Herbicide use: constraints and prospects

In Sudano-Sahelian Africa, particularly in cotton-growing regions, weeds are a major obstacle to crop production, even before soil fertility begins faltering. This problem can be overcome with herbicide treatments, conducted as part of an overall crop management strategy.

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Cropland is increasing in cotton-growing regions, especially due to the mechanization of tilling and sowing (animal or motorized traction). On the other hand, manual weeding operations lead to "bottlenecks" in the cropping calendar. In some situations, due to a shortage of land, farms cannot be expanded nor can fields be left fallow once the weeds become too difficult to control. Farmers continue cultivating the same fields, which are thus progressively overrun with weeds, but there is not enough labour available to sufficiently control them.

Techniques to chemically control weeds in cotton cropfields began being developed in the early 1980s (Figure 1). Extension of this approach to weed control was facilitated by the introduction of low-volume sprayers (30 l/ha of spray mixture). At the beginning of the 1990s, 22% of cotton crops were treated in northern Cameroon, 19% in southern Mali and 32% in northern Côte d'Ivoire (Table 1).

Economic effects

The prime aim of chemical weed control is to protect the crop in the initial growth stages. Crop yields will decline if growth is stalled at this time because of weed competition. Chemical weed control results are as good as can be obtained with careful manual weeding, carried out at the most suitable time with respect to the growth stage of the crop. In practice, manual weeding requires considerable labour, and the cropping calendar has to be organized such that peak working times do not occur simultaneously for different crops in the sequence. This is still unfeasible under Sudano-Sahelian agri-cultural conditions, and hence considerable crop-production losses occur as a result of weed competition (i.e. 35-90%, depending on the crop). In addition to substantial time and labour gains, herbicide treatments generally improve crop yields as compared to those obtained with conventional practices (DEAT, 1973

& 1986; Table 2). By this technique, the first weeding can be postponed or even bypassed. Moreover, the spraying treatments are not as labour-intensive as manual weeding: i.e. around 1 working day/ha for herbicide treatments and 10-20 working days/ha for manual weeding (note that these data can vary markedly, depending on the growth stage of the crop and the extent of weed infestation).

The presence of weeds in cropfields also has an indirect economic impact. Weeds are secondary hosts to insect crop pests. The quality of a harvested crop (fodder, seeds, etc.) will be reduced, and sometimes the whole production even has to be discarded if it is mixed with weed debris or seeds.

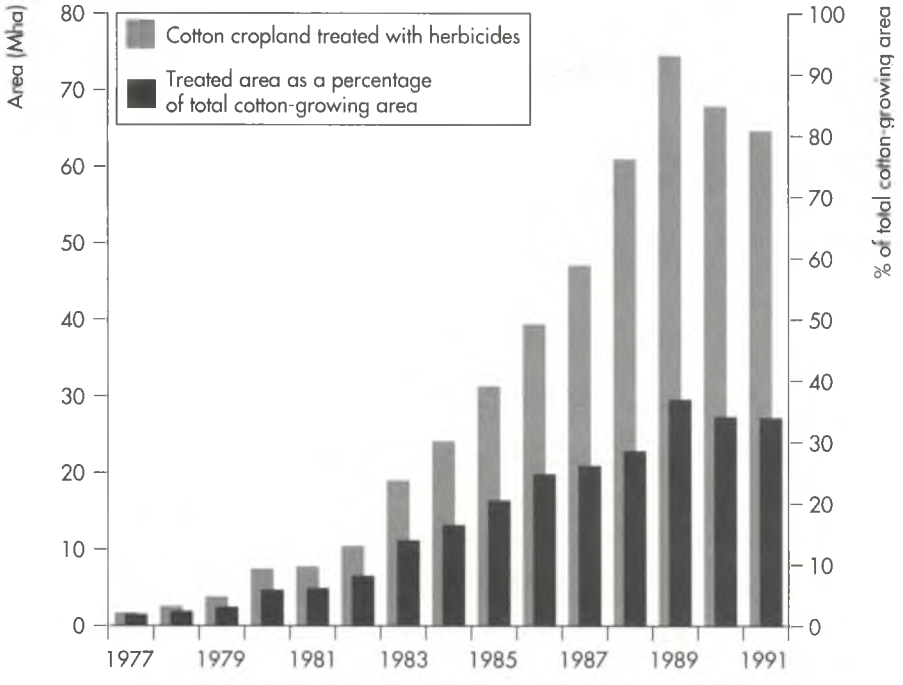


Figure 1. Cotton cropland treated with herbicides in Côte d'Ivoire since 1977 (source : CIDT, Côte d'Ivoire).

Table 1. Cropland (in ha) treated with herbicides (sources: Cameroon, SODECOTON; Mali, CMDT; Côte d'Ivoire, CIDT).

	Cotton		Maize	Rice
Northern Cameroon (1993)	21 159	(22%)*	4 890	–
Southern Mali (1992)	45 025	(19%)*	34 068	4 796
Northern Côte d'Ivoire (1991)	61 651	(32%)*	18 855	21 980

*percentage of total cotton-growing area.

Table 2. On-farm chemical weed control tests in cotton cropfields in 1984 (DEAT, 1984).

Country	Trial	Yield (kg/ha seed cotton)	Yield increase (kg/ha seed cotton)
Côte d'Ivoire	no herbicide, traditional technique	1 748	
	fluometuron 1 750 g/ha	2 081	+ 333
Benin	no herbicide, traditional technique	1 678	
	dipropetryne and metolachlor 1 600 g/ha	2 135	+ 457

Number of tests: 45 in Côte d'Ivoire, 49 in Benin.

Suitable chemical formulations

Fully adapted herbicide formulations have been developed for the main crops (cotton, maize, sorghum, millet, rice, groundnut, yam and cassava) of Sudanese and Sahelian regions (Table 3).

Pre-emergence treatments to be conducted during the sowing period were developed first because they have three major advantages (DEAT, 1988). The spectrum of pre-emergence herbicides is generally wide enough that they are efficient against grasses and broad-leaved weed species. Treatments are persistent, thus protecting the crop during its establishment phase. The treatment period, i.e. the day of sowing or the next day, greatly simplifies extension recommendations.

However, the main factor limiting the extension of herbicide treatments is their cost. In some countries, research and extension services have thus focused on herbicides based on generic molecules, such as atrazine for maize and diuron for cotton. Because of the low cost of these products, chemical weed control can now be used throughout the rural environment.

Lastly, in Sudano-Sahelian cropping systems, the end of the persistence period after pre-emergence herbicide treatments coincides with the time when the fields are earthed-up and urea is applied (30 days after sowing). Earthing-up can be effective

Table 3. Characteristics of herbicides used in Sudano-Sahelian Africa, classified by crop (Sources: ACTA, 1995; MARNOTTE, unpublished; MARNOTTE & TEHIA, 1991).

Active ingredient	Commercial product	Active ingredient concentration	Manufacturer	Dose of commercial product	Treatment period
		Cotton			
fluometuron	Cotoran 500 FW	500 g/l	Ciba-Geigy	3.5 l/ha	pre-emergence
dipropetryn + metolachlor	Cotodon 400 EC	240 + 160 g/l	Ciba-Geigy	4.0 l/ha	pre-emergence
fluometuron + prometryn	Cotogard 500 FW	250 + 250 g/l	Ciba-Geigy	4.0 l/ha	pre-emergence
fluometuron + prometryn	Callifor	250 + 250 g/l	Calliope	4.0 l/ha	pre-emergence
fluometuron + diuron	Flurone D	250 + 250 g/l	Rhône-Poulenc	4.0 l/ha	pre-emergence
pendimethalin	Stomp 400 EC	400 g/l	Cyanamid	3.5 l/ha	pre-emergence, particularly against *R. cochinchinensis*
diuron	many formulations	80%	-	1.0 kg/ha	pre-emergence
haloxyfop-methyl	Gallant Super	104 g/l	DowElanco	0.6 à 0.9 l/ha	post-emergence against grasses
fluazifop-P-butyl	Fusilade X2	250 g/l	Zeneca	1.0 à 2.0 l/ha	post-emergence against grasses
		Maize			
metolachlor + atrazine	Primagram 500 FW	250 + 250 g/l	Ciba-Geigy	4.0 l/ha	pre-emergence
cyanazine + atrazine	Bellater	250 + 250 g/l	Cyanamid	4.0 l/ha	pre-emergence
pendimethalin + atrazine	Tazastomp C	37,5 + 25%	Cyanamid	4.0 kg/ha	pre-emergence, particularly against *R. cochinchinensis*
aclonifen + atrazine	Challenge M	*250* + 250 g/l	Rhône-Poulenc	4.0 l/ha	pre-emergence
		Rice			
oxadiazon	Ronstar 25 EC	250 g/l	Rhône-Poulenc	4.0 l/ha	pre-emergence
pretilachlor + dimethametryn	Rifit Extra 500 EC	375 + 125 g/l	Ciba-Geigy	4.0 l/ha	pre-emergence
bentazone + propanil	Basagran PL2	160 + 340 g/l	BASF	6.0 l/ha	post-emergence
triclopyr + propanil	Garil	72 + 360 g/l	DowElanco	5.0 l/ha	post-emergence
2,4-D	many formulations	720 g/l	-	1.0 à 2.0 l/ha	post-emergence*
propanil	Stam F34	360 g/l	Rohm and Haas	8.0 l/ha	post-emergence*
thiobencarb + propanil	Tamariz	120 + 216 g/l	Procida; Roussel-Uclaf	8.0 l/ha	post-emergence*
thiobencarb + propanil	Rical	115 + 230 g/l	Calliope	8.0 l/ha	post-emergence*
		Groundnut			
dipropetryn + metolachlor	Cotodon 400 EC	240 + 160 g/l	Ciba-Geigy	4.0 l/ha	pre-emergence
		Yam			
metribuzin	Sencor 70 PM	70%	Bayer	2.0 kg/ha	pre-emergence
metolachlor + atrazine	Primagram 500 FW	250 + 250 g/l	Ciba-Geigy	6.0 l/ha	pre-emergence
		All crops: targeted or blanket treatments			
paraquat	Gramoxone	200 g/l	Zeneca	1.5–3.0 l/ha	post-emergence
paraquat	Calloxone	200 g/l	Calliope	1.5–3.0 l/ha	post-emergence
glyphosate	Roundup	360 g/l	Monsanto	4.0–8.0 l/ha	post-emergence against perennial weeds
sulfosate	Ouragan	480 g/l	Zeneca	4.0–8.0 l/ha	post-emergence against perennial weeds

* post-emergence treatment mainly in irrigated ricefields.

Botanical list of species mentioned

Monocotyledons

- Commelinaceae
  - *Commelina benghalensis*
  - *Commelina forskalaei*
  - *Commelina subulata*
- Cyperaceae
  - *Cyperus esculentus*
  - *Cyperus rotundus*
- Poaceae
  - *Cynodon dactylon*
  - *Dactyloctenium aegyptium*
  - *Digitaria argillacea*
  - *Digitaria horizontalis*
  - *Imperata cylindrica*
  - *Pennisetum pedicellatum*
  - *Rottboellia cochinchinensis*

Dicotyledons

- Asteraceae
  - *Launaea chevalieri*
  - *Tridax procumbens*
- Convolvulaceae
  - *Ipomoea eriocarpa*
  - *Merremia emarginata*
- Fabaceae
  - *Desmodium dichotomum*
  - *Tephrosia elegans*
- Lamiaceae
  - *Hyptis spicigera*
  - *Hyptis suaveolens*
  - *Leucas martinicensis*
- Scrofulariaceae
  - *Striga hermonthica*
- Tiliaceae
  - *Corchorus tridens*

Rottboellia cochinchinensis, adult plant.
Photo T. le Bourgeois

in reducing weed populations if carried out before the weeds have grown past the seedling stage.

Difficult weeds to control

In spite of the higher efficacy obtained with herbicide treatments, some species require regular special attention as they are difficult to control.

In recent years, these species include *Commelina benghalensis, Rottboellia cochinchinensis* and *Ipomoea eriocarpa* in northern Cameroon (LE BOURGEOIS & MARTIN, 1990) and *C. benghalensis* and *I. eriocarpa* in Benin. This concerns both traditional cultivation practices and chemical weed control (GABOREL & FADOEGNON, 1991). Surveys carried out in 1992 in rural northern Cameroon revealed some specific problems caused by these two species, and also by *Imperata cylindrica* and *Cyperus rotundus*.

In northern Cameroon, phyto-sociological studies on cotton-cropping systems revealed the effects of agricultural factors on weed development (LE BOURGEOIS, 1993). The results highlighted the relative importance of different weeds, while pinpointing species that should be targeted for control (Table 4). These include widespread and locally distributed species, which can be classified in two groups: many easily-controlled species and around 10 species that are difficult to eliminate.

After several years of cultivation, these weeds tend to overrun all fields in which they are present. Herbicides generally used to treat cotton cropfields have little effect on some species: *C. benghalensis, R. cochinchinensis, I. eriocarpa,* and *Tridax procumbens*. The others are not susceptible to standard pre-emergence herbicides. These are species with nutrient reserve organs, i.e. tubers *(C. rotundus, C. esculentus)*, rhizomes *(I. cylindrica)* or roots

(Launaea chevalieri), along with parasitic species, such as *Striga hermonthica*.

Weeding periods

As agricultural situations vary markedly, technical solutions have to be adapted to the cropping cycle. Spraying treatments can be carried out during tillage, before sowing, during sowing or throughout the cropping period (Figure 2).

Table 4. Agricultural importance of the main weed species of northern Cameroon (from LE BOURGEOIS, 1993).

Distribution	Easy control	Difficult control
General	*Digitaria horizontalis*	*Commelina benghalensis*
	Pennisetum pedicellatum	*Tridax procumbens*
	Leucas martinicensis	*Ipomoea eriocarpa*
	Dactyloctenium aegyptium	*Corchorus tridens*
Local	*Hyptis spicigera*	*Commelina forskalaei*
	Commelina subulata	*Rottboellia cochinchinensis*
	Digitaria argillacea	*Cyperus rotundus*
	Desmodium dichotomum	*Striga hermonthica*
	Merremia emarginata	*Launaea chevalieri*
	Hyptis suaveolens	*Cyperus esculentus*
	Tephrosia elegans	*Imperata cylindrica*

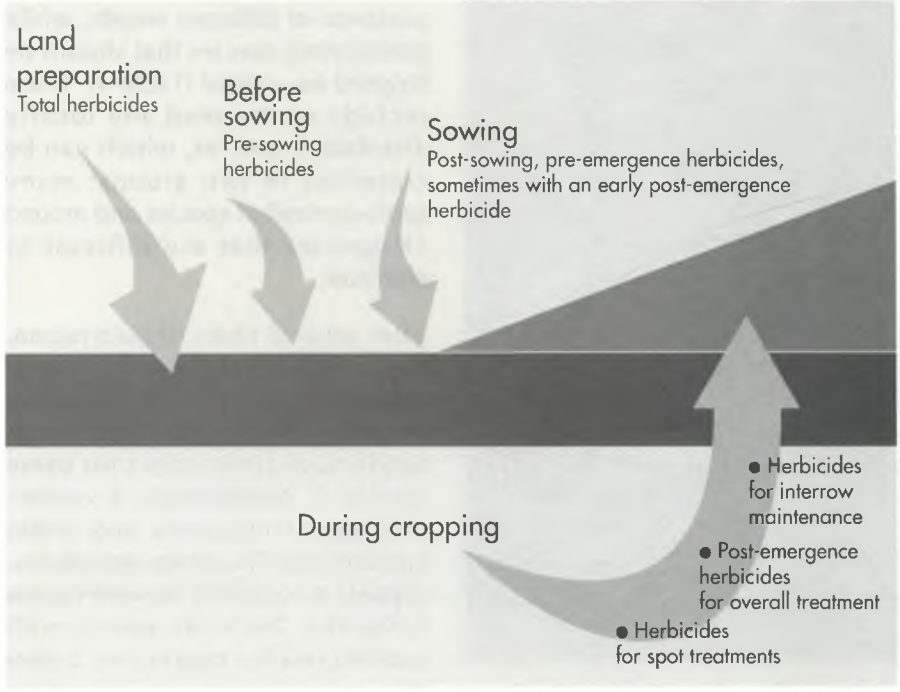


Figure 2. Herbicide treatment periods.

Treatment during tillage

Total herbicides can be used before sowing, during preliminary tillage. There can be several combined objectives:

– to control populations of perennial species *(C. rotundus, I. cylindrica)* with systemic products; treatments can also be done after the preceding crop has been harvested (FEUILLETTE *et al.*, 1994; MARNOTTE, 1994);

– to limit the spread of weeds that, in regions with a long rainy season, begin growing after the first rains, before the fields have a crop cover;

– to destroy weed seedlings that germinated after early ploughing, carried out 4-5 weeks before sowing, e.g. *C. benghalensis* (LE BOURGEOIS & MARNOTTE, 1994);

– to clear fields when zero-tillage cultivation is used.

Treatment before sowing

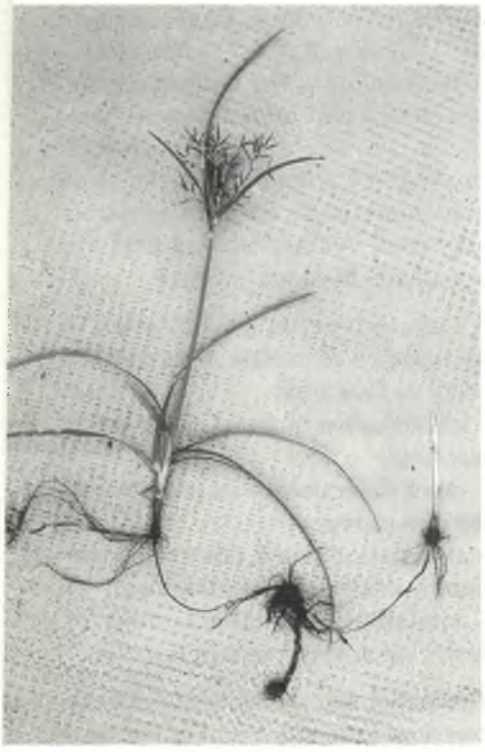
Some pre-sowing herbicides are highly effective (e.g. trifluralin on cotton). Treatments are conducted just before sowing the crop, as the active ingredients are volatile and photosensitive and must therefore be incorporated into the soil. However, it is often impossible to perform this operation efficiently due to a lack of agricultural equipment and manpower, and therefore on-farm pre-sowing weed control is not yet very feasible.

Post-sowing treatments

Post-sowing herbicide treatments are carried out just after sowing, generally the same day or the next day. The different treatment conditions for pre-emergence and early post-emergence herbicides are described below.

Pre-emergence weed control

Although most chemical weed control studies focus on post-sowing herbicides, it is still essential to strive to broaden the technical parameters and diversify the range of these products.



Cyperus rotundus whole plant with offshoots.
Photo CIRAD-AMATROP

Rottboellia cochinchinensis, adult plant.
Photo M. Déat

Treatment definitions

What kind of treatment?

Overall treatment: the whole plot is treated.

Spot treatment: spraying over patches of ground, crops or weeds.

Targeted treatment: with a non-crop selective herbicide, while protecting crop plants during treatment.

When to treat?

Pre-sowing: the herbicide is applied after tillage and before the crop is sown. Volatile and photodegradable products can thus be incorporated into the soil.

Post-sowing: treatments are done just after the crop is sown, the same day or the next day.

Pre-emergence: treatments are done before emergence of the relevant plant (crop or weed).

Post-emergence: treatments are done after emergence of the relevant plant (crop or weed).

Products should be chosen in terms of the dominant weed flora in the field. Effective pre-emergence herbicides should also be available for difficult to control annual species, e.g. *R. cochinchinensis* and *C. benghalensis*. It is important to use several different types of active ingredients, applied alternately throughout the cropping cycles, in order to avoid selection of resistant weeds.

Early post-emergence control

Early weed germination can also occur between the final tillage operations and the pre-emergence herbicide treatment. These weeds are generally not destroyed by pre-emergence herbicides, which act on emerging seedlings. Leaf herbicides should thus be used (a post-emergence crop-selective product, or a total herbicide). The treatment technique used will depend on the weed density in the field:

– at low densities, the product is prepared in the field by adding it to the pre-emergence herbicide spray mixture;

– if weed cover is too dense for the pre-emergence product to reach the soil surface, a separate treatment with a total herbicide is carried out the day before the pre-emergence treatment in order to rapidly dry-up the foliage. The dose is adapted to the extent of weed infestation (e.g. 200-600 g/ha of paraquat).

Treatment conditions during sowing

Pre-emergence herbicides must be sprayed onto a well-prepared, cleared and slightly humid soil. An overly dry soil or the presence of plant debris, clearing or harvest residues, can hinder the diffusion of spray droplets over the soil surface.

Treatment during the cropping period

Three types of weed control can be carried out during the cropping period: overall post-emergence treatments, interrow maintenance or spot weed control.

Overall post-emergence treatment

There are two advantages to conducting post-emergence herbicide treatments. First, the farmer chooses the herbicide that is most suitable for the weed species that is infesting the cropfield — note that for pre-emergence treatments the herbicide

Ipomoea eriocarpa.
Photo T. le Bourgeois

choice is based on the weed flora present with the preceding crop, assuming that the same infestation will be repeated. Secondly, the soil conditions are not important, since contact or systemic herbicides are used, which penetrate *via* the aerial parts of the plant.

However, these treatments have three major drawbacks. The treatment date is difficult to determine, whereas it is accurately defined for post-sowing pre-emergence treatments, and depends on the growth stage of the weed population. Contact herbicides are effective on seedlings at the 2-3 leaf stage. If treatments are carried out too early, subsequently emerging plants will be unaffected, whereas treatments that are too late will not be effective against older weed plants. In addition, the farmer must have full knowledge of the weed flora, particularly with respect to the seedling stage, which is the most difficult for botanical identifications. Most post-emergence products are not persistent and only effective against plants that have already emerged, whereas many pre-emergence herbicides stall weed infestations until the aerial parts of the crop plants have developed enough for the crop to occupy the whole field.

Interrow maintenance

Mechanical weeding is suitable for widely-spaced crops (maize, cotton, sorghum, cassava) in draught or motorized cultivation. However, this can only be done at the start of the growth cycle to avoid damaging the crops. Subsequently, targeted spraying treatments can be conducted with non-crop selective herbicides for the purposes of interrow maintenance. This weed control technique requires a manual-pressure sprayer fitted with a hood to protect the crop plants. This technique is rapid and not as tiresome as manual weeding.

Spot weed control

The farmer must be careful that his fields do not get overrun by dangerous weeds *(C. rotundus, C. esculentus, I. cylindrica, L. chevalieri, S. hermonthica).* The costs of control operations will remain low if these species are controlled through spot treatments during the first stages of infestation (when a few weed plants are noted), without waiting until the population becomes invasive.

A certain level of organization is required to eliminate a weed on a small surface area:
– identification of the plant (previous learning);
– rapid detection of its presence in the plot (surveys);
– scheduling weed control operations over several years (training);
– availability of small quantities of herbicide at very low cost (supply).

The farmer will sometimes have to be prepared to sacrifice part of the crop when non-selective systemic herbicides have to be used, e.g. against *I. cylindrica* (FEUILLETTE *et al.*, 1994).

Experimental procedures and field treatments

Two types of trials were conducted successively with the aim of defining ideal herbicides and treatment conditions (Figure 3). The first tested the efficacy of each herbicide for controlling weeds, while investigating the best dosages and treatment periods. Secondly, selectivity trials were carried out to estimate the risks of herbicide phytotoxicity to the crop.

The residual effects of each herbicide were also assessed to determine the risks of herbicide phytotoxicity to the following crop.

Field trials were then conducted with herbicides selected during the preceding experimental stages to evaluate their practical and economic benefits.

National research and extension organizations, and extension companies then conducted further

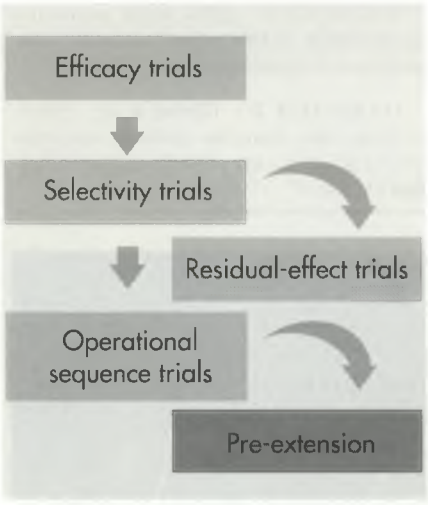


Figure 3. Herbicide treatment testing procedures.

trials and the results were generally suitable for extension purposes. Private herbicide manufacturers also conduct their own trials aimed at developing marketable compounds.

Regular testing

In African agricultural situations, cultural and economic conditions change rapidly. The cost-effectiveness of a herbicide treatment generally depends on these fluctuations, e.g. the cost of imported chemicals, and the existence of commercial networks. In addition, at least 3 years of research are required to adequately test herbicide performance. Regular testing is required to be able to offer reliable technical guidelines, leading to solutions that are adapted to the changing agricultural environment. It is also important to assess new families of herbicides that are constantly being developed by the herbicide industry.

Extension

For extension purposes, it is essential to distribute practical data sheets describing herbicide products, their usage and spraying techniques adapted to the prevailing weed flora and cropping system. Very specific conditions are required for the use of herbicides and spraying equipment (dose, treatment periods, calibration, flow-rate, speed of operation, type of nozzle, spray preparation, etc.), which means that extension companies and services have to provide training.

Supervisory staff training and farmers' awareness campaigns should focus on weed control techniques as well as suitable operational sequences. Weed control programmes must take farm work planning and crop sequences into account. Medium-term weed control is therefore managed in terms of the crop rotation, by:
– choosing, for instance, an inexpensive effective herbicide for maize crops, so as to save time on mechanical or manual maintenance of cotton fields;

Imperata cylindrica.
Photo R. Fauconnier

Commelina benghalensis plantlet.
Photo M. Déat

– destroying grasses in cotton cropfields and broad-leaved weeds in cereal cropfields.

The training and supply situation

Weed management techniques, such as those developed elsewhere for controlling erosion and enhancing soil fertility, are valid if they help stabilize land tenure systems, while enabling farmers to make medium-term investments.

Crop marketing facilities dictate what crops farmers should produce. Similarly, farming operations should be supported by operational input supply networks that offer a wide range of herbicides and spraying equipment, with flexible payment terms.

Herbicides will progressively become an integral component of cropping systems, as has occurred with pesticides. Herbicide treatments will at least replace the first manual weeding operation, which requires substantial labour and cannot be postponed (otherwise it will be ineffective).

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Cyperus rotundus.
Photo CIRAD-AMATROP

Abstract... Résumé... Resumen

P. MARNOTTE — **Herbicide use: constraints and prospects.**

Weed management in Sudano-Sahelian Africa is the main problem for farmers because of the cropping calendar and the labour required for weeding. Crop maintenance is difficult using manual weeding and crops are increasingly overrun by weeds whose density increases with successive cropping cycles. Some species are extremely difficult to eliminate and require spot treatments as soon as the first seedlings appear. Chemical weed control is a solution but it must be designed according to the crop and the rotation. The technique has been used in cotton-growing areas especially in northern Cameroon, southern Mali and northern Côte d'Ivoire. However, it requires favourable economic conditions and good training of extension agents and farmers (flora surveys, herbicide usage conditions, use of spraying equiment).

Keywords: weed, cotton, maize, weeding, herbicide, type of action, Sudano-Sahelian Africa.

P. MARNOTTE — **Utilisation des herbicides : contraintes et perspectives.**

En Afrique soudano-sahélienne, la maîtrise de l'enherbement constitue la difficulté majeure des agriculteurs, en regard du calendrier cultural et de la main-d'œuvre nécessaire pour exécuter les sarclages. Entretenues difficilement par sarclage manuel, les cultures sont de plus en plus envahies de mauvaises herbes dont la densité augmente au fil des cycles culturaux. Certaines espèces sont très difficiles à détruire et demandent des traitements localisés dès l'apparition des premières plantules. Le désherbage chimique constitue une solution, à condition de le raisonner sur le plan de l'assolement et de la rotation. Cette technique est développée en particulier dans les régions cotonnières, notamment dans le nord du Cameroun, le sud du Mali et le nord de la Côte d'Ivoire. Elle implique toutefois des conditions économiques favorables ainsi qu'une bonne formation du personnel d'encadrement et des agriculteurs : reconnaissance de la flore, mode d'emploi des produits, utilisation des appareils de traitement.

Mots-clés : mauvaise herbe, cotonnier, maïs, sarclage, herbicide, mode d'action, Afrique soudano-sahélienne.

P. MARNOTTE — **Utilización de los herbicidas: obligaciones y perspectivas.**

En Africa sudano-saheliana, el control del enyerbado es la principal dificultad de los agricultores frente al calendario de cultivo y la mano de obra necesaria para ejecutar las escardas. Los cultivos, dificilmente cuidados por escarda manual, son invadidos cada vez más por las malezas, cuya densidad aumenta con el correr de los ciclos de cultivo. Algunas especies son muy difíciles de destruir y requieren tratamientos localizados desde la aparición de las primeras plántulas. La desyerba química constituye una solución, a condición de razonarla en términos de rotación. Esta técnica se desarrolla especialmente en las regiones algodoneras, sobre todo en el norte de Camerún, el sur de Mali y el norte de Costa de Marfil, pero supone condiciones económicas favorables, así como una buena formación del personal de dirección y de los agricultores (reconocimiento de la flora, modo de empleo de los productos, utilización de aparatos de tratamiento).

Palabras clave: maleza, algodón, maíz, escarda, herbicida, modo de acción, Africa sudano-saheliana.