III. The importance of the systematic evaluation of weed stands

3.1 The behaviour of weed flora

Unlike other pests, weeds nearly always thrive in a complex of various species, which remain in balance until the ecosystem is disturbed by ploughing or other agronomical practices such as the application of fertilizers, pesticide spraying and irrigation.

Natural flora shift may cause the elimination of some species and the predominance of others that are more resistant and adapted to the commonly used control measures.

Systematic evaluation of the weed population is therefore indispensable in crop areas as a guide for the control measures to be implemented.

3.2 Evaluating weed populations

The evaluation of weed populations can be carried out by using different procedures. These include counting the number of individual species of weeds combined with weight of their total dry mass or by a visual assessment of the existing weed cover, which is a subjective method, but is more productive due to requiring less labour and resources.

Figura 2 Counting weeds using a square frame

There are various methods of weed evaluation, which can be found in several publications and manuals on weed management. The use of a particular method will depend on the personnel available, the precision required and/or the scope of the ongoing programme.

Independently of the chosen method of evaluation, it is most important to have data regularly on:

- the general weed cover;
- the general cover of the most abundant weed species.

Together with the records of the evaluated field, these data will provide a clear idea of the factors affecting the weed population as well as the land preparation, cultivation and chemical control measures to be carried out in the near future. The best way of storing and processing the data is by creating a simple database.

3.3 The importance of the work of the agricultural extension service and farmers in evaluating weed populations

The best way to carry out an inventory of weeds and their level of infestation is through the joint action of the agricultural extension service with farmers. To this aim, they can both be well trained in correctly identifying weeds, evaluating weed cover and recording data. Training of extension workers can be conducted by the weed specialist of the plant protection service in close collaboration with the available weed scientists. This training will enable the extension workers to conduct similar training with farmers.

One of the requirements to develop weed management is to know the abundance of weed species in crop areas.

Data on the level of infestation can be obtained through surveys of weed populations in representative fields.

Frequent recording of such weed infestation data should be stored in a simple, accessible database.

This database may provide important elements for predicting the abundance of some weed species for making further decisions on the control measures to be implemented.

3.4 The importance of correct weed identification

The correct identification of the species is indispensable in evaluating the weed population.

Farmers from one locality in the same country usually name plant species differently than those from another locality, which may create some confusion when using common names.

To avoid these problems, a local herbarium should be prepared jointly by the extension service and farmers with the cooperation of national groups involved in plant and weed taxonomy. In this case, there should be a clear list of common names currently used along with their scientific synonyms.

It is advisable that each country have an illustrated publication of existing weed flora in the country to be used for correctly identifying weeds. Such a publication can also be prepared for geographical regions or groups of neighbouring countries.

A weed evaluation carried out regularly with well processed data is the essential base to establish a technically useful programme for weed control.

3.5 Forecasting weeds

Forecasting weed populations allows for better weed control planning. Unlike other pest organisms, weeds cannot yet be predicted. Forecasting may help to develop better applied systems of weed management in time to make good decision.

Figure 3 Identifying weed species is vital for better knowledge of the species causing major problems in crop areas.

In the past, counting weed seeds in soil was recommended for forecasting future weed populations, which was an extremely laborious and uneconomic method. At present, there are some new recommended methods that seem more practical and less tedious. The methods are based on soil sampling, putting the soil into pots and irrigate them regularly in order to provoke the emergence of viable seeds. The emerged seedlings are counted and recorded. This data provides an idea of the future weed population in terms of number of each weed species (Forcella *et al.*, 2003).

Figure 4 Weed seed bank in soil can now be measured using seedling count from soil samples taken during land preparation. *Photo courtesy of Dr. Frank Forcella, USDA.*

Another suggested method is to evaluate the weed pressure, which is carried out by visual assessments in small field plots. The successive record of weed populations will provide an idea of when they may thrive and their development in the evaluated field (Harvey 1998).

With either method, the short-term forecast of weed populations may become a useful tool to better control the weeds. What is most essential is to initiate the implementation of such a method on a pilot scale, and once the effectiveness and feasibility is validated, to extend its use to other agricultural areas.

IV. Weed Research

Weed research should enable a better understanding of the objective and usefulness of a new control strategy for the farmers. The main scope of these studies should be the understanding of weed biology, its interference with crops and resulting losses, as well as suitable control methods.

The basic elements for applied research in weed management are:

- *ecobiology of the main weed species (life cycle, productivity, reproductive process, viability and longevity of reproductive organs);*
- *interference (weed vs. crop competition, and allelopathy);*
- *development of control or management methods (preventative, cultural, chemical, biological and others).*

4.1 Weed ecobiology

To develop a sound weed control programme, it is important to know the habits of the unwanted plants in crop areas and the ways they interfere with the crop.

According to their life cycles, weeds are classified as annuals (fig. 5) and perennials (fig. 6). The ability to persist for short or long periods is determined essentially by the plants' ways of reproducing.

Plants that reproduce sexually, i.e. through seeds, may persist only for short periods of time that vary according to the species, climate and other

biotic and abiotic conditions, while perennial species may survive for long periods because they reproduce agamically, i.e. through their stolons, rhizomes, tubers and bulbs.

Therefore, in order to have good knowledge of a major weed species, it is important to study:

- the growth of the weed, well defining its life-cycle phases and when exactly it starts its reproduction. In a hot climate country, this study should be conducted in different seasons of the year because some variations of its life cycle may take place.

- level of reproduction under different conditions and seasons;

- viability of reproductive organs, and periods and optimal conditions for germination;

- the number of time that weeds emerge during the crop life cycle.

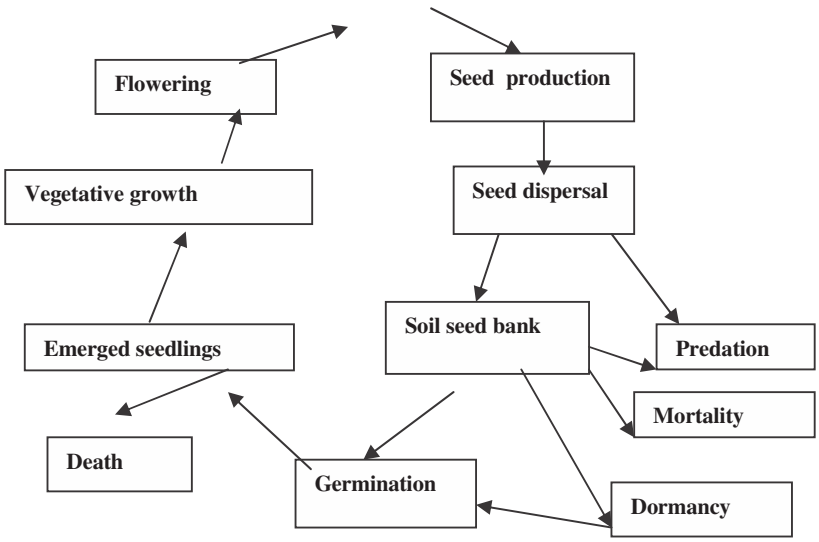

Figure 5 Cycle of an annual weed

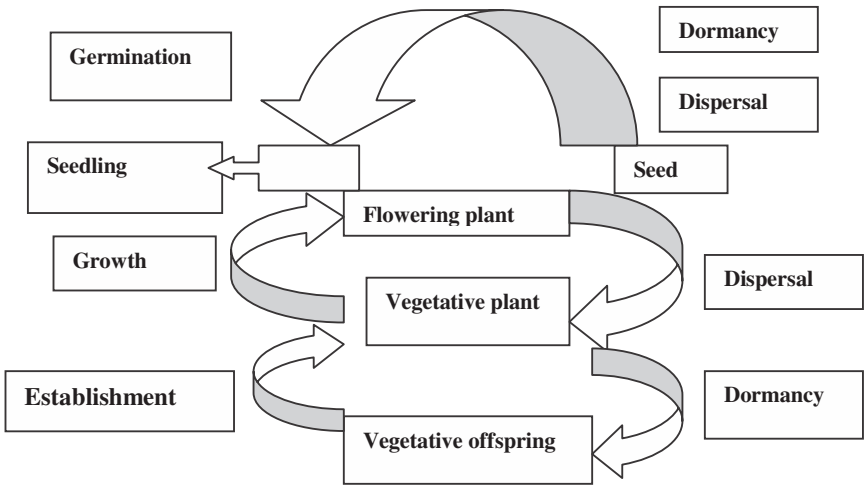

Figure 6 Cycle of a perennial weed

It is essential to recognize importance of the weed seed bank in soil for adopting control strategies, which may reduce the number of viable seeds in the soil in the short and medium term.

4.2 Weed interference with crop

Interference is understood as any damage caused by the weeds to any crop, which can either compete for water, nutrients and light, or by allelopathic effects, which consists of release by the weeds of toxic substances from roots or leaves, which may be damaged the crops.

4.2.1 Weed competition

Weed competition with crops for light, nutrients and water is one of the ways of weeds for interfering with normal growth of crops. For understanding competition, it is common to study the so-called "critical period" of weed competition, which is defined as the period during which weeds must be controlled to prevent crop yield losses.

The critical period is determined experimentally by including weeded treatments during certain periods after sowing or planting, and then conversely, non- weeded treatments in identical periods.

The results in crop yields under the effect of weeds in different periods enable the determination of the most important period to control the weeds.

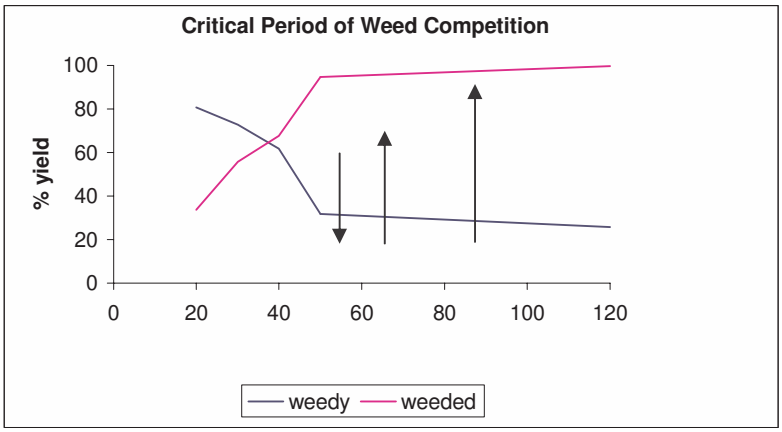

Figure 7 Legend: First ascending and descending arrows show the **critical period of weed competition.** The last ascending arrow shows the **weed-free period**, which indicates that there is no need to weed throughout the whole cycle in order to obtain high crop yields.

Farmers should understand and use critical periods of weed competition to enable them to plan the weed control activities better and to save time and labour. It is not uncommon to see some farmers weeding in periods after the critical period of weed competition, which causes a tremendous waste of time and losses of resources.

The studies of critical periods should be carried out in each locality, always taking into account crop diversity and variation of weed population from one place to another in the same country.

4.2.2 Economic weed thresholds

The use of thresholds is widely utilized in developed nations. Weed stands are generally used to indicate the treatment for the established weed control, which serve as an indication for carrying out the treatment for weed control, particularly herbicide post-emergence applications.

These thresholds are determined through the assessment of yield losses caused by a weed population or weed cover, which will equal the cost of the control measure to be carried out. The threshold therefore economically justifies the implementation of the control operation.

The adoption of these thresholds seems to be more appropriate in those areas where one weed species prevails or where weed populations are not very abundant.

4.2.3 Allelopathy

The phenomenon of releasing phytotoxic or phytostimulant substances by aerial and subterranean parts of the plant is known as allelopathy.

The release of these biologically active substances may also take place from plant residues in the process of decomposition. It is for this reason that the effect of weed residues on the crops in rotation should be studied in order to determine possible damage as well as ways to overcome this problem during the process of land preparation. A badly prepared field, with a high presence of residues of allelopathic weeds, may considerably reduce crop seed germination.

It is also worthwhile to assess the allelopathic potential of crop varieties on major weeds. The use of a productive variety that also possessed inhibitory properties against some weed species has enormous value for integrated weed management.

A crop plant may become allelopathic depending on its planning density, a phenomenon that should not be confused with its competition with weeds. Plant density may generally increase the inhibitory effect of the allelopathic crop against certain weeds, which should also be studied.

4.2.4 Parasitism

Parasitism is another form of interference consisting in the interrelation of two species, where one will benefit at the expense of the other. In contrast to other plants, parasitic ones do not have roots and leaves. However, they possess gross organs called *haustoria* (primary and secondary), which are

attached to the stems, leaves and/or roots of other plants, enabling them to absorb necessary water and nutrients for their growth.

There are hemi-parasitic plants whose parasitism is partial since in their early stage of growth, they have chlorophyll and therefore some capacity for photosynthesis. Holoparasitic plants do not possess chlorophyll and depend entirely on the host plant's nutrients.

Weeds of the genus *Cuscuta* are foliar parasites since their haustoria are attached to the stem or leaves of the host plant, while plants of the genus *Striga, Alectra* and *Orobanche* attach their haustoria to the roots of the host plant and are called "root parasitic plants". *Orobanche* spp. seriously affect a number of crops, such as tomato, tobacco, potato, sunflower and others in various countries of the Middle East and North Africa, while the species of *Striga* and *Alectra* are widely spread in sub-Saharan Africa and are a major constraint to the production of cereals such as maize, sorghum, rice and millet, as well as sugarcane and cowpea.

Generally, a great part of the damage caused by root parasitic plants takes place during their subterranean growth and development. The damage may tend to increase if the seed bank of the species in the soil is left to increase.

Parasitic weed control is difficult since this will regularly require the application of more than one control method. The best option to control these species is to combine preventative measures with others implemented during the life cycle of the host plant, including suicidal emergence through the use of trap crops.

Studying biology and control methods is necessary to develop control systems that can reduce the huge losses caused by these weeds.

4.3 The development of weed control or management strategies

Knowledge of the biology of weeds and losses caused by them is vital for developing appropriate weed control strategies.

In most cases, a single control method does not solve the existing weed problem as generally occurs with the parasitic weed species. It is for this

reason that the tendency should always be to use integrated management methods, which may lead to reduced weed population, including its seed bank in the soil.

The use of herbicides has increased due to the lack of labour for weeding and other economic reasons. This use has increased on the medium- and even small-farm levels. If well-applied herbicides offer a good number of advantages to the farmer; however, it is important to emphasize the need to use other methods to reduce farmers' dependency on herbicides and associated problems, e.g. herbicide resistance.

Methods most used for weed control

- *Preventative methods (legal and quarantine procedures, and others at the farm level);*
- *Cultural methods (crop rotation, land preparation, use of cover crops, polycropping, mulching, water management, hand or mechanical weeding during the crop's life cycle);*
- *Chemical methods (use of herbicides);*
- *Biological methods (classical methods through the introduction of exotic natural enemies and increasing the population of already existing natural enemies);*
- *Other non-conventional methods (soil solarization, use of hot water, and others in development*).

4.3.1 Preventative methods

4.3.1.1 Legal measures

Various methods prevent the introduction and spread of species are various, but the most important are those of a legal nature, which prohibit the movement and/or entry of certain types of imported commodities of plant origin or impose certain restrictions to the entry of such material.

The plant quarantine services should conduct risk assessment on the entry of exotic invasive plants and their likelihood to adapt to the new habitat, and should put together a list of quarantine weed species on the basis of these studies. The list should contain those species with a probability of establishing in the territory of the country. This probability of adaptation should be studied using weed risk assessment procedures. To conduct an appropriate assessment, it is necessary to have information on the ecobiology of those species and their behaviour in various areas or regions of the world. The best procedures for this type of assessment have recently been developed in Australia and New Zealand, whose experts elaborated the final simplified procedures of pre-entry risk assessment within the framework of the FAO panel of experts (FAO, 2005).

In order to prioritize the activities of weed management in any country, it is necessary to develop procedures for post-entry weed risk management, which will ultimately provide a priority list of the introduced weeds that are to be prevented from spread. Again, this type of procedure is regularly used by the above-mentioned Oceania countries.

The FAO procedure on weed risk management (WRM) (FAO, 2006) involves establishing the processes and structures to strategically determine and take action against high priority weed species. Post-border WRM refers to weed species which are already present in a country or region, or which are likely future incursions.

Post-border WRM can provide a decision framework for regulatory management of weeds within countries (e.g., legal restrictions on sale and movement of declared/noxious weeds and legal requirements for their

control), for selecting species priorities for research into improved control techniques and for choosing species targets for eradication.

4.3.1.2 Other preventative measures

Another way of preventing a weed species from entering into an uninfected site from an infected one is by disinfecting all tools and implements used.

The use of animal manure and crop seeds heavily contaminated by weed seeds should also be avoided.

4.3.2 Cultural methods

4.3.2.1 Land preparation

Methods for land preparation have enormous importance for weed control. At the time of choosing a method it is necessary to take into account other factors related to soil characteristics and possibilities of erosion. The methods used should be those that preserve soil fertility.

At present there is an increasing tendency to use minimum and zero tillage on a large number of crops. Here it is essential to disturb the soil as little as possible, restabilising its structure and fertility. All of these combined with an optimal crop rotation and the use of cover crops result in good soil protection. In most areas where these methods are applied, the use of chemical herbicides is common.

After the use of zero or minimum tillage in some areas, certain perennial weeds become a serious problem, which requires, at least as a temporary remedy, the use of conventional tillage with a mouldboard plough to bring the subterranean propagules to the soil surface for further desiccation. This problem occurs often in areas where zero tillage is practised alone, i.e. without good crop rotation and use of living cover crops. A soil layer covered by dried plant material, such as mulch, hinders the penetration of sunlight and may release toxic allelopathic substances, which subsequently inhibit the germination of several weed seeds.

4.3.2.2 Crop rotation

Crop rotation is extremely important to substantially reduce weed infestation from previous crops.

In order to clearly define consistent crop sequences, crop rotations should be studied for periods of two or more years.

In addition to reduction of weeds and weed seed bank and improving crop yields, any rotation should equally take into account possible effects on soil erosion and its structure, as well as the cost/benefit to the farmer.

Nevertheless, rotation of a new crop will be included in a rotation if its produce can be easily marketed. Market forces are essential at the time of making a decision.

4.3.2.3 Intercropping

Intercropping is another way of increasing yields per unit area, particularly in small farm areas. Using this method, the farmer may have more than one crop in the same field. Increased crop density by the presence of two crops reduces the space for weeds to grow. The study of intercropping is usually done by using variants of combined crops as well as individual crops. In such a way, one can determine the equivalent yields and decide whether intercropping is technically and economically feasible.

Here it is important to consider the effect of inter-specific competition between crops to decide on the time of planning of each crop involved in the planned intercropping.

As in the case of crop rotation, the economical aspect and feasibility for marketing crop produce play an important role in adopting these practices.

4.3.2.4 Living cover

Living cover is a type of intercropping that guarantees the presence of an additional crop that will protect the soil, possibly providing it with nitrogen (e.g. leguminous plants) and that competes effectively with weeds.

Living cover planted in the inter-row of fruit trees is highly advisable for reducing weed infestation and avoiding problems of soil erosion.

The studies of living covers that are able to reduce infestations of several weeds are valuable when they can be used for short crop rotation systems. These studies should also take into account the possible smothering effect on weeds as well as on crops.

The use of living cover is gaining popularity in the context of conservation agriculture.

4.3.2.5 Mulch

Mulch helps to preserve soil moisture and inhibits the emergence of many annual weed species. This method can be practised by using various plant residues, some of them toxic to weeds. Black or transparent polyethylene sheets placed over the crop rows are widely used. Before its introduction into agricultural practice in developing countries, the technical and economic effectiveness of the plastic mulch should be evaluated in field tests.

The use of plastic films in large areas also implies the use of machinery for deploying the films as well as disposing them after use in the crop to prevent environmental pollution.

4.4 Chemical control

It is good to differentiate two ways to study herbicides. First, there are simple field trials aimed at gathering useful information for herbicide

registration, while this second is for evaluating the effectiveness of the herbicide in the context of crop and pest management.

4.4.1 Herbicide trials for registration

These trials should be conducted in representative crops and weeds of concern. As a general rule, the trials should be conducted by official personnel of the country using a previously established methodology or protocol. Trials should consist of various treatments (herbicide rates), repetitions and ways of application.

A single trial of herbicide is insufficient to obtain the necessary data for its registration unless the herbicide compound is already known and concerns a generic product provided previously by a different supplier. In such a case, the generic product should be tested against its homologue, which has already been registered and/or is in use.

Well-applied herbicides can be an effective means to control weeds. However, previous training of agricultural technicians and farmers in their correct use and safe handling is required.

The repeated use of the same herbicide, a common practice in areas of monocropping, should be avoided to prevent high weed infestations that are tolerant to the herbicide, and to prevent herbicide resistance in the longer term.

When a soil-acting herbicide is used repeatedly for several years, it is advisable to assess its possible residues in the soil, its leaching, and if necessary, its presence in ground waters.

4.4.2 Evaluating the use of herbicides in the context of crop management

This type of study is usually carried out with compounds of known effectiveness that are already registered in the country. The evaluation could use herbicides combined with any other crop practice for weed control.

Other studies can be used for determining the optimal period of herbicide application for the control of a specific weed or to assess the selectivity of the compound over other crop cultivars.

4.4.3 Herbicide persistence in soil, water and crop produce

To avoid problems of herbicide carry-over in soil, it is vital to know the period of time that the herbicide may be active in soil.

Such studies are conducted, for practical and economic purposes, through bioassays using indicator plants susceptible to the herbicide in use.
If the herbicides are persistent in the soil and a potential problem to subsequent crops in rotation, then physical methods to be implemented during land preparation that dilute the upper layer of soil and reduce problems of residues should be studied.

It is recommended to carry out an analysis of residues in water of herbicides normally applied in rice or in other crops grown under heavy irrigation. In this case, the bioassay may provide a good indication of the presence of the residues, but for contamination criteria of the water, it is necessary to conduct a chemical analysis.

Generally, the herbicides are applied once in the crop cycle at recommended rates so that the possibilities of residues in crop produce are minimal. It is advisable, however, to conduct chemical analysis of residues for those herbicides while they are still in the registration process.

4.4.4 Herbicide-resistant weeds

It is important to differentiate evolved herbicide resistance from tolerance that some species may exhibit after the application of an herbicide.

Unlike other pesticides, herbicides traditionally took a long time to select resistance in target weed populations. Generally, the selection pressure from herbicides is much less than that of other pesticides, particularly systemic insecticides and fungicides. However, some weed species may evolve resistance in short periods of time to herbicides of chemical groups with high selection pressure.

At present, there is information on cases of resistance of various weeds to a number of herbicide compounds of different modes of action. This information would be more valuable if one determines the number of applications and years used of a particular herbicide that cause herbicide resistance in any weed species. It would then be possible to avoid similar use of the herbicide to prevent the resistance. For the time being, however, it is recommended to focus on resistance management, which in many cases consists of replacing the use of a herbicide causing resistance by another one with a different mode of action or by integrating major control measures.

In many cases, resistance is already in place but unknown because there is no monitoring to detect the weed species evolving resistance.

Authorities of the national pesticide registration may agree with herbicide suppliers the ways to cover the expenses for studies on resistance, but plant protection services should assess this problem independently and advise farmers regularly.

When resistance evolves without the farmer's awareness, crop losses may be as high as or sometimes even higher than those caused by common pests.

4.4.5 Genetically modified herbicide-resistant crops (HRC)

Biotechnology has produced crops resistant to particular herbicides. The most successful procedure is inserting a gene of resistance through genetic engineering. There are also mutated crops, not transgenic, developed by radioactive bombardment of a conventional plant for achieving resistance to a particular herbicide.

There are some concerns over the use of herbicide resistant crops (HRC), which are based on issues related to their risks, such as potential transfer of genes from transgenic herbicide-resistant crops to related wild species, which may bring about the appearance of resistant weeds, or the possibility of HRC becoming a volunteer in subsequent crops.

All these concerns show the importance of assessing the risks of HRC usage. In fact, an assessment is required to decide if these crops can be introduced without being a possible hazard to the environment, providing the expected benefits to farmers. To this end, FAO (2003 a) jointly with the Department of Weed Science of the Royal University of Veterinary and Agriculture of Denmark, Copenhagen, have prepared procedures consisting of the use of keys, which enable technical personnel to determine possible environmental problems caused by growing a particular HRC.

In addition, it is also important to monitor the impact of these genetically modified (GM) crops as part of a responsible process of growing this type of crops. The whole process with GM crops should include pre-release, risk assessment and post-release monitoring. The latter is an essential part of the regulatory process of the use of GM crops

4.5 Biological control

The elimination or reduction of weeds to economically acceptable levels through the use of specific organisms is a positive option from the environmental point of view. The biological control agents, once established, may control target weeds in inaccessible places.

Biological control is highly specific and allows for a particular species of weed to be eliminated. It may prove useful when a weed species prevails in the field. Biological control is generally feasible economically, particularly when the agent is locally bred for its further release.

4.5.1 Classical biological control implies the introduction of a natural enemy to control an exotic weed already established and spread throughout the territory of the country. The natural enemy is usually imported from the weed's place of origin and introduced into the country.

For a successful introduction of the biological control agent, various steps are required previous to and after its introduction, such as inanition and selectivity tests of the concerned agent on various important crops in the country under controlled conditions. In conclusion, the agent cannot be released until its usefulness and safety for other organisms are ascertained. In order to develop a coherent process for the introduction of natural weed enemies, it is advisable to follow the Guidelines for the export, shipment, import and release of exotic biological control agents (FAO/IPPC, 2005).

Classical biological control of water floating weeds (*Eichhornia crassipes*, *Salvinia molesta* and *Pistia stratiotes*) has been a success in various countries.

Exotic natural enemies of these species were introduced and reproduced in local units for their further release. The control of *S. molesta* and *P. stratiotes* is usually evident ten months after the release of biological control agents.

FAO has been technically assisting the countries affected by these weeds in the effective implementation of biological control.

FAO has also prepared the Guidelines for the Export, Shipment, Import and Release of Biological Control Agents (FAO/IPPC, 2005), which serves as guideline for the introduction of new biological control agents.

4.5.2 Augmentative biological control is based on the reproduction of an already existing agent in the territory of a country, usually lacking in the sufficient amount to reach the desired level of control. It is for this reason that breeding or mass-producing these organisms is carried out in the laboratory or in specialized facilities for their further release in the field.

With this method it is possible to use insects and mites, but pathogens are usually the most used in this procedure. It is important, therefore, to conduct local surveys of the possible presence of useful agents for the control of major weeds.

4.6 Integrated weed management

Integrated weed management (IWM) rationally uses all available alternatives to reduce weed populations. These measures can be conveniently integrated in the crop according to the locally problematic weed flora. The application of more than one control measure will greatly depend on the type of weeds present and their density.

A single control strategy is usually inadequate for preventing damage caused by weeds in a crop. Integrated management is a system of effectively combining control measures, which may help to reduce the use of herbicides improving the cost-benefit ratios.

Managing the existing weed community in the field should be done through rational implementation of integrated control methods.

Weed management is not a sum of methods to be practised, but the rationality to intervene with the most appropriate method at the right time.

Management of perennial and parasitic weeds requires knowledgeable implementation of control methods. A single control method is usually not effective for controlling these weeds.

4.7 Assessment of the cost/benefit of weed management

Systems or strategies for weed management should be evaluated economically, in comparison with other traditionally used methods. The most complete assessment is achieved when the net return of the new treatment is evaluated. Net return is usually higher when one spends less and crop yields increase, which subsequently provides higher incomes.

It is also sensible to evaluate the impact of weed control measures not only in a single field, but at the whole farm level. Such a study may suggest the level of control to be achieved in order to avoid the spread of a particular weed species inside the farm.

V. The importance of supportive links between research and agricultural extension on weeds

The validity of weed research depends on it being carried out with the purpose of improving agricultural practices. The agronomic effect of the research can be direct or indirect.

If the obtained results are of value, they should be subsequently introduced into agricultural practice. Logically, a weed scientist working alone is limited in disseminating his/her results and achievements. For this reason, it is necessary for him/her to collaborate with the agricultural extension services, for which strong links should be established as a way to spread the use of the achieved results.

FAO experience points to the need to introduce new technologies or methods into agricultural practice through the implementation of training of trainers (extension workers and plant protection technicians). In addition, these trainers should be updated regularly on any new development on matters related to improved weed management.

VI. Working with farmers

For their part, trainers should educate farmers as adult learners who participate fully in designing, implementing, and evaluating their own education.

There are various options to transfer this knowledge to farmers, such as through the establishment of Farmers' Field Schools, which consist of a field plot shared by farmers where they experiment, assess and make their own control decisions. This method has been used extensively by FAO for the development of Integrated Pest Management (IPM). Its advantage is that in the training process the farmer is encouraged to adapt new technologies and/or procedures because he/she is directly acquainted with new developments and adapts them in practice, later deciding on what is most convenient.

Training programmes should include topics related not only to control methods, but to weed biology and competition, thus facilitating farmers' understanding and increasing their technical knowledge. It is important that farmers learn more about crop losses caused by weeds.

Other way for disseminating information could be the organization of field days, where the trainers would give practical ideas on how to implement a particular control method. Demonstrations are more economical than Farmers Field Schools, but their effectiveness is less due to lack of follow-up in many cases. After attending on-field demonstration, the farmer may leave unconvinced of the explanations and not apply any aspect of the new technology in his/her fields.

In any case, with any kind of training, follow-up is necessary to assure its success.

Figure 8 A group of farmers in Timbou (north of Togo) participating in training session on *Striga* parasitic weeds.

VII. The role of the authorities of the Ministries of Agriculture and Rural Development in the implementation of weed management

The agricultural authorities of each country should be informed regularly about the problems caused by weeds in their territories. They should also be aware that neither hand-weeding nor chemical herbicides alone will solve the problems of weeds, even where labour is available. The concept should be to implement integrated weed management through the practice of control strategies economically feasible for farmers in the context of Integrated Crop Management.

In the prospective plans for agricultural development, dealing either with agricultural production or specifically with plant protection, one aspect that must be present is the improvement of weed management. To this end, resources should be given in the same way as for other activities or agricultural sectors.

It is obvious that resources should be mainly given for training of technical personnel and farmers, as well as for the development of applied weed research, which may offer substantial improvement of the systems for weed management in the medium term.

VIII. The importance of implementing projects on weed management

In many developing countries, the resources and funds for economic and social development are not abundant. In addition, funds given by the donor community for agricultural development are seldom used for the improvement of weed management.

The development of weed management requires the implementation of national or regional projects, where training and direct work with farmers should be the priority. A part of the budget should also be allocated for developing research including creating a database of results for their further use by the agricultural extension workers.

Research topics, such as the use of living covers, intercropping, mulching, crop rotation and appropriate methods for land preparation may provide valuable results for the agricultural development of the country. It will be equally important to study weed seed banks in the soil, weed behaviour in different crops, weed seed and the germination and dispersal of other propagules, as well as problems of weed interference.

In these projects, practical manuals should be prepared, including a publication of an illustrated booklet on weeds, if this material is still lacking in the country.

Creating a database on weeds in different crops and regions of the country will also be of indisputable value in the decision-making process.

IX. The importance of publications on weed management

The results of surveys, research and other activities such as workshops and technical meetings will be applied in the long term if they are published and disseminated.

One of the major problems in many developing countries is the lack of technical and scientific publications, which may serve as guide for conducting new research and for avoiding any wasteful duplication. The topic of weeds is well covered in developed nations, which usually publish all their technical and scientific achievements appropriately.

There are regular publications on weeds, such as Weed Science and Weed Technology, published by the Weed Science Society of America (WSSA); Weed Research, a publication from the European Weed Research Society (EWRS); and Weed Biology and Management, published by the Weed Science Society of Japan. These journals often accept papers from developing countries without requiring a fee. The acceptance of the paper depends on its scientific value and quality.

However, little or nothing will be done if a new technology or procedures are published outside the country and the local extension workers and growers are not informed about its content and usefulness. It is important, therefore, to disseminate the results locally making it accessible to all concerned.

As previously mentioned, each country or region requires an illustrated booklet on major weeds. This material will facilitate the identification of weed species by the technical staff of the agricultural extension and plant protection services and by farmers.

X. Useful Literature on Weeds

a) Journals

Weed Science	Official publication of the Weed Science Society of America (WSSA) published six times a year.
Weed Technology	A journal of the Weed Science Society of America (WSSA) published quarterly.
Weed Research	Official journal of European Weed Research Society (EWRS) published six times a year.
Weed Biology and Management	Published quarterly and sponsored by Weed Science Society of Japan

b) Related books, reports and booklets

Auld B., Menz, K.M. & Tisdel, C.A. 1987. *Weed Control Economics*. Academic Press, London, England. 177 pp.

FAO. 1987. *Common weeds of East Africa*, by P.J. Terry & Michieka, R.W. Rome. 184 pp.

FAO. 1991. *Soil solarization.* In J.E. DeVay, J.J. Stapleton, & C.L. Elmore, eds. Proceedings of the First International Conference on Soil Solarization, Amman, Jordan, 19-25 February 1990. FAO Plant Production and Protection Paper No. 109. Rome. 396 p.

FAO. 1994. Weed management for developing countries, edited by R. Labrada, J.C. Caseley & C. Parker. FAO Plant Production and Protection Paper 120. Rome. 381 pp.

FAO. 1996. Weed management in rice, ed. by Auld, B.A: & Kim, K.U. FAO Plant Production and Protection Paper No. 139. Rome. 272 pp.

FAO. 1997. Expert Consultation on Weed Ecology and Management. FAO, Rome, 22-24 September 1997, FAO Plant Production and Protection Division. (in PDF) Url. Available at www.fao.org/ag/AGp/agpp/IPM/Weeds.

FAO. 1998. Soil solarization and integrated management of soilborne pests**.** Proceedings of the Second International Conference on Soil Solarization. Aleppo, Syria, 16-21 March 1997. Stapleton, J.J., DeVay, J.E. & Elmore, C.L., eds. FAO Plant Production and Protection Paper No. 147. Rome. 657 pp.

FAO. 2003. Procedures for ecological risk assessment of herbicide and insect resistant crops- focus on weed aspects. Rome. 21 p.

FAO. 2003. Weed management for developing countries, Addendum I*.,* ed. by R. Labrada, R. FAO Plant Production and Protection Paper 120. Rome. 277 pp.

FAO. 2005. Procedures for weed risk assessment. Plant Production and Protection Division, Rome. 16 pp.

FAO. 2006. Procedures for post-border weed risk management. Plant Production and Protection Division, Rome, 27 pp.

FAO/IPPC. 2005. *Guidelines for the export, shipment, import and release of biological control agents*. ICPM-7 (2005) / REPORT, Publication No. 3, April 2005, Secretariat of the International Plant

Protection Convention, FAO, Rome. Available at: www.ippc.int/servlet/BinaryDownloaderServlet/76047_ICPM_7_report_ISPM_0.pdf?filename=1118408473107_ISPM3_2005.pdf&refID=76047

Gopal B. 1987. *Water hyacinth, aquatic studies.* No. 1. New York, USA, Elsevier. 471 pp.

Häfliger E. & Scholz, H. 1980. *Grass weeds, vol 1. Panicoid weed grasses*. Documenta CIBA- Geigy. Basel, Switzerland. 142 pp.

Häfliger E. & Scholz, H. 1981. *Grass weeds, vol 2*. Documenta CIBA- Geigy. Basel, Switzerland. 137 pp.

Häfliger, E., Kühn, U., Hämet, L., Cook, C.D.K., Faden, R. & Speta. F. 1982. *Monocot Weeds.* Documenta CIBA- Geigy. Basel, Switzerland. 132 p.

Harminder Pal Singh, Daizy Rani Batish & Ravinder Kumar Kohli. 2006. Handbook of Sustainable Weed Management. Haworth Pr Inc. US. 892 pp

Holm, L.G., Plucknett, D.L., Pancho, J.V. & Herberger, J.P. 1991. *The world's worst weeds, distribution and biology*. Malabar, Florida, USA, Krieger publishing company. 609 p.

Holm, L.G., Pancho, J.V. Herberger, J.P. & Plucknett, D.L. A geographical atlas of world weeds. Krieger publishing company, Malabar, Florida, USA. 391 p.

.

Holm, L.G., Doll, J., Holm, E., Pancho, J. & Herberger, J. (1997). *World weeds, natural histories and distribution.* John Wiley and Sons, New York, 1129 pp.

Kroschel, J. 2001. *A technical manual for parasitic weed research and extension*. Kluwer Academic Publishers, Dordrecht, The Netherlands. 256 pp.

LeBourgeois T. & Merlier, H. 1995. Adventrop, les adventices soudano-sahelienne. CIRAD-CA, Montpellier, France. 640 pp.

Musselman, L.J. 1987. *Parasitic weeds in agriculture. Vol. I. Striga.* CRC Press, Boca Raton, Florida, USA. 317 pp.

Parker, C. & Riches, C.R. 1993. *Parasitic weeds of the world: biology and control*. CAB International, Wallingford, Oxon, UK. 332 pp.

Powles, S.B. & Shaner, D.L., eds. 2001. Herbicide resistance and world grains. CRC Press, Boca Raton, 308 pp.

Radosevich S., J. Holt & C. Ghersa. 1996. Weed ecology: implications for management. 2nd edition. New York, USA, John Wiley and Sons, Inc. 589 pp.

Robson T.O., Americanos, P. & Abu-Irmaileh, B.E. 1991. *Major weeds of the Near East. FAO Plant Production and Protection Paper 104.* 236 pages with colour photos of several species from 30 families. Rome.

WSSA. 2002. herbicide handbook, 8th edition. Champaign, Illinois, USA.

c) Available websites on weeds

Asociación Latinoamericana de Malezas	www.gcrec.ifas.ufl.edu/Weed%20Science/alam/Web%20page/ALAM01.htm
International Weed Science Society	http://www.plantsciences.ucdavis.edu/iws/
European Weed Research Society	http://www.ewrs.org/
Weed Science Society of America	http://www.wssa.net/
Near East Weed Science Society	http://www.ju.edu.jo/newss/index.htm
Haustorium Parasitic Newsletter	http://web.odu.edu/webroot/instr/sci/haustorium.nsf
International Survey of Herbicide-Resistant Weeds	http://www.weedscience.org/in.asp
FAO weed pages	http://www.fao.org/ag/AGp/agpp/IPM/Weeds/
Ecoport	http://www.ecoport.org
A Global Compendium of Weeds	http://www.hear.org/gcw/
Encycloweedia	http://www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm
Center for Aquatic and Invasive Plants	http://aquat1.ifas.ufl.edu/welcome.html
The Invasive Species Initiative	http://tncweeds.ucdavis.edu/esadocs.html

CBD Information Centre and Document Search	http://www.biodiv.org/doc/info-centre.shtml
Invasive alien species	http://www.biodiv.org/programmes/cross-cutting/alien/default.asp
APIRS online bibliographic database of aquatic, wetland and invasive plants	http://gcmd.nasa.gov/records/ufl_apirs.html
CRC for australian weed management	http://www.weeds.crc.org.au/index_flash.html
CSIRO entomology	http://www.ento.csiro.au/
Weeds of National Significance (Australia)	http://www.weeds.org.au/natsig.htm

XI. Conclusions

Increased agricultural production is a need and a challenge for the developing countries. One of the reserves of agricultural production is the reduction of the damage traditionally caused by weeds. The development of systems for weed management that make possible the reduction of labour for weeding and increase crop yields cannot longer be delayed.

The agricultural authorities of the developing countries should support and provide resources for the efforts aiming at improving of weed management. This support should be towards the research and training of agricultural extension workers and farmers on matters related to improved weed management.

One way to accomplish these objectives could be the implementation of specific projects on this matter, and to this end the governments should include weed management as one of their priorities for the agricultural development at the time of discussing perspective plans with the donors.

References

Forcella F., Webster T. and Cardina J. 2003. Protocols for weed seed bank determination in agro-ecosystems. In "Weed Management for Developing Countries, Addendum I". Ed: R. Labrada, Plant Production and Protection Paper No. 120, Rome, pp. 3-18

Harvey R. G. 1998. A simple technique for predicting future weed problems and choosing the best weed management practices. In **"**FAO Expert Consultation on Weed Ecology and Management", Rome, 22-24 September 1997. Rome, p. 37-44

Labrada R. 1996. Weed management status in developing countries. *Proc. of the Second Int. Weed Control Congress,* Copenhagen. pp. 579-589.

FAO. 2003 a. Procedures for Ecological Risk Assessment of Herbicide and Insect Resistant Crops- Focus on Weed Aspects. Plant Production and Protection Division, Rome, 21 p.

FAO. 2003 b. Weed Management for Developing Countries, Addendum I., ed. by R. Labrada, plant production and protection paper 120. Plant Production and Protection Division, Rome. 277 pp.

FAO. 2005. Procedures for Weed Risk Assessment. Plant Production and Protection Division, Rome. 16 pp.

FAO. 2006. Procedures for Post-Border Weed Risk Management. plant production and protection Division, Rome, 27 pp.

FAO/IPPC. 2005. *Guidelines for the Export, Shipment, Import and Release of Biological Control Agents.* ICPM-7 (2005) / report, publication no. 3, April 2005, secretariat of the international plant protection convention, FAO, Rome. https://www.ippc.int/servlet/binarydownloaderservlet/76047_icpm_7_report_ispm_0.pdf?filename=1118408473107_ispm3_2005.pdf&refid=76047

Williams P. 2003. *Guidelines for weed risk assessment in developing countries.* In "Weed Management for Developing Countries, Addendum I". Ed: R. Labrada, Plant Production and Protection Paper No. 120, Rome, pp. 37-60.