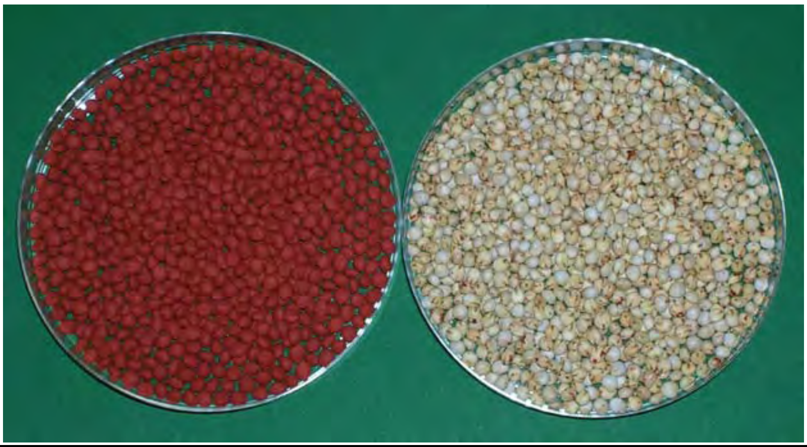
RESEARCH PROGRESS REPORT

Seed treatment technology and Pesta formulation: Efficient delivery systems for *Striga* mycoherbicides – a step towards practical *Striga* control in Africa



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Title of the main activity

Field evaluation of an integrated *Striga hermontica* management in Sub-Saharan Africa: Synergy between *Striga*- mycoherbicides (*Fusarium oxysporum*: Foxy2 and PSM197) and sorghum and maize resistant varieties

Abstract

Striga spp. are important biotic constraints in cereals in semi-arid tropical Africa. An integrated approach, in which biocontrol represents an important component, appears to be an ideal management strategy for *Striga*. For facilitating practical field application, our recent research focuses on the development of appropriate mycoherbicidal formulations and delivery systems of the potential *Striga*-mycoherbicides *Fusarium oxysporum* (Foxy 2 & PSM197). Hence, Pesta formulation, made by encapsulating fungal inoculum in a matrix composed of durum wheat-flour, kaolin, and sucrose, was developed. Further, a seed treatment technology for coating sorghum and maize seeds for further minimizing the inoculum amount and facilitating delivery of *Striga*-mycoherbicides was provided. Both formulations showed promising efficacy in controlling *Striga*. In this study, the integration of *Striga*-mycoherbicides using Pesta formulation or seed treatment technology with *Striga* resistant sorghum and maize enhanced clearly the efficacy of both mycoherbicides in controlling *Striga* under field conditions of Benin. The compatibility and suitability of Pesta and seed treatment technology for formulating and delivering *Striga*-mycoherbicides can contribute to solving the primary difficulties for underemployment of *Striga*-mycoherbicides in large-scale in Africa. The approach of combining host plant resistance and the mycoherbicide might be a good option for subsistence farmers for realization of a successful integrated *Striga* control strategy.

1.1 Background

Root parasitic weeds of the genus *Striga* are important constraints in cereal and legume production in semi-arid to sub-humid areas of Africa, where the livelihood of millions of subsistence farmers is adversely affected, and consequently aggravate hunger and poverty. Therefore, an integrated approach in which biocontrol represents an important component appears to be the ideal strategy for reducing *Striga* infestation. For a practical field application our recent research activities focuse on the development of appropriate formulations and delivery systems of the fungal antagonist *Fusarium oxysporum* (Foxy 2 & Isolate 197) for *Striga* control. Hence, Pesta granular formulation and coated sorghum and maize seeds made with propagules of *Fusarium* strains showed promising efficacy in controlling *Striga* and in improving the panicle yield of host crops under greenhouse conditions.

1.2 Objectives

Evaluating the efficacy of mycoherbicidal formulations (Pesta & seed treatment) containing *Striga*-mycoherbicides *Fusarium oxysporum* isolates (Foxy2 & PSM197) when integrated with *Striga* tolerant/resistant sorghum and maize varieties under field conditions of IITA, Benin. Furthermore, the synergistic effect of the sorghum and maize seed coated with mycoherbicides and some selected fungicides, used as seed treatment, on the control of *Striga* and sorghum and maize fungal diseases simultaneously was evaluated under field condition as well.

The field experiment was carried out in collaboration with scientists of the International Institute of Tropical Agriculture (IITA) in West Africa. West African countries are the important sorghum and maize producing countries with severe *Striga* infestation. IITA has the institutional capability and expertise to carry out the project activities and to make significant contributions towards the goal of the project. Collaboration and arrangement for the field experiments in Benin was done with Dr. Fed Beed (Plant pathologist and Biological Control of Weed specialist), at the IITA Station (Biological Control Center) Benin.

2 Methodology

This research project was carried out using the methodologies and approaches recently developed and optimised by Dr. Elzein at the Institute of Plant Production and Agrarecology in the Tropics und Subtropics, University of Hohenheim, Stuttgart; Germany, where considerable expertise and experience in the research area of concern is available

2.1 Inoculum production, formulation of Pesta mycoherbicides and seed coating at the University of Hohenheim, Germany

2.1.1 Fungal isolates:

1. *Fusarium oxysporum* Foxy2
2. *Fusarium oxysporum* PSM197

2.1.2 Inoculum production

Liquid culture was used for mass production of the fungal inocula. Our strategy was based on developing inoculum mass production techniques using agricultural by-products, which are inexpensive and readily available in the Sahelian and Sub-Saharan zones of Africa where *Striga* is a major problem. This strategy proved to be effective, time-saving and it is very attractive for the economic feasibility of the Pesta formulation (Elzein and Kroschel 2004). Conditions required for chlamydospore production of Foxy 2 was recently optimised (Elzein, 2003), in view of the effect of plant fiber, near ultra-violet (NUV) light, substrate concentrations and combinations (synergism), level of agitation, incubation time and their interaction in liquid cultures**.**

2.1.3 Mycoherbicidal products:

The fungal mycoherbicidal products prepared using two technologies:

1. Encapsulating the fungal isolates into **Pesta** granular mycherbicidal formulation.
2. Delivering the fungal isolates using seed treatment technology (**seed coating**).

Pesta granular formulation: involves encapsulation of the fungal inoculum (fresh chlamydospores) in a wheat-gluten matrix (semolina wheat flour, kaolin and sucrose), using a pasta-like process. Existing protocols for Pesta formulations developed by Connick (1991) and recently optimised by Elzein (2003) were used to provide inoculum for field-testing of *Fusarium oxysporum* strains (Fig. 1).

Seed treatment technology as a delivery system for *Striga* mycoherbicides: involves coating of sorghum and maize seed swith dried fungal inoculum using Arabic Gum as adhesive. The seed coating protocol (procedure) developed and optimized recently by Elzein *et al.* (2006) was used to carry out the foregoing investigations. All processes (steps) of film-coating of sorghum and maize seeds including homogenizing the suspension, distributing the active substances to all individual seed grains evenly, and air-drying were performed by Saat-u. Ernte-Technik (SUET), Eschwege, Germany, using fully modern seed coating technology. The treated seeds were not only uniformly coated, but also abrasion- and dust-free, and with excellent fluidization for assuring high quality seeds. Natural colour was added to the treated seeds in order to be distinguished from the untreated controls (Fig. 2).

2.2 Crops

1. **Maize:** *Striga* resistant and susceptible cultivars
2. **Sorghum:** *Striga* tolerant and susceptible cultivars

The maize breeding lines have been donated by IITA-Nigeria. Dr. Fen IITA-Benin provided sorghum seeds.

The efficacy of the two fungal isolates Foxy 2 and PSM 197 formulated as Pesta granules or delivered as seed treatment, in combination with *Striga* resistant and susceptible maize and sorghum cultivars was evaluated in the field trail.

2.3 Treatments (Total No. is 44)

I. Seed Treatment

Fungal isolates alone + Arabic gum as adhesive

1. Foxy2
2. PSM197

Fungal isolates + Fungicides + Arabic gum

3. Foxy2
4. PSM197

II. Pesta

5. Pesta + Foxy2
6. Pesta + PSM197

III. Controls

Controls without fungal inoculum + *Striga*

7. Crop seeds + Arabic gum
8. Crop seeds + Fungicide + Arabic Gum
9. Un-treated Crop seeds
10. Pesta without fungal inoculum

11. **Controls without fungal inoculum and without *Striga***

Each in combination with:

a) Maize; susceptible variety (8338-1)
b) Maize; resistant variety (TZL Comp1-SYN-WF2)
c) Sorghum; susceptible variety (Kourboula)
d) Sorghum; resistant/tolerant variety (Sarias-o 14)

According to the experiment layout in the filed there were 16 treatments for each fungal isolate for each crop (Table 1, Fig. 3).

Fig. 1a: ‘‘Pesta’’ preparation procedure: “Pesta’’ ingredients and fungal inoculum

Fig. 1b: Inocula of "Foxy 2" used for ‘‘Pesta’’ and seed coating (left) dried chlamydospores, (midle) microconidia, and (right) fresh chlamydospores

Fig. 1c: ‘‘Pesta’’ preparation procedure: cohesive dough on the hand-operated pasta maker

Fig. 1d: ‘‘Pesta’’ preparation procedure: extruded sheet through a small hand-operated pasta maker

Fig. 1e: ‘‘Pesta’’ preparation procedure: the resulting dough sheets and their air-drying on aluminium foil

Fig. 1f: Pesta granules made with fresh chlamydospore of Foxy 2

Fig. 1: Pesta production

Fig. 2a: Coated sorghum and maize seeds with Foxy 2 (lower); control (upper)

Fig. 2b: Maize seeds coated with Foxy 2 (upper); control (lower)

Fig. 2c: Sorghum seeds coated with Foxy 2 (upper); control (lower)

Fig. 2: Sorghum and maize coated seeds with *Striga*-mycoherbicdes

Table 1: Treatments for each fungal isolate (Foxy 2 or PSM197) for each crop (maize or sorghum)

Treatment[a] No.	Treatment abbreviation	Treatment description
T1	**CR**	Control Resistant variety
T2	**CS**	Control Susceptible variety
T3	**CRStr**	Control Resistant variety +*Striga*
T4	**CSStr.**	Control Susceptible variety +*Striga*
T5	**CPR**	Control + uninoculated Pesta + Resistant vareity + *Striga*
T6	**CPS**	Control + uninoculated Pesta + Susceptible vareity + *Striga*
T7	**CCoR**	Control coated Resistant variety + *Striga*
T8	**CCoS**	Control coated Susceptible variety + *Striga*
T9	**CCoRF**	Control coated Resistant variety + Fungicide + *Striga*
T10	**CCoSF**	Control coated Susceptible variety + Fungicide + *Striga*
T11	**PR**	Pesta Resistant variety
T12	**PS**	Pesta Susceptible variety
T13	**CoR**	Coated Resistant variety
T14	**CoS**	Coated Susceptible variety
T15	**CoRF**	Coated Resistant variety +Fungicide
T16	**CoSF**	Coated Susceptible variety +Fungicide

[a] T11-T12: Fungal treatments with Foxy 2 or PSM197

2.4 Field experiment, Benin

Experiments layout and design (Appendix 1)**:**

- One location, highly invested with *Striga*, was selected
- Randomized Complete Block Designs was used
- Plot size: length x width (5 m x 3 m =15 m^2); each with four ridges; with 0.75 m spacing between ridges
- Neighbouring plots were separated by a ridge free of plants and blocks by 1 m. free space
- Planting holes with a diameter of 10-15 cm and a depth of 5 cm were dogged at every ridge with a spacing of 0.5 m.
- Four replicates per treatment were used i.e. 4 plots.

***Striga* seeds**

The *Striga* seeds were collected in 2005, in the north of Benin by INRAB staff from *Striga* plants parasitizing sorghum. A mixture of sand and *Striga* contain approximately 3000 *Striga* seeds (developed from the method of Berner *et al.*, 1997) were added to each of the 7616 planting holes. The mixture sand/*Striga* was supplied by INRAB, Ina.

Sowing

Three maize seeds or five sorghum seeds were sown in each hole of 5 cm depth as per traditional farmers practice (C. Yallou pers. Comm.of INRAB; Ina.). For each treatment there were 9 seed holes per row and thus 108 (9x3x4) or 180 (9x5x4) seeds, respectively, for maize and sorghum were required per treatment per plot. After the mixture of sand/*Striga* was added in the seed holes, the crop seeds were placed and then covered with a layer of soil approximately 1 cm.

Three weeks after sowing the seedlings were thinned so that only one plant remains per seed hole, providing 36 plants per treatment for each plot.

Pesta formulation

In the plots with Pesta treatment, 2 g of Pesta granules were spread over the *Striga* seed-sand mixture per each planting hole for both maize and sorghum.

Other cultural practices

- Weed control was carried out by hoe-weeding three weeks after sowing. From then on, weeds were removed by hand-pulling only in order to avoid interactions with *Striga* development.
- Fertilizer was applied at a rate of 120 kg N per hectare for maize and 64 kg N per hectare for sorghum. This amount was split into two equal parts of N, the first dose was applied in form of compound fertilizer N-P-K (20:10:10) three weeks after sowing, the second dose was applied in form of urea (46% N), six weeks after sowing.
- After harvest, maize cobs, sorghum panicles and plant stalks were sun-dried for five days. Dry weight of the entire cobs and panicles are being recorded before sorghum and maize will be threshed. The grains will be cleaned and weight.

2.5 Out-door pot experiments

With the aim of providing more accurate (precise) additional data for evaluation of the efficacy of *Striga*-mycoherbicides (Foxy 2 and PSM 197), formulated as Pesta granules or delivered as seed treatment, for control of *S. hermontica*, pot trials were conducted at IITA station, Cotonou, Benin. The same treatments that tested under field conditions were used. Loam sandy soil, steam-sterilized for 24 hours, was used in pot trials. Pot trials were conducted in plastic pots (20x20x20 cm) with a capacity of 6 kg soil. The same amount of *Striga* seeds, maize and sorghum seeds, and Pesta granules placed per planting hole in the field trial, was added per each pot. All treatments were replicated four times and arranged as a complete randomized design (Appendix 2, 3). Plants were irrigated periodically whenever necessary and fertilized with the same doses that used in the field.

2.6 Data collection

The potential of *F. oxysporum* to control *S. hermontica* in the field when applied as seed treatment or Pesta granules was evaluated with the following parameters (per plot):

At the begining

- The number of emerged crop plants
- Date of first *Striga* emergence

Weekly assessments:

- The number of emerged *Striga* plants per plot
- Height of crop plants (average of ten plants from the two inner rows)
- The number of diseased and dead emerged *Striga* plants

At harvest:

- The number of *Striga* flowers per plot at the peak of flowering
- The dry weight of *Striga* plants
- The dry weight of crop plants (stalks) separated for cobs or panicles
- Height of crop plants (average of ten plants taken from the two inner rows of every plot)
- The dry weight of the entire cobs and panicles

- The dry weight of 25 maize grains per ears and 50 to 100 sorghum per panicle

Samples for dry weight measurements were placed into labelled paper bags and returned to Cotonou, Benin, for drying in an oven at 70°C.

3 Results summary

3.1 Field trial

- The integration of Pesta formulation and treated seeds containing *Striga*-mycoherbicides (Foxy 2 & PSM197) with *Striga* resistant and susceptible maize and sorghum cultivars under field conditions revealed an additive effect. Both Pesta granular mycoherbicides (Foxy 2 & PSM197) were very effective with same potential, in controlling *Striga* on both resistant and susceptible maize and sorghum cultivars tested, while the effect of their seed treatments was very obvious with *Striga* resistant cultivars compared to the susceptible cultivars where very low effect was recorded.
- The combination Pesta granules x resistant maize and sorghum cultivars enhanced clearly both mycoherbicides efficacy, and showed the strongest suppressive effect on *Striga* compared to the susceptible cultivars (Fig. 3, 4).
- The difference between the resistant and the susceptible cultivars was stronger for maize than for sorghum. On average (i.e. the average effect of both isolates in combination with resistant and susceptible cultivars), they reduced the number of emerged *Striga* plants per plot by 92% or 83% when the two isolates formulated as Pesta granules or delivered as coated seeds, respectively, and combinated with the resistant maize cultivars compared to their respective controls (Fig. 3, Table 2, 3); the reduction was even more strong (96% and 89%, respectively) when compared with the control of the susceptible cultivars. On the other hand, the respective reductions when the two isolates integrated with the susceptible maize cultivars were 85 %, and 21%. Regarding this, the approach of combining host plant resistance and the mycoherbicide might be a good option for farmers and should be tested on farmers' fields. Indeed, it is important to choose the best adapted resistant cultivar for every location as resistance is often regional and also performance depends on local agro ecological conditions.

- With the aim of improving sorghum and maize performance and yield, an investigation on the possibility of delivering both *Striga*-mycoherbicides and some selected fungicides using seed treatment technology to control simultaneously *Striga* and sorghum and maize fungal diseases was made for the first time. Delivering of some fungicides (e.g, Apron XL) with *Striga*-mycoherbicides Foxy2 and PSM197 using seed treatment technology did not interfere with seed coating process as well as with the survival of fungal isolates on coated sorghum seeds. Even this fungicide clearly enhanced the growth, sporulation and viability of both isolates, indicating strong compatibility with *Striga*-mycoherbicides. The integration of fungicide Apron XL with *Striga*-mycoherbicides (Foxy2 & PSM197) and resistant maize cultivars using seed treatment technology showed significant reduction in *Striga* emergence by 90% compared to the respective susceptible control (Table 2, 3) Improved performance of maize and sorghum treated with *Strig*a-mycoherbicides and fungicide was recorded (data not shown).

- Regardless of the formulation technology used, both *Striga*-mycoherbicides Foxy2 and PSM197 were very effective with same potential (i,e., no significant difference between them).

- Maize and sorghum performances (height, grain yield, stalks dry weight, etc.) are currently under evaluation and assessment (data not shown) (Appendix 1).

3.2 Pot trial

- In general, the establishment of the pot trial was very successful. Unfortunately, the germination and establishment of *Striga* were poor due to the unexpected heavy continuous rain at the trial site. However, still the results showed a similar pattern of the field results that the integration of Pesta formulation and treated seeds containing *Striga*-mycoherbicides (Foxy 2 & PSM197) with *Striga* resistant enhanced both mycoherbicides efficacy, and showed the strongest suppressive effect on *Striga* compared to the susceptible cultivars.

Table 2: Effect of Foxy 2 formulated as Pesta granules or delivered as seed treatment on the emergence of *S. hermonthica* on maize

Treatment[a]	**No. of emerged *Striga* (Mean±SE)**
CPS	225.75 ± 41.52 a
CCoSF	143.00 ± 12.80 b
CCoS	128.75 ± 26.18 b
CoSF	102.75 ± 25.82 bc
CSStr	101.50 ± 26.69 bc
CoS	96.00 ± 18.11bc
CPR	48.00 ± 22.69cd
CS	41.25 ± 28.11cd
CCoR	37.50 ± 7.23cd
CRStr	21.00 ± 5.40cd
CCoRF	21.00 ± 8.63cd
PS	20.75 ± 4.46cd
CoRF	15.25 ± 3.70cd
CoR	15.00 ± 7.58cd
PR	2.25 ± 1.32d
CR	0.00 ± 0.00d
P	< 0.0001

[a]C: Control; Co: Coated seed; F: Fungicide; P: Pesta; R: resistant; S: Susceptible; Str: *Striga*. For more describtion about the treatments refer to Table 1.

Table 3: Effect of PSM197 formulated as Pesta granules or delivered as seed treatment on the emergence of *S. hermonthica* on maize

Treatment[a]	No. of emerged *Striga* (Mean±SE)
CPS	143.75 ± 22.80 a
CCoSF	137.25 ± 38.42a
CCoS	125.75 ± 17.44a
CSStr	120.50 ± 11.92a
CoS	93.00 ± 28.36ab
CoSF	86.00 ± 21.82abc
CPR	49.50 ± 13.19bcd
CCoR	45.50 ± 11.10bcd
CCoRF	27.00 ± 12.39cd
PS	22.25 ± 5.17cd
CoR	11.25 ± 1.31d
PR	10.25 ± 7.30d
CoRF	10.25 ± 4.42d
CRStr	9.75 ± 3.88d
CS	3.75 ± 3.75d
CR	0.5 ± 0.5d
P	< 0.0001

[a]C: Control; Co: Coated seed; F: Fungicide; P: Pesta; R: resistant; S: Susceptible; Str: *Striga*. For more describtion about the treatments refer to Table 1.

4 Conclusion

The efficacy of *Fusarium oxysporum* (isolates Foxy 2 and PSM 197), formulated as Pesta granules or delivered as seed treatment, for control of *Striga hermontica* has been proved under field conditions. The integrated approach combining the mycoherbicide with host plant resistance was successful as the two control methods had an additive effect. The suitability of Pesta and seed treatment technology for formulating and delivering *Striga*-mycoherbicides and their compatibility and synergy with *Striga* resistant cultivars are highly relevant to the realization of an integrated *Striga* control approach adoptable and applicable by subsistence farmers in Africa. This might contribute to solving the primary difficulties for underemployment of *Striga*-mycoherbicides in Africa. In addition, the compatibility between *Striga*-mycoherbicides and some fungicides has significant implication for controlling (integratedly) simultaneously *Striga* and sorghum and maize fungal diseases and improving crops performance and yield.

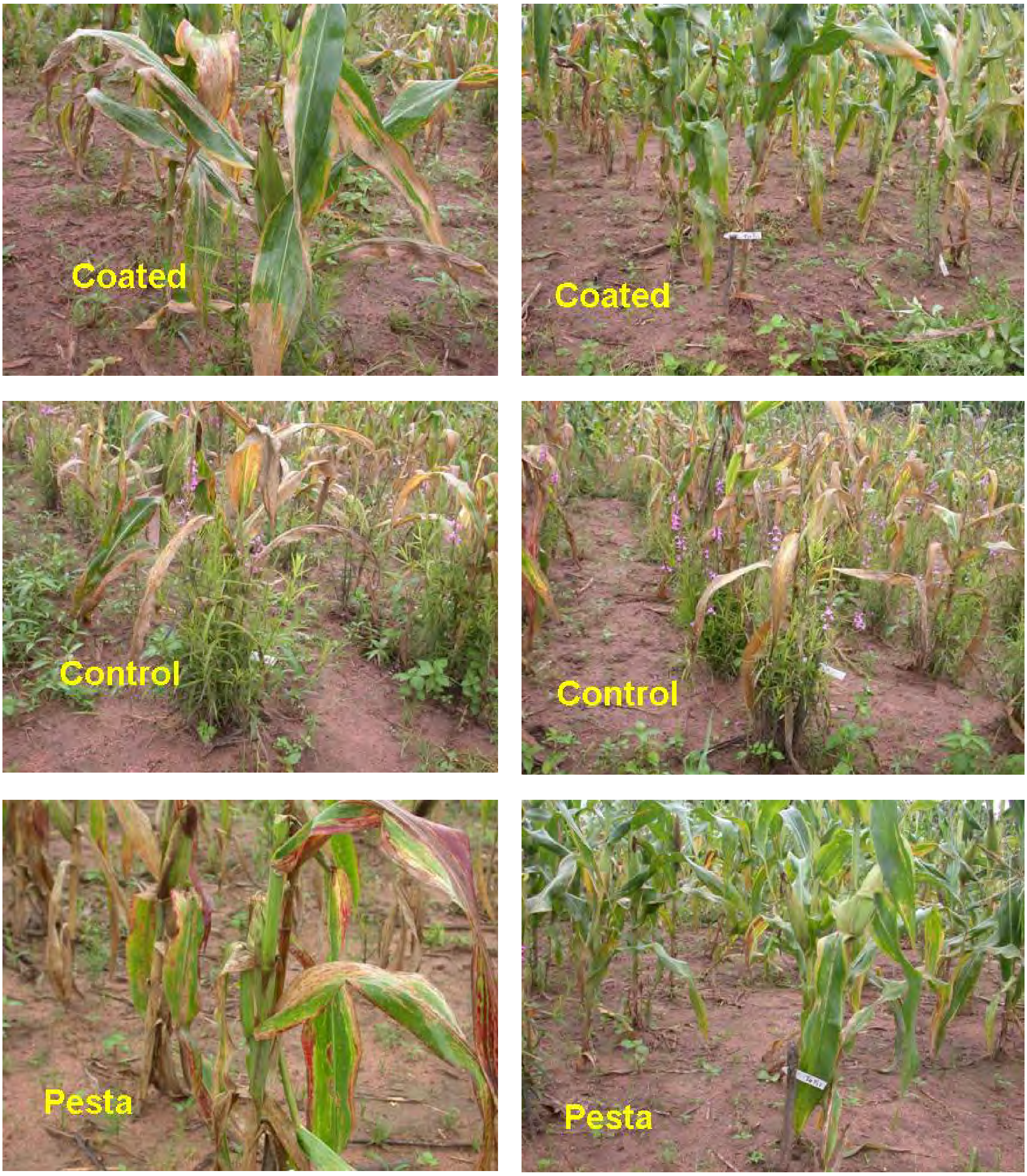

Fig. 3: Emergence of *S. hermonthica* on maize as affected by Foxy 2 (left) or PSM197 (right), formulated as Pesta granules (Pesta) or delivered as seed treatment (Coated).

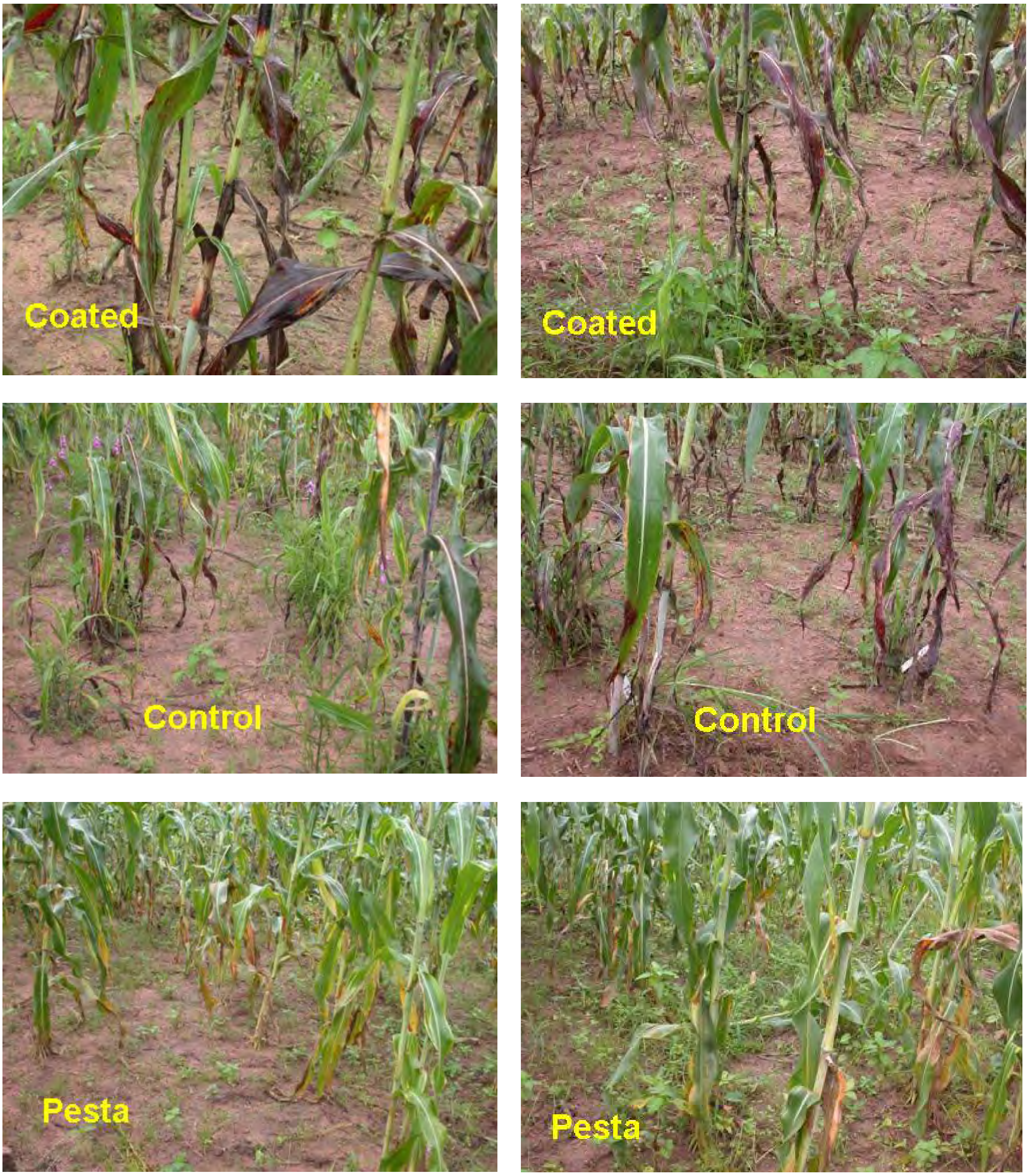

Fig. 4: Emergence of *S. hermonthica* on sorghum as affected by Foxy 2 (left) or PSM197 (right), formulated as Pesta granules (Pesta) or delivered as seed treatment (Coated).

5 Time plan for the ongoing and planned research activities

The time plan is scheduled to complete the research activities as they were proposed in the original proposal. Accordingly, the following experiments are currently being finalized or will be carried out the University of Hohenheim, Germany.

Operation plan

	Time plan																					
	2005					2006												2007				
Results (R) and activities (Act.)	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
R1. Studying the effect of vacuum-packaging system, fungicides and storage conditions on viability (shelf-life) of Foxy 2 and PSM197 on film-coated sorghum seeds																						
Act. 1. Film-coated sorghum seeds prepared for efficacy evaluation (see R2) were used for the shelf-life study																						
Act. 2. Setting-up of experiment (preparation of samples, vacuum packaging, and incubation under different storage conditions)				→																		
Act. 3. Determining CFU/coated seed on regular time intervals (3 months) including serial dilutions and plating on the PDA media								→			→			→			→					
Act. 4. Evaluation (counting of CFU/coated seed)									→			→			→			→				
Act. 5. Statistical analysis of data																		→	→	→	→	→
R2. Histological study on the colonization and the development of *F. oxysporum* (Foxy 2) on the root system of sorghum plant																						
Act. 1. Production of fungal inoculum and preparation of coated seed treatments	→	→	→																			
Act. 2. Setting-up of *in vitro* experiments (filter paper (BP) for the plant material				→	→																	
Act. 3. Sampling and fixation					→																	
Act. 4. Preparing of samples for light microscopy including fixation, embedding, sectioning, staining and mounting coverslips						→	→	→	→	→	→											
Act. 5. Examination of the samples under the light microscope for the presence of the fungal mycelia and spores										→	→											
Act. 6. Preparing samples for scanning electron microscopy (SEM) including fixation, drying, mounting and sputtering												→	→	→	→	→	→	→	→	→	→	
Act. 7. Preparing specimens for transmission electron microscopy (TEM) including fixation embedding, sectioning and staining												→	→	→	→	→	→	→	→	→	→	
Act. 8. Examination with SEM & TEM																→	→	→	→	→	→	
Act. 9. Evaluation of research parameters																	→	→	→	→	→	→
R3. Field experiment at IITA, Nigeria																						
Act. 1. Production of fungal inoculum for Pesta formulations and seed treatments						→	→	→	→	→	→											
Act. 2. Preparation of Pesta formulations										→	→											
Act. 3. Preparation of sorghum and maize coated seeds with fungal inocula and fungicides										→	→											

using seed treatment technology of SUE company (Eschwege-West, Germany)																						
Act. 4. Determining of fungus viability (CFU) per g of Pesta and per coated seeds including serial dilutions and plating on the PDA media										→	→											
Act. 5. Setting-up of the field experiments at IITA, Nigeria												→										
Act. 6. Evaluation of research parameters													→	→	→	→						
Act. 7. Harvesting of the field experiment																→						
Act. 8. Data collection and statistical analysis																	→	→	→	→		
Act. 9. Writing up of scientific articles																			→	→	→	→
R4. Fungal inoculum mass-production using agricultural by-products and industrialized fermenter for economical large-scale application																						
Act. 1. Testing and optimising solid state fermentation technology for massive production of fungal inoculum at Prophyta Biologischer Pflanzenschutz GmbH, Malchow/Poel, Germany																			→	→	→	→
Act. 2. Setting-up of experiments (incubation under different conditions)																			→	→	→	→
Act. 3. Evaluation and statistical analysis of data																					→	→

6 Implication of the results (expected uses and users of research results)

Due to the environmental contamination including harmful effects on non-target organism; contamination of soil, ground water and food, and increasing number of resistant or tolerant weeds, which have been resulted from the intensive use of chemical herbicides in agricultural systems, biological control of weeds has been receiving a considerable attention. Crop production systems in which parasitic weeds (*Striga*) constitute major problems, are subject to a variety of farm management practices. To date, the impact of agroecosystem management on the efficacy of biocontrol agents has rarely been evaluated. Many bioherbicide candidates are still in the developmental stage, including evaluation of formulations and delivery. Therefore, the next step would have to consider how to integrate these biocontrol agents in different crop management systems. Development of easy, effective and inexpensive formulations/delivery systems of biocontrol agents for *Striga* in Sub-Saharan Africa for large-scale use is a priority. The expected outcome of this research is to provide easy and simple delivery systems for mycoherbicides of root parasitic weeds *Striga* spp. These delivery systems (Pesta granular formulation and seed treatment) offer a significant practical and economical solution for large-scale application of *Striga* mycoherbicides, which could probably be a valuable contribution in the development of an effective, environmentally friendly and economically and technically feasible integrated *Striga* control strategies. The users of the research results would be farmers in the savannah regions who are subjected to food insecurity due to the damage caused by *Striga* on cereals. After optimization, the results of this project can be adapted and implemented to other countries in the West and Central African Savanna, and hopefully to be a key for a successful *Striga* management in the future. Of course, the successful achievement of reaching this goal, will definitely lead to the development of an integrated management packages including biocontrol for *Striga* control, acceptable and adoptable to subsistence farmers. In addition, the productivity of cereals will be increased, and the gap of food scarcity in Africa will be narrowed. Finally, the nutritional status and income of the subsistence farmer will be improved.

7 Acknowledgments

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8 Academic contributions in which the financial support of Eiselen Foundation, Ulm, is acknowledged

I Contributions in academic conferences and meetings

1. **Elzein, A.**, J. Kroschel & G. Cadisch (**2007**): Efficacy of Pesta granular formulation of *Striga*-mycoherbicide *Fusarium oxysporum* Foxy 2 after 5-year of storage: step towards practical *Striga* control in Africa. It will be presented at the XIV European Weed Research Society Symposium to be held in Hamar, **Norway**, 18-21 June 2007.
2. **Elzein, A.,** J. Kroschel, P. Marley & G. Cadisch **(2007)**: Advances in *Striga* mycoherbicide research and development: Implications and future perspective for Africa. It will be presented at the XII international Symposium on Biological Control of Weeds and the International Bioherbicide Group (IBG) Workshop, to be held in Montpellier, **France** from 22-27 April 2007.
3 **Elzein, A.,** J. Kroschel G. Cadisch & P. Marley **(2007)**: Molecular Characterization of Potential *Striga* Mycoherbicides "*Fusarium oxysporum* strains": An Evidence for a New *forma specialis*. It will be presented at the XII international Symposium on Biological Control of Weeds, to be held in Montpellier, **France** from 22-27 April 2007.
4 **Elzein, A**., J. Kroschel, P. Marley & G. Cadisch (**2006**): Progress on Mycoherbicide Research and Development Technology for integrated *Striga* control in Africa. Presented at the International Symposium on Integrating New Technology for Striga Control: Towards Ending the Wicht-hunt. November 5-11, 2006, Addis Ababa, **Ehtiopia**. Pp. 4.
5 **Elzein, A.,** J. Kroschel & P. Marley **(2006)**: Mycoherbicide research and development for integrated *Striga* control in Africa: achievements, constraints and future perspective. Presented at the **Deutscher Tropentag 2006** "Prosperity and Poverty in a Globalized World – Challenges for Agricultural Research". University of Bonn, **Germany**, 11 - 13 October 2006. Pp. 63.
6. **Elzein, A.,** J. Kroschel G. Cadisch & P. Marley **(2006)**: Enhancing *Striga* management using Pesta granular mycoherbicidal formulations: Synergy between *Striga*-mycoherbicides and nitrogen fertilizer. Presented at the **Deutscher Tropentag 2006** "Prosperity and Poverty in a Globalized World – Challenges for Agricultural Research". University of Bonn, Bonn, **Germany,** 11 - 13 October 2006. Pp. 205.

II Expected publications from our ongoing research activities where the financial support of Eiselen Foundation, Ulm, will be acknowledged:

1. Elzein et al. (2007). Molecular Characterization of Potential *Striga* Mycoherbicides "*Fusarium oxysporum* strains": An Evidence for a New *forma specialis.*
2. Elzein et al. (2007). Colonization and survival of *F. oxysporum* (Foxy 2) on the root of sorghum plant and its implication for *Striga* control using seed treatment delivery system: Histological study.
3. Elzein et al. (2007). Compatibility of *Striga*-mycoherbicides with fungicides delivered using seed treatment technology and its efficacy on the control of *Striga* and sorghum fungal diseases, **OR**, *Field evaluation of an integrated Striga management in Sub-Saharan Africa: Synergy between Striga- mycoherbicides (biocontrol) and sorghum and maize resistant varieties.*

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Elzein, A.E.M. (2003). Development of a granular mycoherbicidal formulation of *Fusarium oxysporum* "Foxy 2" for the biological control of *Striga hermonthica. In*: "Tropical Agriculture 12– Advances in Crop Research (2)" (J Kroschel., Ed.). Margraf Verlag, Weikersheim, Germany, 190 pp, ISBN 3-8236-1405-3.

Elzein, A. and J. Kroschel (2004). Influence of Agricultural By-products in Liquid Culture on Chlamydospore Production by the Potential Mycoherbicide Fusarium oxysporum Foxy 2. Biocontrol Science and Technology 14(8), 823-836.

Elzein, A., J. Kroschel and V. Leth (2006). Seed treatment technology: an attractive delivery system for controlling root parasitic weed *Striga* with mycoherbicide. Biocontrol Science and Technology, 16(1) 3-26.

10 Appendices

Appendix 1: Field trial lay-out and establishment

Establishment of the trial (10 days after sowing)

Sorghum/Foxy 2

Sorghum/PSM197

Maize/Foxy 2

Maize/PSM197

Appendix 2: Pot trial lay-out

Appendix 3: Pot trials lay-out

NORTH

GROUP 1

T6R1	T12R2	T5R3	T11R4
T12R1	T18R2	T6R3	T17R4
T18R1	T11R2	T17R3	T18R4
T5R1	T17R2	T11R3	T12R4
T11R1	T5R2	T18R3	T6R4
T7R1	T6R2	T12R3	T5R4

T6R1	T12R2	T5R3	T11R4
T12R1	T18R2	T6R3	T17R4
T18R1	T11R2	T17R3	T18R4
T5R1	T17R2	T11R3	T12R4
T11R1	T5R2	T18R3	T6R4
T7R1	T6R2	T12R3	T5R4

GROUP 2

WEST

T1R1	T8R2	T10R3	T4R4
T9R1	T3R2	T1R3	T9R4
T7R1	T1R2	T4R3	T3R4
T3R1	T4R2	T9R3	T2R4
T10R1	T2R2	T8R3	T1R4
T2R1	T9R2	T7R3	T8R4
T4R1	T10R2	T3R3	T7R4
T8R1	T7R2	T2R3	T10R4

T1R1	T8R2	T10R3	T4R4
T9R1	T3R2	T1R3	T9R4
T7R1	T1R2	T4R3	T3R4
T3R1	T4R2	T9R3	T2R4
T10R1	T2R2	T8R3	T1R4
T2R1	T9R2	T7R3	T8R4
T4R1	T10R2	T3R3	T7R4
T8R1	T7R2	T2R3	T10R4

EAST

GROUP 3

T14R1	T21R2	T19R3	T16R4
T16R1	T20R2	T15R3	T22R4
T21R1	T`13R2	T16R3	T20R4
T15R1	T19R2	T14R3	T15R4
T22R1	T15R2	T20R3	T14R4
T19R1	T16R2	T22R3	T19R4
T20R1	T14R2	T13R3	T21R4
T`13R1	T22R2	T21R3	T`13R4

T14R1	T21R2	T19R3	T16R4
T16R1	T20R2	T15R3	T22R4
T21R1	T`13R2	T16R3	T20R4
T15R1	T19R2	T14R3	T15R4
T22R1	T15R2	T20R3	T14R4
T19R1	T16R2	T22R3	T19R4
T20R1	T14R2	T`13R3	T21R4
T`13R1	T22R2	T21R3	T`13R4

SOUTH

- T3 – T22 all plus *Striga*
- T1=CR (control with resistant seed); T2=CS (control with susceptible seed); T3=CR+*Striga* , T4=CS+*Striga*, T5=CPR (control pesta resistant seed); T6=CPS (Control pesta susceptible seed); T7=CCoR (control coated resistant seed), T8=CCoS (control coated susceptible seed); T9=CCoRF (control coated resistant seed + fungicide); T10=CCoSF (control coated susceptible seed + fungicide); T11=PR+Foxy2 (Pesta resistant seed + Foxy2); T12=PS+Foxy2 (Pesta susceptiblet seed + Foxy2); T13=CoR+Foxy2 (Coated resistant seed + Foxy2); T14=CoS+Foxy2 (Coated susceptiblet seed + Foxy2); T15=CoRF+Foxy2 (Coated resistant seed +fungicide+ Foxy2); T16=CoSF+Foxy2 (Coated susceptiblet seed+ fungicide + Foxy2); T17=PR+PS M197 (Pesta resistant seed +PS M197); T18=PS+PS M197 (Pesta susceptiblet seed + PS M197); T19=CoR+PS M197(Coated resistant seed + PS M197); T20=CoS+PS M197 (Coated susceptiblet seed + PS M197); T21=CoRF+PS M197 (Coated resistant seed +fungicide+ PS M197); T22=CoSF+PS M197 (Coated susceptiblet seed+ fungicide + PSM197).

Appendix 4: Thanks

Great thanks to those young people who made the establishment of both field and pot trials possible