ABOUT THE NECESSITY OF STANDARDIZING NO-TILLAGE RESEARCH

DERPSCH, R.,¹ DUIKER, S.,² FRANZLUEBBERS, A.,³ GALL, C.,⁴ KÖLLER, K.,⁵ and REICOSKY, D.C.⁶

¹International Consultant, Conservation Agriculture/No-till, Maciel 322, Dep. 1 - B, Asunción, Paraguay, Phone +595 21 609717 rolf.derpsch@tigo.com.py
²Associate Professor of Soil Management and Applied Soil Physics, The Pennsylvania State University, 16801 University Park, PA, USA. Phone +814-8637637 sduiker@psu.edu
³Ecologist, USDA – Agricultural Research Service, 3127 Ligon St., Raleigh, NC 27607 alan.franzluebbers@ars.usda.gov
⁴University of Hohenheim, Institut für Agrartechnik Hohenheim, 70593 Stuttgart, Germany, Phone +49 711-45923519 c.gall@uni-hohenheim.de
⁵Professor, Institut für Agrartechnik, Universität Hohenheim, 70593 Stuttgart, Germany, Phone: +49 711 45923139 koeller@uni-hohenheim.de
⁶Ret. Soil Scientist, USDA-ARS, North Central Soil Cons. Res. Lab., Morris, MN USA 56267 Cell Phone +1 320-287-2314 don.reicosky@gmail.com

Abstract
No-tillage / zero tillage research has now been performed for more than half a century in many countries around the world but few efforts have been made to standardize research methodology. This has led to a situation where no-tillage research results obtained until now often can not be compared because quite different technologies, methodologies and definitions of no-tillage have been applied. Contradicting results are the consequence. This is because there is a different understanding in what no-tillage means and in general materials and methods used in an experiment are not descriptive enough to unveil the differences. In further cases people use the term no-tillage although a considerable amount of soil movement is performed at the seeding operation burying most crop residues. Therefore a widely accepted definition of no-tillage / zero tillage is needed and has to be agreed on. In this paper an attempt is made to discuss the problems associated with not adequately defining treatments and to the lack of a thorough description of what has been done in the section materials and methods in tillage / no-tillage research, leading to contradicting and confusing interpretations of research results. Often no-tillage research is performed without a systems approach and not applying all available knowledge about the technology. Among other problems this can lead to a yield drag not only in the first years of applying the technology but during the whole duration of the experiment resulting in lower yields of no-tillage, which would not have happened if the technology would have been properly implemented. It is concluded that a standardization of research methodologies in no-tillage is necessary to be able to compare results from different researchers, as well as different regions and countries and to avoid contradicting research results. Adequate experimental protocols need to be elaborated to avoid conflicting results.

Key words: No-tillage, zero tillage, research methodology, no-till research protocol, contradicting no-tillage research results.
Introduction
Worldwide literature on the yield and environmental performance of no-tillage / zero tillage remains controversial. In many cases, contradictory results can be explained by a lack of consistency in how no-tillage is performed. The system of no-tillage is often carried out using different technologies and is sometimes even used synonymously with mulch tillage, reduced tillage, minimum tillage or others, which involve various degrees of tillage disturbances of the soil. This is not only the case among scientists but it happens in practical farming as well. If production systems are named “no-tillage”, but performed differently, results will obviously be contrasting and contradicting. Often conflicting no-tillage research results are the consequence of using local jargon and definitions by different researchers, causing misunderstandings of the implications of no-tillage on crop production and environmental outcomes (Derpsch et al., 2011). Some researchers have found that no-tillage sequesters atmospheric carbon in the soil, while others contend no effect or opposite results, leading to a major confusion in the research community. Reasons for differing results can often be found in the way tillage systems are performed, with little influence due to the technology itself. All too often experimental protocols are not rigorous enough to unveil the difference as illustrated in (Christopher et al., 2009; Calegari et al., 2008; Karlen et al., 1992).

Adding to this is the complexity of researching the no-till system. Frequently, researchers prefer to change only one factor in experiments, such as tilling or not tilling the soil. Some researchers avoid changing several factors at the same time, because this can result in undesired confounding interpretations. But since no-tillage is a completely different production system, it is not enough to change tillage alone. In no till systems, crop residue management plays a more important role than minimum soil disturbance. There is a tight linkage between minimum soil disturbance and good crop residue management that can’t be overlooked. Weed, pest and disease control programs, as well as fertilization, should be changed and adapted to the new system. If optimization of each system is not done, then the results are of reduced value and do not reflect what is done practically by farmers. Unfortunately, consistent guidelines for the implementation of no-tillage experiments have not been developed to date. As long as this remains so, and researchers do not agree on an adequate definition of no-tillage, the literature will continue to be filled with controversial research results about this technology. There is need for science-based quantitative data and accurate descriptions of methods used to describe no till systems to minimize confusion in the literature.

Standardization of definitions and research methodologies in no-tillage systems is necessary to be able to improve interpretations from a diversity of experiments conducted around the world. Researchers reporting their results in scientific articles need to ensure that materials and methods reveal exactly how tillage and management variables were performed. Some of the common questions to ask, so as to report the conditions of importance in such studies are:
What was the soil type, texture, organic carbon content, and slope? Consider the water content at planting, soil temperature, bulk density, and the duration of no till before the current study.

What was previous harvest information, i.e. normal combine versus stripper header and information on the residue distribution?

What were the cropping history and amount and quality (legume versus grass) of soil cover before starting the experiment?

What kind of seeding equipment was used and what was the configuration of the planter (equipment manufacturer, model number, speed of planting and types of press wheels)?

Were uniform seed spacing and depth placement achieved and was plant population the same in all systems?

What percentage of the soil surface was disturbed while seeding?

What was the percentage of soil covered with residues after seeding?

What was the type and amount of biomass produced and returned to the soil in each system per year? Consider C:N ratio of crop, size of residue and orientation.

Was a systems approach used or was tillage the only factor changed?

Which products were used for weed control?

Did weed control include use of different herbicides in different tillage systems?

How efficient was weed control in each system?

Was pest, disease and weed control taken into account for each system separately, or was the same program used in all systems?

Were fertilizer programs and especially N the same in different tillage systems during the first few years after transition?

What crop rotation and/or cover crop system was used? Was the cover crop planted using no till techniques?

Additional questions arise if researchers, technical staff and tractor drivers have enough training, or the necessary knowledge on how a no-tillage system needs to be practically successful. Have steps towards a successful transition to no-till been followed (Duiker and Myers, 2005, Derpsch, 2008). Are researchers applying the same level of technology the majority of no-till farmers do to be successful with their system? Depending on how these questions are answered, quite different research results can be obtained. To achieve valid system comparisons, a minimum assurance of relevance needs to be developed in a research protocol and this need to be reflected in the materials and methods of research publications to make it clear how results were obtained. Therefore, a standardization of research methodologies is needed. Using an internationally agreed upon definition of terms and technology applied will help in making results from different parts of the world understandable. All of this may seem obvious to many experienced research scientists, but in reality all too often some basic elements have not been taken account of in the execution phase of the research. For example, it may be that lower yields obtained in no-tillage, may not be system inherent, but a consequence of the research methodology used or a lack of understanding of how no-tillage performs optimally compared with more traditional tillage systems.
Description of the no-tillage system

No-tillage or zero tillage is a farming system in which seeds are deposited at proper depth directly into untilled soil with previous crop or cover crop residues retained on the surface (Derpsch et al., 2011). Special no-till seeding equipment with discs (low disturbance) or narrow tines/coulters (higher disturbance) open a narrow slot into mulch-covered soil. The aim should be to move as little soil as possible to preserve surface residues and to reduce potential weed seeds from reaching the soil surface to germinate. With no-till, no other soil tillage is needed. If the entire soil surface is disturbed, even only superficially, then the system cannot be termed no-tillage and must be defined as mulch tillage (CTIC, 2011). Seeding systems that till and mix more than 50% of the soil surface while seeding cannot be defined as no-tillage, but some other system, depending on the extent and type of disturbances (Linke, 1998, Sturny et al., 2007). A successful no-tillage system has to have adequate weed control. Therefore, weed control in no-tillage is often performed with (a) the adoption of appropriate crop rotations, (b) use of adapted, aggressive species of cover crops, (c) termination of cover crops with a mechanical non soil engaging tool like the knife roller, and (d) applying appropriate herbicides.

No-tillage technology has been successfully implemented on >100 Mha worldwide (Derpsch et al., 2010) and on about 70% of arable cropland in Brazil, Argentina, Paraguay, Uruguay, Australia and New Zealand. Success of this production system has been based on diversification through crop rotation and cover crops and on its continuous, permanent application, similar to a permanent pasture (Sturny et al., 2007). The system mimics nature, in which soil loosening is performed by roots of plants and soil fauna, as well as by diversified biological activity. The fact that soil is not tilled and remains permanently covered with crop residues leads to reduced soil erosion, soil carbon sequestration, increased soil biological activity, better conservation of water, better efficiency of applied nutrients, increased nutrient availability from biological activity, improved energy efficiency (Sturny et al., 2007), and higher economic returns through time (Derpsch et al., 2010). Moreover, no-till is a key farming system approach that meets the requirements of a sustainable agricultural production, even under extreme soil and climate conditions. The water conservation benefits of no till over traditional till during dry periods is generally accepted. (Baumhardt, R.L. and Jones, O.R. 2002; Derpsch, et al., 1991; Lampurlanés et al., 2002; Reicosky, D., 2011).

Different words can be used to define no-tillage / zero tillage systems, but the most important thing is to ensure that three key principles are achieved:

- Absence of tillage operations for soil preparation other than opening a narrow slot to deposit seeds in the ground, carried out consistently from year to year.
- Permanent organic soil cover (plant residues from previous crops or living plants covering the whole soil surface all year round).
- Diversification of crops through crop rotation, crop associations, and use of cover crops.
These principles are in line with the FAO (2011) definition of conservation agriculture (CA) production systems.

Cropping systems with two crops a year like the rice-wheat production system in the Indo Gangetic Plains (~6 Mha), where the ground is not tilled prior to wheat, but is plowed every year for rice, can not be called no-tillage and are not entering the worldwide estimates of no-till adoption (Derpsch et al. 2010).

Although direct seeding is sometimes used synonymously with no-tillage and it is increasingly being used to place seed directly into undisturbed soil, some machines perform a major amount of soil disturbance that buries or mixes crop residues with the soil. Such techniques should rather be characterized by the umbrella term of mulch tillage and should not be used synonymously with no-tillage.

**Definition of no-till:** No-tillage or zero tillage can then be defined as a conservation farming system in which the seeds are deposited into untilled soil which has retained the crop residues from the previous crop by opening a narrow slot, trench or hole only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done (adapted from Phillips and Young 1973, Köller and Linke, 2001 and Köller, 2003). All aspects of the above description of the no-tillage system are considered to be implicit in this definition.

**Reasons for yield discrepancies with change in tillage**

Experiences worldwide have shown similar or higher yields can be obtained with no-tillage compared with conventional tillage systems (Baumhardt and Jones, 2002; Dick et al., 1997; Defelice et al., 2006; Duiker et al., 2006; Halvorson et al., 2002; Sturny et al., 2007). When yield with no-tillage is lower than with conventional tillage, some of the following reasons may be responsible:

- Lack of knowledge or experience on how to manage crops with no-tillage techniques. Guidance should be sought prior to change from “Critical Steps to Successful No-till Adoption” (Derpsch, 2008) or “Steps Towards Successful Transition to No-Till” (Duiker and Myers, 2005). A learning curve of farmers and researchers can often be the reason for initial yield depression or yield drag with no-tillage.
- Lack of a systems approach in applying no-tillage. It is not sufficient to only stop tilling with all else managed the same way as in conventional tillage systems (e.g. planters should be adjusted for optimum performance in each system, weed control should be optimized in each system, and disease and pest control needs system-level attention).
- No-tillage may have been performed with bare soil conditions or with insufficient soil cover with crop residues. Surface residue cover is a key feature of no-tillage systems. Research by CIMMYT has shown that taking residues away leads to reduced yields in no-tillage (Wall, 1999; Sayre et al., 2006).
- Lack of experience of the machine operator at seeding (e.g. inadequate regulation of seeding equipment, seed furrow staying open after seeding, too deep or too shallow seed placement, soil smearing because of excessive moisture, etc.).
- Inadequate no-till machinery may have been used that led to poor plant establishment. Inadequate seeding and/or furrow closing mechanism and seed placement can lead to poor stand (e.g. seeds are placed too shallow or too deep, or there is not good seed to soil contact). Frequently, researchers lack funds to buy adequate no-till seeding machinery, and sometimes, even conventional tillage seeding machines may have been used in no-till experiments, leading to improper seeding.
- Poor weed control (e.g. inadequate selection of herbicides or weed suppression techniques, too low doses of herbicides, excessive dose of herbicide causing crop injury, poor spraying techniques, etc.). Frequently, researchers insist on using the same herbicide program for all treatments (conventional, minimum and no-till), because tillage is the only variable they want to change. This may favor one system, but be detrimental to another.
- Poor disease and pest control (e.g. using calendar applications for all treatments, instead of using system-specific applications of pesticides). System-specific pesticide applications are needed, because no-till may favor some diseases and pests or vice-versa in comparison with other tillage treatments (Derpsch et al., 1991).
- N fertilization may not have been adjusted during the first few years of applying no-tillage technology or a leguminous crop may not have been seeded previously to provide the additional N needed initially to account for immobilization in surface residues and soil organic matter.
- No-tillage may have been implemented on an extremely degraded and/or eroded soil with very low organic matter content, in which micro- and macro biological activity and fertility limits initial success. On such soils, an advantage to conventional tillage is through mineralization of N with tillage disturbance.
- Comparative research studying conventional and no-tillage systems may have optimized rotations for conventional tillage, whereas sequences may be sub-optimal for no-tillage. No-tillage systems can be optimized with seeding of cover crops at harvest, which may not be possible with conventional systems due to time and moisture lost with tillage.

Unfortunately researchers in many parts of the world have made and continue to make these mistakes. Systems research continues to pose a challenge to researchers, and that is one reason why no-tillage adoption all over the world has been farmer driven and not researcher driven. Farmers are in better position to implement new farming systems than most researchers and university professors. Statistical techniques and requirements by scientific journals support changing only one factor at a time to avoid confounding factors, yet this often makes results of limited value when systems need to be compared. A conscious decision by researchers needs to be taken as to whether the system is more important for evaluation or a simple change of practice. An additional issue is that large plots should be used for experiments comparing tillage systems, but space is often at a premium on research stations.
and unsuitable compromises can be made to use small plots and/or reducing the number of replications. Further, technicians often need to regulate seeding equipment on the actual research plot, but improper regulation may occur prior to completion of seeding. As a result, problems could arise in terms of depth of seeding or leaving an open furrow that exposes seeds to bird and/or rat damage, etc. This can be avoided by incorporating additional plots to the experiment with the same tillage treatments and crops as in the actual experiment, which are exclusively used to be able to adequately regulate equipment.

Researchers have seldom acknowledged their mistakes in scientific manuscripts, but there are some exceptions. Kahnt (1976) reported that his early no-till research (1965 – 1968) led to lower yields compared to conventional plow tillage, because conditions for successful application were missing. He listed 10 conditions for success in no-tillage systems, of which only two or three were met in the early days of his research. He pointed out that not fulfilling one of the following conditions could lead to yield depressions:

1. Sufficient horsepower of the tractor
2. Strong hydraulic system (for operating 3-point-linked equipment)
3. Appropriate seeding equipment
4. Accounting for the possibility of greater N fertilizer application needed with no-tillage
5. Availability of appropriate herbicides
6. Appropriate crop types
7. Adapted varieties
8. Appropriate crops preceding no-tillage establishment
9. More adapted crop rotations for no-tillage
10. Familiarity with the technique and experience of persons involved in the research.

The human factor is very important when it comes to putting no-tillage technology into practice; a factor largely ignored previously. If people involved in the research or in practical farming are not mentally prepared to accept, or do not believe in, the system than it will most likely fail (Bieber, 2000). Often, performance of no-till seeding equipment is highlighted as a reason for success or failure of no-tillage, but the performance of people operating machinery is equally or more important. Therefore, yield differences obtained from various tillage system comparisons may have little to do with the treatments applied, but rather the people involved in executing the research, i.e. technicians, managers, and/or tractor drivers.

“Each farmer, tractor driver and/or extension educator first must get acquainted with innovations and gain experience with them before he can truly understand and accept new agricultural practices. Once he understands and accepts the new practices, he can then apply them and recommend them to other farmers. Getting accustomed to the sight of a no-tilled field after planting is difficult, because our experience and education bias us towards expecting a “clean tilled field” as under conventional tillage. The different goals of tillage operations with their advantages and disadvantages for the soil, plants and economic
Importance of crop residue cover in a no-till system
Soil cover has vital importance in a no-till / zero till system. Almost all the benefits and advantages of a no-tillage system come from the permanent cover of soil and only few from not tilling the soil (Derpsch, 2007) In other words, it is not the absence of tillage, but the presence of crop residues on the soil surface that results in a better performance of no-tillage in comparison with a conventional tillage system, primarily through the surface location and duration of crop residue serving as a primary form of carbon input for the soil biology. Failure to pay attention to soil cover has resulted in poor performance of no-tillage systems (e.g. lower yields, runoff, erosion, low biological activity, etc.). There is sufficient scientific evidence to state that no-tillage without soil cover results in poor crop performance and yields (Ashburner, 1984; Wall, 1999; Sayre et al., 2006).

Crop residue cover is needed to increase water infiltration into soil and reduce runoff and erosion. The percentage of soil covered with plant residues is an overriding factor that influences water infiltration into soil (Roth, 1985; Govaerts et al., 2007). Very high erosion rates were also recorded in no-till without residue (Gomez et al., 2003). Limited crop residue cover leads to high water evaporation, reducing production and water use efficiency.

In a low-rainfall area of Bolivia, highest yields were obtained from no-tillage and crop residue retention, intermediate yields were obtained from different tillage systems with conventional to minimum tillage, and lowest yields were obtained from no-tillage and no residues (Wall, 1999). Similar results were obtained by Sayre et al., (2006) under rainfed conditions in the highlands of Central Mexico. Yield and economic return of wheat and maize were drastically reduced when residues were removed from the no-till system. Sayre et al., (2006) concluded that “no-tillage without crop residues on the soil surface leads to disaster”.

Importance of diversification of crops with crop rotation and cover crops
Green-manure cover crops and crop rotation play an important role to achieve adequate soil cover and diversity in a no-till system. Development of successful cover cropping in no-till systems has been a major factor in the unprecedented growth of this technology in South America.

In drier climates, farmers are often concerned that green manure cover crops take too much moisture out of soil, leaving too little available for crops. This is and should always be a concern. Using crop species that use less moisture and timely management of cover crops are ways of getting around this problem. For example in Argentina, more intensified cropping and use of cover crops increased water use efficiency compared with clean fallow (Roberto Gil, personal communication). This has also been observed by farmers in the United States and elsewhere, in which shading of soil by cover crops results in lower soil temperature and water evaporation. In the northern Great Plains of the
United States, farmers have found opportunities to incorporate cover crops profitably in dryland farming by integrating crop and livestock production (Franzluebbers, 2011). Highly variable precipitation is conducive for selective grazing of cover crops in high-precipitation years, while maintaining sufficient crop residue for system function.

According to the Sustainable Agriculture Network (SARE/SAN, 1998) in the United States, “Cover crops slow erosion, improve soil, smother weeds, enhance nutrient and moisture availability, help control many pests and bring a host of other benefits to your farm.”

Framing a protocol for no-tillage research

There are several issues that should be taken into account to avoid systematic errors leading to skewed results and yield drag when conducting no-till research. A science-based research protocol is needed and the most important points should be highlighted in the materials and methods section of scientific papers when describing the experiment.

1) System description: The system-level strategy should be described and changes made according to that system. Changing only tillage will result in an artificial system and not reflect the conditions of practical farming.

2) Cropping and tillage history: Description of the crops and type of tillage preceding the experiment. Fallow periods before starting the experiment need to be recorded. The duration of the no-till system used prior to the experiment must be addressed.

3) Soil condition before the experiment: Record the soil type, texture, organic carbon content, percent soil cover, amount and quality of crop residues (t/ha), and whether residues were evenly distributed on the soil surface. Drainage status and presence or absence of hardpans needs to be reported.

4) Soil fertility: Report how, when, and if soil pH and nutrient deficiencies were corrected prior to the experiment. Soil fertility needs to be monitored during the duration of the experiment. When necessary, lime applications should be applied frequently in small amounts (not once in 10 years as that can lead to wide swings in surface pH and "acid roof" formation, which can lead to poor weed control besides other problems).

5) Weed control: Adequate techniques need to be used in all treatments. Ground cover should be weed free at seeding (i.e. previous vegetation needs to be killed completely). Weed control needs to be system specific. The name of herbicides used and the date and the amount of product applied need to be recorded. All treatments should be optimized to keep relatively weed free. In general that means different herbicides and techniques need to be used, particular to a system. Weeds need to be monitored during the duration of the experiment.

6) Planting/seeding equipment details: Provide manufacturer, model number, planting speed and configuration used in each treatment. Special attention should be given to soil cutting tools (tines, discs) and furrow-closing devices. Researchers should not be reluctant to mention brand names and models in materials and methods since this information
is very important when interpreting no-tillage experiments. Equipment needs to achieve uniform seed depth and guarantee good seed-to-soil contact. Hairpinning of crop residue, open slots after seeding, compaction of soil on top of the seed, etc., should be avoided but these issues need to be recorded and mentioned in materials and methods when they happen. Approximately the same number of plants/ha need to be achieved in the systems to be compared. Plant counts/m² need to be performed a few weeks after seeding and at least once again at harvest.

7) **Soil moisture at seeding:** Describe soil moisture conditions, as excessive moisture may lead to hairpinning and poor seed to soil contact in a no-till system, which could lead to poor germination. Adequate moisture content for seeding should be achieved in all treatments. This is an especially tricky point in tillage research, because soil moisture varies between tillage systems and conditions for optimal seeding may be different for different tillage systems. Rains on Thursdays are a horror for tillage researchers in warmer climates! On Friday the soil is still too wet to seed and on Monday it is already too dry, as often it is difficult to organize seeding on weekends.

8) **Soil disturbance:** During seeding, level of disturbances (depth and soil volume) even in no-tillage need to be recorded, especially the row spacing and width of the seeding slot. High-disturbance no-till seeding with tines can yield quite different results in terms of soil carbon sequestration and water losses compared to low-disturbance no-till seeding with discs (Reicosky, 2011).

9) **Plant biomass produced:** Seasonal and yearly measurements are needed (t/ha), especially if studying soil carbon sequestration or if organic matter is an important research objective. These measurements are especially important in long-term no-tillage experiments. xxx

10) **Pest and disease control:** Account for differences in the systems and avoid routine calendar applications for all treatments. Continuous monitoring of pest and disease development is necessary. If calendar applications are used, this needs to be recorded.

11) **Nitrogen requirements:** During the first three to five years, no-tillage may require greater N fertilizer inputs than conventional tillage systems (usually around 30 kg N/ha greater). Equal N application rates may lead to a yield drag in no-tillage during initial years of the experiment. Sufficient N has to be applied in the right way to avoid volatilization losses and also to avoid excessive soil disturbance when applying it. If in no-tillage additional N is not applied this has to be specifically mentioned. If a leguminous cover crop is used, an estimate of the nitrogen available to the agronomic plant should be included.

12) **Crop rotation:** Using inadequate crop sequences may be detrimental to one or another system. Monoculture will not likely be an adequate system under no-tillage. Therefore rotations need to be applied that are system neutral. No-till after legumes, and especially perennial legumes, can be a good way to start no-till without a yield drag. Varieties used need to be mentioned as different varieties may react differently to different tillage treatments.

All of this suggests that the best way of conducting robust no-tillage experiments is to involve a multi-disciplinary team in the project.
Conclusions
Depending on how no-tillage research is conducted, different results can be obtained in terms of soil carbon sequestration, soil moisture retention, seed germination / plant establishment, weed infestation, soil fertility, soil biological activity, and crop yields. We suggest that it is imperative to profoundly understand the no-till system before implementing it or attempting to research the system. Until the scientific community agrees on an internationally recognized definition of no-tillage / zero tillage, conflicting and contradictory research results will continue to fill the literature regarding tillage research. Standardized research methodologies are necessary to be able to compare results from different researchers, different regions, and different systems to avoid confusion and misinterpretation.

We contend that elaborating experimental protocols and detailing how tillage / no-tillage research was conducted in materials and methods of scientific publications will rectify some discrepancies in the literature and lead to better system-level development of no-tillage, which is a practically successful system adopted by many farmers all over the world. To achieve comparable results in no-tillage research, a minimum record of practices, equipment details, and crop observations need to be described in a research protocol and reflected in scientific publications to make it clear how the results were obtained. An absolute minimum list of considerations should be:

1) Percentage of soil surface covered with residues (amount and quality) after seeding
2) Percentage of the soil surface that has been disturbed while seeding
3) Crop sequences and/or rotations that have been used
4) Herbicides and rates that have been used for weed control
5) Brand name and model of no-tillage seeding equipment used and planting speed
6) Configuration of the furrow opener and closing devices of the seeder
7) Additional N applications for no-tillage in the initial phase as well as non application.

No-tillage research conducted without considering these items will yield results that may have nothing to do with the treatment, but rather the research methodology used. System-level evaluation of no-tillage requires that complete systems be compared, not just a change in tillage disturbance in the absence of other important components of the system. Previous no-till research needs to be considered in light of these issues to understand the value of the experiments reported.

The unfortunate, but common practice of using laconic, nondescriptive statements in the materials and methods section of publications (e.g. “The experiment included three tillage treatments, conventional, minimum and no-tillage”) or not describing in detail how the experiment and no-tillage system was carried out needs to come to an end and energetically rejected. It is not enough to define no-tillage just briefly like it is often seen in literature “the soil
was left undisturbed from harvest to planting”. Instead a description is needed of the entire no-tillage system or strategy.

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**References**


Duiker, S. and Myers, J.C., 2005. Steps towards a successful transition to no-till. College of Agricultural Science, Agricultural Research and Cooperative Extension, PennState University, 36 pp


No-till farming (also known as zero tillage or direct drilling) is an agricultural technique for growing crops or pasture without disturbing the soil through tillage. No-till farming decreases the amount of soil erosion tillage causes in certain soils, especially in sandy and dry soils on sloping terrain. Other possible benefits include an increase in the amount of water that infiltrates into the soil, soil retention of organic matter, and nutrient cycling. These methods may increase the amount and Conservation farming practices, such as no-tillage and crop residue retention, have been proposed as sustainable management practices. However, it remains unclear how different tillage practices and rice straw retention affect the soil bacterial community (SBC) and the soil C/N ratio in the long term. The objective of this study was to evaluate changes in SBC composition and abundance and soil properties (e.g., carbon (C), nitrogen (N)) and determine their relationship to the soil C/N ratio under long-term no-tillage and straw retention techniques. No-tillage/conservation agriculture systems research has now been performed for more than half a century in many countries around the world, primarily for economic reasons, but also to reduce labour and energy consumption and improve environmental outcomes. However, an integrated approach to understanding this system requires standardized research methodology based on site-specific conditions. We contend that broad understanding is lacking of what conservation agriculture systems research means. This has led to a situation of conflicting research results because different technologies, methods