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Minimization of Soil Disturbances for Improving Soil Health and Crop Yield

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Abstract—*Deterioration of soil health is one of the major constraint responsible for decreasing trends in agricultural production and productivity in specific. Organic matter depletion due to past degradation is alarming since the mid 20th century. Soil organic matter losses even a small pool will have not only major impact on productivity of crops but also has major effect on soil physical properties, chemical properties, soil flora and fauna and soil health in total. The advent of reduced-and no-till systems has greatly influenced to capture and retain moisture in the soil during cropping non crop periods to a great extent and it made possible to reduce fallow intensity and in turn helped in increasing cropping intensity in the production systems. In this paper, different types of tillage systems have been discussed in order to minimize the soil disturbance and to increase the soil health.*

1. INTRODUCTION

The world is facing population explosion one side and on the other side there is an urgent need to increase farm productivity and total food production on sustainable basis without deteriorating the natural resource base and environment. Several efforts were made to improve the efficiency of production system and resulted in different variable. Now, this paper concentrating on tillage, is first and an important step and an integral part of in crop production. The basic objective of tillage is to modify soil physical conditions favorable for crop growth and development. Tillage is the single most expensive component of crop production and cost of cultivation can be reduced be reduced if tillage operations are minimized or reduced to the possible extent where ever possible to achieve sustainable productivity. To overcome the weed menace due to minimum tillage, herbicides (weedicide) introduced in the agriculture during 1960s, led to the change in the concept of intensive tillage to less intensive tillage operations like conservation tillage, reduced tillage or zero tillage and no tillage. Further, climate change, health risks are associated with chemical agriculture and global warming issues are immediate concern to mankind. In modern agriculture, more emphasis is being given to carbon sequestration in soil increase soil carbon content. All the above factors forced the agricultural scientists to rethink about the utility of tillage for safe crop production.

Depending upon the kind, amount and sequence of soil disturbance during seedbed preparation, tillage systems may be grouped in to two classes a) Conventional tillage b) Conservation tillage.

Conventional tillage: It refers to a tillage system that has been developed traditionally and followed by the farming community depending on the type of soil, climate, crop and socio-economic status. It includes a combination of primary and secondary tillage operations normally performed to grow a particular crop in a given geographical area. It is also known as 'clean tillage'. SSSA (1987) defines conventional tillage as "a process of ploughing and cultivation which incorporates all residues and prevents growth of all vegetations, except the particular crop desired during the growing season".

Conventional tillage is a system that involves maximum tillage operations in two steps: primary tillage (cutting and loosening of soil and incorporating crop residues/stubbles into the soil), and secondary tillage operations (pulverization and compaction of pulverised soil, after sowing operations, weed controlling, intercultural operations, etc.). Although definition of conventional tillage (clean tillage) by SSSA (1987) emphasizes the incorporation of all crop residues, conventional tillage also includes systems in which crop residues are either removed for cattle feed, fuel or fencing material, etc., or heaped in the field and burnt before tilling the land.

The resource poor farmers in developing countries traditionally use animal drawn wooden ploughs (country ploughs) for cutting and loosing the compact soil followed by wooden planks, with or without iron nails, etc., moved repeatedly on the soil surface to break clods, pulverise soil, level field and slightly compact the soil surface. Seed is sown

by broadcast method or in rows behind the plough manually or by using animal drawn seed drills. Light planking is done after sowing. In mechanized farming (developed countries) tractor drawn heavy ploughs, such as mold board or disc ploughs are used for cutting, loosening and inverting the soil. The large clods are broken and soil is pulverized by using disc harrows or rotary tillers. In the conventional tillage system, the soil surface at the time of seeding is practically bare. And these are following advantages of conventional tillage are as follows

- No or minimum interference of crop residues with sowing
- Incorporation of fertilizers and other amendments is facilitated
- Water infiltration is improved
- Increased roughness at soil surface enhances temporary surface water storage, thereby decreasing surface runoff and increasing infiltration
- Decreases mechanical impedance in the seedbed and root zone
- Incorporation of organic residues favours microbial activity in soil
- Controls proliferation of insect, pests and diseases by burying residues in soil

Disadvantages of conventional tillage are:

- It makes soils loose and bare, and thus increases their vulnerability to erosion by water and wind
- Repeated conventional tillage results in decline in soil organic matter content
- Destroys soil aggregates and deteriorates soil structure
- It is cost-intensive

Conservation Tillage: Conservation tillage in a broad sense is tillage operation that is less intensive than conventional tillage. In this conservation tillage, land preparation and sowing operations are combined in one operation or primarily tillage operations are eliminated altogether. The most important component of conservation tillage is the retension of crop residues on soil surface.

The Conservation Technology Information Centre (CTIC, 1993) in India, USA, has defined conservation tillage as "tillage and planting system in which atleast 30% of the soil surface is covered by plant residue after planting to reduce erosion by water and wind atleast 1000lbs of flat small grain residue per acre (1120 kg/ha) should be put on the surface during the critical erosion period. Conservation tillage is an umbrella term and covers all tillage systems that are less intensive than the conventional tillage. The CTIC has sub-divided the conservation tillage into four systems:

a) No-tillage (also called no-till, zero tillage, slot planting, sod planting, ecofallow, chemical fallow, direct drilling)
b) Reduced tillage
c) Stubble mulch tillage, and
d) Ridge tillage (Parr et al., 1990).

Some researchers are of the view that reduced/minimum tillage or zero/no-till system should be considered under conservation tillage only if it does not destroy or burry all plant residues, and leaves some residues as soil cover.

The success or failure of conservation tillage depends on the use of herbicides, crop residues management and efficiency of planting equipments to place seed in soil below the residues. Conservation tillage has the following advantages:

- Protects land against erosion
- Increases soil organic matter content
- Increase activity of soil flora and fauna
- May cntrol some plant diseases by encouraging activity of organisms in soil that are antagonistic to pathogens, or may modify soil environment to favour multiplication of selected organism
- Improves soil structure and associated soil physical properties
- Lowers cost of cultivation

Limitations of conservation tillage are as follows

- The residues left on soil surface may lead to phytotoxicity or allelopathy on the subsequent crops.
- It may increase the incidence of plant diseases by providing crop residues left on soil surface as a source of overwintering survival rate of pathogen propagules.
- Sowing of seed under crop residues requires special planting equipments.

No-tillage: It is a method of planting crops that involves no seedbed preparation, other than the opening of soil for placing seed at the intended depth (SCSA, 1982). In this tillage system, crop residues are largely retained on soil surface without removed or burnt or animal grazing, etc. The seed is placed in soil by cutting small slits or by punching holes in the soil. In extreme cases, seed is broadcast on untilled soil and the germination is assured by covering seed with residues (protected against bird damage) and by regulating optimum soil moisture regime through irrigation management. This practice is being followed in the rice growing areas of Nepal, where wheat is broadcasted in wet/moist rice stubbles after rice harvest (2-3 days of rice harvest) In the north western parts of India, planting of linseed immediately after rice

harvest in untilled wet/moist soil is a common practice (paira cultivation) and later weeds are controlled by herbicide usage.

Repeated tillage operations are performed by farmers basically for two reasons, one to weed control menace and to get congenial environment for seed to germinate and establishment. In no till system, herbicides replace tillage for weed control, and favourable environment to seeds is provided by the decaying crop residues on soil surface, which acts as mulch to conserve soil and moisture and improve soil productivity and soil health (chemical, physical and biological).

No tillage system has the following advantages:

- Saving in time, energy and labour and cost effective.
- Favours timely sowing ofcrops; particularly usefull in rice-wheat syatem, where wheat yields are low due to its late planting because of large turn-around time between rice and wheat caused by slow drying of wet rice soils.
- Increase in soil organic matter content.
- Moisture conservation, by decreasing evaporation losses and increasing water retention properties of soil.
- Soil conservation by reducing water and wind erosion.
- Improvement in soil structure and associated soil physical properties (aeration, water retention, infiltration, drainage).
- Favours prolific growth of soil flora and fauna beneath the litter. Increased earthworm and arthropod activities have been observed under no-till system. They improve soil quality in the long run by improving soil structure and other soilproperties.
- In hot climates, residues with no-tillage system keep the soil temperatures coolerthan under conventional/clean-tillage system by increasing albedo. Crop residues also reduce heat fluxes into soils as the thermal conductivity is lower of residues than of a mineral soil. It benefits crops by avoiding high temperatures that may be detrimental to root growth and soil faunal activities.

Limitations of no-till are:

- Harbor incidence of disease and pests as crop residue act as source of inoculums
- Delayed germination, emergence and establishment due to change in the microclimate and crop residue act as physical barrier
- In humid and high rainfall area, reduced aeration leads to less evaporation resulting in waterlogged condition and poor drainage resulted in enhanced nitrate leaching and denitrification have been observed (Rice and smith, 1982; Blevins *et al*., 1985)
- No-till if, sufficient surface cover (crop residues) to the desired level not put, autimatically decreases infiltration and increases surface flow in hard-setting soils or clay soils in arid/semi-arid regions results in formation of surface crusts after heavy rainstorms.
- In arid, tropics and subtropics, major constraint in adoption of no- till system is non availability residues, as there is huge demand for crop residues as cattle feed, fuel or fencing material.
- Requires special equipments for sowing of seeds under crop residues incorporated field.

2. REDUCED/MINIMUM TILLAGE

As the name indicates, it is a tillage system less intensive and name indicates elimination or reduce one or more tillage operations which are not so essential and won't affect the crop productivity due reduced tillage operations and are absolutely necessary for crop production under a given set of soil, crop and climatic conditions. Generally primary and secondary tillage operations are combined together in reduced tillage. Land preparation and seeding is done in one operation. Primary tillage is eliminated; crop residues may or may not be retained on the soil surface. Crop residue is retained on soil surface to conserve soil and soil moisture during the rainfed areas. Under irrigated conditions, reduced tillage system may be practiced after removing residues from the soil surface. The practice has largely been adopted in alluvial soils of the Indo-Gangetic Plains, where wheat is planted with minimum tillage operations in lean fields. Several variations of minimum tillage systems are in use globally, varying in degree from almost no tillage to nearly full conventional tillage (Unger, 1984).

The major advantages of minimum tillage over conventional tillage may include:

- Better soil and water conservation
- Time, energy, labour and cost effective

Disadvantages associated with minimum tillage system are;

- Poor seed be preparation resulting in reduced germination and crop stand
- Problems of diseases and pests

3. STUBBLE MULCH TILLAGE

Any tillage operation that retains crop residues on the soil surface is called as stubble mulch. It is defined as "tilling thesoil so that plant residues or other materials are retained to cover soil surface" (SCSA, 1982). It is also known as mulch farming, mulch tillage or ploughless farming.

In the stubble mulch farming, soil surface is undercut to control weeds and prepare the seedbed in such a way that most of the crop residues are retained on the soil surface. Subsurface tillage implements like chisel ploughs are used for the tillage purpose. Stubble mulch tillage was basically designed to control wind erosion, but it controls water erosion as well.

Advantages of stubble mulch tillage are:

- Wind and water erosion control
- Cost effectiveness

The main disadvantages of this system are:

- Difficulty in performing tillage operations in the presence of large amounts of residues
- Difficulties in tilling due to higher soil and water content as a result of reduced evaporation and poor weed control when precipitation occurs soon after tillage.
- Requires special implements for sowing.

4. RIDGE TILLAGE

Ridge tillage is "a method of land preparation whereby the top soil is scraped and concentrated in a defined region to deliberately raise the seedbed above the natural terrain" (Lal, 1990). In this system, crops may be grown on ridges or in furrows depending on the moisture status of soil. In poorly drained, wet soils, crops are grown on ridges with one or more rows per ridge. In dry and sub-humid areas, crops are grown in furrows, which favour in-situ moisture conservation by retaining rain water and decreasing evaporation losses.

Ridge tillage is adapted to a wide range of soils, crops, rainfall regimes, ecological environment, socio-economic and cultural conditions (Lal, 1990). On sloping landscapes (with usually less than 7% slope), ridge planting is particularly effective in soil and water conservation. The excess surface water can easily and safely be disposed off on sloping lands via furrows. However, ridge furrows need to be properly designed and constructed, otherwise surface water may concentrate at spots above the ridges and cause their breaching, resulting in severe erosion damage.

The concept of raised-bed planting, another variation of ridge tillage, was recently experimented by Rice-Wheat Consortium (CIMMYT, IRRI, NARS and IARCs) in the Indo-Gangetic Plains cultivating rice-wheat system. The objective eas to economize on irrigation water in rice cultivation and increases water productivity in wheat cultivation. In this system, rice is planted on permanently maintained broad-beds (30-40 cm), 2-3 rows per bed. Irrigation is applied in furrows at the defined intervals. The furrows cover about 40% area in the plot. Since rice is sown on about 60% area of the plot, there is a saving of seed. The yield loss due to decrease in plant population is expected to be compensated by realizing the border effect on raised beds. The studies have revealed that growing rice on permanently raised beds, under aerobic condition may save 35-40% of irrigation water, without showing a significant yield decline. The saving in water could be more if the technology is combined with (LASER) field levelling and better farm layouts. Coupled with water saving, bed planting shows promise for better nitrogen management. The technique, however, needs thorough investigation to answer several questions on irrigation scheduling, weed control, suitability of rice cultivars for bed planting, salt dynamics in normal and salt affected soils, etc.

Significant advantages of ridge tillage system are:

- Effective soil and water conservation technique on sloping lands.
- Effective in conserving water in root zone in semi-arid to sub-humid regions; in dry-land farming helps to conserve soil moisture.
- On shallow soils, cultivating crops on ridges increase the effective rooting volume.
- On poorly-drained soils, ridge tillage improves soil aeration and makes possible the successful cultivation of upland crops.

The limitations of ridge tillage include:

- Requirement of special equipment for establishing ridges.
- If ridges are maintained permanently for few cropping seasons, especially under low rainfall conditions, there is danger of increase in salt content in ridges due to upward flux of salts along with water.
- Involves additional cost if ridges are to be constructed every cropping season.

5. CONCLUSION

Resource base conservation tillage systems like no-tillage, reduced tillage, stubble mulch tillage, ridge tillage systems helps in improving the soil fertility and health by incorporating the part of the crop residues. The crop residue left on the soil surface increases soil organic matter content and microbial population and also acts as a barrier for soil erosion due to water and wind. Finally protects the top soil which is foremost important for crop production. Reduced/minimum or no tillage or stubble mulch not conserve the resource base but also reduces the cost of production, environment and can achieve the ecological base for the future generation.

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