WHY AND HOW TO USE GREEN MANURE COVER CROPS IN A NO-TILL SYSTEM.

Experiences from Latin America.

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Reading the title of this paper some people may ask if the growing conditions in Latin America are not too different from the ones in the United States. When looking at the experiences in Latin America we of course can not "copy" what is done there. Farming is always site specific, but the principles of using cover crops are valid all over the world. The experiences from Latin America are especially interesting for no-till farmers, because they have played a key role in further developing and perfecting the no-tillage system. We should be aware that some cover crop species adapt to a very wide range of climatic and soil conditions. Several cover crop species used in South America are well adapted to the conditions of northern United States. We should also be aware that "no matter where you farm, there are cover crop species that meet your needs" (USDA-ARS, 2002).

While the US has the biggest area under no-tillage worldwide (about 22.4 million ha), the quality of this technology is often far from being satisfactory. According to CTIC (Dan Towery, personal communication 2002), only about 25% of no-tillage is practiced permanently, that means that most farmers use rotational tillage. On the other hand cover crops and crop rotations are generally missing in the system. In order to achieve maximum benefits of the no-tillage technology the system has to include these elements:

- permanent no-till (permanent soil cover),
- crop rotations and
- cover crops.

The use of green manure cover crops (GMCC) and crop rotation as well as permanent no-till are the key factors for the unprecedented growth of no-tillage especially in Brazil and Paraguay. Only those farmers that have understood the importance of these practices are obtaining the highest economic benefits from this system. While in some regions of the world farmers concentrate on avoiding tillage, Latin American farmers have understood that adequate production and management of crop residues are key issues in the no-tillage system. Cover crops do not cost but will pay. When practiced in monoculture or even in double cropping, i.e. when the same crop or crops are repeated on the same land each year, no-tillage is an imperfect and incomplete system, in which diseases, weeds and pests tend to increase and profits tend to decrease. Adaptive research in this area is the most important factor to make no-tillage work, that

is take advantage of all the benefits of the system, reduce weed pressure and increase economic returns!

Advanced no-till farmers in Latin America see it as good farming practice to use GMCC and crop rotations independently of the price situation of crops. Once farmers have discovered the benefits of these practices they don't want to miss them. Sorrenson (1984), among others, has clearly shown the economic advantages of using crop rotation and the right cover crops. While many people still think that when using GMCC you are adding costs without getting anything back, farmers especially in Brazil and Paraguay have learned that economics of no-tillage can be substantially increased with their use.

Research performed in Brazil has shown significant yield increases of some GMCC on cash crops. In the average of two years, the highest yield of soybeans (2670 kg/ha) could be achieved after black oats (Avena strigosa) as a green manure crop. This yield was 770 kg/ha higher than the average of all other treatments. It was also shown that black oats used as a green manure cover crop before soybeans can increase soybean yield by as much as 63% as compared to soybeans after wheat (Derpsch, et al., 1991). Phaseolus beans also produced the highest yield after black oats. Corn (without N) responded with the highest yields after white lupins (Lupinus albus) (6.410 kg/ha) and hairy vetch (Vicia villosa) (6320 kg/ha) as compared to yields of less than 4.100 kg/ha after wheat, oats and rye. Also after oilseed radish (Raphanus sativus) a high grain yield of corn (without N) was achieved (5.800 kg/ha). Higher crop gross margins could be achieved when using black oats as a cover crop before soybeans as compared to double cropping wheat and soybeans.

Good knowledge about green and dry matter production and profitability of green manure cover crops, how to fit them into different crop rotations and what residual fertilizer effect we can expect of each GMCC planted before the main cash crops is essential for dissemination of their use. A number of publications have contributed in filling this knowledge gap in Latin America (Sorrenson and Montoya, 1984; Monegat, 1991; Derpsch, 1991; Derpsch and Calegari, 1992; Calegari et al., 1992). Several publications on the use of cover crops have appeared in the US in the last decade, i. e., (Cover crops for clean water, W. L. Hargrove, Ed. 1991; Managing Cover Crops Profitably, SAN - SARE, 1998: www.sare.org). There is increasing information on cover crops also in web sites. A very recommended web site with comprehensive information on this topic is

- http://www.notill.org/cover_crops/cover_crops.htm In this site you find links to:
  - http://www.sare.org/handbook/mccp2/index.htm SARE handbook
  - http://www.sare.org/handbook/mccp2/pests.htm SARE, S.C. Pahtak
  - http://www.barc.usda.gov/anri/sasl/covercrops.html USDA-ARS
  - http://www.ces.ncsu.edu/depts/hort/hil/hil-37.html North Carolina State U.
  - http://www.attra.org/attra-pub/covercrop.html ATTRA Arkansas
  - http://www.attra.org/attra-pub/nematode.html ATTRA Arkansas

- http://www.ianr.unl.edu/pubs/FieldCrops/g1146.htm#ccs (Univ. of Nebraska)
- http://www.kbs.msu.edu/extension/covercrops/home.htm (MSU, Michigan)
- http://www.gov.on.ca/OMAFRA/english/crops/facts/cover_crops01/covercrops.htm, Ontario, Canada

Many more sites can be found using normal search engines.

PRINCIPLES OF GREEN MANURE COVER CROPS (GMCC) AND CROP ROTATIONS

It is not possible to talk about green manure cover crops without talking about crop rotation. In a no-till system we can not talk about crop rotation without talking about cover crops. Maximum diversification of the system should always be a goal when applying no-tillage techniques. Mixtures of cover crops should be preferred over the use of a single species.

Green manure cover crops are the cornerstone of sustainable agriculture and should always be included in sound crop rotations. Green manure's and cover crops are used as synonyms in this paper. In a no-till system cover crops are incorporated biologically and not by tillage implements.

Green manure cover crops should:

- be of low cost (seeds)
- be easy to seed and manage
- provide good weed control and shading
- produce a positive residual fertilizer effect on following cash crops
- they should not compete in area, labor, time and space with cash crops

Monoculture, that means the continuous seeding of the same crop, in the same place during many years has only been possible in the case of rice. This crop has been cultivated as the only crop sometimes for centuries in highly populated areas in Asia. In general monoculture results in diminishing productivity per unit area, the maintenance of low productivity's, or in extreme cases the complete loss of production.
In general the following factors are responsible for this situation (Franke, 1976, 1980):

- Increase of specific diseases and pests
- Increase of specific weeds
- Reduced availability of nutrients due to changes in biological activity and physical degradation of the soil
- Reduced root development
- Accumulation of specific toxic substances that inhibit growth

The principles and fundamentals of crop rotation are:

- To alternate plant species
- with different rooting depth
- with different ability to absorb nutrients
- that are susceptible to diseases with those that are resistant

- taking into account positive & negative effects of one crop on the next
- that tend to mine with those that tend to increase soil fertility
- with different needs in terms of labor peaks, machines & implements, water, etc. (Arnon, 1972).

In a no-till system the use of crop rotation is much more important than in conventional tillage systems. Experience has shown, that tillage negates cover crops. Also cover crops are essential for producing the mulch needed in the no-tillage system. Cover crops have to be integrated in the agricultural system of each farm and show their beneficial effects. Cover crops, in combination with no-tillage and crop rotations ensure the sustainability of agricultural production. "But, rotation isn't just a helter-skelter array of crops" (Rick Bieber, 2000). Without the knowledge of positive or negative residual effects of one species on the succeeding crop, any attempt of organizing a crop rotation is merely a theoretical model. Not only legumes are adequate green manure cover crops. Black oats for instance (Avena strigosa Schreb) are planted on 3,2 million ha in the States of Paraná and Rio Grande do Sul in Southern Brazil. They are planted on more than 300.000 ha in Paraguay.

DETERMINE HOW THE FARMING SYSTEM CAN ACCOMMODATE COVER CROPS

One of the biggest challenges is to fit green manure cover crops into your current crop rotation, or to develop new rotations that take full advantage of their benefits. Each farmer has to find the "window or niche" where a specific cover crop will fit to accomplish specific purposes. It has to be kept in mind, that in general cover crops function in the "off season" of crops but they may also be intercropped with cash crops. Remember that "no matter where you farm, there are cover crop species that meet your need. However, your success will depend on identifying the problem(s) that you want the cover crop to solve. Decide where and when you want to use the cover crop, and determine its fitness in the crop rotation. You may conclude that the main problem is soil erosion or low nitrogen or heavy weed pressure or all these". (USDA-ARS, 2002).

In order to find those "windows or niches" research in Latin America has focused on:

- Screening adequate GMCC for different agro ecologic regions
- Studying the residual fertilizer effect of GMCC on following cash crops
- Showing the economics of cover crops.
- Without this basic and site specific information it will be difficult to determine which cover crop to use when.

FUNCTIONS OF GREEN MANURE COVER CROPS

Provide soil cover for:

- no-tillage
- increasing water infiltration into the soil
- reducing water evaporation
- reducing soil temperature
- protection against erosion

- reducing weed infestation
- accumulation of organic matter in the soil
- adding and recycling nutrients
- improve soil structure
- promotion of biological soil preparation

Adding of organic matter in the soil is often mentioned in the literature as one of the main objectives of cover crops, but this can in general and (especially in warmer climates) only be achieved in the no-tillage system.

BENEFITS OF GREEN MANURE COVER CROPS

Cover crops are a key element to make sustainable agriculture possible and have shown the following benefits in Latin America:

- Higher economic returns when appropriately chosen
- Reduce the need for herbicides and pesticides
- Improve yields of following cash crops
- Conserve soil moisture (when properly managed)
- Prevent soil erosion
- Enhance organic matter content of the soil
- Provide nitrogen
- Avoid leaching of nutrients and improve soil fertility
- Reduce fertilizer costs

POSSIBILITIES OF REDUCING WEEDS AND HERBICIDES COSTS WITH THE USE OF COVER CROPS IN NO-TILLAGE:

One of the most recent and fruitful lessons we have learned in the no-tillage system is that farmers should, if possible, never leave the land in fallow. In general fallow periods of only a few weeks will result in weed proliferation, seeding of weeds, reduction of soil cover, soil erosion as well as lixiviation (leaching) of nutrients. The old farmers rule is still true, “one years seeding means seven years weeding”. If instead of leaving the land in fallow, farmers seed any crop immediately or as soon as possible after harvest of the previous crop, they will reduce weed proliferation, avoid that weeds produce viable seeds, increase soil cover and the biomass returned to the soil, increase organic matter content of the soil, avoid soil erosion as well as washing out of nutrients, and improve biological conditions of the soil.

Research conducted by Kliewer et al., (2000) in Paraguay has shown, that crop rotation and short term GMCC can reduce the cost of herbicides drastically to US$ 43,05/ha in the case of sunnhemp (52 days growth period) and to US$ 39,27/ha in the case of sunflower (57 days growth period), as against costs of US$ 105,10/ha when only herbicides and monoculture were used. Kliewer et al., (1998) also reported soybean yields after black oats of 2600 kg/ha without using any herbicides at all. Weed measurements 96 days after seeding soybeans showed 93 kg/ha of dry matter of weeds/ha after black oats, as against 7390 kg/ha after fallow. In the last case, soybeans yielded not more than

780 kg/ha. Using a rotation where long and short term GMCC or cash crops are seeded as soon as possible after harvesting the previous crop, or after rolling down GMCC with a knife roller, it was possible not to use herbicides in no-tillage for as much as three years in a row. In some cases, when farmers are using crop rotations, only eliminating weeds with a burndown herbicide before planting is necessary, without any herbicide application during the growing season at all.

MAIN COVER CROPS USED IN SOUTH AMERICA ESPECIALLY IN PARAGUAY AND BRAZIL

After initiating a more intense and systematic research with GMCC in the late 1970's, testing more than a 100 species and some varieties of these same species, a range of crops have been identified and are now available for the use by farmers especially in Brazil and Paraguay. Some of the winter cover crops are black oats (Avena strigosa Schreb), rye (Secale cereale L.), triticale (Tritico-cereale), oilseed radish (Raphanus sativus var. Oleiferus Metzg), white bitter lupins (Lupinus albus L.), blue bitter lupins (Lupinus angustifolius L.) common vetch (Vicia sativa L.), hairy vetch (Vicia villosa Roth), forage peas (Pisum sativum subspecies arvense), chick peas (Lathyrus sativus L.), serradela (Ornitophus sativus Brot.), sunflower (Helinthus annuus L.), rygrass (Lollium multiflorum L.) etc. The most commonly used summer cover crops are millets (Penisetum americanum L., Sorghum bicolor L etc), foxtail or German millet (Setaria italica L.), sunnhemp (Crotalaria juncea L.), lab-lab (Dolichos lablab L.), pigeon pea (Cajanus cajan L.). Even plants that up to now have been considered to be noxious weeds like Brachiaria plantaginea are used in the Cerrados of North-Central Brazil as cover crops in no-tillage. The Cerrados have only one growing season. Here farmers and researchers have developed production systems where cover crops are established immediately after harvest of the main crop. If cover crops die in the dry season it is not a problem as long as they have produced enough biomass. In Southern Brazil and Paraguay conditions are such, that some cash or GMCC can be seeded at any time of the year if soil moisture is available.

CLIMATIC CONDITIONS IN EASTERN PARAGUAY (CLOSE TO THE BRAZILIAN BORDER)

The climate of Colonia Yguazú, 45 km from the city of Iguassu Falls, Brazil, is classified as Cfa by Koeppen

AVERAGE PRECIPITATION IN YGUAZÚ, EAST PARAGUAY, 1972 – 1999 = 1590 MM											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
148	130	117	141	138	133	73	102	125	174	136	171
AVERAGE AIR TEMPERATURE IN YGUAZÚ, EAST PARAGUAY, 1972 – 1999 = 21,6°C											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
26,1	25,6	24,7	21,6	18,4	16,5	17,8	17,9	19,2	22,1	23,8	25,4

MANAGING GREEN MANURE COVER CROPS

The knife roller to flatten and kill green manure cover crops and leave the plant residues on the soil surface is an essential tool for cover crop management. This implement is not terribly expensive and in many cases can be made locally or by the farmer himself. The implement can be pulled by medium sized tractors or by animal traction and has contributed a lot in reducing herbicide rates in the no-tillage system. The

knife roller has become an essential tool for managing GMCC in many countries of South America. Alternatively steel bars can be welded on top of the discs of disc harrows and the implement used for the same purpose. The use of machines that chop cover crops like a rotary mover is not recommended in warmer climates because residues decompose too rapidly.

Dimensions of a knife roller: The Knife Roller consists of a hollow steel cylinder, 6mm thick, approx. 115 - 200 cm wide and 60 -70 cm in diameter. Ends are welded to be filled with water if needed. Approx. 8 - 12 blunt knives are placed every 19 cm. The knives are about 7 – 10 cm high and are placed parallel to the cylinder at an angle of 45º or 90º. Weight of each 200 cm cylinder is approx. 400 kg empty and 800 kg full of water. Three cylinders are often placed in such a way that two run in front and one in back allowing for greater working width. Cylinders are mounted on a frame to allow hydraulic lifting.

Pictures of a knife roller can be seen in www.rolf-derpsch.com under “news”.

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