International Journal of Science, Environment and Technology, Vol. 6, No 2, 2017, 1215 – 1222
ISSN 2278-3687 (O)
2277-663X (P)

Review Paper

MANAGEMENT OF SOIL PHYSICAL CONSTRAINTS –A REVIEW

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Abstract: The enhanced soil productivity and assured sustainability are the two major issues of concern in order to feed the increasing population of the world. The alleviation of soil physical constraints limiting crop production is considered important to increase agricultural production and sustaining the productivity of soils. The major soil physical constraints include high soil permeability, soil surface crusting, sub-surface mechanical impedance and soil hardening. Studies indicated that management of highly permeable soils such as by compaction increased yields of various crops. Soil surface crusting could be managed by application of FYM on seed lines at the rate of 4 t/ha. Application of tank silt has improved the physical properties of soil like reduces the bulk density and improved the water holding capacity of the soil. The objective of this paper is to present the various results of several field experiments conducted during the last two and a half decades to identify soil physical constraints limiting crop production and different options for their management.
Keywords: compaction, Physical constraint, Soil crusting, compaction.

Introduction

The enhanced soil productivity and the assured sustainability are the two major issues of concern in order to feed the increasing population of the world. There is growing realisation that the crop yields are now more often limited by the soil physical conditions rather than plant nutrient status in the soil. This envisages that for increasing crop production, soil must be maintained in such a physical condition so as to allow adequate crop growth (Agarwal, *et.al.,* 1995) The major emphasis for the development of management technology had been the manipulation of soil physical conditions through tillage, soil amendment and crop residue management, to improve crop growth and better utilisation of water and nutrients.

Soil compaction

Soil compaction (Silent thief)

Compaction occurs when a force compresses the soil and pushes air and water out of it so that it becomes denser. Compaction is more severe when the soil is wet and less able to withstand compression (Ghildyal, 1969). Dense layer may develop either due to formation of

*Received Feb 24, 2017 * Published Apr 2, 2017 * www.ijset.net*

a plough sole as in the case of rice fields on medium textured soil, use of heavy machinery on a moist soil or presence of kankar (calcium carbonate) layers. These layers are relatively impervious and as a result water may stagnate on the soil surface after heavy rainfall or irrigation causing oxygen stress to the crops. Thus, shallow root system makes the plant drought prone during dry spells and promotes lodging during unusually wet conditions.

Compaction is a concern because it affects plant growth. There are not enough pores or spaces in compacted soil to allow unrestricted root movement, infiltration, drainage or air circulation. Restricted roots are often unable to take up sufficient water or nutrients from the soil. Result is less plant growth and lower yields, particularly during periods of drought.

Causes of soil compaction

Most common causes of compaction on farms are animals and machinery, mostly tractors and heavy cultivation and harvesting equipment. The degree of compaction depends on the force compressing the soil, the contact area with the soil, the strength in the soil and the type of soil. Animal hooves and tyre width has effect on soil compaction. The near-surface compaction is reduced as tyres become wider. If we plough regularly to the same depth the soil compacts under the plough and forms a plough pan. Ploughing wet soil causes greater compaction than ploughing dry soil. As well, it may reduce water and air movement. Some soils are more prone to compaction than others, particularly soils with a lot of fine sand and silt and little organic matter. Wet clay is much more easily compacted than dry sandy soil. Some clay is more prone to compaction than others because of their high sodicity (high levels of sodium in the clay).Tillage is often required to correct these problems to facilitate proper seed placement for the next crop. ***Phogat*** and ***Dahiya*** **(2002).**

Effect of compaction

Soil layers are relatively impervious and as a result water may stagnate on the soil surface after heavy rainfall or irrigation causing oxygen stress to the crops. Thus, shallow root system makes the plant drought prone during dry spells and promotes lodging during unusually wet conditions.

The Direct sowing treatment resulted in a significantly lower maize yield than the Chiesal Plough and mouldboard Plough. The percentage decreases ranged between10.7 and 15.2%, respectively. Although soil compaction was much greater in the first 200 mm in direct sowing than in Chiesal Plough and mouldboard, these differences were small. An overriding factor may have been that for the three growing seasons, the rainfall patterns were particularly favourable for maize growth. This favourable rainfall may have overridden the higher compaction level in the direct sowing treatment. (Botta *et al.,* 2010)

Preventing and Remediating Soil Compaction

Soil compaction can be best prevented by staying off wet fields. Subsurface drains and contouring promote drainage helping the soil dry out. Tire inflation pressure may be lowered as this spreads the axle load over a larger surface area. This is especially effective when all field implements have the same working widths (preferably large). Because the suppressed growth strips are narrow, plants growing adjacent to the compacted tramlines will have access to additional light, water and nutrients, hence produce compensatory growth. Soil Hydro-Physical Characteristics are highly influenced by the application of organic residue management which in turn increased the yield in paddy. (Saha and Mishra, 2009).Always driving over the same tracks (tramlines) reduces overall field compaction. Deep tillage is often suggested as a method of breaking up plough pans. Deep tillage is likely to be most effective if performed when the soil is very dry in late summer after harvest of a cereal or forage crop. It may be best to try deep tillage in a small test area known to have a subsurface compaction problem**.**

Chisel technology for sub soil hard pan

In Tamil Nadu red soils occupy 8 million hectares which constitutes 62 per cent of the total geographical area. The occurrence of hard pan or soil compaction at shallow depths is the major prevalent soil constraints in these soils. Agricultural crops are not able to enjoy the full benefits of the soil fertility and nutrient use due to this soil compaction.Reason for the formation of sub soil hard pan in red soil is due to illuviation of clay to the sub soil horizons coupled with cementing action of oxides of iron, aluminium and calcium carbonate. Sub soil compaction – high bulk density (> 1.8 Mg m^{-3}) which leads to lower infiltration, lower water holding capacity, lesser available water and reduced air movement and nutrients with concomitant adverse effect on the yield of crops. Basker *et. al.,*(1995) reported that if the bulk density increases the yield of the crops such as Sunflower, Bhendi and Greengram get reduced drastically. In the same experiment they could find that there is an inverse relationship between Hydraulic conductivity cm/h) and Bulk Density Mg /m^3. Bulk density of the soil has great influence on maize yield (Jat *et. al*., 2006)

Types of soil compaction

Soil compaction is classified as surface and subsurface compaction. Surface compaction is usually caused by high contact pressure between the wheel and the soil surface, and is related to the tyre inflation pressure. Surface compaction is a smooth shiny surface of wheel tracks due to reduced pore space, and water laying in the wheel tracks due to reduced natural drainage. Freeze-thaw cycles in spring and Use of forage crops in a rotation naturally loosen compacted soil. Surface compaction can be reduced by reducing traffic, using lighter machines, using dual wheels and larger tire sizes and reducing tire inflation pressure.

Subsurface compaction, often called a plough pan, is usually more problematic than surface compaction. Since it is not easily detected and is not corrected by natural freeze thaw cycles. It caused both by tillage and by traffic with heavy field machinery. Repeated tillage operations over several years can contribute to both the formation and downward extension of a plough pan**.** Ishaq *et. al.*, (2001**)** reported that subsoil hardpan reduced the uptake of NPK nutrient in wheat grain and straw during two years of their study**.**

Soil compaction is becoming a more serious problem for farmers. Field machines tend to be heavier, and there is motivation for farmers to work the soil when it is too moist. Because compacted soil has smaller pores and fewer natural channels, water infiltration is drastically reduced. This causes greater surface wetness, more runoff, which in turn increases erosion, and longer drying time. Wet fields delay planting and harvesting and decrease crop yields. Plant roots don't grow well in dense soil. Inadequate moisture and nutrients reach the plant, and yield is reduced. The level of compaction is specific for specific soil-climate crop combination. (Bandyopadhyay *et .al.,*2007)

Fluffy paddy soil

Low bulk density of the topsoil, sinking of farm animals and labourers and Poor anchorage to paddy seedlings are the major characteristics of fluffy paddy soil. It is Caused due to puddling, which breakdowns the soil aggregates into a uniform structureless mass and flooding which leads to soil in the state of flux so that mechanical strength lost. For managing these soils techniques like eight times passing of 400 kg stone roller or oil drum with sand inside, Soil should be semi dry condition, addition of lime @ 2t /ha once in three years can be used.

The conventional method of tillage and planting for rice (*Oryza sativa* L.) production in central Iran is wet tillage (puddling) and manual transplanting. In this region, four-wheel (two-wheel drive) tractors are commonly used as the power unit for the puddling operation.

The sinkage of tractor wheels during the puddling may deepen the hardpan layer and would create problems if mechanical transplanting was adopted due to the difficulty of the traction wheels moving through the puddle soil. Due to the shortage of irrigation water and increasing labour cost in recent years, researchers are seeking alternative soil management that would reduce water requirement and facilitate mechanisation of rice transplanting.

Two systems of soil preparation (compaction and puddling) were studied for possible utilisation with a two-wheel rice transplanter in a very gravelly clay loam soil (Typic Haplocalcids, USDA; Haplic Calcisols, FAO). Compaction was done with a tractor equipped with a 5Mg roller, whilst a rotary tiller and a locally made rigid-tine field cultivator, named Khishchee, were used for puddling.

The transplanter worked well following both compaction and puddling rice soil preparation treatments. However, wheel slippage of the transplanter following compaction was less than after puddling. Transplanting was more uniform and seedling establishment was high after the compaction treatment as compared to puddling. In the soil compaction treatment, paddy yield was higher and plant lodging was lower than after puddling. Soil compaction reduced both water requirement and growth period of rice. These results suggest that soil compaction is a practical and perhaps a better method for mechanized rice transplanting than puddling in very gravelly soils (Hemmat and Taki, 2003).

Plant residue is very important for regeneration and maintenance of soil structure in the transplanted rice ecosystem, but for various reasons, the amount of residue being returned to the soil is inadequate. Organic matter is known to improve soil physical health, and its effect is commonly associated with sustainable crop production.

Incorporation of organic materials, either in the form of crop residues or farmyard manure (FYM), enhances the organic matter of the soil which has direct and indirect effects on soil physical properties and processes. Application of plant residue to soil is known to have beneficial effects on soil nutrients, soil physical condition, soil biological activity, and crop performance (Lal,1985; Sharma and Bhagat, 1993; Tanaka, 1984).

Monocropping of lowland rice is the predominant system in valley land and high-rainfall regions of northeastern India. Recently, the unsustainability of this system has owing to soil structural deterioration and nutrient depletion, become evident, resulting from continuous puddling on the same piece of land even if recommended inorganic fertilizers have been applying regularly. To regenerate and maintain soil structure in rice fields, farmers in this region frequently use farm yard manure (FYM), but low availability of FYM because of its other uses indicates that it could not meet the organic matter requirements of this system. (Phogat and Dahiya, 2002)

Hemmat and Taki (2002) reported that compacted rice soil requires less water and yield of the crop is also get increased due to reduced percentage of crop lodging. We evaluated the long term effects of different locally available jungle grasses and weeds on soil hydro-physical properties and rice yield through a 5-year field experiment (2000 to 2005) at the Indian Council of Agricultural Research (ICAR) Complex for North Eastern Hilly (NEH) Region, Umiam, Meghalaya, India and also compared their negative or positive effects with FYM in acidic, Typic Hapludalf soil.

The objective was to determine whether locally available grasses (Jungle grass) and weeds (Ambrosia sp.) could be used as alternative sources of organic materials for lowland rice in scarcity of FYM. Results showed that incorporation of FYM or jungle grass or Ambrosia sp., continuously for 5 years in puddled rice soil improved soil organic carbon (SOC) by 21.1%; the stability of micro-aggregates, moisture retention capacity, and infiltration rate of the soil by 82.5, 10, and 31.3%, respectively; and soil bulk density decreased by 12.6%. Application of FYM produced better soil physical environment than that under jungle grass and Ambrosia sp.

However, as these grasses and weeds contained higher nutrient levels than FYM and increased the SOC slowly, these organics may serve as alternative to FYM and may have a dramatic effect on long-term productivity of rice. The gradual improvement in soil physical properties led to a significantly higher yield of rice (Saha and Mishra., 2009). Phogat and Dahiya,(2002) reported that application of green manure and FYM increased the bulk density of rice soils there by it increased the rice yield .

Soil compaction with six passes of 1,500 kg tractor driven roller was found to be effective in water and nutrient retention, and the yield of various crops in highly permeable sandy soils. Application of FYM on seed lines at the rate of 4 t ha^{-1} as mulch was very helpful in reducing the ill-effects of surface crust on seedling emergence and crop establishment in crust prone sandy loam and loamy sand. Tillage operations with chiseller was effective in breaking the high bulk density sub-soil layer and resulted in increased water entry and crop yields. Burning of the residues of rice and wheat gave higher yields of both the crops in rice-wheat cropping system. Use of *sesbania* as a green manure was found to be helpful in sustaining the productivity of this system with reduced fertilizer inputs.

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