1.7 HOW TO PRODUCE MORE BIOMASS FOR DIRECT SEEDING MULCHED BASED CROPPING SYSTEM IN SUB-SAHARIAN AFRICA ? EXAMPLE IN NORTH CAMEROON

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Abstract

In North Cameroon, from 2001 to 2006, more than 250 farmers tried direct seeding mulch-based cropping systems (DMC) in their fields. DMC systems were based on farmer traditional rotation i.e. cereal//cotton. Farmers compared on their own field cereals (maize, sorghum, millet) cultivated with conventional techniques and the same cereal conducted with DMC techniques i.e. : i) intercropped with a cover crop (*Mucuna pruriens*, *Brachiaria ruziziensis*, *Crotalaria retusa*, *Vigna unguiculata*, *Dolichos lablab*), ii) sowed without ploughing from the first or the second year of experimentation. Associations were made for the following objectives: i) produce aboveground biomass to produce mulch for the following crop (mainly cotton), ii) improve the soil's physical and chemical quality through the contribution of associated plants, iii) produce forage, iv) help to control weed, v) protect the soil surface against erosion and rain impacts, vi) produce grains for human or animals consumption. Each of the 5 cover crops used are different regarding their fulfilments of above objectives and their adaptation to North Cameroon local agro-climatic conditions (rainfall from 700 to 1200 mm). Thus, *Brachiaria ruziziensis* produces aboveground biomass in quantity (4-5 T of dry matter/ha even when associated with cereal) and quality (persisting of the mulch for over one year after production). Further, it seems to be very efficient in controlling Striga hermonthica and it is a good forage. However, it can impoverish the soil if its biomass is exported several times without any fertiliser or manure input. *Crotalaria retusa* is a nitrogen fixing legume and thus can improve soil fertility. Furthermore, this plant is non edible for cattle, which is an advantage for farmers who cannot protect their field from grazing during the dry season. *C. retusa* is also very efficient to fight against other weeds. Six years of experimentation with farmers permits us to produce practical recommendations for intercropping of cereals with cover crops: sowing date, crop type, tolerance to herbicides, limitation of competition with cereals, etc. This experimentation has also allowed us to see what is the behaviour of the 5 cover crops in farmer's conditions.

Key-words: on-farm trial, no till, mulch, conservation agriculture, brachiaria, crotalaria, DMC

Introduction

Geographical context

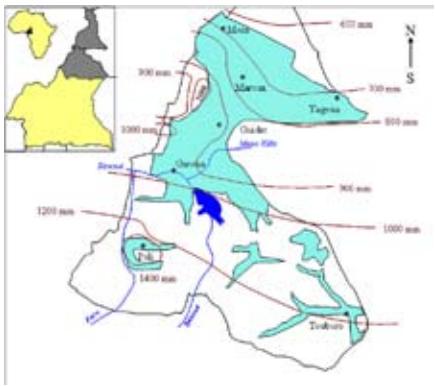

Figure 1 : North and Far-north Cameroon. Blue: cotton culture area in 2001

The North and the Far-north provinces of Cameroon are very heterogeneous regarding rainfall (600 to 1400 mm) (Figure 1), relief (vast plains and steep mountains) and population density (200 inhab./km^2 in the mountains to 20 inhab./km^2 in the North). Main crops are millet, rainfed sorghum, transplanted sorghum, cotton, cowpea and rice. Major crop rotations are cotton//cereal or cotton//groundnut//cereals. Fallows are scarce. Livestock raising is based on transhumance except in the more densely populated areas (mountains and east of the Far North province). The average farm size is from 2 to 3 ha.

Institutional context

Cameroon a pilot country

North Cameroon is part of 5 pilot countries (Laos, Madagascar, Tunisia, and Mali) where CIRAD is trying to adapt and transfer direct seeding mulch-based cropping systems (DMC) with the assistance of French aid: AFD (Agence française de Développement), FFEM (Fond français pour l'Environnement Mondial), MAE (Ministère des Affaires Etrangères). The first trials started in 2000 and the actual project began in 2001.

DMC trials were implemented by the fertility branch of DPGT (Développement Paysanal et Gestion de Terroir) project from Sodecoton. From 1994 to 2001 the DPGT fertility branch had established 150 000 ha with anti-erosive measures (grass and stone lines, trees protection). In 2002, at the end of DPGT project, ESA project (Eau, Sol, Arbre) was set with the objective to extend the DPGT's soil fertility and water harvesting activities on a large scale, including DMC implementation.

Sodecoton the major rural development actor in the area

Sodecoton (in 2005):

+ has 1 700 agents to assist 380 000 farmers divided into 1 800 farmers' association
+ organises the production of over 200 000 ha of cotton
+ provides loan for fertiliser, herbicides, and insecticides to every single village
+ fixed the cotton price before the beginning of the growing season
+ purchased all the cotton harvest, even in most remote area
+ insures the commercialization of cotton fibre in the international market

Agrarian context

The conventional farming system

Main farming systems are based on:

+ A rotation of cotton//maize//groundnut in the North and rotation of cotton//sorghum in the Far-north.
+ The use of ploughing for crops sown after 20th May (cotton, maize mainly). Crops like sorghum and groundnut are usually sowed before, without any ploughing.

+ The use of fertilisers (NPK and urea) on cotton and maize.
+ The exportation of the major part of cereal stalks by animals (without any contract on manure), the burning of the cotton stems and the remaining stalks not consumed by the animals. This system is of no contribution in term of soil organic matter.

The livestock situation in northern Cameroon
The traditional Mbororo cattle raising system is an extensive farming method that utilizes transhumance and necessitates large surfaces for pastoralism. Besides farmers also rear animals on a small scale and these serve two purposes: draught and income (the family hardly benefits from milking). However, the integration of farming and animal husbandry is very poor and the production of fodder is practically inexistent. The use of organic manure is not common, often due to the lack of transportation means. Shortly after the harvest, cattle from the various types of husbandry system are allowed to feed on the crop residues, weeds and sorghum regrowth; this is the common land right. This traditional right is not often associated to a manure contract as it is the case in other region of Africa south of Sahara.

DMC: Direct seeding mulch-based cropping system
FAO define Conservation Agriculture (CA) on the basis of three principles:
+ Continuous minimum mechanical soil disturbance.
+ Permanent organic soil cover.
+ Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.
The definition of Derpsch (2007) is similar.
Thus DMC "Direct-seeding Mulch-based Cropping system" can be seen as synonymous with CA. However, we will use DMC because it is a less ambiguous than CA. Although CA has been correctly defined, it is still often used to refer to cropping systems without permanent cover and/or without adapted crop rotations Baudron (2005), Ribeiro (2005), or with topsoil disturbance Ambiguity is greater with terms such as "conservation tillage" or "minimum tillage" which do not imply the use of crop rotation or cover crop and can imply "tillage" at least within the row and sometimes up to 100 % of the soil surface. Table I summarizes the main terms used in the domain of conservation agriculture.

Table I: Definition of main terms used to define conservation agriculture practices regarding soil cover and soil disturbance. Adapted from WASWC (2007), FEBRAPDP (2003), ACT (2005)

Soil disturbance / Soil cover	Tillage	Minimum tillage	Direct seeding
Bare soil		MT	DS / NT / ZT / CT
Crops residues		CA	DMC
Cover crop during inter-crop period			
Association of main crop with cover crop			

CA: conservation agriculture
CT: conservation tillage
DMC: direct-seeding mulch-based cropping system
DS: direct seeding
NT: no till or no tillage
MT: minimum tillage or mulch tillage
ZT: zero till or zero tillage

Recent research has described biophysical effects of DMC techniques, for example on the water balance (Scopel et al., 2004); C sequestration (Bernoux et al., 2006, Metay et al., 2007, Reicosky 2007); soil biology, (Blanchard et al., 2007, Brévault et al., 2007, Reeleder et al., 2006). Few articles deal with CA techniques dissemination and adoption (Lal 2007, Ereinstein 2003).
Since the 90's CIRAD has been involved in the transfer of DMC knowledge acquired first in Brazil and then applied to other tropical developing countries (Séguy et al., 2006). Countries concerned are Madagascar, Laos, Vietnam, Cambodia, Cameroon and Mali. Madagascar was the first country where this work to extend knowledge from Brazil started (Séguy et al., 2003).

In these systems, the soil is never tilled but permanently kept covered by dead or living mulch. The mulch comes from plants that are used as «biological pumps» in intercropping or relay-cropping systems. These plants have strong and deep root systems and can thus recycle nutrients from deep horizons for subsequent use by the main crop. They also have a high and fast biomass production and are able to grow in adverse conditions, for instance during the dry season, on compacted soil or under high weed pressure.

There are three main ways of implementing DMC (Séguy et al., 1998):
+ **Importing mulch from surrounding areas**. These systems are very simple but are labour intensive and improvement of soil structure and nutrient recycling are limited.
+ **Producing the mulch in the field**, using natural vegetation, crop residues or a cover crop. This requires limited technical skills and labour but the cover crop can compete, in time or in space, with the main crop.
+ **Using a cover crop kept alive** in association with the main crop. This system is the most efficient but it requires high technical skills and is hardly feasible in semi-arid conditions.
Systems with imported mulch are usually tried first by farmers. Although their performances are limited, farmers can discover the advantages of mulch regarding weeds control, water retention, erosion control, etc. However, for semi-arid conditions, systems based on mulch production in the field can be recommended.

To produce an important biomass four main options can be proposed in north Cameroon:
+ **Reclaiming fallow land**, using natural vegetation (e.g. Andropogon sp.) as mulch.
+ **Improving the fallow lands** with cultivating, for at least one year, perennial legumes (e.g. Stylosanthes sp. or Crotalaria sp.) or grasses (e.g. Brachiaria sp.) which produce an important biomass and can rapidly improve degraded soils. These systems however are adapted only where population density is low enough to allow fallow periods.
+ **Produce biomass at the beginning of the rainy season** just before plantation of the main crop. This kind of system can be carried out for cotton in areas with 6 to 7 seven months of rain. For culture such as cowpea, this system is feasible in areas with a 5 months long rainy season.
+ **Associating**, at least one in two years, **a cover crop to the main crop** in order to produce a sufficient amount of crop residues for the next season. The cover crop grown in association is chosen according to the main crop (usually, association cereal + legume), its main role (soil structure improvement, N –fixation, etc.) and the possible uses for human and/or animal consumption.

All these ways are tried in north Cameroon but this paper will only focus on the last option: associating a cover crop with a cereal.

Experimentation design

The results shown below are those obtained from experiments in farmers' fields. These experiments are included in a larger framework aiming to test and extend DMC in northern Cameroon.
The first experiment in farmers' fields started in 2001 with 17 farmers. In 2004 about 150 farmers were experimenting DMC (figure 2). They were spread all over the cotton growing area of the North and Far-North province of Cameroon.

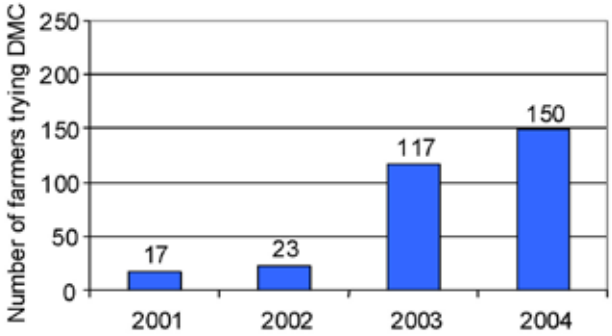

Figure 2 : number of farmers trying DMC in their fields

The fields cultivated by the farmers are neither multi-local trials (repetition of a fixed protocol in different localisation) nor extension. The objectives for these fields are:
+ Observe the feasibility of DMC by the farmers using their own means.
+ Collect farmer opinion on possible improvements to our technical recommendations. o grain yield
    o biomass production
    o economic results
    o labour organisation
    o various indicators :weed, soil characteristics
+ Train farmers and technicians on DMC in almost 50 villages in the North and the Far-North of Cameroon.
How do the fields look like?
The arrangement of fields varies, generally they measure 2 500m^2 and are divided:
+ either into 2: one part as a control plot (cereal alone) and another part DMC plot (cereal associated to a cover crop)
+ either into 4 : 2 parts as a control plot and 2 parts as DMC plot, each comprising two different cover crop (figure 3)

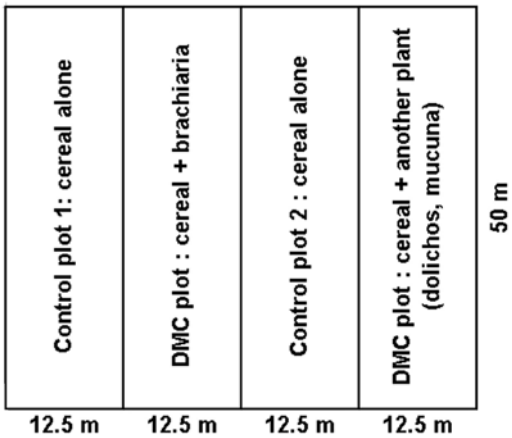

Figure 3 : example of arrangement of experimental fields

What is the contract with the experimenting farmers?
The farmer who agrees to carry out field experiments receives from the project:
+ Cover crop seeds.
+ Advice on how to run the field, and regular visits by the technician (at least twice a month).
+ The chemicals for seed treatment, if they were not able to get them from the Sodecoton store.
+ A compensation in kind (bag of cereal) in case the yield is lower on the DMC plot because of inadequate advice by the project technician.
+ A subsidy to install a live fence by seedling or plantation if he wishes.
The entire work is done by the farmer himself, member of his family or labourers employed and paid by the farmer. Once a farmer starts the experiment, he will be assisted for as long as he wishes. This is how some have been assisted since 2001. The selection of farmers was done at the beginning through a network of farmers that are involved in other ESA project activities or through the local representatives of Sodecoton. Therefore, once the collaboration starts with 1 or 2 farmers in a village, the rest of the villagers can request to try on their own the DMC in their farm. In practice, the information network of Sodecoton being dense, the farmer requests overflow. We have limited the number of farmers in order to promote quality rather than quantity. In 2004 the 200 farmers spread over 50 villages, were assisted by 4 technicians and 2 engineers. At this stage of the implementation it is more important to have a reasonable number of fields with a very good follow-up, than having a large numbers of fields with farmers poorly advised.
During the first intervention year in a village we try as much as we can to encourage volunteers to visit our experimental sites. During that visit, the farmers that still show interest in DMC trials can select the type of cover crop they would prefer to associate with their cereal. In general, we recommend that during the first year, each farmer should try at least two different types of cover crop; within a village all the farmers should not choose the same type of plants. The objective here is to enable farmers of each village to select the suitable plant by observing neighbouring field. From the second year of collaboration with the project, the farmer selects the plants of his choice (according to available seed resources) and suitable rotation.

<u>What is the interest of this process?</u>
+ Demonstration of interest in practicing DMC under real conditions by the farmers.
+ Feed-back information by the farmers on practicability and interest of proposed systems.
+ Test of the proposed system under multiple human and physical conditions.
+ Demonstration of DMC in almost 50 villages in the North and Far-North of Cameroon.

<u>What are the limits of this process?</u>
+ Expensive follow-up (villages are too scattered and accessibility sometimes difficult).
+ Risk of counterexample if technical recommendations are not followed carefully.
+ It is sometimes difficult to extrapolate from the obtained results, because several parameters vary from one field to another (soil, rainfall, sowing date, species, and weed control).

Figure 4 and Figure 5 : Farmers' fields, two years rotation in Mambang village, sorghum in 2003 and cotton in 2004. Right plot, DMC: sorghum + *Brachiaria ruziziensis* in 2003 and cotton under dead mulch in 2004. Left plot, control: sorghum direct sowing (without cover) in 2003, cotton after ploughing in 2004. Notice in 2003 the absence of Striga hermonthica when the sorghum is grown with *Brachiaria ruziziensis* and in 2004 the better growing of cotton on DMC than on control plot.

Results

Table II: main plants associated to cereals with advantages, disadvantage, and management

	**Figure 6 :** *Crotalaria retusa*	
	Seeds easily available. Improvement of soil structure and fertility. Allelopathic effect on weeds. Adapted to several environment. Not eaten by cattle: doesn't need protection in dry season.	No forage production. Seeds need hot water treatment for better germination.
	1 or 2 rows of crotalaria between 2 rows of cereals (0.8*0.25 m) sowing shifted by 1 month	
	**Figure 7 :** *Brachiaria ruziziensis*	
	Good hay production (quality and quantity fodder production) Competition with weeds (striga) Improvement of soil structure. Adapted to several environment. Leaves are resistant to termites even when dead.	Competition with cereal Can export a lot of nutrient if totally grazed Sometimes difficult to grow Poor seed production Needs protection against grazing during dry season
	1 row of brachiaria in between 2 rows of cereals (0.8*0.25 m) sowing shifted from 1 week to 10 days	
	**Figure 8 :** *Mucuna pruriens*	
	High seed production Good forage Seeds consumable by humans and animals (if treated) Improvement of soil fertility	Obstruction between cereal rows Less adapted to poor and stony soils Poor biomass residues for mulching Needs protection against grazing during dry season
	1 row of mucuna in between 2 rows of cereals (0.8*0.8 m) sowing when cereal at knee level	
	**Figure 9 :** *Vigna unguiculata*	
	Seeds consumable Good fodder Improvement of soil fertility Adapted to several environment	Needs insecticide treatment for seed production Labile biomass Needs protection against grazing during dry season
	1 row of Cowpea in between rows of cereals (0.8*0.5 m), sowing when cereal at knee level	

	Figure 10 : *Dolichos lablab*	
	Seeds consumable by humans and animals Long cycle, deep rooting Improvement of soil fertility	Obstruction between cereal rows Poor biomass residues for mulching, Poor seed production Needs protection against grazing during dry season
	1 row of Dolichos in between 2 rows of cereals (0.8*0.8m), sowing when cereal at knee level	

Agronomics results

Aboveground biomass

The main objective of associating cover crops to cereals is for the production of aboveground biomass that will serve as mulch the year after. Figures 11 and 12 show the quantity of dry biomass obtained in farmers' fields, with maize or sorghum associated with brachiaria or crotalaria.

Maize is mostly cultivated in the North province, where rainfall range from 900 to 1 110mm. Under these conditions, brachiaria and crotalaria produce biomass easily, they produce as much as the maize. Addition of a cover crop to cereals allows the doubling of aboveground biomass production of the field in comparison to cereal alone.

Sorghum is mostly cultivated in the Far-North province where there is less rainfall, between 700 to 900mm. Even under these conditions the brachiaria biomass remains quite equal than in North province, regardless to the rainfall constraint. However, the one of crotalaria drops to less than 1 t/ha, due to fast sorghum development and limited rainfall season length. Under such conditions the growth of crotalaria is not satisfactory. In order to resolve this problem we now recommend to sow two rows of crotalaria in between sorghum rows, instead of one.

Besides of the biomass quantity it is also important to look at the quality. Maize straw disappears very fast from the soil surface while sorghum straw can resist longer. Therefore in the north province, sorghum straw produced in 2002 is still present on the soil in 2005 even after 3 dry and 2 rainy seasons (Figure 13). This biomass persistence is interesting for soil cover quality and length. However sorghum residues with high C/N ratio can be responsible of nitrogen deficiency of the next crop.

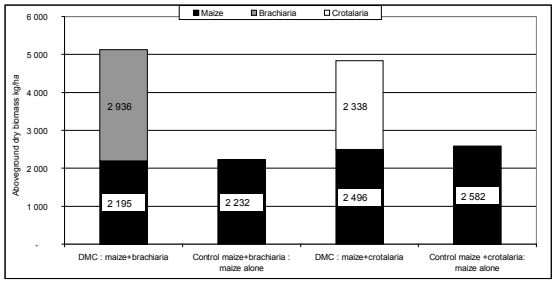

Figure 11 : biomass (Kg of dry matter/ha) produced by maize, crotalaria and brachiaria.
North, 2003/04/05/06, control DMC brachiaria: 17 plots, DMC Brachiaria: 15 plots, control DMC crotalaria: 35 plots, DMC crotalaria: 32 plots.

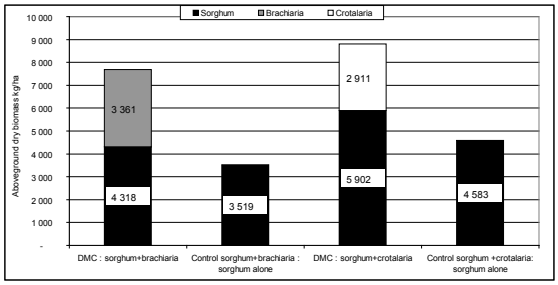

Figure 12 : biomass (Kg of dry matter/ha) produced by sorghum, crotalaria and Brachiaria.
Far North, 2003/04/05/06, control DMC brachiaria: 21 plots, DMC Brachiaria: 59 plots, control DMC crotalaria: 17 plots, DMC crotalaria: 23 plots.

Figure 13 : April 2005, straw from cereals cultivated in 2002. Left: maize. Right: sorghum. Notice the remainder of sorghum straws even after 3 dry and 2 rainy seasons.

If cereal cover crop association can improve biomass production, it is important to avoid cereal grain yield depletion. Table III and IV show yield of maize alone, intercropped with brachiaria or with crotalaria. None of the difference between maize grown alone or grown with brachairia or crotalaria are statistically significant with a Tukey test at 95 %. However brachiaria seems to have an negative influence on the maize yield in the North, The combination of brachiaria to maize need good management skills, but those who know how to go about it can practice it without any effect on the maize. Crotalaria does not seem to compete with maize. Sorghum is less sensitive than maize to the competition with brachiaria.

Table III : yields of maize alone or associated with brachiaria and crotalaria, North province, years 2003/04/05/06

		Average	n	SD
DMC brachiaria	DMC : Maize + brachiaria	2 197	33	1 190
	Control : Maize alone	2 434	41	1 396
DMC crotalaria	DMC : Maize + crotalaria	2 026	32	946
	Control : Maize alone	2 106	28	924

Table IV : yields of sorghum alone or associated with brachiaria and crotalaria, Far North province, years 2003/04/05/06

		Average	n	SD
DMC brachiaria	DMC : Sorghum + brachiaria	1 352	79	802
	Control : Sorghum alone	1 443	74	1 037
DMC crotalaria	DMC : Sorghum + crotalaria	895	21	533
	Control : Sorghum alone	874	16	503

For 22 fields of the 29, sorghum yield is equivalent or better when cultivated in association to brachiaria than when it is alone. This is surely due to the effect of soil surface improvement than a synergic effect of brachiaria on sorghum. Figure 14 shows sorghum yield according to the amount of residues present on the soil during the sowing of the cereals. These residues are coming from cereals from the 2 previous years, from weeds and at times stems of the last year's cotton. These residues are present only in small quantity, less than 3 t/ha, but can have a significant impact on water management (Scopel et al., 1999).

In this study, we have not directly quantified, the positive effect of residues on water infiltration and evaporation, but we know that it mostly determine the yield in the Far- North province of Cameroon (Soutou et al., 2005). Generally the yields of cereals positively match the quantity of mulch present on the soil during sowing.

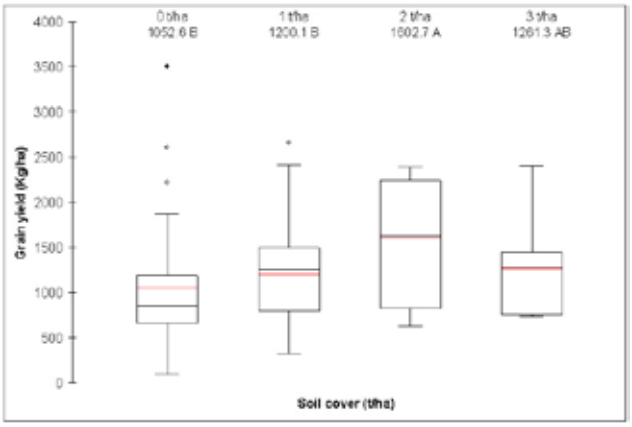

Figure 14 : Far North, DMC plots, sorghum yield according to soil coverage at the sowing of cereal. Box: first to third quartile. Circle: outliers. Black line median, red line: mean. (0 t/ha: n= 39, 1 t/ha: n= 41, 2 t/ha: n= 15, 3 t/ha: n= 7)

Weed cover

Weed cover on DMC and control plots has been recorded every 10 days from sowing to harvest. It is estimated on a visual scale varying from 0 to 9. Either on maize or sorghum fields, control plots often have more weed coverage than DMC plots (figure 15 and 16). On the other hand, the evolution of the weed is different on maize fields situated in the North, due to higher rainfall, than the sorghum fields situated in the Far-North.

On maize fields (figure 15), weeds begin to grow at the end of the maize cycle when maize leaves dehiscence begins and due to the last rains month of the season. In case of inter-rows not being occupied by a cover crop, weeds can grow easily and produce seeds, increasing the infestation potential for the following years. On DMC plots though cover crop occupies this space and prevents weeds from growing. On sorghum fields, weed invasion was not noticed at the end of cropping season since rains stop early in the Far-North province, and leave dehiscence is reached later than it is for maize.

In the Far-North brachiaria seems to be very effective in avoiding Striga hermonthica development (Figure 4). It is perhaps due to the shade provided by brachiaria which reduces soil surface temperature and avoids striga germination.

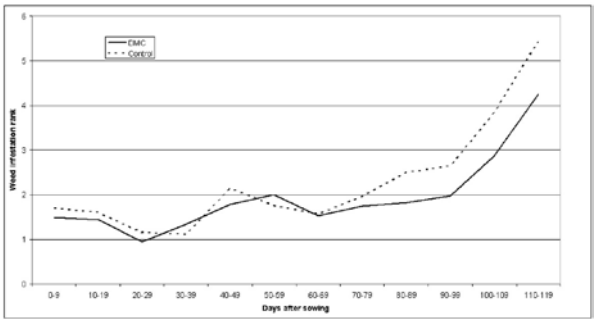

Figure 15 : weed infestation in maize field: control and DMC plot. Weed rank : 2=7% of soil covered by weed, 3= 15 %, 4=30 %, 5=50 %. (17 fields, 52 plots)

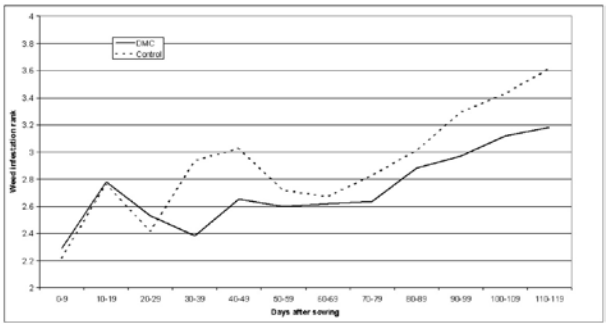

Figure 16 : weed infestation in sorghum field: control and DMC plot. Weed rank: 2=7% of soil covered by weed, 3= 15 %, 4=30 %, 5=50 %. (19 fields, 66 plots)

Work organisation

In order for farmers to easily accept the system the use of crop should not be responsible of to much extra-work (Seugé et al., 2005). Through the DMC techniques, the extra work consist of the cover crop sowing operation and manual weeding instead of mechanical weeding. However tillage and tasseling are abolished and the number of weeding decreased.

Usually diminution and extra-work caused by the DMC techniques are balanced. Farmers who master the technique well, or have 3 to 4 years of DMC experience, consider the gain more important than the extra work. This then explain the representation of farmers' fields classification according to differences in working time between the DMC and control plots, as illustrated on the profile of figure 17 and 18.

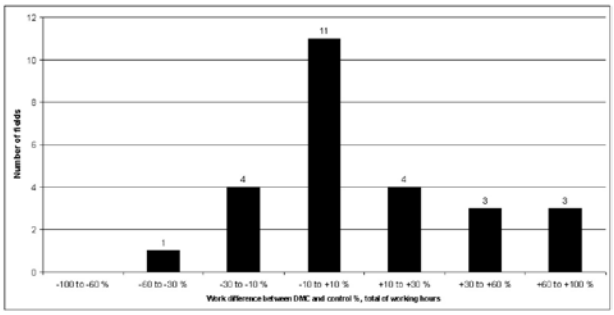

Figure 17 : classification of farmers' fields according to differences in working time between the DMC and control plots. (26 fields of maize).

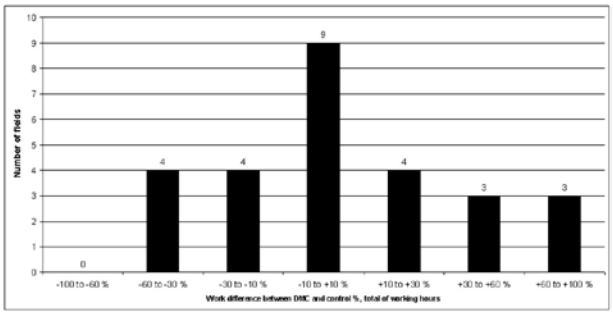

Figure 18 : classification of farmers' fields according to differences in working time between DMC and control plots. (37 fields of sorghum).

Conclusion

During these 6 years of experimentation farmers enabled us to improve on the selection of plants to associate with cereals. These plants are cultivated for multiple objectives: biomass production for mulching, forage production, weed control and soil improvement. There is no miracle plant, each possesses specific characteristics and must comply with environmental conditions and farmers objectives. The most commonly tested plants by Cameroonian farmers are: *Brachiaria ruziziensis, Crotalaria retusa, Vigna unguiculata, Dolichos lablab, and Mucuna pruriens.*

Brachiaria ruziziensis as a grass is not a plant usually associated to cereals in Africa, which widely use to be legumes. However we noticed that it has interesting characteristics: biomass resistance to termites, good coverage even with few biomass, striga infestation reduction, and strong roots. Results from water balance study (Soutou et al., 2005) confirms that it is one of the best preceding for cotton mainly by improving soil physical properties improvement. *Brachiaria* sp. is now commonly used in Brazil in association with maize for pasture establishment Landers (2007). *C. retusa* is a common "weed" in Africa, it is an interesting cover crop for the production of aboveground biomass which is not endangered by cattle grazing. *C. retusa* is also a good preceding plant for cotton regarding nitrogen fixation and weed control. In addition, its association with cereals does not need high technical skills as *Brachiaria* sp. At least, *C. retusa* is also useful for the cereal they are cultivated with by reducing weed infestation. A last we shown that is possible to produce twice the amount of biomass when adding a cover crop to the cereal even in farmers conditions.

Based on these first results the Sodecoton team is now working on further topics:
+ Find out local plants that can be used as cover crop
+ Better quantify the effects of each cover crop on soil properties and weeds. Set up recommendations on differential fertilisation according to plants used during rotation
+ Produce practical recommendations on the dual use of plants as cover crop and forage.
+ Set up new cropping systems with biomass production the same year as the main crop.

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