when the crop can coexist with the invasive community before interference is able to impair crop yield. In two experiments held in the State of São Paulo, the effect of pruning was not observed, indicating that the Pre-Interference Periods (PAI) were the same in treatments carried out with and without drastic pruning (PERESSIN, 1997).

In the first and second experiments, the Pre-Interference Periods (PAI) for root yield were 30 and 60 days after the treatments, respectively.

The Total Interference Prevention Periods (PTPI) in the second cassava crop cycle are those that follow the drastic pruning, or the leaf fall and metabolic activity reduction phase (Fig. 7).

The crop should be kept clear from invasive community presence, so that the invasive plants that germinate after this period no longer interfere and hinder the crop's yield. In two experiments carried out in the State of São Paulo, the effect of pruning was not observed, indicating that the Total Interference Prevention Periods (PTPI) were the same in the treatments both with and without drastic pruning (PERESSIN, 1997). In the first and second experiments, the Total Interference Prevention Periods (PTPI) for root yield were 30 and 30 days after the treatments, respectively.

Main Weed Control Methods in Cassava Crops

Weed control includes all practices by which weed infestations are reduced but not necessarily eliminated. The degree to which weeds can be controlled depends on the characteristics involved and the effectiveness of the control methods used. From the emergence of agricultural activity until the mid-20th century, ploughing and hoeing were the only means of weed control, although other methods such as fire, flooding, mulching, and crop rotation were of some importance at that time.

As in other crops, there are various options for weed control in cassava. The search for cultural weed control methods, such as the selection of vigorous genotypes with highly competitive ability; dense population planting; the use of dead or live mulches; no-tillage planting; double-row planting; and intercropping has intensified. Mechanical systems such as manual hoeing, animal-drawn or mechanized cultivators, and even hand weeding have also been used in weed control. Nevertheless, chemical control has increased in recent years.

In 1988, there were only 3 herbicide formulations registered for use in Brazilian cassava crops. At present, there are 82 (Source: http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Accessed on 14 Oct. 2021).

Chemical control is gaining increased importance mainly due to a growing shortage of rural labor. In general, all these systems have been used in an integrated way for weed control in cassava crops. The greater or lesser degree of adoption of any of the practices in particular depends, above all, on the labor and capital available to farmers.

Cultural weed control in cassava crops

Cultural weed control includes all agricultural practices that, if efficiently managed, ensure vigorous growth of the main crop so that it can advantageously compete with weeds. Practices that contribute to good crop establishment and development, such as the selection of well-adapted varieties; the use of good quality stem cuttings; and correct planting density will provide significant cultural weed control.

Cultural weed control in cassava crops is difficult, especially during a crop's first stage of development, given that the initial growth of a cassava plant is very slow. Nevertheless, some cultural weed control measures will be addressed below.

Planting material quality

Stem selection is one of the most important aspects for a successful crop, since it determines the initial vigor of the cassava plant. In many cases it is even more important than the variety. This is the reason for the saying: "A good stem from a bad variety is better than a bad stem from a good variety".

Good stem health is fundamental for its use as planting material. The plot that will provide the stems for planting should be chosen through periodic inspections, especially from December to February, the best time to evaluate its health.

Healthy, mature stems of good diameter, generally between 8 and 12 months of age, should be chosen from the middle and lower thirds of the plant where the leaves have already fallen. Due to their thickness, the accumulated nutrient reserves will most likely ensure the best sprouting and survival rates for the plant.

Cuttings are "pieces" of stems (planting material) and should be cut at an angle perpendicular to the length of the stem, about 20 cm long, with 2 to 3 cm in diameter and 5 to 7 buds.

These practices ensure high quality and good initial vigor and can have a favorable effect on weed competition.

Planting depth

In Brazil it is common to plant cassava cuttings in a horizontal position. In this case planting should be done at a shallow depth, namely from 5 to a maximum of 10 cm. This practice results in faster sprouting of the cuttings, for it is at this depth that the best aeration conditions for root formation are found.

Planting density

In a completely weed-free field a crop can make maximum use of the nutrients in the soil, as well as the available water and light. Under these conditions a low plant population can yield as much as a larger population. Logically, this low plant population will depend on the size and branching habit of the cultivar.

In contrast, when there is a high weed population in a given area, higher crop populations are better able to compete with the weeds than the lower ones.

NO-TILLAGE, CROP ROTATION, AND COVER MANAGEMENT

Crop cover management and no-tillage planting contribute to more environmentally correct weed control and soil protection, nutrient cycling, a gradual increase of soil organic matter and consequent carbon sequestration, and mitigation of greenhouse gas emissions. Besides aiding in the management of resistance, it also reduces the seed bank in the soil, enabling planting without weeds and spacing variation. This is where double-row planting comes into play, as it further facilitates crop control, the use of cover crops, and no-tillage planting. This is done in pasture renewal in the South-Central of Brazil, where the desiccation of the perennial grasses is carried out with no-tillage cassava planting (Fig. 11).

Integrating weed management strategies is essential to reduce the emergence of difficult-to-control weed species, whether or not they are tolerant of herbicides. The use of cover crops is one of the essential tools in integrated weed management.

Weed-free planting allowed by good cover crop management prior to cassava planting provides a competitive advantage for crops due to reduced weed infestation.

Figure 11. No-tillage single-row cassava planting after signal grass (*Urochloa decumbens*) desiccation in pasture renewal.
Photo: Carvalho, J. E.

In South-Central Brazil a fall-winter cassava crop cover may be grown from late March to June using radish (*Raphanus sativus*), black oat (*Avena strigosa*), and a mixture of black oat (*Avena strigosa*) and grass pea (*Lathynus sativus*) for example, mainly to reduce the population of hairy fleabane (*Conyza bonariensis*), sourgrass (*Digitaria insularis*), and Italian ryegrass (*Lolium multiflorum*). Then, the cassava is introduced in the weed-free soil in July/August under the no-tillage system. This practice promotes easier weed control, reduced infestation, smaller plants due to the straw effect, and decreased use of herbicides.

Another perfectly feasible alternative is rotation with off-season corn, preferably intercropped with Congo grass (*Urochloa ruziziensis*). This is because off-season corn, in a good rainy year, is planted in January and harvested between May and June, and cassava can be planted from July/August in the no-tillage system. After the corn harvest, mulch the straw and desiccate the Congo grass (*Urochloa ruziziensis*) for cassava planting.

The mulch from off-season corn and Congo grass (*Urochloa ruziziensis*) also plays a role in the weed-free planting system because of the physical effect it has on germination, emergence, and development of weeds through shading. This is especially true for positive photoblastic species (seeds that depend on light to germinate) and also by suppressing the growth of volunteer plants, giving rise to smaller plants, facilitating chemical control and helping in resistance management. Weeds that grow in the straw mulch have less leaf waxiness due to the shading, thus facilitating herbicide penetration to control troublesome weeds such as hairy fleabane (*Conyza bonariensis*) and sourgrass (*Digitaria insularis*) in South-Central Brazil. The mulch also acts by chemically controlling weeds through the release of compounds (allelochemicals), which is known as allelopathy, in an interaction between the donating plant (mulch) and the receiving plants that are intended to be controlled.

Thus, planting and soil preparation alternatives emerge, such as minimum cultivation and cover management (mulch management/no-tillage). In these systems weeds are controlled by herbicides, mulch, vigorous cover crops, or a combination of these methods.

Findings show that the no-tillage system is an excellent alternative for cassava cultivation as it renders the production system more sustainable. The formation and maintenance of topsoil mulch is one of the main factors for a successful no-tillage system and minimum or reduced tillage.

The double-row planting system enables even more integrated weed control by combining chemical, mechanical, and cultural control methods. Cultural weed control is enhanced in this system, both by the speedy soil coverage of the area between the two single rows of cassava—due to the reduced spacing—and by the closing of the double rows caused by intercropping, which are usually faster growing than cassava. Thus, the dependence on labor for mechanical control and/or herbicide costs is potentially reduced (Fig. 12).

No-tillage double-row cassava planting in previously worked areas

Crop rotation with soybeans (*Glycine max*), off-season corn (*Zea mays*), or even Congo grass (*Urochloa ruziziensis*) in the total planting area as a waiting crop, minimum tillage desiccating the grass only in the strips where the crop lines will be in double rows (3.0 m x 0.50 m x 0.50 m) and plant the cassava around 30 days later. Then, and if necessary, apply pre and postemergence herbicide just on the cassava planting lines in double rows. After planting the cassava, begin the introduction of Congo grass (*Urochloa ruziziensis*) between the double rows using the central and lateral brush-cutting strategy. After seed production, the space between the double rows should be mowed to enrich the seed bank in the soil, which increasingly ensures this cover's perenniality.

This alternative also allows for alternate cultivation in the same planting area every two cassava cycles in pursuit of good soil development, improving its physical, chemical, and biological attributes. Thus, the Congo grass (*Urochloa ruziziensis*) takes the cassava's place where the latter had been grown for two consecutive cycles. The next turn of cassava planting is then carried out no-tillage in the Congo grass' (*Urochloa ruziziensis*) straw mulch.

When managing vegetation cover in the spaces between the double rows, as well as when planting an intercrop, a distance of 0.80 m from the cassava planting line must be maintained to avoid competition for water and nutrients. This measure of weed control can also be applied by producers who carry out winter pruning of cassava for second-cycle harvest, either due to the need for cuttings/seeds or to achieve greater yield. Thus, planting cassava in the double row system will contribute to reducing the control cost in this second cycle by managing the perennial grass cover between the spacing of the double rows, preventing the emergence of spontaneous plants therein, and producing green biomass for mulch formation in the spacing between the double rows. As a management strategy central and lateral brush cutters are used, which will aid weed control with glyphosate herbicide applied to the planting lines right after pruning.

As a last alternative for integrated weed management, if the cassava grower does not opt for minimum tillage, no-tillage, cover cropping, and intercropping in the double-row planting system, he or she can apply preemergence herbicide only in the planting rows and in the space between the double rows to manage the spontaneous vegetation (Fig. 12).

OTHER CONSIDERATIONS

Crop rotation is a cultural method used to prevent the emergence of high populations of certain weed species adapted to a particular crop. When the same cultivation practices are applied repeatedly, year after year on the same soil, the weed-crop association tends to multiply rapidly, increasing its interference on the crop.

Figure 12. Mechanical weed control between double rows and chemical control in planting lines.
Photo: Sousa, D. H. S.

Green cover crops, such as jack bean (*Canavalia ensiformis*), are usually very competitive with weeds. The main objective of these covers is to improve the physical and chemical properties of the soil. Many of these plants have great inhibitory power over certain invasive plant species and can form a mulch over the soil.

Nevertheless, there is no point in using the aforementioned cultural practices without good soil preparation for planting, adequate soil fertility for the nutritional requirements of the cassava crop, the use of cultivars well-adapted to the region, and timely planting under ideal conditions, especially regarding soil moisture.

MECHANICAL WEED CONTROL IN CASSAVA CROPS

Soil plowing for planting, especially in newly cleared areas, is considered a primary mechanical measure for weed control. With soil inversion, especially when moldboard plows are used, many seeds that had been deposited on the soil surface get buried and some of them die. The survival of many of these seeds is due to numerous and complex mechanisms of propagule dormancy (both vegetative and of the seeds themselves); resistance to soil decomposers; great discontinuity in germination and seedling emergence; and the ability to germinate and emerge from deeper soil layers. In addition, it is interesting to note that with successive years of plowing and harrowing in areas that have been cultivated for several years, there is a uniformity in seed distribution throughout the profile of the arable layer. Thus, plowing in intensively cultivated soils is no longer considered a highly efficient weed control technique.

In the specific case of cassava crop in rotation with depleted pastures (pastures that have gone without soil mobilization for 10 years), soil inversion buries a large number of seeds. This process places the seeds at a depth where they do not germinate during the cassava growing cycle, thus becoming a very interesting method of mechanical weed control in cassava crops in this case.

Mechanical weed control methods include but are not limited to manual weed control and cultivation which will be described below.

Manual control

Manual weed control in cassava crops is a practical and efficient method of eliminating weeds in places where it is difficult or impossible to use another method, especially in the case of annual or biannual weeds, since they do not usually recover from root fragments that may be left in the soil. Conversely, when perennial weeds are present, manual control usually leaves root or rhizome remnants in the soil, which can resprout.

Among the manual control methods used in cassava crops, hand weeding and manual hoeing should be highlighted. Hand weeding or pulling is the oldest method of weed control. In the cassava crop, this method is mainly used to remove weeds between the cassava plants in the crop rows, where it is more difficult to reach with a hoe. Manual weeding by hoeing is a highly effective method of weed control and is still widely used in cassava cultivation. Nevertheless, manual weeding is no longer a widely employed control method in large-scale commercial crops due to the increasing cost of manual labor. Despite this, it is still widely used by small producers in the final stages of crop development in places where subsistence farming predominates, and as a complement to other control techniques.

Cultivation

Animal or tractor-drawn cultivation implements are methods of combating annual, biannual, and perennial weeds with the use of plows, harrows, and cultivators. The use of implements such as plows and harrows has been discussed above; therefore, this section will focus on cultivators equipped with pointed or long-wing sweeps, which are widely used in cassava farming, be they animal or tractor-drawn. Control using this type of equipment is obtained by: 1) disruption of the intimate soil-root relationship and the consequent suspension of water uptake; 2) burial of small plants and consequent death by suffocation; 3) severing of the plants below their growth buds.

Annual weeds are easily controlled by mechanical cultivation, which is most effective under warm and moderately dry soil conditions. In wet soils, or if rain occurs soon after cultivation, their roots can quickly re-establish, impairing or even rendering the operation useless.

In the case of seedlings of annual or perennial plants derived from seeds, cultivation is intended to dislodge them from their intimate contact with the soil, either killing the plant or delaying its initial growth and thereby favoring the crop's settlement. Hence, the cultivation must be introduced in a timely manner, for any delay may decrease efficiency as plants could have accumulated enough reserves to survive the cultural treatment's impact and quickly regrow.

Thus, control of the invasive community by means of cultivation in cassava crops should start as soon as crop development begins. Cultivation can be carried out at different stages of crop development up to the stage that precedes the total shading of the area by the crop. Initially, cultivation is carried out throughout most of the extension between the crop rows; however, with the development of the cassava plants, cultivation is restricted to the central region, due to the beginning of the cassava tuberization process.

Chemical weed control in cassava crops [1]

The chemical method of weed control is carried out with the use of synthetic products called herbicides. Herbicides are compounds that, when applied to plants, react with their morphological constituents or interfere with their biochemical systems, promoting morphological or physiological effects of varying degrees, and may lead to their partial or total death.

Also, herbicide selectivity is known to be relative due to the interactions established between herbicide formulations and several other factors such as dosage, time of application, soil type, and environmental conditions, among others. In fact, in a more comprehensive manner, it can be said that selectivity is a function of selectivity factors linked to plants; selectivity factors linked to herbicides; selectivity factors linked to the environment; interactions between products affecting selectivity, and possible interactions between factors linked to selectivity.

In chemical control, it is important to use all available scientific knowledge to allow for the correct placement of the necessary amount of biologically active product on its target, in an economical manner, and with minimum contamination of other areas (MATUO, 1990).

Chemical weed control in cassava crops has already been extensively addressed by the authors of this book (PERESSIN & CARVALHO, 2002; CARVALHO et al., 2006; PERESSIN, 2013; PERESSIN, et al., 2015; PERESSIN, 2020; PERESSIN, 2021).

[1] The information contained in this item is purely technical in terms of the selectivity and agronomic efficiency of the different herbicides. Legislation in force must be followed when using pesticides, that is, the recommendation and application of pesticides must be prescribed in an agronomic recipe by a duly qualified specialist.

CHEMICAL WEED CONTROL IN THE FIRST CASSAVA CROP CYCLE

Herbicides can be used at various stages of crop and weed development (DEUBER, 2003). In the specific case of cassava, they can be classified according to the time of application in:

A) HERBICIDES FOR PRE-PLANTING APPLICATION

These are herbicides applied before planting, intended to reduce the weed population in the cultivation area. A common example is the use of glyphosate in postemergence before soil preparation throughout the area to control *Urochloa decumbens* when the cassava crop is rotated with pastures. Such application can also be done with subsequent cassava planting in the no-tillage system (Fig. 13).

Figure 13. Effects of applying 1,440 g e.a. ha^{-1} of glyphosate for signal grass (*Urochloa decumbens*) control in weed postemergence and before crop planting. Detail of the area with subsequent planting in the no-tillage system.
Photo: Takahashi, M.

Glyphosate can also be used in the same rotation system in the form of "scavenging", when, after soil preparation, the emergence of *Urochloa decumbens*, plants concentrated in small regions of the total prepared area occurs and coming mainly from vegetative plant parts which resisted the soil preparation methods used. This process can also be done in the case of perennial weed infestation, e.g., Bermuda grass (*Cynodon dactylon*), sourgrass (*Digitaria insularis*), itch grass (*Rottboellia exaltata*), Guinea grass (*Panicum maximum*), etc.

B) Herbicides for preemergence application

Are those applied before crop and/or weed emergence.

B-1) Herbicides for crop preemergence and (early) weed postemergence application

These are herbicides applied after planting before crop emergence, but after weed emergence.

Weed emergence prior to the crop's, at sometimes prolonged intervals, occurs quite frequently in cassava plots in Brazil's South-Central region, especially when planting during the cooler and drier periods of the year from May to August.

Thus, when the planting area has already been prepared but the crop cannot be planted due to low soil moisture, one may wait for the rain to do so without, however, conducting additional soil preparation, especially if the goal is to control weeds that emerge during this period. Consequently, the invasive community will emerge earlier than the crop (Fig. 14A), requiring herbicide application to control the emerged weeds. For this type of application, formulations of the herbicide flumioxazin are recommended, which has a residual effect (Fig. 14B). As per the manufacturer's recommendation: for cassava, the application should be made at weed preemergence after planting the stem cuttings. If weed emergence occurs and the cassava crop is not yet emerged, we recommend adding 0.5% adjuvant or mineral oil to the solution (https://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Accessed on 14 Oct. 2021).

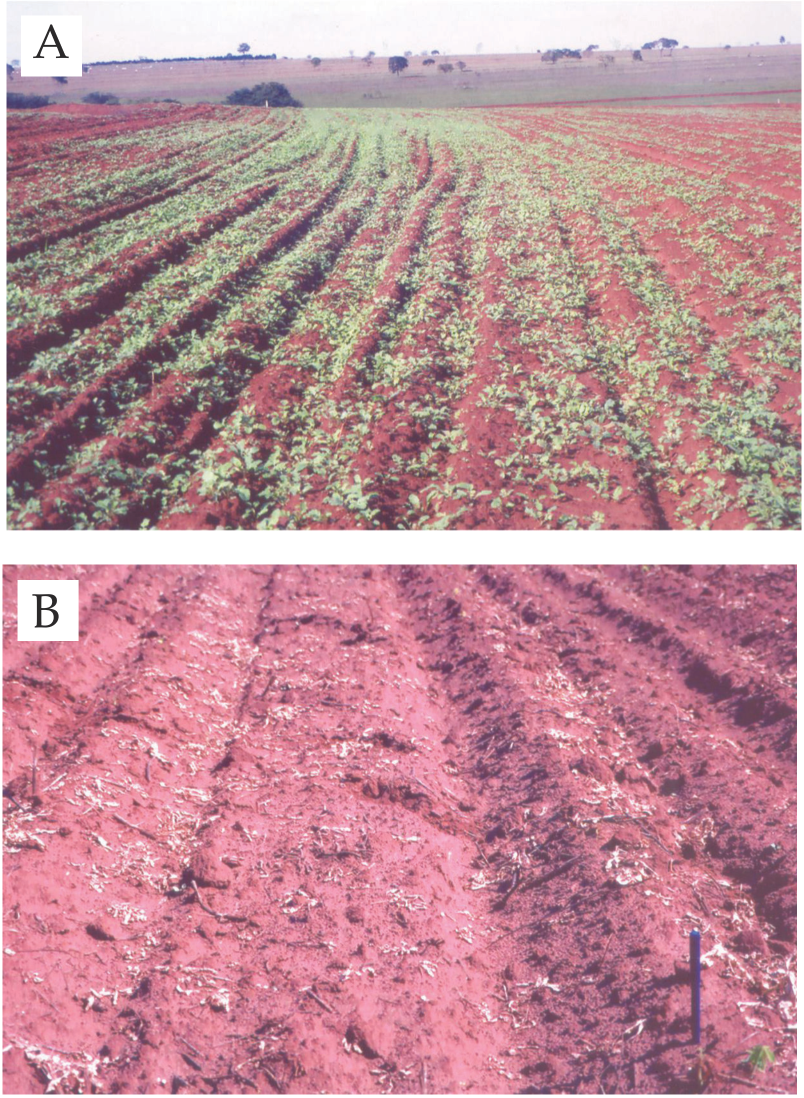

Figure 14. Effects of applying herbicides in crop preemergence and weed (early) postemergence. (A) Before application, (B) After application. Photo: Peressin, V. A.

Regardless of the above condition, when weeds emerge before the crop the use of herbicides—in effect, powders—is very advantageous in invasive plant control, also associated with a residual power effect. However, for decades, tank mixing could not be recommended by technicians who issue pesticide prescriptions, but it was used in almost all applications which polemicized the issue (GAZZIERO et al., 2021). Since the creation of "Instrução Normativa no. 40" [Normative Instruction no. 40] of 11 October 2018 (BRASIL, 2018; MAPA, 2018), tank mixing has been regulated and allowed in agronomic prescriptions, provided it is signed by an agronomist.

B-2) Herbicides for crop and weed preemergence application

Are those applied after planting the crop and before the emergence of the crop and weeds. Through experiments in this area, numerous herbicide formulations have been evaluated, among which we discuss those that were selective to the crop, emphasizing the active ingredients that have herbicide formulations registered for cassava crops in Brazil.

The treatment groups shown in figure 15—without weed control—and in figure 16—in the absence of weeds—are from an experimental area with mainly two occurrent invasive species: 1) Jamaican crabgrass (*Digitaria horizontalis*) and 2) tropical Mexican clover (*Richardia brasiliensis*). The control of Jamaican crabgrass was observed to be very efficient in the isolated applications of 1,000 g ha^{-1} of clomazone (Fig. 17) and in the tank mix applications with 480 g ha^{-1} of metribuzin (Fig. 18). The control of tropical Mexican clover, however, was only efficient in the treatment in which the tank mixture with metribuzin was used (Fig. 17 and 18).

Figure 15. Treatment group without weed control at 33 DAA.
Photo: Peressin, V. A.

Figure 16. Treatment group with weed control at 33 DAA.
Photo: Peressin, V. A.

Figure 17. Effects of applying 1,000 g ha^{-1} of clomazone[2] for Jamaican crabgrass (*Digitaria horizontalis*) and tropical Mexican clover (*Richardia brasiliensis*) control in weed preemergence, at 33 DAA.
Photo: Peressin, V. A.

Figure 18. Effects of applying 1,000 g ha^{-1} of clomazone tank-mixed with 480 g ha^{-1} of metribuzin[3] for Jamaican crabgrass (*Digitaria horizontalis*) and tropical Mexican clover (*Richardia brasiliensis*) control in weed and crop preemergence, at 33 DAA.
Photo: Peressin, V. A.

---

[2] Commercial formulation used: Gamit
[3] Commercial formulation used: Sencor 480

The treatment groups shown in figure 19—without weed control—and in figure 20—with weed control—are from an experimental area with a single predominantly occurrent invasive species: signal grass (*Urochloa decumbens*). The control of signal grass, evaluated at 33 days after herbicide application (DAA), was observed to be very efficient in applications of 1,000 g ha^{-1} of clomazone in a tank mixture with 480 g ha^{-1} of metribuzin (Fig. 21) and poor in isolated applications of 1,000 g ha^{-1} of clomazone. Other experiments show that the control of signal grass evaluated at 51 days after herbicide application (DAA) was poor in the isolated applications of 1,000 g ha^{-1} of clomazone and reasonable in the isolated applications of the formulated mixture[4] consisting of 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn.

Figure 19. Treatment group without weed control at 33 DAA.
Photo: Peressin, V. A.

[4] Commercial formulation used: SINERGE EC

Figure 20. Treatment group with weed control 33 DAA.
Photo: Peressin, V. A.

Figure 21. Effects of applying 1,000 g ha^{-1} of clomazone tank-mixed with 480 g ha^{-1} of metribuzin, for signal grass (*Brachiaria decumbens*) control in weed and crop preemergence, at 33 DAA.
Photo: Peressin, V. A.

In fact, the control of signal grass when cassava is rotated with depleted pastures is very difficult. This takes place after several years of pasture cultivation, i.e. from 10 (ten) to 15 (fifteen) years. In this condition, the amount of signal grass seeds deposited in the soil is very large.

Considering that an area under cultivation with pasture produces, on average, 1 (one) ton of signal grass seeds per ha/year, at the end of the period the number of seeds deposited in the soil profile can range from 10 (ten) to 15 (fifteen) tons. Thus, with excellent soil preparation using moldboard ploughs and harrows as described above, the result will be good control of this weed for periods ranging from 30 to 45 DAA; however, additional control with the integration of other methods is inevitably required, such as inter-row cultivation with manual hoeing and row weeding or the application of herbicides selective for cassava with graminicide properties in crop and weed postemergence.

The treatment groups shown in figure 22—with weeds—and in figure 23—without weeds—are from an experimental area with a single predominantly occurrent invasive species: wild radish (*Raphanus raphanistrum*). At 60 days after herbicide application (DAA), it was observed that wild radish control was very efficient in isolated applications of the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn), applied at a 5 L ha^{-1} dosage, i.e., using 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn (Fig. 24), as well as in isolated applications of 10 L ha^{-1}, i.e., using 2,000 g ha^{-1} of clomazone + 3,000 g ha^{-1} of ametryn (Fig. 25). It should be noted that, under these conditions, the official recommendation for this formulation is 4.0-5.0 L ha^{-1}.

Figure 22. Treatment group without weed control at 60 DAA.
Photo: Peressin, V. A.

Figure 23. Treatment group with weed control at 60 DAA.
Photo: Peressin, V. A.

Figure 24. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) applied at a 5 L ha^{-1} dosage, i.e., using 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn, for wild radish (*Raphanus raphanistrum*) control in weed and crop preemergence, at 60 DAA.
Photo: Peressin, V. A.

Figure 25. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) applied at a 10 L ha^{-1} dosage, i.e., using 2,000 g ha^{-1} de clomazone + 3,000 g ha^{-1} of ametryn, for wild radish (*Raphanus raphanistrum*) control in weed and crop preemergence, at 60 DAA.
Photo: Peressin, V. A.

The treatment groups shown in figure 26—without weed control—and in figure 27—with weed control—are from an experimental area with three predominantly occurrent invasive species: 1) wandering jew (*Commelina benghalensis*); 2) bristly starbur (*Acanthospermum hispidum*); and 3) small-flowered nutsedge (*Cyperus difformis*). The control of wandering jew was observed to be very efficient in isolated applications of 1,000 g ha^{-1} of clomazone (Fig. 28), in isolated applications of 1,250 g ha^{-1} of clomazone (Fig. 29), and in applications in which it was tank-mixed with 450 g ha^{-1} of linuron (Fig. 30). In such treatments, control was practically 100%, until 80 DAA. In other experiments with isolated applications of clomazone at the same dosages, the treatments were not as efficient. Some authors suggest that there are different biotypes of wandering jew that differ in their susceptibility to herbicides. In the specific case of bristly starbur and small-flowered nutsedge, the applications left much to be desired—they were less efficient.

Figure 26. Treatment group without weed control at 80 DAA.
Photo: Peressin, V. A

Figure 27. Treatment group with weed control at 80 DAA.
Photo: Peressin, V. A.

Figure 28. Effects of applying 1,000 g ha^{-1} of clomazone for wandering jew (*Commelina benghalensis*), bristly starbur (*Acanthospermum hispidum*) and small-flowered nutsedge (*Cyperus difformis*) control in weed and crop preemergence, at 80 DAA.
Photo: Peressin, V. A.

Figure 29. Effects of applying 1,250 g ha^{-1} of clomazone for wandering jew (*Commelina benghalensis*), bristly starbur (*Acanthospermum hispidum*) and small-flowered nutsedge (*Cyperus difformis*) control in weed and crop preemergence, at 80 DAA.
Photo: Peressin, V. A.

Figure 30. Effects of applying 1,000 g ha^{-1} of clomazone tank-mixed with 450 g ha^{-1} of linuron[5] for wandering jew (*Commelina benghalensis*), bristly starbur (*Acanthospermum hispidum*) and small-flowered nutsedge (*Cyperus difformis*) control in weed and crop preemergence, at 80 DAA.
Photo: Peressin, V. A.

[5] Commercial formulation used: Afalon SC

Interestingly, there was no increase in efficiency when the isolated dose of clomazone was increased from 1,000 g ha^{-1} (Fig. 28) to 1,250 g ha^{-1} (Fig. 29), which suggests that the most appropriate dose is 1,000 g ha^{-1}, in line with what is recommended and used in practice.

In applications of 1,000 g ha^{-1} of clomazone tank-mixed with 480 g ha^{-1} of metribuzin (Fig. 31) or with 1,500 g ha^{-1} of ametryn (Fig. 32), and in isolated applications of the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) applied at 5 L ha^{-1} dosage, i.e., using 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn (Fig. 33), control of these three weed species (bristly starbur, wandering jew and small-flowered nutsedge) was practically 100% for all treatments until 80 DAA.

Figure 31. Effects of applying 1,000 g ha^{-1} of clomazone tank-mixed with 480 g ha^{-1} of metribuzin for wandering jew (*Commelina benghalensis*), bristly starbur (*Acanthospermum hispidum*) and small-flowered nutsedge (*Cyperus difformis*) control in weed and crop preemergence, at 80 DAA.
Photo: Peressin, V. A.

Figure 32. Effects of applying 1,000 g ha^{-1} of clomazone tank-mixed with 1,500 g ha^{-1} of ametryn[6] for wandering jew (*Commelina benghalensis*), bristly starbur (*Acanthospermum hispidum*) and small-flowered nutsedge (*Cyperus difformis*) control in weed and crop preemergence, at 80 DAA.
Photo: Peressin, V. A.

Figure 33. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) applied at a 5 L ha^{-1} dosage, i.e., using 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn, for wandering jew (*Commelina benghalensis*), bristly starbur (*Acanthospermum hispidum*) and small-flowered nutsedge (*Cyperus difformis*) control in weed and crop preemergence, at 80 DAA.
Photo: Peressin, V. A.

[6] Commercial formulation used: GESAPAX 500 CIBA-GEIGY—currently this formulation is not registered for the cassava crop (http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Accessed on 15 Oct. 2021)

B-3) HERBICIDES FOR WEED PREEMERGENCE AND CROP EARLY POSTEMERGENCE APPLICATION

These are herbicides applied in crop early postemergence and weed preemergence. In the specific case of cassava, they can be applied in the whole area or sprayed on target, depending mainly on the crop development stage and the herbicide in question—in the early stages of crop development, following weed control through cultivation and hoeing. Studies were conducted using two herbicide formulations: 1) with the herbicide clomazone, applied at 1,000 g ha^{-1} (Fig. 34) and 2,000 g ha^{-1} (Fig. 35); and 2) with a formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) applied at 5 L ha^{-1} dosage, i.e., using 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn (Fig. 36) and at 10 L ha^{-1} dosage, i.e., using 2,000 g ha^{-1} of clomazone + 3,000 g ha^{-1} of ametryn (Fig. 37). Such studies highlight the possibility of using the herbicide clomazone in the early stages of crop development immediately following weed control (Fig. 34 and 35). In the case of the formulation containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn, it can only be applied at full crop preemergence (Fig. 36, 37, 38 and 39).

Figure 34. Effects of applying 1,000 g ha^{-1} of clomazone alone in weed preemergence and, after planting, in crop postemergence, at 28 DAA. Photo: Peressin, V. A.

Figure 35. Effects of applying 2,000 g ha^{-1} of clomazone alone in weed preemergence and, after planting, in crop postemergence, at 28 DAA. Photo: Peressin, V. A.

Figure 36. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) alone applied at a 5 L ha^{-1} dosage, i.e., using 1,000 g ha^{-1} of clomazone + 1,500 g ha^{-1} of ametryn, in weed preemergence and, after planting, in crop postemergence, at 30 DAA. Photo: Peressin, V. A.

Figure 37. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) alone applied at a 10 L ha^{-1} dosage, i.e., using 2,000 g ha^{-1} of clomazone + 3,000 g ha^{-1} of ametryn, in weed preemergence and, after planting, in crop postemergence, at 30 DAA. Photo: Peressin, V. A.

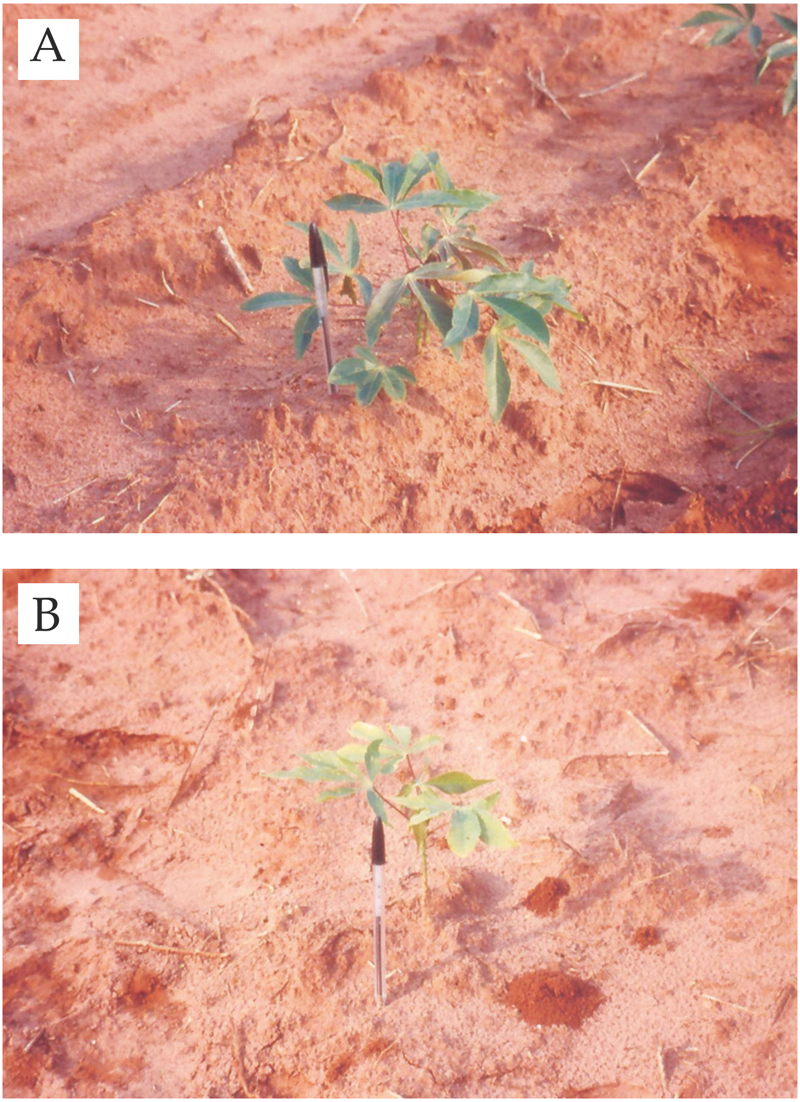

Figure 38. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) alone applied at 5.0 and/or 10 L ha^{-1} dosage in weed preemergence and, after planting, in crop postemergence (symptom evolution). (A) Treatment group without herbicide application, (B) Treatment group with herbicide application.
Photo: Peressin, V. A.

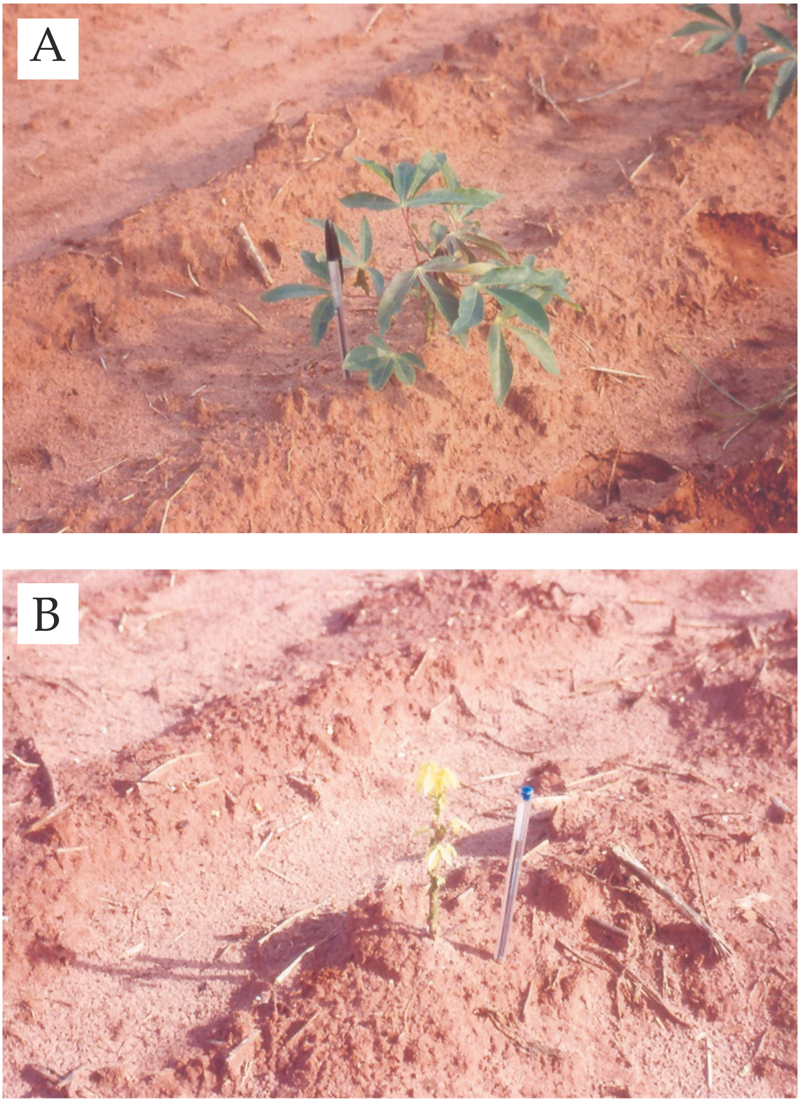

Figure 39. Effects of applying the formulated mixture (containing 200 g L^{-1} of clomazone + 300 g L^{-1} of ametryn) alone applied at 5.0 and/or 10 L ha^{-1} dosage in weed preemergence and, after planting, in crop postemergence (symptom evolution). (A) Treatment group without herbicide application, (B) Treatment group with herbicide application.
Photo: Peressin, V. A.

C) Herbicides for postemergence application

These are herbicides applied after crop and weed emergence. After crop establishment, i.e., crop and invasive plants postemergence, the use of herbicides in full-area applications is restricted to very selective products, such as certain graminicides like Fluazifop-P-butyl (Fig. 40) and clethodim (Table 3). The application of such herbicides is limited to the early tillering stage of the grasses.

With respect to *Urochloa plantaginea* and *Digitaria insularis*, in the evaluated dosages, clethodim showed a control rate of 90% or higher from the 30th day after application, maintaining this efficiency until 60 days after application (Table 3).

Figure 40. Effects of applying 180 g ha^{-1} of Fluazifop-P-butyl[7] in Jamaican crabgrass postemergence, after planting and in cassava crop postemergence. Photo: Peressin, V. A.

[7] Commercial formulation used: FUSILADE 250 EW + non-ionic surfactant at the dose recommended by the manufacturer.

Table 3. Percentage averages of creeping signalgrass (*Urochloa plantaginea*) and sourgrass (*Digitaria insularis*) control at the development stage from one to two tillers as a function of dosages and time of assessment

	Dosages	% of control (1)							
Treatments	g ha^{-1}	*Urochloa plantaginea*				*Digitaria insularis*			
		7 DAA	15 DAA	30 DAA	60 DAA	7 DAA	15 DAA	30 DAA	60 DAA
clethodim (2)	72	70.00 a	90.00 c	91.25 b	90.00 c	65.00 ab	88.75 c	92.50 b	91.25 c
clethodim	84	67.50 a	92.50 bc	93.75 b	93.75 b	70.00 a	91.25 bc	92.50 b	95.00 b
clethodim	108	72.50 a	97.75 ab	100.00 a	100.00 a	75.00 a	95.75 ab	100.00 a	100.00 a

(1) The averages followed by the same vertical letter do not differ using the Tukey test, at 5% de probability.

(2) Clethodim was used with the adjuvant dytrol, consisting of 756 g mineral oil and 107 g inert per liter, emulsifiable concentrate formulation.

Source: adapted from BELLETTINI et al. (1997).

Chemical weed control in the second cassava crop cycle

In the second cassava crop cycle, weed control is done after drastic pruning of the cassava plants. Figure 41 demonstrates the application of 1,440 g e.a. ha^{-1} of glyphosate. Figure 42 shows that the drastic pruning of cassava plants must be carried out at a maximum height between 5.0 and 10.0 cm, and herbicides applied from two to three days after pruning in order to reduce product uptake and avoid likely phytotoxic effects.

Figure 41. Effects of applying 1,440 g e.a. ha^{-1} of glyphosate in the second cassava crop cycle 2 (two) days after drastic plant pruning, at 55 DAA. Photo: Feltran, J. C.

Figure 42. Effects of drastic plant pruning height in the second cassava crop cycle and of applying 1,440 g e.a. ha^{-1} of glyphosate, at 50 DAA.
Foto: Peressin, V. A

Table 4 shows the herbicides registered for use in cassava crop in Brazil. There are currently 82 herbicide formulations registered for use in cassava crops in Brazil, and 11 different active ingredients among them.

Table 4. Herbicides registered for use in cassava crops in Brazil [8]

Active ingredient	Comercial name	Dosage (L or kg ha^{-1} of the comercial product)	Time of application (Overview)
Ametryn	1) Ameforce; 2) Ametrex WG; 3) Ametrina CCAB 800 WG; 4) Ametrina 800 WG CHDS; 5) Ametrina 800 WG Rainbow; 6) DK Plus; 7) Gesamena Plus; 8) Herbipak WG; 9) Hipertrina; 10) Kaner 800 WG; 11) Listar; 12) Megatrina; 13) Sugarina Plus; 14) Sultão.	2.0 – 3.0	Preemergence of the crop and weeds. It should be applied preferably around two days after planting the crop before emergence, in preemergence of invasive plants.
Carfentrazone-ethyl	1) Aurora; 2) Aurora 400 EC.	0.05 – 0.075 0.5% of mineral oil recommended by the manufacturer.	Application in postemergence of invasive plants and the crop.
Clethodim	1) Cartago; 2) Cletodim BRX; 3) Cletodim CCAB 240 EC; 4) Cletodim Nortox; 5) Cletodim 240 EC PROVENTIS; 6) Cletodim 240 EC PLS CL 1; 7) Freno 240 EC; 8) Grasidim; 9) Interllect; 10) Jaffa; 11) Kraken 240 EC; 12) Lord; 13) Poquer; 14) Proteno; 15) Select 240 EC; 16) Viance.	0.35 - 0.45 Add mineral oil to the spray solution at a 0.5 a 1.0% v/v concentration as recommended by the manufacturer.	Postemergence of the crop and weeds.
Clethodim	1) Select One Pack.	0.70 to 0.90 Contains adjuvant in its composition.	Postemergence of the crop and weeds.

to be continued

[8] According to current legislation, an agronomic prescription filled out and signed by a responsible technician is required for the recommendation and application of pesticides. Pesticide registration is dynamic and the Agrofit database should be constantly checked.

Table 4. Cotinuation

Active ingredient	Comercial name	Dosage (L or kg ha^{-1} of the comercial product)	Time of application (Overview)
Clomazone	1) Carimbo 500 EC; 2) Clomazone CCAB 500 EC II; 3) Clomazone Nortox; 4) Clomazone 500 EC FMC; 5) Gamit; 6) GrandeBR; 7) Gunter; 8) Maxclom 500 EC; 9) Scirocco; 10) Sirtaki 500 EC; 11) Trovati; 12) UP-Stage; 13) Zelig.	2.0 - 2.5	Preemergence of invasive plants and the crop.
Clomazone	1) Bonanza; 2) Gamit 360 CS; 3) GIGANTE 360 CS; 4) Kaivana; 5) Reator 360 CS.	2.8 - 3.5	Preemergence of invasive plants and the crop.
Flumioxazin	1) Flumyzin 500; 2) Flumyzin 500 SC; 3) Osbar 500 WP; 4) Pledge SC; 5) Sumisoya; 6) Sumisoya 500 SC; 7) Sumyzin 500; 8) Sumyzin 500 SC.	0.12 - 0.20	Recommendations (1)
Fluazifop--P-butyl	1) Fontfop; 2) Fusilade 250 EW; 3) Pilot.	0.5 – 0.75	Postemergence of the crop and weeds.
Isoxaflutole	1) Atitude Gold 750 WG; 2) Blexis; 3) Palmero; 4) Provence 750 WG; 5) Sunaim; 6) Sunpass; 7) Tandera; 8) Viana.	0.1 – 0.125	Preemergence of weeds immediately after planting the crop.

to be continued

Table 4. Conclusion

Active ingredient	Comercial name	Dosage (L or kg ha^{-1} of the comercial product)	Time of application (Overview)
Linuron	1) Afalon SC; 2) Afalon 450 SC	1.6 – 2.2	Preemergence of the crop and invasive plants.
Metribuzin	1) CoronelBR; 2) Greener; 3) Sencor 480; 4) Unimark 480 SC.	0.75 – 1.0	Preemergence of the crop (immediately after planting the cassava) and weeds.
Ametryn + Clomazone	1) Crossover; 2) Sinerge EC; 3) Sirtaki Gold	4.0 – 5.0	Preemergence of the crop (immediately after planting the cassava) and weeds.
Pyroxasulfone + Flumioxazin	1) Falcon	0.3 – 1.0	Preemergence of the crop and preemergence of the invasive plant.
Glyphosate	1) Xeque Mate	Xeque Mate	Full-area application after winter pruning of the cassava crop.

Source: http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Accessed on 14 Oct. 2021.
([1]) Application in the postemergence of weeds, before planting the crop (desiccation of weeds in the no-tillage system); b) Application in directed postemergence; c) Application in preemergence of the crop and weeds. If there is weed emergence and the cassava crop has not yet emerged, it is recommended to add 0.5% of adjuvant or mineral oil to the spray solution. For cassava crop, apply once shortly after planting the stem cuttings, which can be extended up to 15 days after planting, before crop emergence.

REFERENCES

ALBUQUERQUE, J. A. A.; SEDIYAMA, T.; SILVA, A. A.; CARNEIRO, J. E. S.; CECON, P. R.; ALVES, J. M. A. Interferência de plantas daninhas sobre a produtividade da mandioca (*Manihot esculenta*). **Planta Daninha**, Viçosa, v. 26, n. 2, p. 279-289, 2008.

ALBUQUERQUE, J. A. A.; SEDIYAMA, T.; SILVA, A. A.; ALVES, J. M. A.; FINOTO, E. L.; NETO, F. A.; SILVA, G. R. Desenvolvimento da cultura de mandioca sob interferência de plantas daninhas. **Planta Daninha**, v. 30, n. 1, p. 37–45, 2012.

ALCANTARA, E. N. de; CARVALHO, J. E. B. de; LIMA, P. C. Determinação do período crítico de competição das plantas daninhas com a cultura da mandioca (*Manihot esculenta* Crantz). In: EPAMIG (Belo Horizonte, MG). **Projeto Mandioca**; relatório 76/79. Belo Horizonte, 1982. p.127-129.

ANDRADE, J. S.; VIANA, A. E. S.; CARDOSO, A. D.; MATSUMOTO, S. N.; NOVAES, Q. S . Épocas de poda em mandioca. **Revista Ciência Agronômica**, v. 42, n. 3, p. 693-701, 2011.

BELLETTINI, N. M. T.; OSIPE, R.; ENDO, R. M.; MEYRING, E. E. Controle de *Brachiaria plantaginea* (Link) Hitchc. e *Digitaria insularis* (L.) Mea ex Ekmam com herbicida clethodim na cultura da mandioca. **Revista Brasileira de Mandioca**, Cruz das Almas, v. 16, n. 2, p. 137-143, 1997.

BIFFE, D. F.; CONSTANTIN, J.; OLIVEIRA JR., R. S.; FRANCHINI, L. H. M.; RIOS, F. A.; BLAINSKI, E.; ARANTES, J. G. Z.; ALONSO, D. G.; CAVALIERI, S. D. Período de interferência de plantas daninhas em mandioca (*Manihot* *esculenta*) no noroeste do Paraná. **Planta Daninha**, v. 28, n. 3, p. 471-478, 2010.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Instrução Normativa nº 40, de 11 de outubro de 2018. **Diário Oficial da República Federativa do Brasil**, Seção 1, n. 198, p. 3, 15 out. 2018. Available on https://www.defesa.agricultura.sp.gov.br/legislacoes/instrucao-normativa-sda-n-40-de-11-de-outubro-de-2018,1191.html. Accessed on 30 Aug. 2021.

CARVALHO, J. E. B. de; CALDAS, R. C.; COSTA NETO, A. de O.; CARDOSO, S. da S.; MASCARENHAS, L.; BARBOSA, C. V. Período crítico de competição das plantas daninhas com a cultura da mandioca em um ecossistema do Nordeste brasileiro. **Revista Brasileira de Mandioca**, Cruz das Almas, v. 12, n. 1/2, p. 85-93, 1993.

CARVALHO, J. E. B.; ARAÚJO, A. M. de A.; AZEVEDO, C. L. L. **Período de controle de plantas infestantes na cultura da mandioca no Estado da Bahia**. Cruz das Almas: Embrapa, 2004. 7 p. (Comunicado Técnico, 109)

CARVALHO, J. E. B.; PERESSIN, V. A.; ARAUJO, A. M. A. Manejo e controle de plantas daninhas. In: SOUZA, L. da S. (Ed.). **Aspectos socioeconômicos e agronômicos da mandioca**. Cruz das Almas: Embrapa, 2006. p. 560-590.

CIAT – THE INTERNATIONAL CENTER FOR TROPICAL AGRICULTURE. **Yuca: investigación, producción y utilización**. Cali, Colombia: CIAT, 1982. 660 p.

COSTA, N. V.; RITTER, L.; PERES, E. J. L.; SILVA, P. V.; VASCONCELOS, E. S. Weed interference periods in the 'Fécula Branca' cassava. **Planta Daninha**, v. 31, n. 3, p. 533-542, 2013.

DEUBER, R. **Ciência das plantas infestantes fundamentos**. 2. ed. Jaboticabal: Fundação de Estudos e Pesquisas em Agronomia, Medicina Veterinária e Zootecnia, FUNEP, 2003. v. 1. 452 p.

GAZZIERO, D. L. P.; OLIVEIRA, R. B.; OVEJERO, R. F. L.; BARBOSA, H. N.; PRECIPITO, L. M. B. **Manual técnico para subsidiar a mistura em tanque de agrotóxicos e afins**. Londrina: Embrapa Soja, 2021. 23 p. (Documentos 437).

JOHANNS, O.; CONTIERO, R. Efeitos de diferentes períodos de controle e convivência de plantas daninhas com a cultura da mandioca. **Revista Ciência Agronômica**, Fortaleza, v. 37, n. 3, p. 326-331, 2006.

LORENZI, J. O.; DIAS, C. A. C. **Cultura da mandioca**. Campinas: SAA/CATI, 1993. 41 p. (Boletim Técnico, 211)

MAPA - Ministério da Agricultura, Pecuária e Abastecimento. Instrução normativa nº 40, de 11 de outubro de 2018 [Normative Instruction no. 40, of 11 October 2018]. **Diário Oficial da União**. Availabe on: https://www.defesa.agricultura.sp.gov.br/legislacoes/instrucao-normativa-sda-n-40-de-11-de-outubro-de-2018,1191.html. Accessed on 18 Aug. 2021.

MATUO, T. **Técnicas de aplicação de defensivos agrícolas**. Jaboticabal: FUNEP, 1990. 140 p.

NORMANHA, E. S.; PEREIRA, A. S. Aspectos agronômicos da cultura da mandioca. **Bragantia**, Campinas, v. 10, p. 179-202, 1950.

PERESSIN, V. A. **Matointerferência na cultura da mandioca (*Manihot esculenta* Crantz) em duas regiões do Estado de São Paulo**. 1997. 132 f. Tese (Doutorado em Produção Vegetal) - Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal, 1997.

PERESSIN, V. A. MONTEIRO, D. A.; LORENZI, J. O.; DURIGAN, J. C.; PITELLI, R. A.; PERECIN, D. Acúmulo de matéria seca na presença e na ausência de plantas infestantes no cultivar de mandioca SRT 59 – Branca de Santa Catarina. **Bragantia**, v. 57, n. 1, p. 135-148, 1998.

PERESSIN, V. A.; CARVALHO, J. E. B. **Manejo integrado de plantas daninhas em mandioca**. In: CEREDA, M. (Coord.). Agricultura: Tuberosas Amiláceas Latino Americanas. São Paulo: Fundação Cargill, 2002, v. 2, p. 302-349.

PERESSIN, V. A. **Manejo integrado de plantas daninhas na cultura da mandioca**. 1. ed. 3. tiragem. Campinas: Instituto Agronômico, 2013. 54 p.

PERESSIN, V. A.; FELTRAN, J. C.; AGUIAR, E. B. **Manejo integrado de plantas daninhas na cultura da mandioca**. In: IKEDA, F. S.; INOUE, M. H. (Editoras técnicas). Manejo Sustentável de Plantas Daninhas em Sistemas de Produção Tropical. Brasília: Embrapa, 2015, p. 103-117.

PERESSIN, V. A. **Controle do mato: herbicidas registrados**. In: PERESSIN, V. A. (Coord.). Webinar: Manejo e controle de plantas daninhas em mandioca - Um desafio ambientalmente correto. Duration: 2h14min45seg, 26 Aug. 2020. Available on https://youtu.be/0jCiHob7VgA. Accessed on 30 Aug. 2021.

PERESSIN, V. A. **Controle do mato: herbicidas registrados**. In: PERESSIN, V. A. (Coord.). Webinar: A Cultura da Mandioca: desafios e perspectivas. Duration: 2h45min30seg, 12 May 2021. Available on https://www.youtube.com/watch?v=QLuJvzYGzcE. Accessed on 30 Aug. 2021.

PITELLI, R. A., DURIGAN, J. C. Terminologia para períodos de convivência e de controle das plantas daninhas em culturas anuais e bianuais. In: CONGRESSO BRASILEIRO DE HERBICIDAS E PLANTAS DANINHAS, 15. e CONGRESO DE LA ASOCIACION LATINOAMERICANA DE MALEZAS, VII, 1984, Belo Horizonte. **Resumos...** Belo Horizonte: SBHED, p. 37-38.

PITELLI, R. A. Interferência de plantas daninhas em culturas agrícolas [Weed interference in agricultural crops]. **Informe Agropecuário**, Belo Horizonte, v. 11, n. 129, p. 16-26, 1985.

PITELLI, R. A. **Efeitos de períodos de convivência e de controle das plantas daninhas no crescimento, nutrição mineral e produtividade da cultura de cebola (*Allium cepa* L.)**. 1987. 140 f. Tese (Livre-docência em Produção Vegetal) - Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal, 1987.

TAKAHASHI, M. Épocas de poda na cultura da mandioca na região noroeste do Paraná, Brasil. **Brazilian Archives of Biology and Technology**, v. 41, n. 4, p. 495-500, 1998.

Instituto Agronômico
Av. Barão de Itapura, 1.481
13020-902 - Campinas (SP) BRASIL
Fone: (19) 2137-0600

www.iac.sp.gov.br

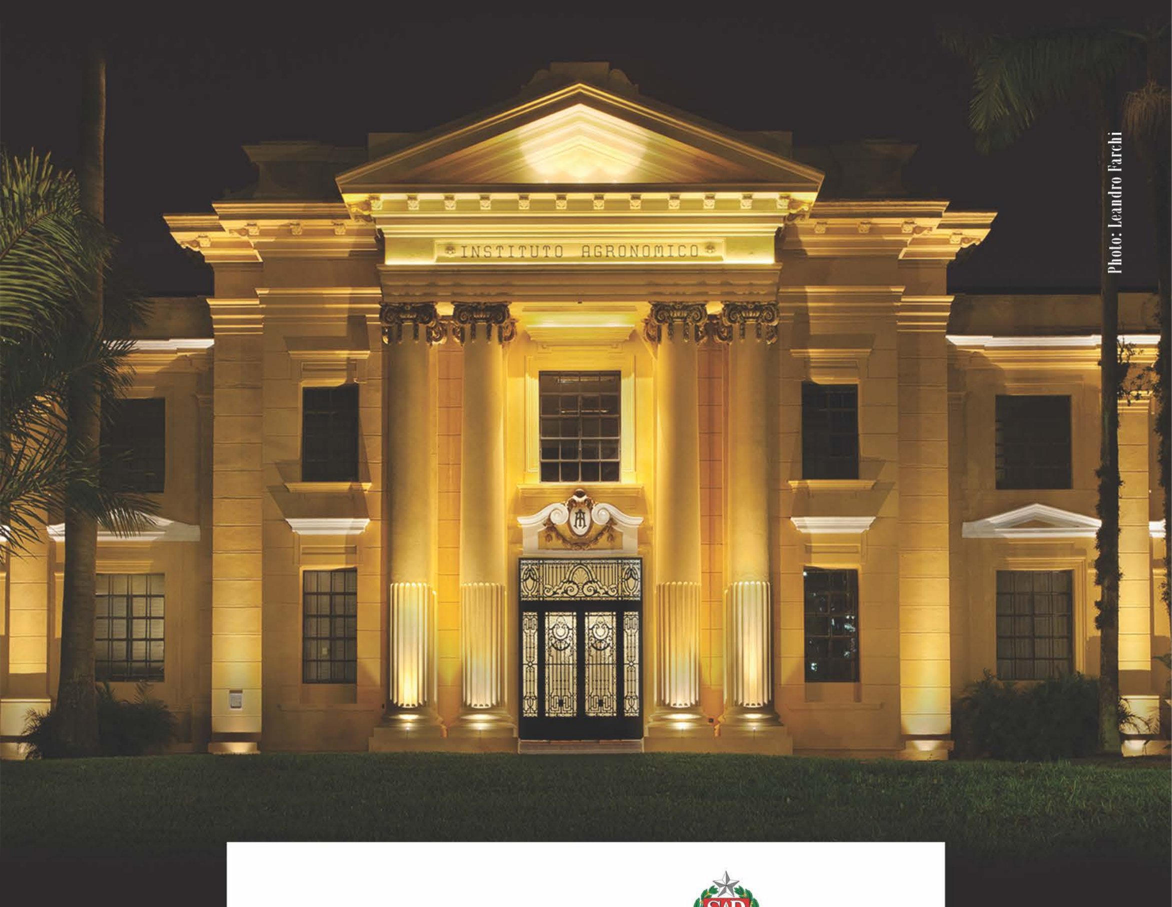

Photo: Leandro Farchi

IAC
apta
GOVERNO DO ESTADO DE SÃO PAULO
Secretaria de Agricultura e Abastecimento