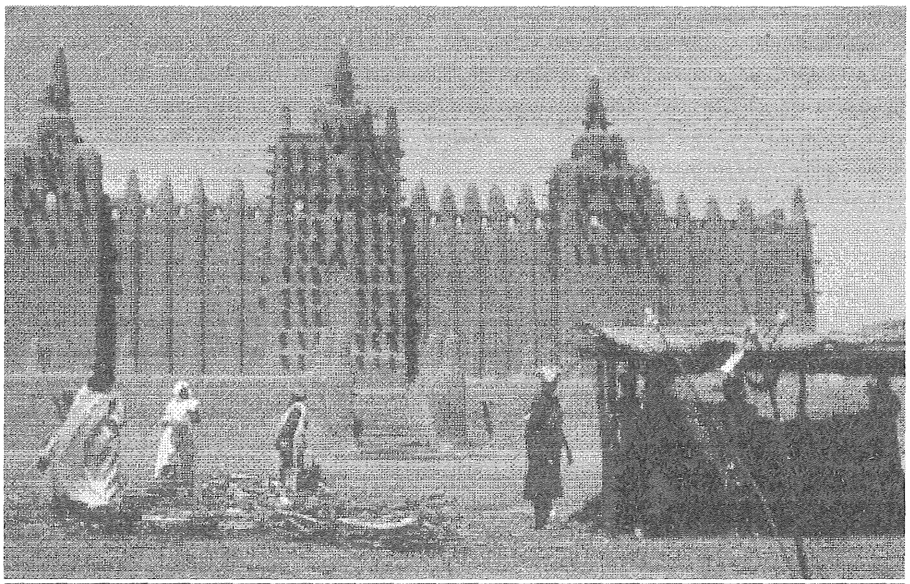
Striga hermonthica:

Dispersal, Longevity and Dormancy of *Striga* seeds



(The mosque in Djenné, Mali)

by Emiel Snel
under the supervision of
Ing. Aad van Ast
at the department of Theoretical Production Ecology
of the Wageningen Agricultural University
in
The Netherlands.
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Contents

		Page
1. General introduction		3
2. Crop seed contamination study		6
2.1	Materials and methods	6
2.1.1	Seed collecting	6
2.1.2	Interviews	6
2.1.3	Laboratory experiments	7
2.2	Results	9
2.2.1	Seed collecting	9
2.2.2	Interviews	9
2.2.3	Laboratory experiments	14
2.3	Discussion	16
3. Seedbank study		18
3.1	Materials and methods	18
3.2	Results	20
3.2.1	Viability	20
3.2.2	Germination	26
3.3	Discussion	32
Acknowledgements		34
Abstract		35
Annex 1 (Farmers that donated seeds for the crop seed contamination study)		36
Annex 2 (Farmers that participated in the interviews)		38
Annex 3 (Questionnaire used in the interviews)		41
Annex 4 (Traditional treatments of crop seeds against *Striga* or other diseases)		42
Annex 5 (Scatterplots of '% viability' and '% germination' vs. 'Day')		43
Annex 6 (Scaled down graphs from the seedbank study results)		45
Literature		46

1. General Introduction

Striga, of the *Scrophulariaceae*-family, is a parasitic weed that can be found in the semi-arid regions of the tropics (Ayensu et al., 1984). There are about 25 different species of *Striga*. Some of these species, like *S. hermonthica, S. asiatica, S. gesnerioides* and *S. densiflora*, are notorious parasites of important cereal crops (Ramaiah et al., 1983). The host plants of *Striga* are mainly grasses (*Graminaceae*), but also species from the *Leguminaceae, Solanaceae, Euphorbiaceae, Pedaliaceae* and *Convolvulaceae* can be parasitised. *Striga* parasitises the host plant by a haustorium on the root of the host. The haustorium is a connection with the vascular system of the host. From there, *Striga* takes up water, assimilates and nutrients (Dembélé et al., 1994).
The uptake of water, assimilates and nutrients only accounts for 20% of the total influence that *Striga* has on its host. The pathological effects of *Striga* are much more severe. When attacked by *Striga*, the root : shoot ratio changes in favour of the roots. The root system is greatly stimulated, while the shoot system hardly shows any growth. In the xylem sap cytokinins and gibberellins are greatly reduced and abscisic acid and farnesol are increased. The effects of *Striga* on its host are almost the same as found with drought stress. Chlorotic symptoms, like small elongated yellowish blotches can be seen. A severe infestation can lead to generalised chlorosis, scorch and collapse of leaf tissue. Also the efficiency of the hosts' photosynthesis is reduced. This is probably caused by an alteration in the water balance of the host, which causes the stomata to close, possibly combined with a loss of nitrogen (Parker and Riches, 1993).
Striga cannot parasitise just any plant, because the seeds of *Striga* only germinate, when they receive a certain chemical, a root exudate, and not all plants excrete this specific root exudate (Ramaiah et al., 1983). This chemical has been isolated and synthesised in the laboratory and is called Strigol (Hassanali, 1984).
The uptake of assimilates, nutrients and water and the pathological effects can be such a strain, that the host is not only retarded in growth and development, but can even die without producing any seeds. This illustrates immediately the agricultural problem. When a farmers' field is heavily infested with *Striga*, the yield can be reduced to zero (Ramaiah et al., 1983).
The seeds of *Striga* are minute, they are about 0.2 x 0.3 mm in size, and produced in huge quantities. Each flower on a *Striga* plant can produce up to 500 seeds. Their small size and the great number of seeds allow *Striga* to spread rapidly. The seeds are mainly dispersed by wind, water, humans and animals. *Striga* seeds can remain viable for a long time (Ramaiah et al., 1983). When *Striga* seeds don't germinate (because they didn't receive a germination stimulant), they probably go into a state of secondary dormancy. Dormant they bridge the unfavourable dry-season. Next year, at the beginning of the rainy season, they awaken and are again susceptible for a germination stimulant, excreted by potential hosts (Pieterse and Verkleij, 1994).
Removing all *Striga* from a field, by weeding, has only little effect. In the soil a lot of seeds still remain. Next year part of these seeds will germinate, when they receive a germination stimulant. It's possible to get rid off *Striga* by weeding for many years, but this can only be effective when there's no influx of seeds from the outside. In practice,

this never happens. *Striga* can be found on neighbouring fields, fallow grounds or in the wild. As said, *Striga* seeds are dispersed relatively easy and therefore *Striga* is very hard to get rid off.

This paper concerns two studies:
A crop seed contamination study and a seedbank study.

<u>The crop seed contamination study</u>:
The crop seed contamination study focuses on the possible contamination of crop seeds with *Striga* seeds.
Because *Striga* seeds are minute in size, it's not unthinkable that they could 'stick' to crop seeds and be dispersed along with them, when the farmer sows the crop seeds to produce the next crop. According to Berner et al.(1994), crop seed contamination is a very important factor in the dispersal of *Striga* seeds. The method of harvest is said to be important in determining the level of contamination. Concluded is, that man is, through agricultural practices and animal movement, the primary factor in dispersal of *Striga* ssp..
The purpose of this study is to determine whether crop seeds can be contaminated with *Striga* seeds and whether *Striga* seeds are being dispersed in this fashion. If this is a possibility for dispersal, maybe a measure can be found to prevent the spread of *Striga* (-seeds) in this way.
The study consists of three parts. First of all, seeds of *Sorghum bicolor* (sorghum), *Zea mays* (maize), *Pennisetum americanum* (millet) and *Vigna unguiculata* (cowpea) were collected in 12 villages in Mali (Africa) and checked in the laboratory for the presence of *Striga* seeds. Second, the farmers that donated the seeds were interviewed. The aim of the interviews was to learn what knowledge farmers have of *Striga*, what their farming practices are and whether those practices sort an effect on the degree of contamination of their crop seeds. Third, a laboratory experiment was done, in which *Striga* seeds and crop seeds were mixed on purpose to learn what percentage of a predetermined quantity of *Striga* seeds will stick to a certain amount of crop seeds.

<u>The seedbank study</u>:
In the seedbank study the longevity and the dormancy patterns of *Striga hermonthica* seeds are investigated, in two different climatic zones in Mali, during a period of two years.
In the last couple of years some contradictionary articles were published about the longevity and dormancy patterns of *Striga* seeds in the soil. This asked for more research to gain insight into the factors that influence the survival of *Striga* seeds in the soil. Ramaiah et al. (1983) mention a longevity of *Striga* seeds in the soil up to 15-20 years. Bengaly et al. (1996) report that long fallow periods are not a viable solution for the *Striga* problem, because in regions where farming practices are more intense, the *Striga* infestation is much lower. In the regions with permanent agriculture there's hardly any fallowing of the land. Production is increased by fertilisation (organic and chemical) and crop rotation. This suggest that *Striga* seeds remain viable during the fallow period, but that the occurrence of Striga can be diminished by fertilisation and crop rotation.

In 1984, Pieterse et al. published a reinvestigation of secondary or wet dormancy. After prolonged in vitro conditioning *Striga* seeds seemed to enter a state of secondary dormancy. They do have their doubts about the occurrence of secondary dormancy under field conditions.
Recently, results of field studies in Benin (Gbehounou et al., 1996a) and Kenya (Pieterse et al., 1996) led to believe that the longevity of *Striga* seeds could be much shorter than generally assumed.
Gbehounou et al. (1996a) found that the germination rate and viability of *Striga hermonthica* seeds decreased steadily in the course of the rainy season. It was concluded that *Striga* seeds do not enter a stage of secondary dormancy, which implies that fallowing of the land (without the presence of wild hosts) would dramatically decrease the number of viable *Striga* seeds in the soil.
In Kenya, Pieterse et al. (1996) came to similar results. They also found a rapid dying off of *Striga* seeds under field conditions. Here, however a lot of seeds seem to have died as a result of suicidal germination caused by ethylene producing micro-organisms or by remnants of plant roots producing natural germination stimulants.
Pieterse et al. (1996) came also to the conclusion that seeds don't enter a state of secondary dormancy. They think crop rotation could be an effective control method against *Striga*, because *Striga* seeds die rapidly in the course of the rainy season.

To get a better insight into what's really happening to *Striga* seeds in the soil, this comparative seedbank study was conducted. With the seedbank study it is hoped to get a better understanding about the longevity and the dormancy patterns of *Striga hermonthica* seeds in the soil.

2. Crop seed contamination study

2.1 MATERIALS AND METHODS

The study was mainly conducted in the West-African republic of Mali in co-operation with the ESPGRN institute in Sikasso. Some work was done at the department of Theoretical Production Ecology of the Wageningen Agricultural University in The Netherlands.

In Mali seeds were collected in the following villages:
-Region of Koutiala: N'Goukan, Try I and II, N'Peresso, Faroula.
-Region of Kadiolo: Kafono, N'GoloPéné, Ouatialy, Zankundougou.
-Region of Bougouni: Kodialan, Sola, Banco, Sorona.
Most of the farmers that donated the seeds also participated in the interviews.
In the villages Gongasso and Noyaradougou (Region of Sikasso) only interviews were held, but no seeds were collected. (For a detailed list of participants: see ANNEX 1 for the seed collecting and ANNEX 2 for the interviews).

2.1.1. Seed collecting:

Samples of crop seeds were collected by the 'enquetteurs' of the participating villages. We strived to get crop seed samples from 10 farmers per village.
When possible, from each farmer crop seed samples were collected of *Sorghum bicolor* (sorghum), *Zea mays* (maize), *Pennisetum americanum* (millet) and *Vigna unguiculata* (cowpea). Each sample had a weight of approximately 250 grams. Only untreated seeds, destined for the sowing of next years crop, were collected. This to keep the samples alike. A treatment could reduce the degree of contamination of the crop seeds and therefore would make it very complicated to compare different treated samples with each other. By taking a quantity of seeds at the top, the middle and the bottom of a storage container we hoped to get a representative sample of the contents of the container.
In the laboratory, each sample was thoroughly stirred to obtain a homogeneous mixture. Afterwards, 25 grams of maize (± 70 seeds) or 15 grams of sorghum (± 680 seeds), millet (± 680 seeds) or cowpea (± 100 seeds) were put into a petri-dish. These weights are based on the amount of seeds necessary to cover the bottom of the entire petri-dish with one layer of seeds. Several layers of seeds would complicate the finding of *Striga* seeds on sight. The crop seeds in the petri-dish were checked for the presence of *Striga* seeds under a dissecting microscope.

2.1.2. Interviews:

The interviews were held by or with the aide of native Bambara speakers.
This to solve communication problems and to prevent errors. Most of the farmers don't speak French and a many of them can't read or write. A lot of interviews were held by the 'enquetteurs' of the villages, for which we are very grateful. It saved a lot of time.

For a copy of the questionnaire see ANNEX 3.
The questions asked only apply to the crops sorghum, maize, millet and cowpea, because those are the crops of which the farmers donated seeds for the seed contamination study.

A short description of the questions and some remarks follow below:
1) Where did the farmer obtain the seeds?
-Did he use seeds from last years harvest?
-Has he bought the seeds and if so, where?
-Or in another way?
2) Does the farmer know the seeds of *Striga*?
We marked a positive response when a farmer said he had seen the seeds, but also if he believed the flowers produced the seeds although he had never seen them. This to make a distinction between farmers who think or know the flowers of *Striga* produce seeds and farmers who think seeds are produced in some other way or aren't produced at all.
3) Does the farmer know his crop seeds could be contaminated with *Striga* seeds?
If he does: Does the farmer think his crop seeds are contaminated with *Striga* seeds?
With this combination of questions we wanted to find out whether farmers consider crop seed contamination as a possibility for *Striga* seed dispersal and whether they think it is actually taking place.
4) How does the farmer harvest its crops and how does he collect the crop seeds?
The aim is to find out what the harvesting methods are and whether they facilitate contact between *Striga* seeds and crop seeds.
5) Are the farmers' fields infested with *Striga*?
6) What variety of sorghum does the farmer use? Panicle spreading (Guinea type) or compact? The sorghum varieties with the compact panicles are less tolerant to parasitation by *Striga*, than the varieties with spreading panicles.
7) Does the farmer treat his seeds?
Does the farmer treat his crop seeds to prevent *Striga* germinating (or to protect its crop against diseases)? Farmers use 'modern' treatments (chemical fungicides, insecticides, etc.) and/or 'traditional' treatments (ancient farming practices/knowledge, use of natural products).

Also some supplementary questions were asked:
-How many different *Striga* species are known by the farmer?
-For how long, the farmer thinks, *Striga* seeds remain viable in the soil?
-In what ways, the farmer thinks, *Striga* seeds spread from one field to another?
-What kind of action the farmer takes to prevent or reduce *Striga* on his fields?

2.1.3. <u>Laboratory experiments:</u>

In the laboratory in Wageningen, *Striga* seeds and crop seeds were mixed on purpose (because no contamination of crop seeds with *Striga* seeds was found in the crop seed samples (see RESULTS, <u>Seed collecting</u>)). By mixing crop seeds and *Striga* seeds on purpose it was hoped to determine conclusively, whether it's possible that crop seeds are contaminated with *Striga* seeds or not. 3 maize varieties (LG 2217, LG 11 and Agadir)

and 12 sorghum varieties (see Table with the results of the Laboratory experiments) were used. The LG 11 and Agadir samples were of treated seeds. This means they were supplied by a (European) company, that has washed the seeds, selected them for size and has coated the seeds with an insecticide. Before use in the experiments, the insecticide was washed off. The LG 2217 sample was collected at an experimental field in Wageningen. These seeds, in contrast to the treated LG 11 and Agadir, had still the little filmy scales at the foot of the seeds. The maize seeds used by the farmers in Mali also have these little filmy scales. The sorghum seeds were collected in Mali and were untreated. From each sample, two plastic jars were filled. Each jar containing 40 grams of maize seeds or 15 grams of sorghum seeds. Afterwards 0.05 grams of *Striga hermonthica* seeds (about 7500 seeds) were administered to each jar. The jars were closed and thoroughly shaken. To determine also the possible effect of air humidity (in Mali the humidity during the rainy season is between 80% and 95%) on the amount of *Striga* seeds that stick to the crop seeds, the plastic jars were placed (opened) in two separate incubators. Both had an inner temperature of 35°C. The humidity in one incubator was approximately 40% and in the other it was approximately 90%.
After 24 hours the jars were closed, shaken once more and taken out of the incubators for the actual testing. The contents of a jar was transferred onto a sieve, then shaken back and forth five times, to simulate the handling of the crop seeds by the farmer, transferred again onto another sieve and washed with water. The water was passed over some filter paper in a Büchner-funnel. The *Striga* seeds trapped on the filter paper were counted.
The LG 2217 samples were visually checked after washing, with a dissecting microscope, because these were the only seeds with filmy scales at the bases of the seeds. It's possible to wash all the *Striga* seeds off from maize seeds without filmy scales, but from seeds with scales it's much more difficult. The *Striga* seeds found trapped under the filmy scales were counted and added to the amount that washed off.

2.2 RESULTS

2.2.1 Seed collecting:

All the collected samples were thoroughly examined and sometimes re-examined by a colleague, but no *Striga* seeds were found in any of the samples.

2.2.2 Interviews:

In total 127 farmers were interviewed in 14 different villages (Try I and II are counted as one village), in 4 regions. The number of farmers interviewed per village is given between brackets.
Region of Koutiala: N'Goukan (10), Try I and II (7), N'Peresso (10), Faroula (9).
Region of Kadiolo: Kafono (7), N'GoloPéné (10), Ouatialy (9), Zankundougou (10).
Region of Bougouni: Kodialan (11), Sola (7), Banco (7), Sorona (10).
Region of Sikasso: Gongasso (10), Noyaradougou(10).

Question 1: Where did the farmer obtain the seeds?
In all the regions similar results are found. All farmers use crop seeds from the previous year to sow next years crop. Usually the seeds are from their own crops, but some farmers (on average 12% (0% - 45%)) also obtained sowing seeds from other farmers in the village. Only 1 farmer bought Maize seeds from the CMDT. (4 farmers bought cotton seeds from the CMDT). The CMDT (Compagnie Malienne pour le Développement des Textiles) is a nation-wide co-operation in Mali that co-ordinates the production of cotton in Mali and also supplies farmers with means and knowledge to do so.

Question 2: Does the farmer know the seeds of *Striga*?
The majority of the farmers believe or have actually seen that the flowers of *Striga* produce seeds. However this can differ considerably between villages and to a lesser extent between regions.
Region of Koutiala: on average 47% (20% - 70%).
Region of Kadiolo: on average 89% (56% - 100%).
Region of Bougouni: on average 51% (29% - 70%).
Region of Sikasso: on average 85% (80% - 90%).

Question 3: Does the farmer know his crop seeds could be contaminated with *Striga* seeds?
Not many farmers know it's possible that their crop seeds could be contaminated with *Striga* seeds.
Region of Koutiala: on average 25% (10% - 67%).
Region of Kadiolo: on average 10% (0% - 29%).
Region of Bougouni: on average 13% (0% - 20%).
Region of Sikasso: on average 15% (0% - 30%).

If he does: Does the farmer think his crop seeds are contaminated with *Striga* seeds?
Of these farmers, that know their crop seeds could be contaminated, on average 57% think that their seeds are contaminated and on average 22% has no idea if their crop seeds are contaminated or not.

Region of Koutiala: contaminated: 54% (17% - 100%), don't know: 21% (0% - 83%).
Region of Kadiolo: contaminated: 75% (0% - 100%), don't know: 0%.
Region of Bougouni: contaminated: 33% (0% - 100%), don't know: 33% (0% - 100%).
Region of Sikasso: contaminated: 67% , don't know: 33%.

Question 4: How does the farmer harvest its crops and how does he collect the crop seeds?
No two harvesting methods are the same. Often they are very alike, but always there are small differences. Nevertheless, a description was made for each region.

maize:

Region of Koutiala: The plants are left standing at the field until they're dry. The corn is harvested by cutting the panicles of with a knife and they are collected under a tree. Here the leaves are removed. Afterwards the corn is sometimes dried again. This is done in the village or at the field. After drying the corn is stored in the 'grenier'.

Region of Kadiolo: The plants are put on bundles and left to dry for some weeks. Then the corn is harvested and the leaves are removed at the same day. Afterwards the corn is stored in the 'grenier' or it's left to dry lying down or hanging from some leaves that weren't removed.

Region of Bougouni: The same as in the region of Kadiolo, but after harvest, the corn is sometimes dried in the 'grenier', by lighting a small fire underneath the 'grenier'.

Region of Sikasso: The plants are left standing at the field until they're dry. Some leaves are removed and the corn is hung out to dry, hanging from the remaining leaves. When the corn is destined for consumption, all the leaves are removed after drying. When the corn will be used for sowing of next years crop, the remaining leaves are not removed. The corn is stored in the 'grenier'.

sorghum:

Region of Koutiala: Children push the plants down. The adults follow and cut the panicles. The panicles are tied up into bunches and laid down on the remains of the sorghum plants to dry. After drying the sorghum is stored in the 'grenier'.

Region of Kadiolo: Children push the plants down. The adults follow and cut the panicles. The panicles are tied up into bunches and laid down on a 'hangar' to dry. A 'hangar' is a platform made of branches, about a meter above the ground. 'Hangars' can be found on or alongside the fields. After drying the sorghum is stored in the 'grenier'.

Region of Bougouni: Children push the plants down. The adults follow and cut the panicles. The panicles are tied up into bunches and laid down on a 'hangar' to dry. Sometimes the sorghum is dried on the remains of the sorghum plants. The sorghum is stored in a 'grenier' or on the 'hangar' (sometimes covered with a layer of straw).

Region of Sikasso: Children push the plants down. The adults follow and cut the panicles. The panicles are tied up into bunches and laid down on a 'hangar' or on the remains of the sorghum plants to dry. The sorghum is stored in the 'grenier'.

millet:

The way in which millet is harvested is the same as for sorghum, although sometimes the whole plants are cut off and left to dry lying down on the field, before the panicles are collected. This is done in the region of Kadiolo. In the region of Sikasso the panicles are dried on a cleared or on a dusted with ashes piece of the field.

cowpea:

Region of Koutiala: The pods are left to dry on the plant. The pods are harvested, when dry. The seeds are removed from the pods and stored, mixed with ashes, in a sack. Some farmers dry the cowpea on the roof of their house and store the seeds destined for the sowing of next years crop in an empty insecticide container.

Region of Kadiolo: The pods are left to dry on the plant or are dried on the roof. The seeds are removed and stored in the 'grenier'. The seeds destined for the sowing of next years crop are stored in an empty insecticide container.

Region of Bougouni: The pods are left to dry on the plant. The pods are harvested. The seeds are removed and stored in a 'grenier' with no roof.

Region of Sikasso: The pods are harvested and dried on the roof of a house, on a 'hangar' or on the field. The seeds are stored in the 'grenier'. The seeds destined for the sowing of next years crop are stored in an empty insecticide container.

Question 5: Are the farmers' fields infested with *Striga*?

Almost all the farmers' fields were infested with *Striga*.

Region of Koutiala: on average 84% (60% - 100%).
Region of Kadiolo: on average 94% (89% - 100%).
Region of Bougouni: on average 95% (82% - 100%).
Region of Sikasso: on average 100%.

Question 6: What variety of sorghum does the farmer use?

Of the farmers that grow sorghum, nearly all use a sorghum variety with a spreading panicle (Guinea type). Sorghum varieties with a spreading panicle are more tolerant to *Striga* parasitation, than varieties with compact panicles.

Region of Koutiala: compact panicle: on average 10% (0% - 40%).
Region of Kadiolo: compact panicle: on average 0%.
Region of Bougouni: compact panicle: on average 4% (0% - 14%).
Region of Sikasso: compact panicle: on average 0%.

Question 7: Does the farmer treat his seeds?

Most of the farmers treat their seeds. In the region of Kadiolo almost all the farmers treat their seeds (see below).

Region of Koutiala: on average 82% (67% - 100%).
Region of Kadiolo: on average 92% (80% - 100%).
Region of Bougouni: on average 57% (20% - 100%).
Region of Sikasso: on average 65% (60% - 70%).

The farmers that treat their seeds can give their seeds a 'modern' treatment, a 'traditional' treatment or both (see below).

Region of Koutiala: modern: 43% (0% - 100%); traditional: 48% (0% - 100%).
both: 15% (0% - 38%).
Region of Kadiolo: modern: 67% (13% - 100%); traditional: 5% (0% - 20%).
both: 28% (0% - 88%).
Region of Bougouni: modern: 51% (0% - 100%); traditional: 40% (0% - 100%).
both: 9% (0% - 36%).
Region of Sikasso: modern: 93% (86% - 100%); traditional: 7% (0% - 14%).
both: 0%.

Modern treatments are treatments with chemical fungicides or insecticides.
The most popular chemical is 'Thioral rouge'. The farmers call it 'Si'Jiolan'. Second to this is 'Apron +', but this chemical is only used by a few farmers. One farmer said he used 'Ektafes 1000'.
Traditional treatments are treatments with substances containing (parts of) plants or animals. The farmers prepare and perform the treatments on the basis of ancient knowledge, passed down the generations of the family. Sometimes farmers were reluctant to share their secrets or they didn't know the names of the plants or animals they used. In ANNEX 4 a list is given of all the different traditional treatments.

Question 8: How many different *Striga* species are known by the farmer?

Farmers distinguish *Striga* species on basis of flower colour, leaf shape/size, place of occurrence and host specific parasitation. On average, most farmers know 2 different *Striga* species, fewer farmers know 1 species and still fewer farmers know 3 *Striga* species. This can differ considerable between villages as indicated by the variation in the data.

Region of Koutiala: on average 1 spp.: 25% (0% - 100%); 2 spp.: 31% (0% - 86%).
3 spp.: 3% (0% - 10%).
Region of Kadiolo: on average 1 spp.: 45% (14% - 100%); 2 spp.: 32% (0% - 56%).
3 spp.: 3% (0% - 10%).
Region of Bougouni: on average 1 spp.: 46% (20% - 91%); 2 spp.: 45% (0% - 80%).
3 spp.: 6% (0% - 14%).
Region of Sikasso: on average 1 spp.: 0% ; 2 spp.: 65% (40% - 90%).
3 spp.: 30% (0%- 60%).

Question 9: For how long, the farmer thinks, *Striga* seeds remain viable in the soil?
Usually farmers have no idea about the longevity of *Striga* seeds in the soil. Their response is a guess, but sometimes a well argumented guess.
The answers can roughly be divided into two categories. The majority thinks *Striga* seeds remain viable somewhere between 1 and 4 years. The others think *Striga* seeds stay alive for a long time. Between a time span of 10 to 40 years, with excesses to 85 years, infinity or as long as the soil is poor. On average it's 26 years.
There is no distinction between regions.

Question 10: In what ways, the farmer thinks, *Striga* seeds spread from one field to another?
This question reflects the farmers opinion, about the ways by which *Striga* seeds are dispersed. No suggestions were made to the farmers, they thought of these ways of dispersal themselves. Farmers could give multiple answers, so percentages don't add up. (A farmer could for example say, that he thinks *Striga* seeds are dispersed by water and wind).

Dispersal by	Koutiala	Kadiolo	Bougouni	Sikasso
water	17%(0-56%)	53%(44-60%)	59%(29-90%)	50%(40-60%)
wind	19%(0-56%)	28%(0-40%)	32%(0-71%)	45%(20-70%)
animals	5%(0-11%)	22%(10-40%)	11%(0-43%)	5%(0-10%)
humans	3%(0-10%)	3%(0-11%)	11%(0-43%)	0%
Striga roots	0%	0%	0%	15%(0-30%)
crop seed contamin.	0%	0%	4%(0-14%)	0%
ants	0%	5%(0-20%)	0%	0%
transportation of soil	0%	8%(0-33%)	0%	0%
there's no dispersal	0%	15%(0-60%)	4%(0-14%)	10%(0-20%)

Question 11: What kind of action the farmer takes to prevent or reduce *Striga* on his fields?
The farmers take the following measures against *Striga* on their fields.

Measure	Koutiala	Kadiolo	Bougouni	Sikasso
organic fertilisation	46%(10-78%)	0%	33%(0-71%)	80%
chemical fertilisation	14%(0-56%)	0%	5%(0-20%)	25%(10-40%)
resistant crops	3%(0-11%)	0%	0%	0%
abandon fields	0%	25%(0-100%)	6%(0-14%)	0%
crop rotation	3%(0-11%)	3%(0- 10%)	15%(0-60%)	0%
sow early	0%	16%(0- 56%)	4%(0-14%)	5%(0-10%)
sow late	0%	6%(0- 22%)	0%	0%
hand weeding	6%(0-22%)	8%(0- 22%)	8%(0-14%)	0%

Some farmers take some unusually measures against *Striga*. One farmer buries a small dog, form which the eyes haven't opened yet, on the field against *Striga*.

Remarks:
-There are farmers who see the presence of *Striga* on their field as an act of God. Because the seeds of *Striga* are so small and therefore not often seen, some farmers find it mysterious why *Striga* sprouts on their fields. They often have a religious or superstitious explanation.
-A farmer told he could tell *Striga* was present on his field, when his crops got a deep green colour.
-A lot of farmers told that a white powder on the ground (poudre blanche) was an indication for the presence of *Striga* on that spot.
-Often it was said, that where 'Kolokolo' trees grow, *Striga* is bound to be present in the ground. Also the trees 'Magalani-bin', 'Sonni-bo', 'Mounougan', the herb 'Mankalati' of the *Antropogon* family and the plant 'Shiri' are indicative for the presence of *Striga.*
-Many farmers said that the poverty of the ground increases or provokes the amount of *Striga* on the field.
-Some farmers think the flowers of *Striga* don't produce seeds. The seeds are produced by the roots or the seeds are just present in the ground.
-The tree 'Toutou' could be the cause of *Striga* on a field.
-One farmer noticed the connection between *Striga* roots and the roots of his crops.

2.2.3 <u>Laboratory experiments:</u>

First of all, it's striking that only very few *Striga* seeds stick to the crop seeds (see Table below). With the exception of LG 2217 (the maize with filmy scales), it's always less than 1% of the total added amount.
In the column "difference 90% compared to 40%" it can be seen, that for 13 of the 15 seed samples, more *Striga* seeds stick to the crop seeds when the crop seeds are kept in humid conditions.

Table: results of the laboratory experiments.

Crop variety	Retrieved number of *Striga* seeds at 40% humidity	Retrieved number of *Striga* seeds at 90% humidity	Crop			
LG 2217	47	333	maize			
LG 11	2	14	maize			
Agadir	2	15	maize			
KLM 2	1	14	sorghum			
Sege tene	4	7	sorghum			
CSM 417	6	12	sorghum			
Najaugaula	5	6	sorghum			
CMDT 115	7	21	sorghum			
DJL 2	3	3	sorghum			
Foulatieba	4	10	sorghum			
IS.15401	8	3	sorghum			
Sariaso 1	18	0	sorghum			
Goo 2	5	6	sorghum			
ICSV905NG	8	54	sorghum			
MDM	1	3	sorghum			
Crop variety	retrieved percentage *Striga* seeds at 40% humidity	Crop variety	retrieved percentage *Striga* seeds at 90% humidity	Crop variety	difference 90% humidity compared to 40% humidity	
LG 2217	0.63	LG 2217	4.44	LG 2217	3.81	
Sariaso 1	0.24	ICSV905NG	0.72	ICSV905NG	0.61	
IS.15401	0.11	CMDT 115	0.28	CMDT 115	0.19	
ICSV905NG	0.11	Agadir	0.20	Agadir	0.17	
CMDT 115	0.09	LG 11	0.19	KLM 2	0.17	
CSM 417	0.08	KLM 2	0.19	LG 11	0.16	
Najaugaula	0.07	CSM 417	0.16	CSM 417	0.08	
Goo 2	0.07	Foulatieba	0.13	Foulatieba	0.08	
Sege tene	0.05	Sege tene	0.09	Sege tene	0.04	
Foulatieba	0.05	Najaugaula	0.08	MDM	0.03	
DJL 2	0.04	Goo 2	0.08	Najaugaula	0.01	
LG 11	0.03	DJL 2	0.04	Goo 2	0.01	
Agadir	0.03	IS.15401	0.04	DJL 2	0.00	
KLM 2	0.01	MDM	0.04	IS.15401	-0.07	
MDM	0.01	Sariaso 1	0.00	Sariaso 1	-0.24	

2.3 DISCUSSION

From this study appears that crop seed contamination is not an important factor in the dispersal of *Striga* seeds in the regions Koutiala, Kadiolo, Bougouni and Sikasso in Mali. In all of the seed samples collected in Mali, no *Striga* seeds were found, no matter what the harvesting methods of the farmers are. The farmers themselves didn't think highly about crop seed contamination as a way of dispersal (see the response to question 10). When farmers were asked whether they think their crop seeds could be contaminated or whether they think their crop seeds are contaminated (question 3), not many farmers thought so. Amazingly, in the region of Koutiala and Sikasso, where the *Striga* infestation is less, than in the other regions (Bengaly et al., 1996), more farmers think their crop seeds could be or are contaminated with *Striga* seeds. This could be explained by the fact that *Striga* infestation is less in regions of Koutiala and Sikasso, because farmers are more aware of the possibility of crop seed contamination. However, when farmers were asked what measures they take against *Striga* (question 11), nobody said they took care to prevent a contamination of their crop seeds. In support of the article of Bengaly et al. (1996), farmers in the regions of Koutiala en Sikasso apply more fertiliser to their fields as an action against Striga, than farmers in the other regions (question 11). So the conclusion of Bengaly et al. (1996), that a lower *Striga* infestation in the semi-arid climate zone is a result of intensive farming, could be right. It's interesting to see that a lot of farmers give their seeds a traditional treatment against *Striga* with mistletoes (ANNEX 4 and question 7). It could be worthwhile to investigate the effectiveness of the traditional treatments, done by the farmers. Maybe, an environment friendly herbicide against *Striga* can be found.
The results of the laboratory experiments show that when crop seeds were contaminated on purpose with a great quantity of *Striga* seeds, only very low numbers of *Striga* seeds were found back. The tests did show an influence of humidity on the degree of contamination of crop seeds. A higher humidity resulted in a higher degree of contamination in almost all cases. The tests also showed that appendages on seeds increase the degree of contamination. This is clearly shown by the results of the LG 2217 samples (maize with filmy scales) in comparison to the LG 11 and Agadir samples (maize without filmy scales). The maize seeds used by the farmers in Mali all have filmy scales. However the degree of crop seed contamination in the laboratory experiments was extremely high. Very much higher, than ever can be expected to occur under normal farming conditions. Therefore, the above indicates that when contamination of crop seeds occurs, this is a rare event and that the degree of contamination will be very low.
It could be that some *Striga* seeds are transported along with crop seeds, but when this happens it will be of very little importance in an area where *Striga* already occurs. There are other ways of dispersal which function more effective. The contamination of crop seeds can have severe consequences, when these crop seeds are sown in an area where *Striga* doesn't occur. When the conditions are favourable, a few *Striga* seeds carried along could lead to a successful introduction of *Striga* into such an area.
The results found by Berner (et al., 1994) seem rather doubtful after this study. Although they used a more refined method to filter the *Striga* seeds out of the crop seeds, it seems very unlikely that we've failed to spot the quantities of *Striga* seeds they found in their

crop seeds samples. Berner et al. (1994), concluded, that annual influxes of *Striga* seeds by wind do not appear to occur in farmers' fields, but that man, through agricultural activities and animal movement, is the primary factor in the dispersal of *Striga* seeds. Localised eradication could therefore be made effective by stopping recontamination of fields by man and by appropriate control measures aimed at existing *Striga* populations. Berner et al. investigated wind dispersal and they found that *Striga* seeds can be dispersed by wind over a maximum distance of 12 meters and a maximum height of 2 meters. However, most seeds aren't dispersed more than 80 cm by wind. It's not clear why Berner et al. disregard *Striga* dispersal by wind, when they found *Striga* seeds can be dispersed up to 12 m by wind. Wind dispersal clearly isn't important for long distance dispersal, but for dispersal over short distances it could be quite effective.
The results from our study show that crop seed contamination isn't an important factor in the dispersal of *Striga* seeds and an evolutionary explanation for the development of a dispersal mechanism for *Striga* seeds, with man as the dispersing factor is hard to find. *Striga* species that parasitise plant species in the wild have the same seeds as *Striga* species that parasitise crops. So it could be concluded that they are dispersed in the same way (by man) as the *Striga* species that parasitise crops. This of course isn't the case and therefore we must conclude the seeds of *Striga* are mainly dispersed by another factor than man. The high infestation of farmers' fields is probably better explained by the permanent growth and the monocultures of *Striga* hosts on the farmers' fields. In nature the density of *Striga* plants is low, because the host density is low. On a farmers' field the host density is incredibly high and therefore after a few years of growing these monocultures the *Striga* density also becomes very high. This is also the reason why the effects of *Striga* on its host are much more severe on an farmers field, than in wild vegetation. Hosts in the wild suffer less from *Striga* parasitation, because *Striga* densities are much lower. In the wild a host is generally parasitised by one or two *Striga* plants, but hosts on a farmers' field are often parasitised by numerous *Striga* plants.
Wind dispersal seems an important way of dispersal for *Striga* seeds over short distances. When *Striga* is present on a field at low densities, dispersal of the seeds by wind over a distance of 80 cm (Berner et al. 1994) could be enough to severely increase the *Striga* density on field in a couple of years.
Localised eradication, as mentioned by Berner et al. (1994), doesn't seem a good approach in solving the *Striga* problem, because *Striga* is a R-strategic. R-strategists are pioneering species, they spread rapidly and quickly establish a foothold in new (or cleared) areas. With a maximum wind dispersal distance of 12 m (Berner et al. 1994), it seems possible that there are annual influxes of *Striga* seeds onto farmers' fields, when the surroundings of those fields aren't completely free of *Striga*. The fields of a village usually cover a considerably surface. When taking the interviews we often visited the farmers while they were working on their fields. To reach the next farmer participating in the studies, we frequently had to pass through several kilometres of farmland. It doesn't seem possible farmers can spare the time and the effort to keep, not only their fields, but also the surroundings of their fields completely free of *Striga*.

3. <u>Seedbank study</u>

3.1 MATERIALS AND METHODS

Near the villages of N'Goukan (region of Koutiala) and Kafono (region of Kadiolo) *Striga hermonthica* seeds were buried in two experimental fields.
The region of Koutiala is situated in the south Soudanian climate zone with an annual rainfall of 900-1100 mm. The region of Kadiolo lies in the north Guinean climate zone with an annual rainfall of >1100 mm (Berthe et al., 1991).
The seeds buried at N'Goukan were collected, in November 1996, at the nearby village of N'Peresso. The seeds buried at Kafono were collected, at the same time, at the nearby village of Zankundougou. The seeds were buried in small, nylon, gauze bags, each bag containing approximately 1000 seeds. In N'Goukan the seeds were buried at a depth of 5 cm on the 24th and 25th of March 1997. Later, on the 11th of June 1997, more *Striga* seeds were buried, but now on a depth of 10 cm. On this date also a few bags were buried at a depth of 5 cm. The thought behind this, is to find out what the effect of burial depth is. Gradients can be expected in the soil regarding: temperature fluctuations, moisture content, nutrient content (especially nitrogen) and the occurrence of soil organisms.
The bags buried on the 11th of June at 5 cm act as a control on the bags buried at 10 cm.
In Kafono seeds were buried at 5 cm on the 19th and 20th of March 1997. On the 2nd of July 1997 seeds were buried at 10 cm and some again at 5 cm.
The fields were visited every three weeks. At each visit, the fields were weeded to prevent premature germination of the *Striga* seeds in the bags, because some weeds produce the root exudate which causes *Striga* seeds to germinate.
Every three weeks, 4 bags were dug up from 5 cm depth. Every six weeks, 4 bags from 5 cm and 4 bags from 10 cm depth were dug up. The selection of the bags to be dug up was completely random. The only criterium was, that the bags shouldn't come all from the same spot, but be scattered over the experimental field.
The bags were transported in sealed plastic bags to the laboratory.
In the laboratory two tests were done: a viability test and a germination test.
From the approximately thousand seeds in each bag 200 were taken out for conditioning, another 200 were tested immediately and the remaining seeds were counted.
From each batch of 200 seeds, a 100 seeds were for the viability test and the other 100 for the germination test. The conditioning of the seeds is done by putting them, for 14 days at 30°C in the dark, under humid conditions, in an incubator. The conditioning is necessary to brake the dormancy of dormant seeds and as a result, to obtain the highest possible percentage of germination (for details see: Pieterse et al, 1984). After conditioning the seeds receive the same treatment as the non-conditioned seeds.
The viability test is a Triphenyl Tetrazolium Chloride staining test (TTC) (for details see: Moore, 1973). When the seeds show respiratory activity they colour reddish. At day 0, TTC was administered to the seeds. The petri-dishes with the seeds were then stored in the incubator at also 30°C, in the dark. Results of the test were scored at day 5, under a dissecting microscope. The same procedure goes for the germination test.

The germination test is done with a derivative of Strigol called GR-24. (for details see: Gbehounou et al, 1996a)
The application of GR-24 (0.2 mg/l GR-24: 1,0 ml/ 100 seeds) causes the *Striga* seeds to germinate. When the seeds have germinated, clear glass roots can be seen. After conditioning the maximum possible amount of seeds will germinate. Dormant seeds are alive, but don't germinate.

The collected data were statistically analysed. The analysis is just a preliminary analysis, because at the moment of writing this report the seedbank study had still another year to go. Nevertheless, the results are presented with a lot of detail, not only to make the used analysis method more comprehensible, but also to aide future students with the analysis and interpretation of newly gathered data. The results presented below cover only the first 5 excavations of the study. (These cover the period from 5-08-'97 till 11-11-'97).

The experiments can be represented by the following schedule:

Groups	"Treatments"
Region	Region-effect
Replicate	
Bag	Day, Depth
Batch (~100 seeds)	Conditioning

Within this schedule:

Region	= factor	2 Regions: Koutiala, Kadiolo.
Replicate	= factor	4 Replicates per Region (= 4 Bags).
Depth	= factor	Bags are buried at 5 or 10 cm Depth.
Day (1-01-1997 is day 1).	= factor/ variate	In time Bags are being dug up. The moment is different for each Region. Koutiala: 217, 240, 261, 287, 309. Kadiolo: 221, 245, 269, 290, 315.
Bag	= factor	Per Replicate, per day, a bag was dug up.
Conditioning (2 Batches from each Bag).	= factor	Seed treatments: + = with conditioning. - = without conditioning. From each Bag, 2 batches of ~100 seeds were conditioned, another 2 batches weren't conditioned.

Day could be defined as a factor, but it's more logical to make Day a variate, because Day represents a sequence of succeeding days. Besides, Day as a factor would cause an 'alias' with the factor Region, because the excavation of the bags wasn't done at the same day in each Region (the two regions couldn't both be visited on the same day).

3.2 RESULTS

3.2.1 Viability

The results of the viability data analysis will be presented first. In chapter 3.2.2, the results of the germination data analysis can be found.

The observation 'viability' (number of seeds that are alive per batch) has a binomial distribution; it's a fraction of the total number of seeds in a batch.
Because the analysis involves different strata (splitplot) and a non-ordinary distribution of the observations, the analysis can be done using the IRREML-method. IRREML is a procedure, within the computer program Genstat, for the analysis of unbalanced splitplot experiments in combination with a non-ordinary distribution of the observations. The experiments are unbalanced, because the observations are not of an ordinary distribution.

IRREML-analysis produced a Wald-statistics table (see below). These statistics have a Chi^2-distribution with matching degrees of freedom (d.f.). The table shows besides some major effects (Region, Day, Depth, Conditioning) also three 2-factor-interactions (Region.Conditioning/Day.Conditioning/Depth.Conditioning). There are no 3-factor-interactions.

Table: Wald test (output of IRREML)

*** Wald tests for fixed effects ***		
Fixed term	Wald statistic	d.f.
Region	7.0	1
Day	22.2	1
Depth	13.6	1
Conditioning	17.6	1
Region.Day	0.5	1
Region.Depth	0.3	1
Day.Depth	0.0	1
Region.Conditioning	8.2	1
Day.Conditioning	11.7	1
Depth.Conditioning	5.0	1
Region.Day.Depth	0.2	1
Region.Day.Conditioning	0.9	1
Region.Depth.Conditioning	0.2	1
Day.Depth.Conditioning	0.2	1

(All Wald statistics are calculated ignoring terms fitted later in the model).

When all non-significant terms are removed from the model, the following table remains:

*** Wald tests for fixed effects ***		
Fixed term	Wald statistic	d.f.
Region	7.0	1
Day	23.9	1
Depth	14.5	1
Conditioning	18.1	1
Region.Conditioning	8.3	1
Day.Conditioning	12.3	1
Depth.Conditioning	5.1	1

(All Wald statistics are calculated ignoring terms fitted later in the model).

The output of the IRREML-analysis also contained a scatterplot: '% viability' vs. 'Day' (see ANNEX 5).

Below, the results can be found of the analysis of the viability data, done per region. This makes it possible to compare the two regions with each other. The final results are presented in two graphs (one for each region), showing the course of the proportion viable seeds in time. It has to be kept in mind that the data in the graphs are predictions of the proportion of viable seeds and not actual values. The data in the scatterplot (ANNEX 5) are the same as the data in the graphs for each region, but in the scatterplot the two regions aren't separated.

Region of Koutiala:(viability)

Regression analysis

Table: Accumulated analysis of deviance

Change	d.f.	Deviance	Mean Deviance	Deviance Ratio
+ Depth	1	213.42	213.42	9.60
+ Conditioning	1	97.43	97.43	4.38
+ Day	1	494.09	494.09	22.23
+ Conditioning.Depth	1	17.81	17.81	0.80
+ Day.Conditioning	1	10.69	10.69	0.48
+ Day.Depth	1	0.17	0.17	0.01
+ Day.Conditioning.Depth	1	14.79	14.79	0.67
Residual	56	1244.95	22.23	
Total	63	2093.35	33.23	

Table: Predictions of response variate 'viability', followed by standard errors.

Depth	Day	Conditioned	s.e. cond.	Non-conditioned	s.e. non-cond.
5 cm	220	0.3405	0.0769	0.2738	0.0784
	240	0.2688	0.0494	0.2080	0.0473
	260	0.2074	0.0357	0.1546	0.0336
	280	0.1571	0.0347	0.1130	0.0326
	300	0.1171	0.0370	0.0815	0.0336
	320	0.0863	0.0374	0.0582	0.0326
10 cm	220	0.6342	0.0949	0.3259	0.0941
	240	0.5295	0.0769	0.2819	0.0663
	260	0.4221	0.0616	0.2417	0.0515
	280	0.3216	0.0589	0.2055	0.0513
	300	0.2352	0.0629	0.1736	0.0585
	320	0.1664	0.0639	0.1457	0.0662

(S.e.s are approximate, since model is not linear)
(S.e.s. are based on the residual deviance)

Table: Estimates of regression coefficients

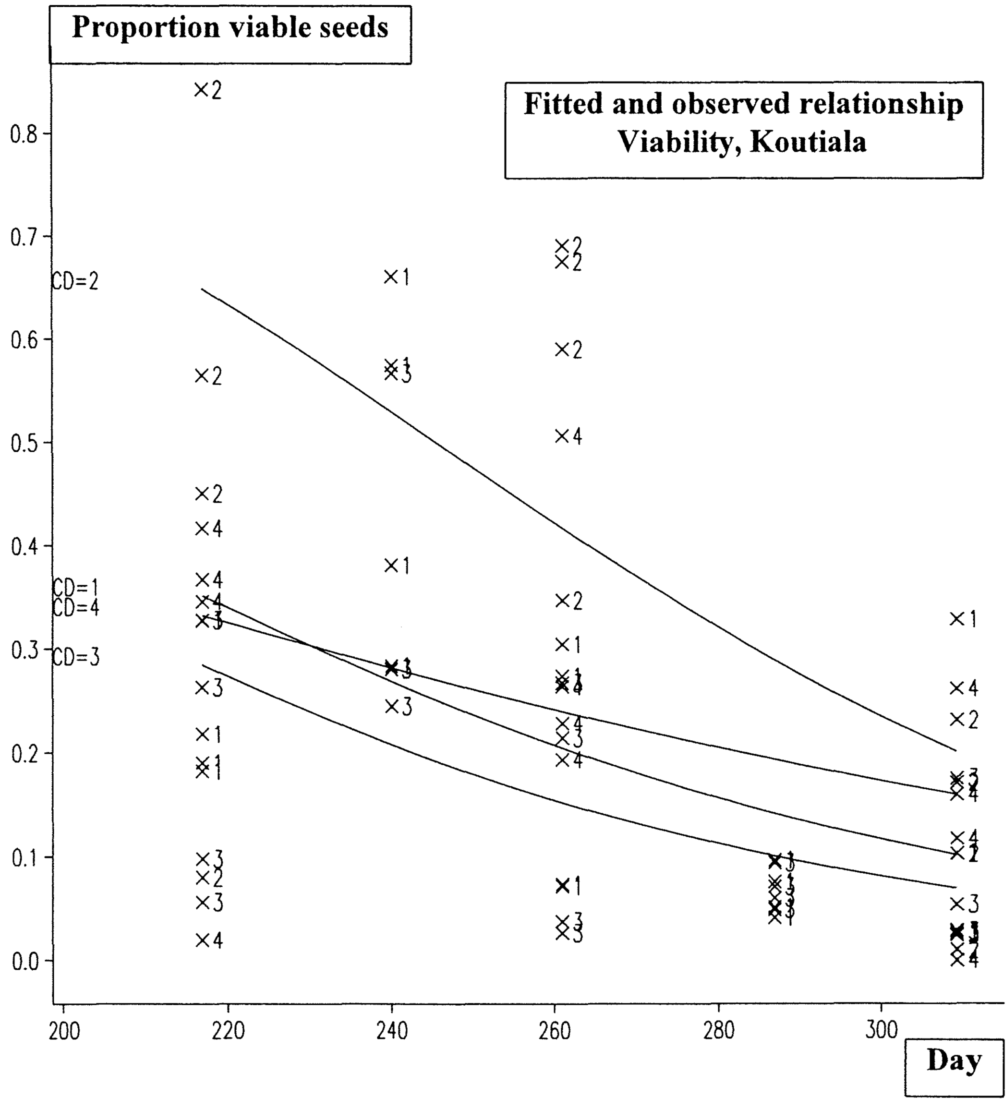
	Estimate	s.e.	t (56)
Constant	3.08	1.79	1.72
Day	-0.01699	0.00687	-2.47
CD 2	2.23	2.61	0.85
CD 3	-0.07	2.81	-0.03
CD 4	-1.51	2.72	-0.56
Day.CD 2	-0.00463	0.00989	-0.47
Day.CD 3	-0.0011	0.0108	-0.10
Day.CD 4	0.0066	0.0104	0.63

(S.e.s are based on the residual deviance)

Table: The 4 graph lines on a linear scale are:

Depth/Conditioning	Line formula	Line number (see graph)
5 cm, conditioned	Y = 3.08 - 0.01699*Day	1
10 cm, conditioned	Y = 5.31 - 0.02162*Day	2
5 cm, non-conditioned	Y = 3.01 - 0.01809*Day	3
10 cm, non-conditioned	Y = 1.57 - 0.01039*Day	4

Back transformation with the following formula:
V (change on being alive) = exp(y)/(1+exp(y))



Graph: Predictions of the proportion of viable seeds in the course of time. Each line corresponds with the lines formulated in the table above. The 'CD=' on the Y-axis indicates the line numbers of the different lines (see also the table above). Each cross with number represents the predicted proportion of viable seeds from a certain batch on a certain day. The lines are fitted on basis of the crosses. Therefore, the numbers belonging to the crosses have the same meaning as the line numbers.

<u>Region of Kadiolo</u>:(viability)

Regression analysis

Table: Accumulated analysis of deviance

Change	d.f.	Deviance	Mean Deviance	Deviance Ratio
+ Depth	1	497.46	497.46	20.48
+ Conditioning	1	12.90	12.90	0.53
+ Day	1	480.32	480.32	19.78
+ Conditioning.Depth	1	7.76	7.76	0.32
+ Day.Conditioning	1	55.26	55.26	2.28
+ Day.Depth	1	1.12	1.12	0.05
+ Day.Conditioning.Depth	1	1.59	1.59	0.07
Residual	56	1359.96	24.29	
Total	63	2416.39	38.36	

Table: Predictions of response variate 'viability', followed by standard errors.

Depth	Day	Conditioned	s.e. cond.	Non-conditioned	s.e. non-cond.
5 cm	220	0.4659	0.0779	0.3371	0.0778
	240	0.3775	0.0552	0.3055	0.0541
	260	0.2966	0.0361	0.2755	0.0393
	280	0.2267	0.0351	0.2475	0.0383
	300	0.1693	0.0397	0.2214	0.0474
	320	0.1241	0.0419	0.1974	0.0589
10 cm	220	0.7226	0.0812	0.5700	0.0960
	240	0.6455	0.0705	0.5195	0.0744
	260	0.5600	0.0595	0.4687	0.0588
	280	0.4709	0.0583	0.4185	0.0568
	300	0.3835	0.0686	0.3699	0.0678
	320	0.3031	0.0808	0.3238	0.0838

(S.e.s are approximate, since model is not linear)
(S.e.s. are based on the residual deviance)

Table: Estimates of regression coefficients

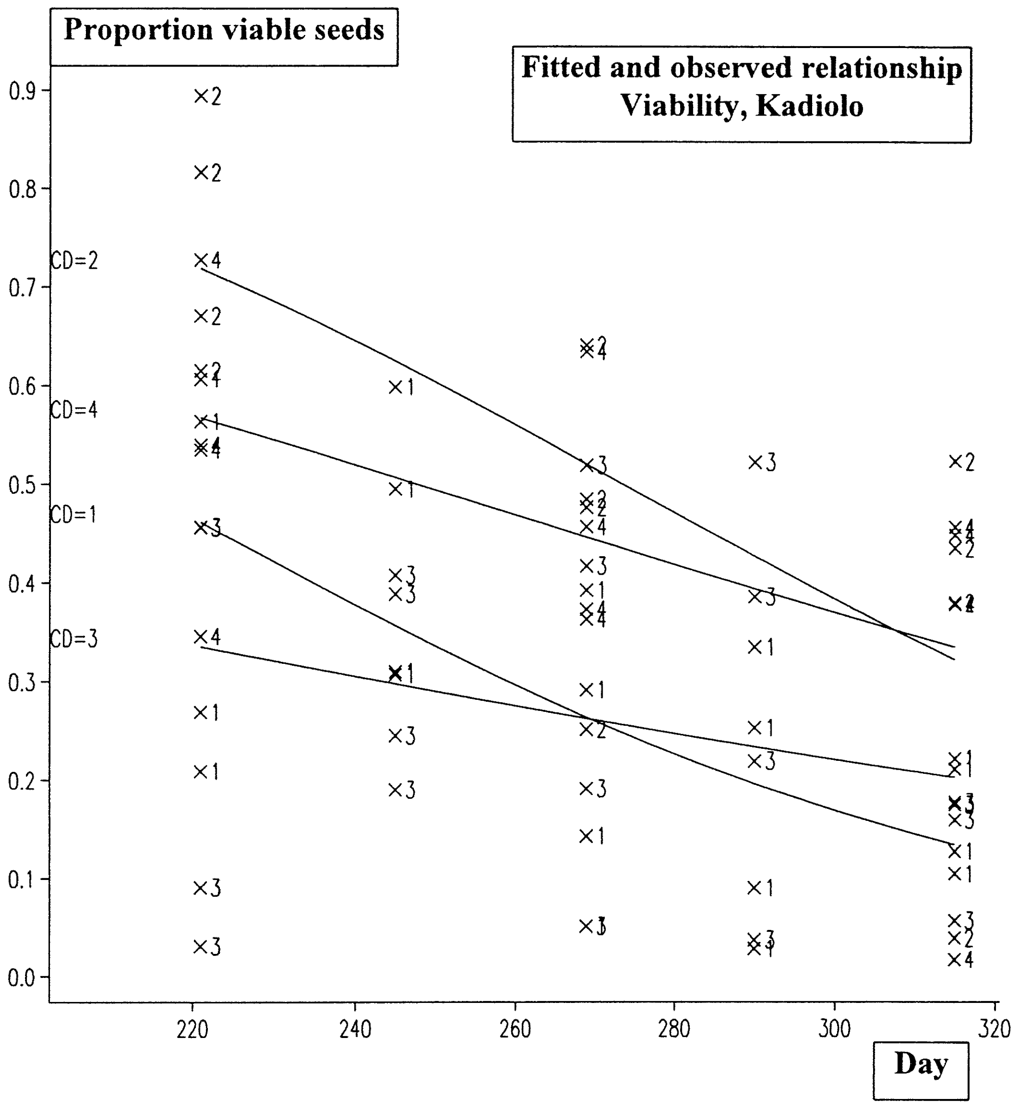
	Estimate	s.e.	t (56)
Constant	3.86	1.60	2.41
Day	-0.01817	0.00606	-3.00
CD 2	1.03	2.38	0.43
CD 3	-2.94	2.30	-1.28
CD 4	-1.34	2.35	-0.57
Day.CD 2	0.00027	0.00882	0.03
Day.CD 3	0.01091	0.00860	1.27
Day.CD 4	0.00799	0.00873	0.91

(S.e.s are based on the residual deviance)

Table: The 4 graph lines on a linear scale are:

Depth/Conditioning	Line formula	Line number (see graph)
5 cm, conditioned	Y = 3.86 - 0.01817*Day	1
10 cm, conditioned	Y = 4.89 - 0.01790*Day	2
5 cm, non-conditioned	Y = 0.92 - 0.00726*Day	3
10 cm, non-conditioned	Y = 2.52 - 0.01018*Day	4

Back transformation with the following formula:
V (change on being alive) = exp(y)/(1+exp(y))



Graph: Predictions of the proportion of viable seeds in the course of time. Each line corresponds with the lines formulated in the table above. The 'CD=' on the Y-axis indicates the line numbers of the different lines (see also the table above). Each cross with number represents the predicted proportion of viable seeds from a certain batch on a certain day. The lines are fitted on basis of the crosses. Therefore, the numbers belonging to the crosses have the same meaning as the line numbers.

3.2.2 Germination

The germination data were linked to the viability data and therefore had to be recalculated using the viability data, before the data could be statistically analysed. The germination test distinguishes between seeds that germinate and seeds that don't. The seeds that don't germinate could be dormant or they could be dead. The germination data had to be linked with the viability data to determine what proportion of the seeds that didn't germinate is dead and what proportion is dormant. This can only be done when the batches used in the germination test and the viability test are (assumed being) of equal composition. In other words, the content of the little bag, from which the batches were taken should be homogeneous. If the content isn't homogeneous, results can be expected that aren't possible from a biological point of view. For example: 110% germination of the seeds, when the number of viable seeds is lower, than the number of germinating seeds. However, the used batches are considered being of equal composition, because before use, the seeds were transferred from the little bag into a petri-dish and than stirred in the petri-dish. Also the quantity of seeds in a batch (about a 100) and that quantity in comparison to the number of seeds in a bag (about a 1000), is considered to be big enough to prevent sample errors.
A similar problem that can arise with linking the data is that it's possible to find zero viable seeds in one batch and still some germination in another batch taken from the same bag of seeds. This occurred ones. In the analysis this was treated as a missing value. Also two times the number of germinated seeds was higher, than the number of viable seeds. In the analysis this was also treated as missing values.

The germination data is linked to the viability data as follows:
Percentage germination = 100 * (number of germinating seeds/(total number of seeds used for the germination test * (number of viable seeds/ total number of seeds used for viability test))).

The observation 'germination' (number of seeds that germinated per batch) has a binomial distribution; it's a fraction of the total number of seeds in a batch. Therefore the analysis could again be done using the IRREML-method.

IRREML-analysis produced a Wald-statistics table (see below). The table shows besides some major effects (Region, Day, Depth, Conditioning), two significant 2-factor-interactions (Region.Day/Day.Conditioning). These 2-factor-interactions aren't as important as they seem. They can also be found in the 3-factor-interactions (Region.Day.Conditioning/Day.Depth.Conditioning).

Table: Wald test (output of IRREML)

*** Wald tests for fixed effects ***		
Fixed term	Wald statistic	d.f.
Region	10.1	1
Day	58.0	1
Depth	9.0	1
Conditioning	2.6	1
Region.Day	11.8	1
Region.Depth	1.1	1
Day.Depth	2.0	1
Region.Conditioning	1.0	1
Day.Conditioning	5.9	1
Depth.Conditioning	1.8	1
Region.Day.Depth	0.4	1
Region.Day.Conditioning	7.3	1
Region.Depth.Conditioning	0.2	1
Day.Depth.Conditioning	9.9	1

(All Wald statistics are calculated ignoring terms fitted later in the model).

The output of the IRREML-analysis contained again a scatterplot:
'% Germination' vs. 'Day'(see ANNEX 5).

On the next pages the results of the analysis of the germination data, done per region can be found, presented in the same way as was done with the viability data.

Region of Koutiala:(germination)

Regression analysis

Table: Accumulated analysis of deviance

Change	d.f.	Deviance	Mean Deviance	Deviance Ratio
+ Depth	1	58.737	58.737	20.43
+ Conditioning	1	1.825	1.825	0.63
+ Day	1	134.893	134.893	46.92
+ Conditioning.Depth	1	0.000	0.000	0.00
+ Day.Conditioning	1	46.431	46.431	16.15
+ Day.Depth	1	6.531	6.531	2.27
+ Day.Conditioning.Depth	1	4.075	4.075	1.42
Residual	55	158.123	2.875	
Total	62	410.615	6.623	

Table: Predictions of response variate 'germination', followed by standard errors.

Depth	Day	Conditioned	s.e. cond.	Non-conditioned	s.e. non-cond.
5 cm	220	0.13183	0.04025	0.07752	0.03508
	240	0.08256	0.01952	0.07044	0.02270
	260	0.05064	0.01803	0.06396	0.02359
	280	0.03064	0.01749	0.05804	0.03215
	300	0.01839	0.01493	0.05264	0.04148
	320	0.01098	0.01166	0.04772	0.04964
10 cm	220	0.44661	0.05396	0.21286	0.05826
	240	0.20340	0.03372	0.18140	0.03929
	260	0.07475	0.02242	0.15369	0.03338
	280	0.02492	0.01173	0.12953	0.03714
	300	0.00802	0.00520	0.10869	0.04309
	320	0.00255	0.00211	0.09085	0.04774

(S.e.s are approximate, since model is not linear)
(S.e.s. are based on the residual deviance)

Table: Estimates of regression coefficients

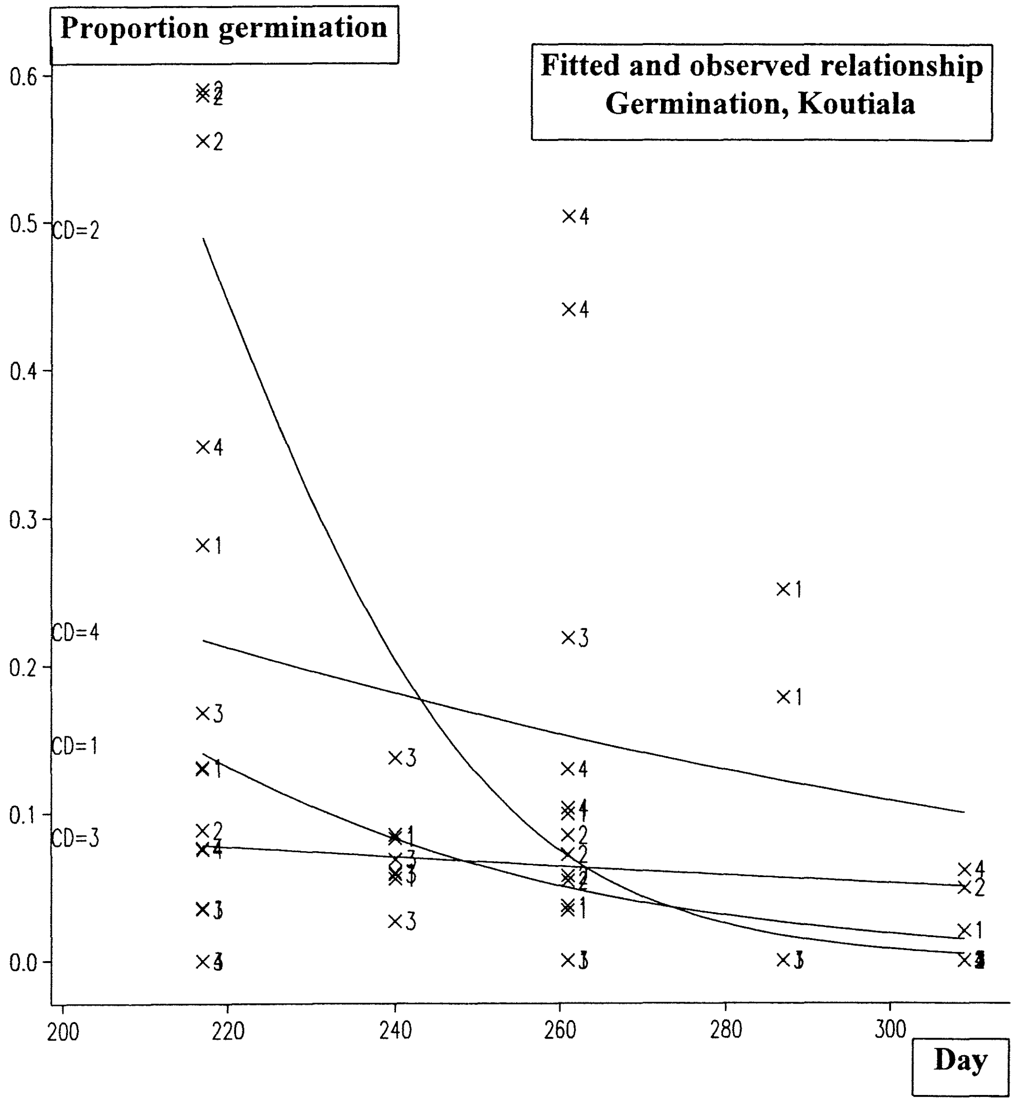
	Estimate	s.e.	t (56)
Constant	3.87	3.07	1.26
Day	-0.0262	0.0128	-2.04
CD 2	8.57	3.73	2.30
CD 3	-5.21	4.61	-1.13
CD 4	-2.99	3.63	-0.82
Day.CD 2	-0.0314	0.0157	-2.00
Day.CD 3	0.0210	0.0189	1.11
Day.CD 4	0.0162	0.0149	1.09

(S.e.s are based on the residual deviance)

Table: The 4 graph lines on a linear scale are:

Depth/Conditioning	Line formula	Line number (see graph)
5 cm, conditioned	Y = 3.87 - 0.0262*Day	1
10 cm, conditioned	Y = 12.44 - 0.0576*Day	2
5 cm, non-conditioned	Y = -1.34 - 0.0052*Day	3
10 cm, non-conditioned	Y = 0.88 - 0.0100*Day	4

Back transformation with the following formula:
G (change of germinating) = exp(y)/(1+exp(y))



Graph: Predictions of the proportion of germination in the course of time. Each line corresponds with the lines formulated in the table above. The 'CD=' on the Y-axis indicates the line numbers of the different lines (see also the table above). Each cross with number represents the predicted proportion of germination from a certain batch on a certain day. The lines are fitted on basis of the crosses. Therefore, the numbers belonging to the crosses have the same meaning as the line numbers.

<u>Region of Kadiolo</u>:(germination)

Regression analysis

Table: Accumulated analysis of deviance

Change	d.f.	Deviance	Mean Deviance	Deviance Ratio
+ Depth	1	36.663	36.663	4.12
+ Conditioning	1	57.660	57.660	6.48
+ Day	1	1377.785	1377.785	154.94
+ Conditioning.Depth	1	10.311	10.311	1.16
+ Day.Conditioning	1	0.807	0.807	0.09
+ Day.Depth	1	65.039	65.039	7.31
+ Day.Conditioning.Depth	1	20.429	20.429	2.30
Residual	54	480.182	8.892	
Total	61	2048.876	33.588	

Table: Predictions of response variate 'germination', followed by standard errors.

Depth	Day	Conditioned	s.e. cond.	Non-conditioned	s.e. non-cond.
5 cm	220	0.550709	0.080373	0.489501	0.125795
	240	0.373074	0.051627	0.232766	0.063570
	260	0.224151	0.044583	0.087583	0.039583
	280	0.123011	0.042679	0.029476	0.022331
	300	0.063756	0.033824	0.009518	0.010407
	320	0.032003	0.023171	0.003031	0.004351
10 cm	220	0.826244	0.055394	0.754607	0.083824
	240	0.452035	0.082722	0.448542	0.086511
	260	0.125193	0.054808	0.177051	0.064339
	280	0.024225	0.017778	0.053842	0.033129
	300	0.004288	0.004390	0.014829	0.013116
	320	0.000747	0.000980	0.003965	0.004580

(S.e.s are approximate, since model is not linear)
(S.e.s. are based on the residual deviance)

Table: Estimates of regression coefficients

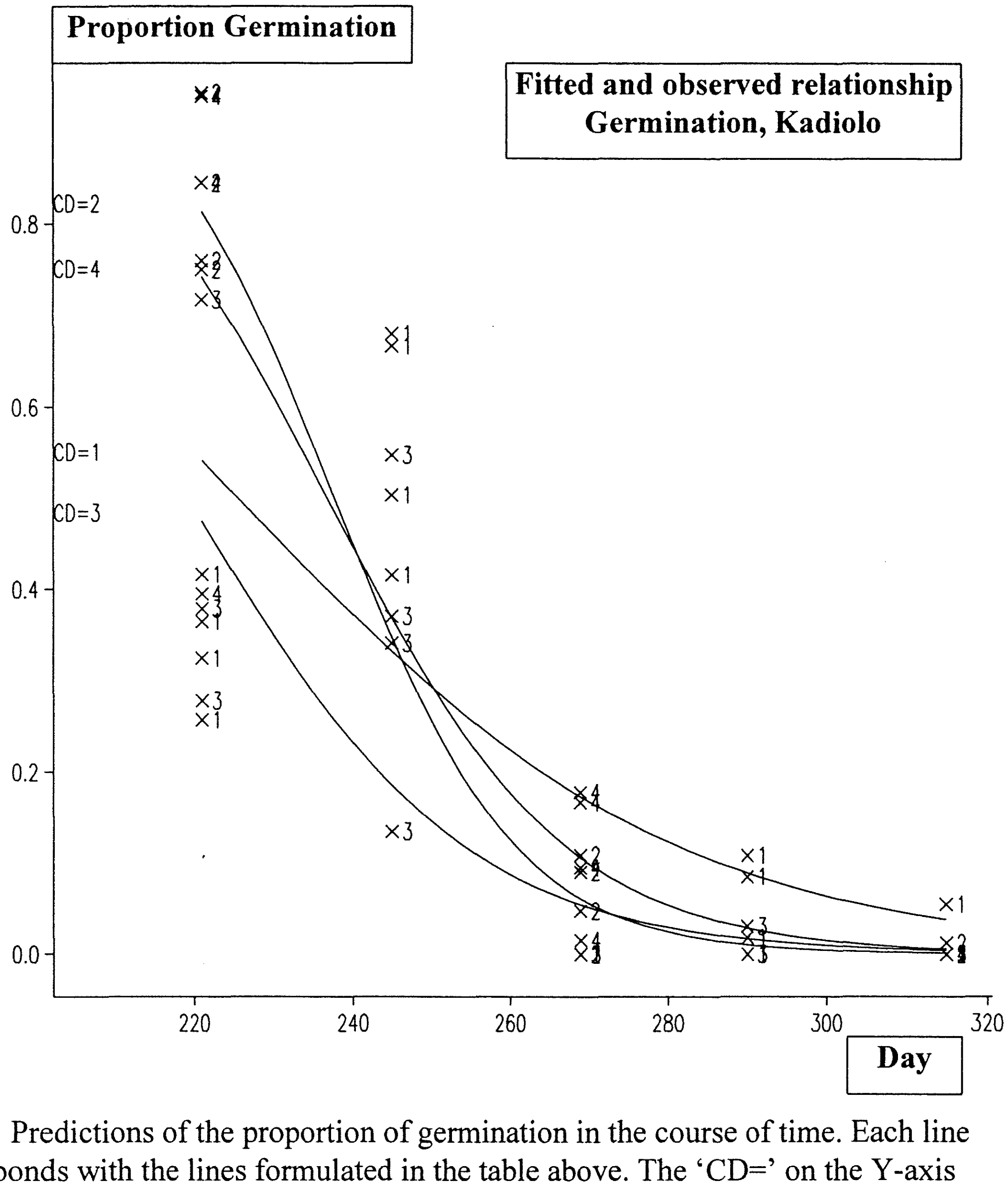
	Estimate	s.e.	t (56)
Constant	8.15	2.37	3.44
Day	-0.03613	0.00960	-3.76
CD 2	12.68	4.22	3.01
CD 3	4.46	4.84	0.92
CD 4	7.60	4.12	1.85
Day.CD 2	-0.0515	0.0177	-2.91
Day.CD 3	-0.0214	0.0200	-1.07
Day.CD 4	-0.0304	0.0169	-1.79

(S.e.s are based on the residual deviance)

Table: The 4 graph lines on a linear scale are:

Depth/Conditioning	Line formula	Line number (see graph)
5 cm, conditioned	Y = 8.15 - 0.03613*Day	1
10 cm, conditioned	Y = 20.83 - 0.08763*Day	2
5 cm, non-conditioned	Y = 12.61 - 0.05753*Day	3
10 cm, non-conditioned	Y = 15.75 - 0.06653*Day	4

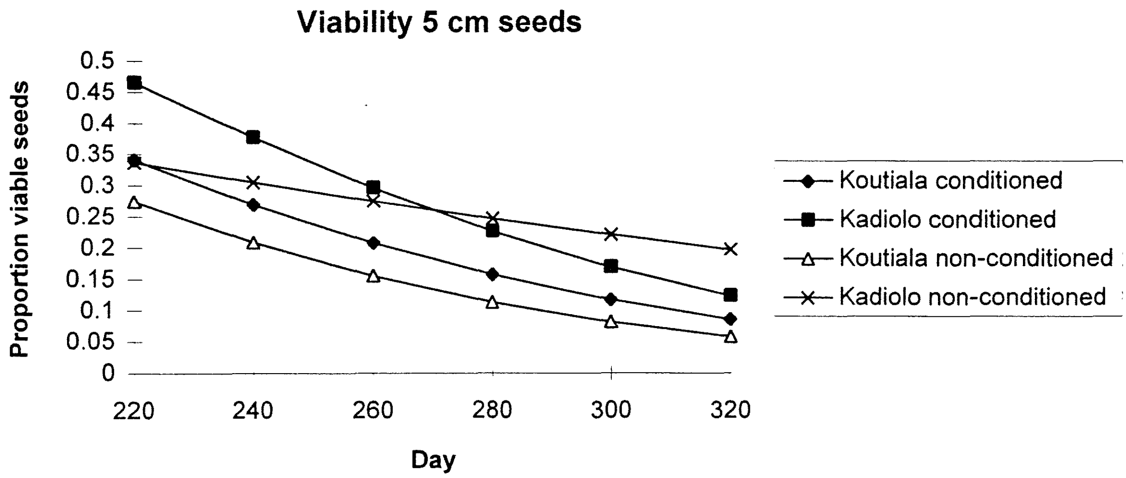
Back transformation with the following formula:
G (change of germinating) = exp(y)/(1+exp(y))

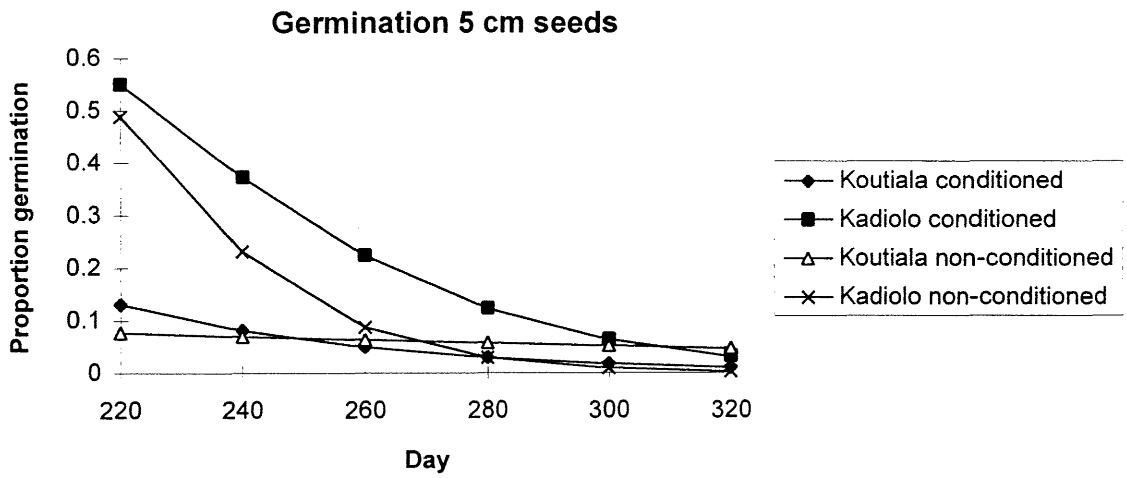


Graph: Predictions of the proportion of germination in the course of time. Each line corresponds with the lines formulated in the table above. The ‘CD=’ on the Y-axis indicates the line numbers of the different lines (see also the table above). Each cross with number represents the predicted proportion of germination from a certain batch on a certain day. The lines are fitted on basis of the crosses. Therefore, the numbers belonging to the crosses have the same meaning as the line numbers.

3.3 DISCUSSION

It is not possible to draw final conclusions on basis of the results from the seedbank study. The study has just started, but it is possible to distinguish some trends.
First of all, in all the graphs (see below and ANNEX 6) a decline can be seen in the proportion germination and viability in time. For the viability this decline is more or less linear, but the germination shows a exponential decline in the rainy season. The seeds buried at 10 cm depth (see ANNEX 6) show the same trend as the seed buried at 5 cm, only later, because the seeds buried at 10 cm depth were buried about 11 weeks after the seeds at 5 cm. When the graphs of the 10 cm seeds are moved back in time, the graphs could probably give an indication of the course of the 5 cm graphs before Day 220.





(The graphs above show the course of the proportion viable seeds and the proportion germination in time of seeds buried at 5 cm depth. See also ANNEX 6 for easy comparison of the graphs presented in the results).

It could be a coincidence, but it's remarkable that in the graph 'Viability, Kadiolo' (see ANNEX 6) the two lines of the 10 cm seeds cross just like the lines of the 5 cm seeds, but 6 weeks later.
When the region Kadiolo is compared with the region Koutiala, it's clear that the proportions germination and viability, halfway in the rainy season, are lower in Koutiala. When this is held back against the climates of the regions, the results show that in the drier region of Koutiala seeds not only go dormant faster, they also die quicker.
In the discussion of the seed contamination results, the article of Bengaly et al. (1996) was mentioned in which Bengaly et al. state that there's less *Striga* in the region of Koutiala as a result of more intense farming practices (including applying fertilisers). As the experiment was done on farmland (as well as in Kadiolo) it could be that the seeds in Koutiala died faster, because the soil was more fertile. Therefore it's questionable whether the seeds died faster in Koutiala because of the difference in climate or because of the difference in soil fertility. This can only be determined after soil analysis.
It's clear from the viability graphs that the majority of the seeds died in the course of the rainy season. This supports the field studies of Gbehounou et al. (1996a) and Pieterse et al. (1996), in which they found a steadily decrease of the viability of *Striga* seeds in the soil during the rainy season. Our results don't support the findings of Ramaiah et al. (1983) and Bengaly et al. (1996), who claim a much longer longevity of *Striga* seeds in the soil.
There doesn't seem to be an effect of burial depth on the germination or viability of the seeds (see ANNEX 6). Only a delay in time can be seen, caused by the later time of burial of the seeds at 10 cm depth. The graphs from seeds buried at 10 cm depth aren't exact copies of the graphs from the seeds buried at 5 cm depth. This is probably due to the different humidity regimes that the seeds have been exposed to, since the time of burial. The seeds at 5 cm depth were buried before the start of the rainy season and therefore in very dry conditions. The seeds at 10 cm were buried in the rainy season under humid conditions. As a result, the conditioning of the seeds in the soil has been a bit different for the seeds at 10 cm depth than for the seeds at 5 cm depth. Seeds at 5 cm depth could adjust more gradually to the increase of humidity than the seeds at 10 cm depth (the conditioning period in the soil was longer for the seeds at 5 cm depth).This probably is the main reason for the steeper decline of the 10 cm graphs in comparison to the 5 cm graphs. But it's too early to draw a conclusion on this point. A conclusion can only be drawn at the end of the experiment, when all the bags from 5 cm depth, that were buried at the same time as the bags on 10 cm depth, are dug up. When these bags give the same results as the bags that were buried at 10 cm depth, it can be concluded that there is no effect of burial depth.

In the viability graphs (see graphs above and ANNEX 6) the proportion viable seeds is most of the time higher for the conditioned batches of seeds, than for the non-conditioned batches. This can probably be explained by the sensitivity of the interpretation of the results from the TTC test. The TTC acts on the respiratory activity of the seeds (see Moore, 1973). Probably the respiratory activity from the non-conditioned seeds is lower and therefore the coloration of the seeds is less, in comparison to the conditioned seeds.

The conditions in the soil probably aren't optimal for the seeds. When seeds are conditioned in the incubator the conditions become better for the seeds. As a result their respiratory activity increases, which causes a better coloration of the seeds. It is assumed that the proportion viable seeds are the same in the non-conditioned and conditioned batches, but that the coloration of the seeds is better visible in the conditioned batches. The reason that at a later moment the lines of conditioned seeds drop below the lines of the non-conditioned seeds, can probably be explained by the duration of the conditioning of the seeds. In the article from Pieterse et al., (1984) it can be read that 14 days of conditioning causes the maximum number of seeds to germinate and that prolonged conditioning causes the seeds to go dormant again. The seeds in the soil undergo conditioning. At a certain moment it could be that seeds have been conditioned for such a long time in the soil, that conditioning in the laboratory doesn't uplift any dormancy, but causes even more seeds to go into dormancy and reduces even further the respiratory activity of the seeds. At this moment the graph of the conditioned seeds will drop below the graph of the non-conditioned seeds. In the region of Koutiala (see ANNEX 6), this hasn't happened (yet), but the lines from the conditioned and non-conditioned seeds do converge like the lines of the conditioned and non-conditioned seeds in the region of Kadiolo did, before they crossed.

The results regarding the longevity of *Striga* seeds are supported by the results from the questionnaire. The majority of the farmers estimate the longevity of *Striga* seeds somewhere between 1 and 4 years (question 9). When the viability graphs are extrapolated, these estimates seem very reasonably.
About dormancy patterns, little can be said at this moment. In the germination graphs high proportions of dormancy can be seen (1 - the proportion germination), but it is impossible to predict whether the proportion germination will rise again the next rainy season. If this happens, it shows that there is secondary dormancy possible under field conditions, because the dormancy is broken at the beginning of the next rainy season. If the proportion germination doesn't rise the next rainy season, there probably isn't any secondary dormancy of the seeds. Hopefully there are still some seeds alive next rainy season.

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ABSTRACT

Striga, a parasitic weed of the *Scrophulariaceae*-family, is a very troublesome weed for many farmers in the semi-arid regions of the tropics. *Striga* is a root parasite of some important cereal crops, like *Sorghum bicolor* (sorghum), *Zea mays* (maize), *Pennisetum americanum* (millet) and *Vigna unguiculata* (cowpea). An infestation of a farmers' field with *Striga* can greatly reduce yield. A *Striga* plant produces thousands of tiny seeds, that will only germinate, when they receive a certain chemical stimulant from the roots of a host plant.

This paper concerns two studies: a crop seed contamination study and a seedbank study. The crop seed contamination study focuses on the possible contamination of crop seeds with *Striga* seeds as a way of dispersal for *Striga* seeds. For this study crop seed samples were collected in three regions in Mali (Africa). The seed samples were checked for the presence of *Striga* seeds. The farmers that donated the crop seeds were also interviewed. The interviews were held to learn what knowledge farmers have of *Striga*, what their farming practices are and whether those practice sort an effect on the degree of contamination of their crop seeds. Finally, a laboratory experiment was done, in which *Striga* seeds and crop seeds were mixed on purpose, to learn what percentage of a predetermined quantity of *Striga* seeds will stick to a certain amount of crop seeds.

The results from the crop seed contamination study indicate that crop seed contamination isn't an important factor in the dispersal of *Striga* seeds in the regions of Koutiala, Kadiolo, Bougouni and Sikasso in Mali. The interviews gave some very interesting results regarding the ideas of the farmers about *Striga*, but also about traditional farming practices against *Striga.* The laboratory experiment confirmed the results from the collected seed samples, the degree of the contamination of crop seeds will be very low.

In the seedbank study the longevity and the dormancy patterns of *Striga hermonthica* seeds are investigated, in two different climatic zones in Mali, during a period of two years. This to gain more insight into the factors that influence the survival of *Striga* seeds in the soil. For this study *Striga hermonthica* seeds were buried in small, nylon, gauze bags on two experimental fields in Mali. The two experimental fields were situated in two different climatic zones in Mali. A sub-humid zone with an annual rainfall of > 1100 mm and a semi-arid zone with an annual rainfall of 900-1100 mm. Every three weeks some bags were dug up and taken to the laboratory. In the laboratory a viability test and a germination test were done.

The preliminary results from the seedbank study make it possible to distinguish some trends in the germination and viability of *Striga* seeds in the course of the rainy season. Although it's to early to draw final conclusions, it's possible to hypothesise about the processes that are going on.

ANNEX 1 (Farmers that donated seeds for the crop seed contamination study)

Village	No. of Farmer	Farmers' name	maize	millet	cowpea	sorghum
N' Goukan	205031	Denis Dembélé	x	x	-	x
	205017	Sama Dembélé	x	-	x	x
	205015	Yelemigue Dembélé	xx	x	-	x
	205025	Fatie' Dembélé	xx	-	x	x
	205022	Niguitan Dembélé	xx	x	-	x
	205006	Nachy Dembélé	x	x	-	x
	205003	Nafo Dembélé	x	x	-	x
	205001	Mamourou Dembélé	x	x	-	x
	205011	Baba Dembélé	x	x	x	x
	205027	Siaka Dembélé	x	x	-	x
Try I	201022	Elie Diabaté	x	x	x	x
		Issa Diabaté	x	x	-	x
		Bakary F. Coulibaly	x	x	x	x
	201011	Aly Coulibaly	-	x	-	x
Try II		Madou W. Coulibaly	x	x	x	x
	202052	Doulaye Coulibaly	x	x	-	x
		Fousseny Kané	-	x	-	x
N' Peresso	204007	Moussa Coulibaly	x	x	x	x
	204006	Abdoulaye Coulibaly	x	x	x	x
	204009	Tidiani Coulibaly	x	x	x	x
	204013	B. lo Kassoun Coulibaly	x	x	-	x
	204030	Adama Dembélé	x	x	x	x
	204008	Nian Coulibaly	x	x	-	x
	204001	Balla Coulibaly	x	x	-	x
	204016	Zonga Bakary Coulibaly	x	x	-	x
	204026	Dramane Coulibaly	x	x	x	x
Farouala	206022	Bégué Traoré	x	x	x	x
	206020	Oumar Traoré	x	x	x	x
	206030	Giriba Traoré	x	x	x	x
	206028	Sidiki Traoré	x	x	x	x
	206023	Mamadou Traoré	x	x	x	x
	206004	Ningui Traoré	x	x	-	x
	206006	Adama Traoré	x	x	-	x
	206001	Solomane Traoré	x	x	x	x
	206007	Bégué Abdoulaye Traoré	x	x	-	x
Kafono	601007	Drissa Dialla	x	x	-	x
	601005	Diakalia Sanogo	x	x	-	x
	601017	N' golo Koné	x	x	-	x
	601015	Abou Koné	x	x	-	x
	601006	M' Bè Diarra	x	x	-	x
	601014	Moussa Sanogo	x	x	-	x
	601018	Siaka Sangaré	x	x	-	x

Village	No. of Farmer	Farmers' name	maize	millet	cowpea	sorghum
N' golo pênê	604010	Seydou Sogodogo	x	x	-	-
	604022	Adama Danioko	x	x	-	x
	604008	Diakariako Sogodogo	x	x	-	x
	604004	Karim Traoré	x	x	-	x
	604021	Nouhoun Danioko	x	x	-	x
	604023	Karim Danioko	x	x	-	x
	604026	Mamadou Sogodogo	x	x	-	x
	604032	Amidou Sogodogo	x	x	-	x
	604003	Sekou Danioko	x	x	-	x
	604005	Diakaridia Sogodogo	x	x	-	x
Ouatialy	603030	Adama Traoré	x	x	x	x
	603077	Zoumana Koné	x	x	x	x
	603004	N'Golo Amara Sogodogo	x	x	x	x
	603005	Abibou Sogodogo	x	x	x	x
	603096	Youssouf Koné	x	x	x	x
	603039	Yacouba Diabaté	x	x	x	x
	603074	Oumar Ouattara	x	x	x	x
	603060	Zana Diarra	x	x	x	x
	603026	Wayerma Traoré	x	x	x	x
Zankundougou	602016	Adama Diarra	x	x	-	x
	602010	Madou Traoré	x	x	x	x
	602023	Gue'yaga Ouattara	x	x	-	x
	602003	Lamissa Ouattara	x	x	x	x
	602022	Yssouf Zana Ouattara	x	x	-	x
	602018	Yacouba Ouatarra	x	x	-	x
	602007	Daouda Traoré	-	x	-	x
	602028	Adama Porna Traoré	x	x	-	x
	602011	Seydou Doh Ouattara	x	x	x	x
	602019	Bêdjan Traoré	x	x	-	x
Kodialan	706013	Tagafing Togola	x	-	-	x
	706021	Adama Togola	x	-	-	x
	706001	Madoudjan Togola	x	-	x	x
	706015	Madou Togola	-	-	-	x
	706024	Aboudou Togola	x	-	-	x
	706009	Issa Diarra	x	-	x	x
	706004	Ladji S. Diarra	x	x	x	x
	706007	Ladji B. Diarra	-	-	-	x
	706018	N' Famara Togola	x	x	x	x
	706005	Solomane D. Togola	-	x	x	xx
	706025	Bakary Bagayogo	x	x	-	-
	706013	Brehimadjan Togola	-	x	-	-
	706022	Alou Togola	x	-	-	-
	706031	Modibo Bâh	x	-	-	-
	706003	Siaka Diarra	-	-	-	x
	706014	Wodjouma O. Togola	-	-	x	-

Village	No. of Farmer	Farmers' name	maize	millet	cowpea	sorghum
Sola	705047	Sidi Mariko	x	-	x	x
	705064	Salia Koné	-	x	-	x
	705057	Sidiki Mariko	-	-	-	-
	705008	Moussa Mariko	-	-	-	x
		Brehima Mariko	-	-	-	x
	705020	Moussa Mariko	-	x	-	-
		Moriba Issa Mariko	-	-	-	x
	705022	Tiefolo Mariko	-	-	-	x
Banco	703099	Aboudou Sangaré	-	-	-	x
		N' Fassery Sangaré	-	-	-	x
	703055	Salif Sidibé	-	-	-	x
	703041	Kerma Diakité	x	-	-	-
	703075	Yousouf Sangaré	-	-	-	x
	703046	Amara Traoré				
	703020	Doudou Sangaré	x	-	-	x
Sorona	704006	Ibrahima Sangaré	-	-	-	x
	704039	Amadou Sangaré	-	-	-	x
	704056	Bakary Coulibaly	-	-	-	x
	704037	Yacouba Samaké	x	-	-	x
	704007	Layi Bagayogo	-	-	-	x
	704028	Diagassan Mariko	-	-	-	x
	704001	Yaya Sangaré	-	-	-	x

ANNEX 2 (Farmers that participated in the interviews)

Village	No. of Farmer	Farmers' name	Village	No. of Farmer	Farmers' name
N' Goukan	205031	Denis Dembélé	Kafono	601007	Drissa Dialla
	205017	Sama Dembélé		601005	Diakalia Sanogo
	205015	Yelemigue Dembélé		601017	N' golo Koné
	205025	Fatie' Dembélé		601015	Abou Koné
	205022	Niguitan Dembélé		601006	M' Bè Diarra
	205006	Nachy Dembélé		601014	Moussa Sanogo
	205003	Nafo Dembélé		601018	Siaka Sangaré
	205001	Mamourou Dembélé	N' golo pênê	604010	Seydou Sogodogo
	205011	Baba Dembélé		604022	Adama Danioko
	205027	Siaka Dembélé		604008	Diakariako Sogodogo
Try I	201022	Elie Diabaté		604004	Karim Traoré
		Issa Diabaté		604021	Nouhoun Danioko
		Bakary F. Coulibaly		604023	Karim Danioko
	201011	Aly Coulibaly		604026	Mamadou Sogodogo

Village	No. of Farmer	Farmers' name	Village	No. of Farmer	Farmers' name
Try II		Madou W. Coulibaly	N' golo pênê	604032	Amidou Sogodogo
	202052	Doulaye Coulibaly		604003	Sekou Danioko
		Fousseny Kané		604005	Diakaridia Sogodogo
N' Peresso	204007	Moussa Coulibaly	Ouatialy	603030	Adama Traoré
	204006	Abdoulaye Coulibaly		603077	Zoumana Koné
	204009	Tidiani Coulibaly		603004	N'Golo Amara Sogodogo
	204013	B. lo Kassoun Coulibaly		603005	Abibou Sogodogo
	204030	Adama Dembélé		603096	Youssouf Koné
	204008	Nian Coulibaly		603039	Yacouba Diabaté
	204001	Balla Coulibaly		603074	Oumar Ouattara
	204016	Zonga Bakary Coulibaly		603060	Zana Diarra
	204026	Dramane Coulibaly		603026	Wayerma Traoré
	204021	Issa Coulibaly	Zankundougou	602016	Adama Diarra
Farouala	206022	Bégué Traoré		602010	Madou Traoré
	206020	Oumar Traoré		602023	Gue'yaga Ouattara
	206030	Giriba Traoré		602003	Lamissa Ouattara
	206028	Sidiki Traoré		602022	Yssouf Zana Ouattara
	206023	Mamadou Traoré		602018	Yacouba Ouatarra
	206004	Ningui Traoré		602007	Daouda Traoré
	206006	Adama Traoré		602028	Adama Porna Traoré
	206001	Solomane Traoré		602011	Seydou Doh Ouattara
	206007	Bégué Abdoulaye Traoré		602019	Bêdjan Traoré
Kodialan	706013	Tagafing Togola	Gongasso		Solomane Diabaté
	706021	Adama Togola			Yayou Bengaly
	706001	Madoudjan Togola			Lassina Bengaly
	706015	Madou Togola			Dramane Diabaté
	706024	Aboudou Togola			Adama Diabaté
	706009	Issa Diarra			Arouna Sogodogo
	706004	Ladji S. Diarra			Ibrahima Diabaté
	706018	N' Famara Togola			Janmary Bengaly
	706005	Solomane D. Togola			Mamary Bengaly
	706025	Bakary Bagayogo			Fatogoma Bengaly
	706003	Siaka Diarra			

Village	No. of Farmer	Farmers' name	Village	No. of Farmer	Farmers' name
Sola	705047	Sidi Mariko	Noyaradougou	14	Abou Kamanou Diamoutènè
	705064	Salia Koné		27	Drissa Diamoutènè
	705057	Sidiki Mariko		35	Diakaridia Diamoutènè
	705008	Moussa Mariko		7	Karim Diamoutènè
		Brehima Mariko		6	Adama Coulibaly
	705020	Moussa Mariko		5	Siaka Coulibaly
	705022	Tiefolo Mariko		36	Dramane Diamoutènè
Banco	703099	Aboudou Sangaré		1	Ibrahima Diamoutènè
		N' Fassery Sangaré		3	Kadary Diamoutènè
	703055	Salif Sidibé		16	Nangoudo Diamoutènè
	703041	Kerma Diakité			
	703075	Yousouf Sangaré			
	703046	Amara Traoré			
	703020	Doudou Sangaré			
Sorona	704006	Ibrahima Sangaré			
	704039	Amadou Sangaré			
	704056	Bakary Coulibaly			
	704037	Yacouba Samaké			
	704007	Layi Bagayogo			
	704001	Yaya Sangaré			
	704057	Danseni Sangare			
	704041	Mamadou Samake			
	704004	Bourama Sangare			
	704001	Adama Sangare			

ANNEX 3 (Questionnaire used in the interviews)

Enquête sur la contamination des semences

-ESPGRN/Sikasso
-KIT/Amsterdam
-LUW/Wageningen

Date:

Village:

Nom du paysan:

Numéro du paysan:

1- Comment le paysan s'est procuré les semences?
 * pendant la récolte précédente [ ]
 * achetées [ ] Où ? ______________________________
 * autre façon [ ] ______________________________

2- Est-ce que le paysan connaît les graines de Striga?
 Oui [ ] Non [ ]

3- Est-ce que le paysan sait que ses semences peuvent être contaminées par des graines de Striga?
 Oui [ ] Si oui, Est-ce que le paysan croit que ses semences sont contaminées par des graines de Striga?
 Oui [ ] Non [ ] Ne sait pas [ ]
 Non [ ]

4- Comment sont récoltées les céréales et les semences?

5- Est-ce que les champs du paysan sont infestés par le Striga?
 Oui [ ] Non [ ]

6- Quelle variété de sorgho est utilisée par le paysan?
 - Panicule lâche [ ]
 - Panicule compact [ ]

7- Est-ce que le paysan fait un traitement des semences?
 Oui [ ], avec______________________
 Non [ ]

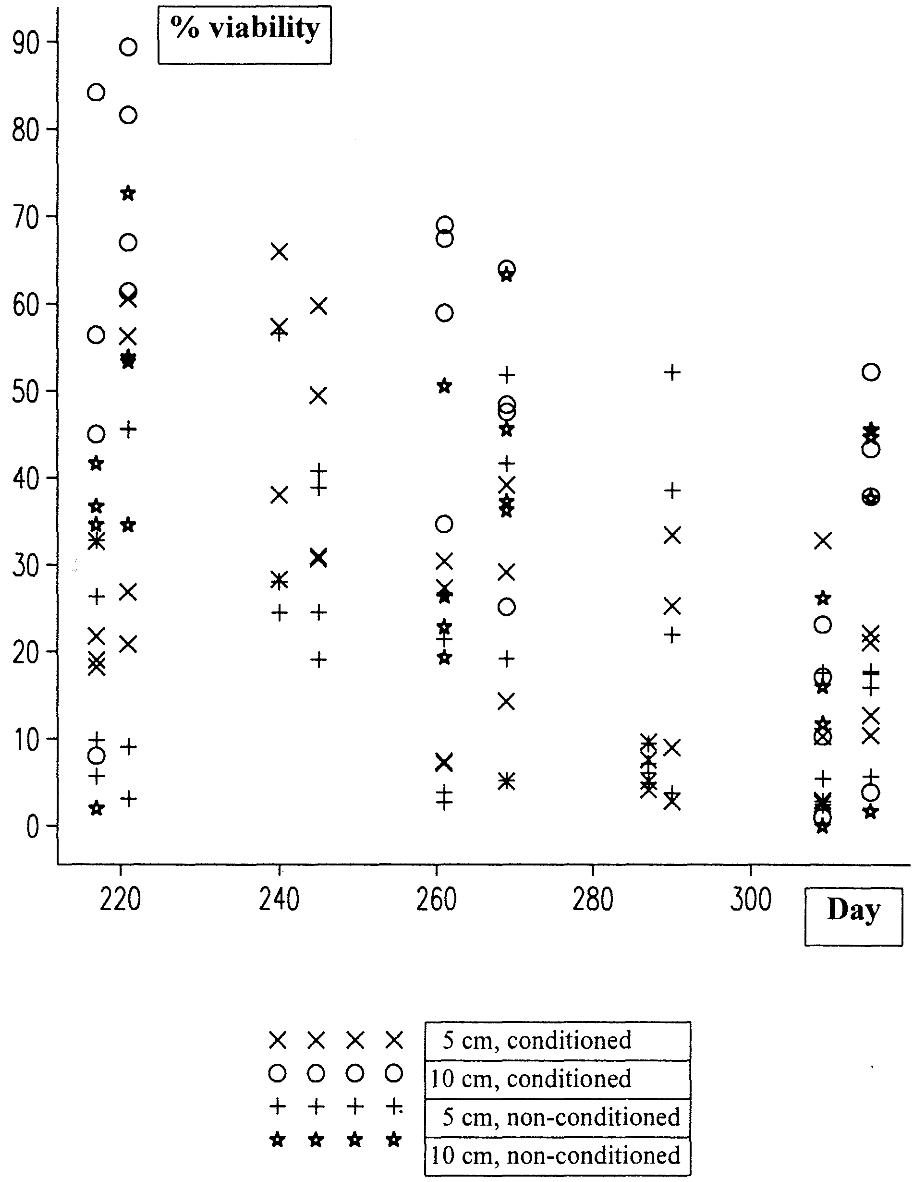
8- Commentaires

ANNEX 4 (Traditional treatments of crop seeds against *Striga* and other diseases)

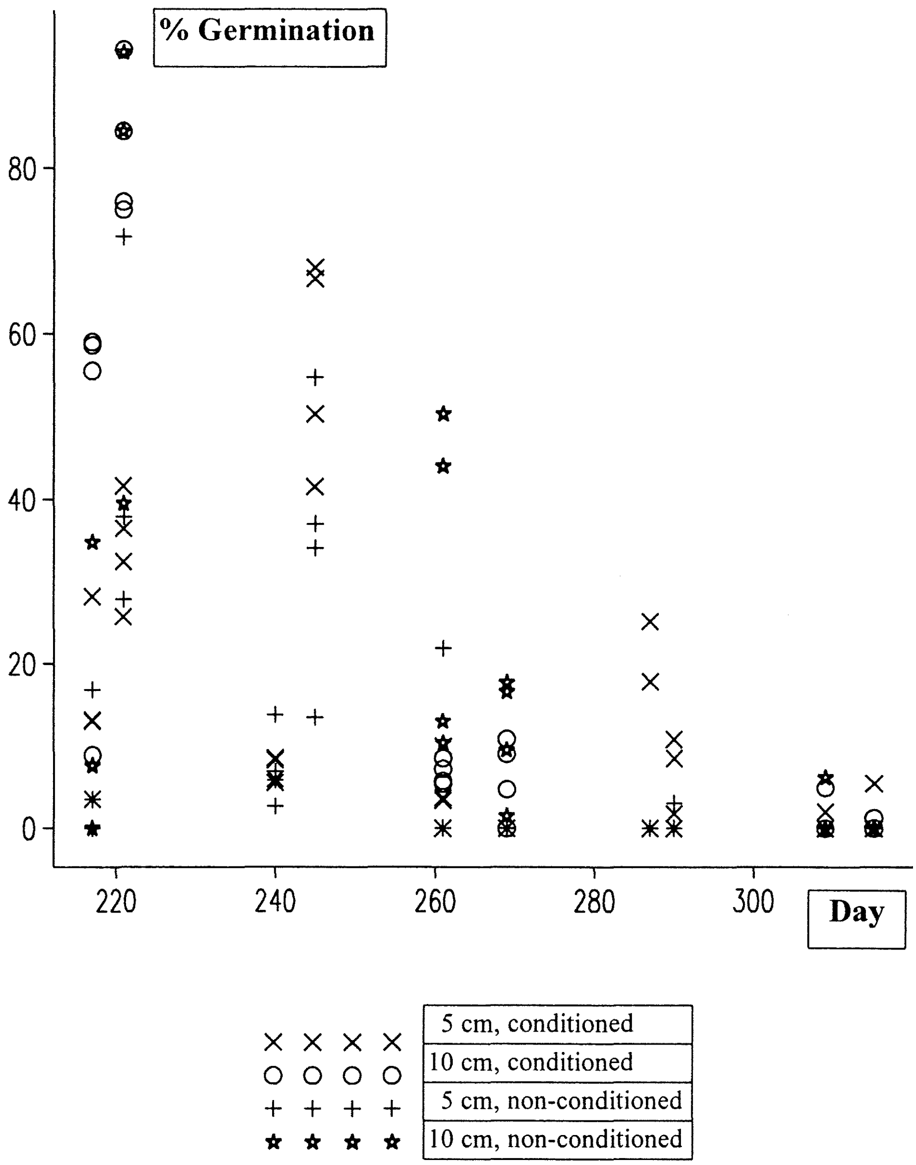
The species' names between '' are (probably) in Bambara, it's not certain they're correct or that they are spelled right. It's likely that sometimes the same name is spelled in different ways.

-A piece of Donkey skin mixed with the seeds.
-Intestines of an Eel reduced to powder, scattered along the four sides of the field.
-The pulverised mistletoe 'Migon' mixed with the seeds.
-Pulverised leaves of the 'Koladiéké' tree mixed with the seeds.
-Intestines of the 'Wóto' fish reduced to powder mixed with the seeds.
-Ashes of burned wood mixed with the seeds.
-A bad smelling weed 'Daba', that can only be found when a lot of rain has fallen, pulverised mixed with the seeds.
-Placing bones of the wild animal 'Danié' between the seeds. The bones can be used several times.
-The roots of the 'Dioro' tree (*Securidaca longepedunculata)* reduced to powder mixed with the seeds.
-The skin of a Hippopotamus.
-The pulverised mistletoe 'Bégou' mixed with the seeds.
-Part of the 'Torouwmon ladon' tree is mixed with the seeds for a good yield.
-Leaves of the 'Kaladjégué' tree are mixed with the seeds against blight (charbon).
-The mistletoe 'Tabacounba ladon' is mixed with the seeds.
-The mistletoe 'Torobonbo ladon'(*Ficus* species) and its fruits are mixed with Sorghum seeds.
-The mistletoe 'Balangan ladon' (of *Acacia albida*?) is mixed with the seeds of Sorghum.
-The mistletoe of the *Balanites aegytiaca* (Sèguènè).
-The roots of the 'Joro'.
-The bark of the 'Dengio'.
-The powder of the fruit of the Fig tree and the mistletoe of this tree mixed with the crop seeds.
-Washing the crop seeds with water.
-Old *Striga* plants, the scales of a fish (languille) and bread in a barrel. Reduce this to powder and mix this with the seeds.
-Ashes of old *Striga*, cereal plants and something which originates from the Koran.
-Water from a ordinary Canary 'Denkorojun' against evil spirits and people.
-The seeds are washed with a extract of the bark of the 'Joro boulla' tree.
-Boiling crushed leaves of 'Tiétioro' or 'Djoro' and afterwards washing the seeds with this extract. This gives the seeds a nice colour.
-Washing the seeds with an extract of the mistletoe of the 'Karité'.
-Washing the seeds with an extract of the roots of the 'Filigama'.
-Washing the seeds with an extract from the roots of 'Tiékoro' and 'Samakara''.
-Washing the seeds with an extract from the roots and bark of the 'Dioro' tree.
-The mistletoe of *Securidaca longepedunculata* and another tree against blight.

ANNEX 5 (Scatterplots of '% viability' and '% germination' vs. 'Day')



Scatterplot: The percentage viable seeds at a certain time is shown in the scatterplot above. Each symbol represents a batch of seeds used in the viability test (see also the index underneath the scatterplot).

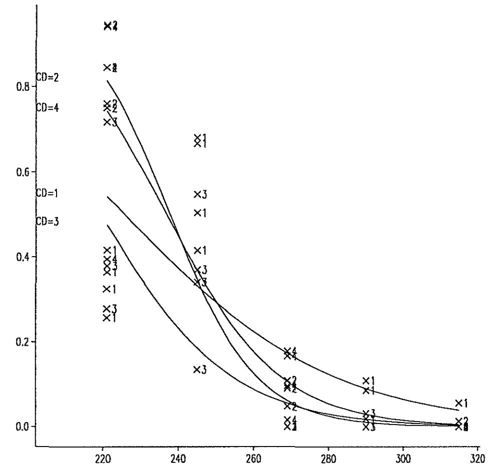


Scatterplot: The percentage germination at a certain time is shown in the scatterplot above. Each symbol represents a batch of seeds used in the germination test. (see also index underneath the scatterplot).

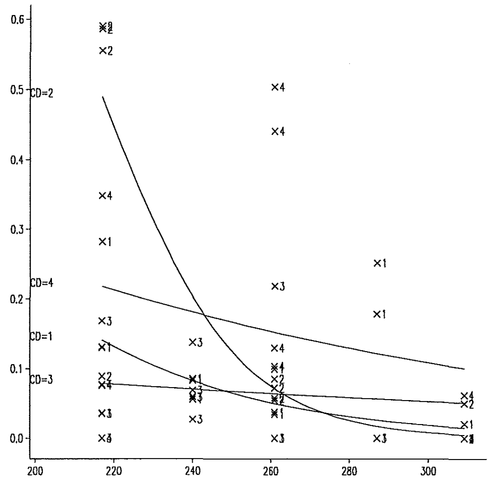
ANNEX 6 (Scaled down graphs from the seedbank study results)

The graphs presented in the seedbank study results have been scaled down to allow for easy comparison of the graphs. The information in the graphs hasn't changed.

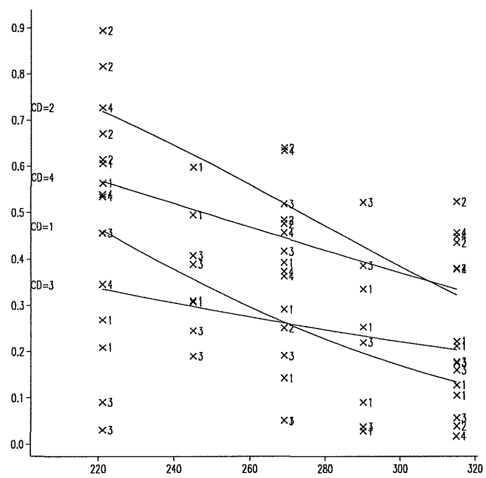
Germination Kadiolo



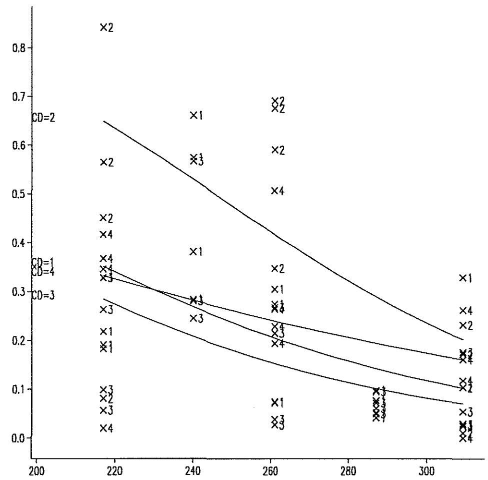
Germination Koutiala



Viability Kadiolo



Viability Koutiala



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