The Pharma Innovation Journal 2022; SP-11(8): 183-188

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(8): 183-188

www.thepharmajournal.com
Received: 25-05-2022
Accepted: 29-06-2022

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Reducing and eliminating tillage in order to promote sustainable agriculture

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Abstract
Tillage is the process by which soil is physically manipulated with the help of tools and implements in order to manipulate the soil. In soil manipulation, the term tillage refers to a method of manipulating the soil so that it can be manipulated in such a way that seed sowing and intercultural operations can be made easier. As a result of its use, tillage is very necessary for the production of the crop since it makes it easier to produce the crop and it increases its yield. In the soil, tillage improves water retention by increasing evaporation, infiltration and the rate of water permeability. The excessive tillage of soil disturbs the structure of the soil, which causes increased evaporation, the incidence of insects and pests, and a loss of crop yield as a result of the disturbance of soil structure. In order to overcome this problem, a number of tillage reduction methods are being used, such as conservation tillage, minimum tillage, no-tillage, and ridge tillage, for instance. In this review, we are going to provide an overview of the use of tillage and tillage reduction techniques that have been applied to reduce the use of tillage. These techniques are used to minimize tillage in order to ensure that soil structure is not disturbed at a high level by a high level of tillage. It is not necessary to use a lot of tillage on the soil. At least 50% of the crop residues are left in the soil so the proper nutrients can be absorbed by it. In order to maintain the health of the soil, it is very important to reduce the amount of tillage. It is the main goal of this paper to provide detailed information about tillage, its types, tillage practices, its importance, and the techniques that are used to reduce the amount of tillage.

Keywords: Agriculture, poverty, sustainability, crop, implements, reduction, minimum, nutrients, tillage

Introduction
In agriculture, tillage is the process of manipulating the soil so that crops can be grown in the soil. The different types of mechanical techniques that were used included stirring, overturning, digging, and a variety of other techniques. During the primitive period, most of the tools used by man for the sowing of seeds were made of wood that disturbed the soil. There are various types of soil characteristics that can be improved by tillage, such as the rate of infiltration, the rate of evapotranspiration, and the retention of moisture, or the ability to maintain the ideal conditions for the germination of seeds, crop growth, as well as the installation of seedings properly (Seymour *et al*., 2015) [30]. It is also critical to realize that tillage affects soil properties chemically, biologically, and physically. There is a physical condition of the soil that can be determined by the tillage process which determines the tilth of the soil. There are various grades of fineness, moderateness, and of course tilth when it comes to it. A certain type of tillage may be done in both seasons, either in the off-season or in the season (Sommer *et al*., 2012) [31]. As the operations of tillage are carried out for the purpose of raising the crop in a similar season and in the season of the onset of the crop, this is known as on-season type of tillage, whereas off-season tillage refers to conditions used to prepare the land for the upcoming main crop season. When the tillage is deep and thorough, then it is classified as the primary type of tillage. However, when it is schematic and selective for a particular location, then it is classified as the secondary type of tillage. There are several types of tillage, but the primary type involves plowing the soil to form the surface smoother than what is necessary for the proper seedbeds to form in different crops (Kumar *et al*., 2016) [14]. There should be a combination of secondary tillage and initial tillage performed within one operation in order to maximize yield.
Tillage's goal is to create the best possible conditions for crop establishment and growth, by creating the best possible soil conditions. There is a correlation between growth during the early stages of crop development and the final yield within certain limits, especially for winter crops, but high yields may not be possible after poor establishment, particularly if adverse soil

conditions persist during the growing season. Brewster and J.L. (2018) [5] believe that emergence can play a crucial role in ensuring uniform maturity for spring-sown crops, particularly high-quality vegetable crops, due to the importance of rapid and uniform emergence (Brewster & J.L. 2018) [5]. There are many different aspects of the crop environment that are affected by tillage. In addition to having a direct effect on soil aeration and compaction, aeration and compaction can also have a direct impact on water supply and soil temperature (even in the absence of crop residue), all of which can have a positive impact on root growth and vegetative growth of plants. Kumar *et al*. (2011) [17] found that germination and emergence of plants in coarse cloddy seedbeds may be delayed or inconsistent, especially when environmental conditions are dry (Kumar *et al*., 2011) [17]. As a result of unsuitable soil conditions or the need for time-consuming tillage practices, seedlings of autumn-planted crops may experience lower temperatures that can negatively affect growth rate; late-planted spring crops are more likely to experience water stress that will negatively affect growth rate.

Importance of TLLAGE: Traditional cultivation has had two main purposes: it has served the purpose of removing weeds, as well as creating an environment in which seeds can germinate successfully. Seedlings have the ability to grow and develop. It is assumed that weeds can be controlled chemically in order to prevent them from spreading. Excessive tillage, on the other hand, can be harmful to the soil, especially if the soil's true contents are high and too much tillage is being done. The soil structure can deteriorate due to the acceleration of the oxidation of organic matter, as well as mechanical damage, such as compaction and smearing. This interferes with the movement of air and water in the soil and exposes the soil surface to wind and rain erosion. There may only be one way to mitigate the negative effects of soil damage where serious damage has been sustained to the soil structure. This is done by deep cultivation and subsoiling the soil when the soil is sufficiently dry. It is especially relevant when it comes to root crops that require deep planting and a lot of soil disturbance when they are being harvested. As a general rule, tillage can be divided into two categories: primary tillage and secondary tillage. There is no doubt that soil puddling is a type of secondary tillage, but its primary objective is to prevent water from moving through the surface layers of the soil (Ahmad *et al*., 2018) [1].

1. Primary tillage

As soon as a crop has been harvested, primary tillage is the first soil tillage that is performed before the next crop is sown into the soil. The plowing process is usually done when the soil is moist enough to permit plowing but firm enough to allow adequate interactions between the plows and the soil. At the beginning of the next dry season or right after the harvest of the crop, this can happen immediately after the harvest of the crop. We were aiming to get a maximum depth of 10 to 15 cm of soft soil. In addition, we were aiming to get clods of a variety of sizes in a reasonable amount of time. It is possible to kill weeds either by burying or cutting their roots and exposing them to the air. The purpose of soil aeration and water accumulation during a rainstorm is to aerate the deep layers of soil and trap the water at the bottom. In some cases, this effect can be observed depending on the type of soil and the type of plow that is used. It is important to chop and incorporate crop residues into the soil as soon as possible. For primary tillage within an animal-powered system, moldboard plows are the most common implement used within this system, which is powered by an animal. Before tillage can be done on clay soils, the fields must be completely saturated. The use of tillage can be done at moisture levels below the field capacity of lighter textures of soil such as loam or sand. There are two types of plows that are used in 2-wheel-driven systems: moldboard plows and disc plows (one-way discs). The disc is typically preferred because it requires less energy and is more capable of overcoming obstacles. Ploughs with three discs, seven discs, and offset ploughs are the most common types of ploughs used on a four-wheel tractor system. In upland systems, tinted plows have been found to be more effective than plain plows, but they are still not widely available in Asia (Keen *et al*., 2013) [13].

2. Secondary tillage

During a secondary tillage operation, any work that is done after primary tillage, such as reducing the size of the clods, controlling weeds, adding fertilizers, puddling, and leveling the soil surface, is referred to as secondary tillage. When it comes to primary tillage, it tends to be more aggressive and deep, while when it comes to secondary tillage, it tends to be shallower and less aggressive. As part of the animal-powered system, the moldboard plough is used during the second phase of the process when the field and soil are fully saturated and ready for the work to commence. As part of the final stage of the process, peg tooth harrows are used to finish the final work. They puddle the soil as well as level the surface, preparing it for planting. In a 2-wheel tractor system, the moldboard, disc, and rotovator are utilized to perform the second action. If it is not possible to hire rotavators or peg tooth harrows for a particular task, then peg tooth harrows can be used as a substitute for rotavators. In every soil type, the tractor cage wheels have to interact with the soil in order for puddles to form. This interaction is necessary for the tractor cage wheels to work effectively. Most of the time, the use of tinted cultivators, seven-disc ploughs, offset disc ploughs, and rotavators is the most common equipment used for second works, as these are some of the most common equipment found on 4-wheel tractors. In this system, all fields are puddled mechanically using tractors with both rotovators and leveling boards, or they can be equipped with large cage wheels and harrows if the tractor is equipped with large cage wheels and harrows (Upadhaya *et al*., 2019) [33].

Reduction of tillage: In order to reduce tillage, there are two types of reduced tillage: conserved tillage and traditional tillage. The concept of conservation tillage refers to the practice of planting crops with the least amount of disturbance to the soil. In other words, the crop residue or stubble is left on the ground instead of being thrown away. Reduced tillage practices can range from reducing the number of tillage passes to completely eliminating tillage (zero tillage). For a variety of reasons, tillage reduction is beneficial to the environment in terms of soil health. There is no doubt that crop residues protect valuable topsoil from erosion by acting as a barrier against water and wind erosion. Because it is not necessary to use heavy machinery (which can cause soil compaction) and the soil tilth has not been artificially altered, soil structure improves when heavy machinery is not used (which can cause soil compaction). In the absence of regular disturbances of earthworms, deep tillage increases the number of earthworms. This results in increased soil aeration, fertility,

and microbial activity in the soil as a result of the increased activity of earthworms in the soil. In addition to reducing the use of fossil fuels on the farm through reduced tillage, reduced tillage also has the additional environmental benefit of reducing the use of fossil fuels.

Techniques for reducing tillage: Subsoil tillage refers to the process of preparing soil beneath the surface by tillage. In order to decrease compaction, a specific tillage operation (chiselling) is used to break down the dense pan beneath the plough layer in order to decrease compaction. It is recommended that subsoiling takes place every four to five years in areas where heavy machinery is used for field operations, sowing, harvesting, and transporting (Cai *et al*., 2014) [5]. There are several advantages to subsoiling, including expanding the amount of soil available for crop cultivation, recharging the underground permanent type water table by allowing the free water to percolate downward, reducing the runoff of water, as well as allowing the roots of plants to go deeper in the soil to extract moisture from the water table and to reduce soil erosion. There has been abundant research demonstrating the benefits of deep tillage, including subsurface tillage and deep plowing, in terms of improving soil physicochemical properties, reducing soil bulk density and penetration resistance within the tilled layer and breaking the plough pan in difficult soils (Berhe *et al*., 2013, Mu *et al*., 2016) [2, 22]. As well as boosting the activity of subsoil enzymes, deep tillage also promotes the concentration of nutrients in the soil, enhances the capacity of the soil to store water, and regulates the ratios of liquid, gas, and solid phases in the soil. Despite the fact that deep tillage has many benefits, it also requires a lot of energy and expense, which makes it less economical in many cases. As a result of the varying tillage levels, soils with different textures will experience different impacts from different levels of tillage (Chamen *et al*., 2015) [6]. Depending on the soil type, tillage as deep as 30 cm may be profitable on sandy soils, while tillage deeper than 20 cm on clay or clay loamy soils is likely to be unprofitable (Tian *et al*., 2019) [32]. The result of alternating between no-tillage and deep tillage each year might increase the production of macro-aggregate, but it may also increase the level of a nutrient in the soil by increasing the level of no-tillage (rotation tillage). In the case of deep tillage, the soil environment can be enhanced as well as the root growth of the crop can be stimulated. Research in the field focuses primarily on the phenotype of roots, the rate of absorption of nutrients and water by roots, and its reviews also demonstrate that deep tillage has a negative effect on the growth of plant roots and the release of hormones during development (Jibran *et al*., 2013) [11]. It is widely known that plants are complex creatures and that their metabolic activities are intimately linked to hormone interactions that are responsible for regulating plant growth (Okamoto *et al*., 2016). During the growth of Arabidopsis seedlings in hard soils, ethylene production increased significantly in the roots, resulting in a redistribution of indole acetic acid (IAA) within the elongation region, preventing root cell elongation and prolonging the time of root emergence (Mu *et al*., 2016; Cai *et al*., 2014) [22, 5].

Conservation tillage: During the conservation tillage process, organic residues that have been removed from the soil are not reworked into the soil, in other words, they are not returned to it. By leaving them on the surface rather than using them as a barrier, it prevents soil moisture loss through evaporation or erosion. When stubble is raked over the soil surface, it forms a layer that protects it from erosion and can be referred to as stubble mulch tillage (Saras *et al*., 2016) [28]. It is not uncommon for residues left on the soil surface to hinder the process of planting. This is because they prevent the seed beds from being prepared and the planting of seeds being completed. Throughout the year, this technique is used for the control of weeds in a variety of fields by employing devices that undercut residues, deplete the soil, and kill the weed roots and their seedlings. As a result of this technique, there are many advantages, including the ability to reduce the need for tillage, which is an energy-saving measure, thus leading to energy savings (Schonbeck *et al*., 2011) [29]. In order to be able to improve the soil in a positive way, you will have to make changes to it in order to enhance its physical properties. By using these methods, it will be possible to reduce the amount of water that evaporates from fields. This is a result of the evaporation of water through the use of these methods.

It is possible to consider a tillage approach as conserving tillage if it reduces soil or water losses in comparison to moldboard plowing in the following ways: if it reduces soil or water losses in comparison to moldboard plowing by reducing soil or water losses in comparison to moldboard plowing, etc. Pratibha *et al*., 2019 [26] explain the normal practice of tillage in conventional systems. This is for the initial tillage of the soil to be done with a moldboard plow and then for seedbed preparation to be done with harrows. In addition to planting on ridges and slopes, contouring is one of the conservation tillage techniques used for planting across slopes as well as planting on ridges. Logan and T.J. (2018) [20] have demonstrated that conservation tillage is a highly effective means of controlling erosion in small watersheds and field plots (Logan and T.J., 2018) [20]. Using maize residue in the Midwest has resulted in a continuous reduction of 75% in soil loss as a result of the use of maize residue as crop residue. Even more erosive methods like corn and soybean rotations can be implemented to achieve this result, and we believe we can achieve it. As a result of the use of conservation tillage, you will be able to minimize erosion by as much as 50 percent as compared to conventional tillage. It has been shown that when 30% of the soil is covered with vegetation as opposed to bare soil, the amount of erosion can be half as much (Prasuhn, 2012) [25].

No tillage (Zero Tillage): Essentially, no-till agriculture is the practice of planting a new crop in the residues of a previous crop without doing any soil tillage or seedbed preparation before planting the upcoming crop and it is only possible when the weeds are controlled by herbicides before the upcoming crop is planted (Weber *et al*., 2017) [35]. Generally speaking, zero tillage is applicable to soils that have a coarse-textured surface horizon, efficient internal drainage, a large amount of biological activity in the soil fauna, a favorable soil structure from the beginning, and an adequate quantity of crop residue for mulching. There are a variety of Ultisols, Alfisols and Oxisols found in humid and subhumid tropics, which generally exhibit these conditions (Dalal *et al*., 2020) [8]. It is possible to achieve zero tillage in several ways, including the use of till planting techniques. It is necessary to clear the previous row of crops with a wide sweep and the refuse bar, then open a narrow strip into which seeds are sown and covered by the planter (Kumar *et al*., 2016) [14]. This case

involves the expansion of herbicide functions. The existing vegetation must be systematically destroyed before seeding can begin, which is done with a broad spectrum of non-selective herbicides such as glyphosate, paraquat, and diquat. Among the benefits of zero-tilled soils are the fact that they generally have a more homogeneous structure and have a higher concentration of earthworms (Piron *et al*., 2017) [24]. Due to the lack of mineralization, the organic matter content of the soil rises as a result. There is a reduction in surface run-off due to the presence of mulch. It can often be estimated that the yields of crops grown through no-tillage agriculture are equivalent to or higher than those of crops grown through conventional tillage agriculture, especially on soils that are well-drained to moderately well-drained. The water content of the soil in the vast majority of cases, with a few exceptions, is much higher in a no-till system than it is in a standard tillage system when it comes to soil water content (Derpsch *et al*., 2014) [9]. The presence of a mulch on the soil surface results in a significant reduction in the evaporation of water on the soil surface when the crop canopy is not covering the soil surface, since the mulch prevents water evaporation on the soil surface. The amount of soil water evaporation from the soil is not significantly different between traditional tillage and no-tillage techniques until the crop canopy is fully developed and most cropland has developed a canopy of crops (Dai *et al*., 2021) [7].

Minimum tillage: Keeping tillage operations to a bare minimum is the key to ensuring a good seed bed by keeping tillage operations to a bare minimum. With minimum tillage, there are a number of benefits as compared to conventional tillage, including the reduction of field operations (Boserup *et al*., 2013) [3] and the reduction of field preparation costs and time. Compared to other soil types, the soil structure is not affected by the compaction of the soil as it is relatively low. As a result of runoff and erosion, only a small amount of water is lost to the environment. There has been an increase in the water storage capacity of the plough layer (Xu *et al*., 2018) [36]. There are two ways by which tillage can be reduced: by omitting operations that do not generate enough benefit for the cost to justify the effort. It is possible to combine agricultural operations such as seeding and fertilizer application in order to save time and resources. It is imperative to note that there are many types of minimum tillage systems, which include (a) row zone tillage, in which the primary tillage is done with a mould board plough across the entire field, and the secondary tillage operations such as discing and harrowing are limited to the row zone. Following the primary tillage, a specific planter is employed to sow plough plant tillage after the primary tillage. A planter is able to pulverize the row zone in a single pass across the field, and then broadcast the seeds in one pass. In the wheel track, ploughing is carried out as usual, but primary ploughing is done as usual (Ahmad *et al*., 2018) [1]. In order to sow, a tractor is used, and the tractor's wheels are used to pulverize the area where the seed is to be planted. These three types of tillage systems all use the same type of tillage as a primary method. Secondary tillage is being replaced by direct sowing. In this case, the seed is sown directly into the row zone and covered by the machinery that is used for doing so. There is a strong correlation between the structural condition of the soil and its fertility. As a direct result of the tillage system, the first changes that can be observed are the crushing of the structure and a change in the physical properties. The temperature, chemical, and biological regimes of the soil are regulated by the solid phase/porous space ratio (Moraru *et al*., 2015) [21]. In terms of soil structure, minimal tillage technologies contribute to the rebuilding of the soil structure by reducing the number of interventions made on the soil surface. This leaves more organic matter on the surface of the soil. It has been found that the mulch present on the soil surface protects and improves the structure of the soil (by transforming under the influence of macro-and microorganisms in the soil) (Zavalin *et al*., 2018) [38].

Ridge tillage: As the name suggests, ridge-tillage is the process of scraping and concentrating topsoil in a specific area in order to raise the seedbed above the natural topography of the area. It seems that the ridge-tillage system is also an essential component or sub-system of a successful market-oriented agriculture strategy in order to establish a sustainable agricultural system in an environmentally sound manner (Wani *et al*., 2016) [34]. It is common throughout modern agriculture to use tractor-driven ridge-tillage implements as opposed to conventional hand-operated implements in order to perform this task. There has been a long history of the use of ridge-tillage in traditional agriculture across a variety of soil types, rainfall regimes, and biological environments, as well as crops, socioeconomic conditions, and crops of the past (Lal *et al* 2020) [19]. In order to dig a 12-20 centimeter trench between rows of maize (*Zea mays*) or soybeans (*Glycine max*), a special cultivator is used. The same crops are grown on top of the same high hills every year, no matter what the weather is like. It is thus a type of reduced-tillage system, in which weeds can be controlled to a certain extent by inter-cultivation done at the time of reforming/forming ridges at four to six weeks after the sowing of a row crop. Inter-cultivation at the time of reforming/forming ridges is thus a type of reduced-tillage system in which weeds can be controlled to some extent by inter-cultivation done at the time of reforming/forming. Efforts are being made to eliminate secondary and primary tillage, as well as to reduce the use of herbicides in order to reduce costs. As with the old method, ridge-tillage also has significant advantages in terms of water management and erosion control in modern agriculture, just as the old method did (Yang *et al*., 2021) [37].

Puddling or wet tillage: Wet tillage, or puddling, is a tillage process that is usually applied to soils that have standing water and are known as wet soils. This type of tillage is usually performed on soils that have standing water. A puddling operation can be defined as plowing the soil repeatedly in standing water until the soil becomes soft and muddy as a result of repeated plowing. An impervious layer beneath the surface of a pond can reduce water loss through deep percolation, as well as provide a soft seed bed for growing rice (Kumar *et al*., 2019) [15]. Ponding can have many benefits, including creating an impervious layer beneath the surface to reduce water loss through deep percolation (Kumar *et al*., 2019) [15]. The most effective way to incorporate green manures and weeds into the soil is for them to be puddled in both directions at the same time. It is well known that wet tillage destroys the soil structure and the soil particles that are separated during puddling settle later on as they are reabsorbed back into the soil as they are reintegrated back into the soil. It is clear that wet tillage is the only method that can be used when it comes to preparing the land for the

transplantation of semi-aquatic crop plants such as rice. Although this is true, depending on the type of soil and the texture of the soil, puddling can have a wide range of effects on soil quality (Zhou *et al*., 2014) [39]. It is commonly found that fine-textured soils with a well-developed soil structure and a high percentage of water-stable aggregates primarily contain sesquioxides and nonexpanding clay minerals. In the absence of a puddle, these soils retain a large portion of their soil aggregates even when immersed in water (Kalita *et al*., 2020) [12]. Soil aggregates in these soils must be removed intensively by puddling. When aggregates are destroyed in soils, the physical and chemical properties of these soils are significantly affected (e.g., pH, potential, and the solubility of plant nutrients), as a result. Despite the fact that clay minerals are found in a wide range of forms, fine-textured soils can scatter rapidly without wet tiling even when they contain many varieties of clay minerals (Quesada *et al*., 2011) [27].

Conclusion

The modernization of agriculture has resulted in an increase in intercultural operations as well. In the course of intercultural operations, the use of machines results in the disruption of soil quality and soil structure as a consequence of the use of machines. It is tillage operations that are primarily responsible for distorting the soil structure as a result of soil disturbance. When carried out over the course of a short period of time, tillage can be very beneficial if done in a timely manner. However, in today's world, people are using too much tillage, resulting in soil properties being damaged due to excessive tillage. As a means of managing these effects, tillage reduction techniques are employed. In the minimal tillage system, only minimal tillage operations are performed, and approximately 50% of the crop residue is left in the soil after harvesting has taken place. There are certain tillage operations that are only done when ridge tillage is used. It is also important to note that mulching practices improve the moisture content of the soil and prevent soil erosion as well. As a result of all of these methods, we are able to reduce tillage. This is able to save the soil structure from destruction and increase crop yields at the same time.

Acknowledgement: It is with great appreciation that the authors would like to acknowledge the Department of Agronomy at Lovely Professional University for their constant support and encouragement throughout the research process.

Author contributions: In addition to contributing to the outline, the author is responsible for leading the draft and editing of the manuscript. It was MS and RK who conducted an extensive literature search and contributed to the writing of sections and the construction of figures and tables. In addition, they contributed to the construction of figures and tables. In addition to providing professional advice, PK helped revise the final version of the document and participated in its revision. In the end, all authors read and approved the final version of the manuscript.

Conflicts of interest: None.

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