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Role of cover crops in improving intensively exploited soils in agriculture: A review

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Abstract
Cover crops are helpful in sustaining the once fertile soils that has been exploited scientifically to produce more food for the population. Cover crops are the plants that are grown for protection and enrichment of soil, managing soil erosion, maintaining soil fertility, smothering weeds, enhance water availability, help to control pest and diseases and to increase microbial biodiversity in the soil environment. Naturally with benefits comes the Limitations of cover crops and pose some small problems.

Keywords: Cover crops, Soil quality, Soil fauna, Nitrogen management, Weeds suppression

Introduction
Agrarian's most important concern at global level is how to overcome the environmental pollution excessive and non-judicious use of pesticides, pesticide residual load in environment and exhaustion of natural resources. These have impelled the researchers towards sustainable agriculture. Sustainable agriculture comprises of different components like retaining crop residues on soil surface, crop rotation, minimum tillage and another important component of sustainable agricultural is cover crops. Earlier the cover crops were used to grow as green manure crops, as animal feed or to surpass the drought period in rainfed areas but now a days the most important use of cover crops is for the conservation agriculture mainly in no-tillage or reduced tillage farming systems. The cover crops used to control wind and water erosion (Naderman, 1991) [47], suppress weeds, improve nutrient and water availability (Sullivan *et al*.,1991; Sainju and Singh 1997 and Kasper *et al*., 2001) [53, 1, 30], improve water quality by reducing nitrate leaching (Kinyangi *et al*., 2001) [31], integrated pest management, etc. These may be annual, biennial or perennial and can be legume or non-legume. Residues of cover crop abet in escalating organic matter content of the soil. The remains of the cover crop on the surface decompose and also benefit to make contribution to the system. As most of the organic matter comes from them (Kuo *et al*., 1997) [33]. The sowing of cover crops can be initiated in same ways like as green manure, utilized as living mulch and as a companion crop along with the main crop.
Cover crops act as scavenger of residual nitrogen (N). Leguminous cover crops convert residual N to proteins. Nitrogen uptake by the succeeding crop depends on cover crop species grown, seed rate, time of planting and the most important is stage of harvesting and climate. The non-leguminous cover crops are also grown to endow soil cover and in improving the biological, chemical and physical characteristics of the soil. Green manures mainly helps to augment soil fertility levels and organic matter (Doran and Smith, 1987; Power, 1987) [16] and in increasing nutrient holding ability (Drinkwater, *et al*., 1998; Dinnes, *et al*., 2002) [17, 14]

Soil Parameters
i. Soil quality
By providing the soil stabilizing root system and the large quantity of crop residues on soil surface, the cover crops are considered as the tool for improving soil quality and reducing soil erosion (Hargrove, 1991) [25]. Although cover crop residue helps reducing soil erosion as the residues on the surface act as a physical blockade which dispel raindrop energy and protect the top fertile soil from the runoff effect as compared to bare soil surface (Edwards and Burney, 1991) [19]. Cover crops also act as hurdle to wind and water erosion by slowing down wind and water velocity at ground level (Walker, *et al*., 2006) [63]. The roots of these crops also helps to increase soil porosity and infiltration which will also help to reduce the surface

runoff from the field which will in turn results in reduction of nutrient leaching losses and thus improve the soil and water quality also (McVay, *et al*. 1989; Kinyangi, *et al*. 2001) [42, 31]. An increase in soil moisture is linear proportional to the amount of cover crop residue on soil surface in a conservation tillage system compared to other tillage systems. Crop residue left on surface or added to the soil increase in soil organic carbon (Larson, *et al*. 1978; Havlin, *et al*. 1990) [35, 26]. Cover crop roots have symbiotic relationship with mycorrhizal fungi that secretes glomalin (glomalin is a water insoluble protein that helps in soil aggregation) into the rhizosphere (Wright and Upadhyaya, 1998; Wright, *et al*. 1999) [65] The soil aggregate stability depends upon the amount of dilute acid extractable polysaccharides (act as binding agents) in soil which was improved by the cover crops (Liua, *et al*., 2005) [36]. Cover crops also help in sustaining the nutrient status of the soil not only by scavenging atmospheric nitrogen but also by recycling the nutrients especially phosphorous. Cover crops like buckwheat (*Fagopyrum esculentum* Moench) and white lupin (*Lupinus albus* L.) by secretes acids that convert the unavailable insoluble phosphorus to soluble form in the soil. Similarly deep rooted cover crops helps in upward movement of calcium and potassium to the root zone.

ii. Soil Moisture

Cover crops improve water infiltration, decrease evaporation and to remove excess water for timely establishment of next crop (Unger, *et al*., 1998) [60]. Cover crop biomass acts as an obstacle between rainfall and the soil surface, which reduce the intensity with which raindrops fall on the soil resulting in steadily trickle down of the raindrop through the soil profile. Cover crop root growth enhance the soil macrofauna habitat resulting in the formation of soil pores, thus increasing water infiltration rate rather than draining off the field as surface flow. Increased water infiltration in turn recharge the water aquifers and soil water storage (Joyce, *et al*., 2002) [29]. The environmental risks to waterways and ecosystems downstream could often be reduced through growing cover crops which hindered the rate and quantity of water that drains off the field (Dabney, *et al*., 2001) [12]. Cover crops improved the bulk density and water retention capacity of different soils (Fageria, et., 2005; Villamil, *et al*., 2006) [20, 61].

iii. Nitrogen Management

Increased concentration of green house gases particularly CO_2 and N_2O in the atmosphere results in global warming which is a major concern now a days. The best way in reducing the concentration of CO_2 and N_2O in the atmosphere is to fix them in the plants and sequester them in the soil. The leguminous crops have a potential to biologically fix the atmospheric N in their root nodules thus reducing the N fertilizers requirement for the succeeding crop (Singh, *et al*., 2004; Decker *et al*., 1994) [52, 13].

The legume cover crops have an ability for enriching the soil with inorganic N whereas the non-legume cover crops enriched the soil with organic N through increased biomass production as compared with fallow/ no cover crop (Kuo, *et al*., 1997) [33]. It was also reported that N leaching from the soil profile can be reduced by incorporating non-legume cover crops in rotation which are better than legume or no cover crops (Meisinger, *et al*., 1990; McCracken, *et al*., 1994) [43, 41]. To sequester atmospheric C and N the agricultural soils can act as sink Lal, and Kimble, 1997 [34]. C and N in both particulate and mineral-associated soil organic matter was improved by growing cover crops compared to bare soil (Bayer, *et al*., 2001) [5].

iv. Nitrate Leaching

The cover crops have an ability in decreasing the nutrient particularly nitrogen requirement by succeeding crop by recapturing the nitrogen in its roots and biomass and also by prohibiting its downward movement through the soil profile and nitrate leaching into groundwater (Madson, 1998; Gabriel, *et al*., 2013) [39]. Ryegrass cover reduced the NO_3-N in the leachate considerably less than 5 mgL^{-1} compared to 10-18 mgL^{-1} without cover crop and reduced the total amount of NO_3-N leached i.e; 22 kg ha^{-1} without cover crop to 8 kg ha^{-1} with ryegrass inter seeded as cover crop in barley (Bergstrom and Jokela, 2001) [6]. In soil monoliths studies in a corn–soybean rotation reported that when oat and rye cover crops were interseeded in the rotation potentially reduce NO_3 leaching from lysimeters and recommended that the same trend would be true in the field (Logsdon, *et al*., 2002) [37].

v. Mycorhizal fungus

Mycorhizal fungus have a symbiotic relationship with plant roots for water and nutrient uptake. Cover crops enhance the arbuscular mycorrhizal fungi that can assist with water and nutrient uptake in plant roots and soil (Zak, *et al*., 1998) [69]. The soil aggregate stability was affected no -tillage management practices, active root growth and by proteins, particularly glycoprotein and glomalin, which are secreted by the mychorrhizal fungi which was increased by addition of cover crops in crop rotations (Wright, *et al*., 1998) [65]. In 1998, the workers reported that mychorrhizal fungi is essential for quick germination, growth and survival of some exhaustive crops like cotton (Zak, *et al*., 1998) [69].

vi. Soil fauna

In various studies on tillage and cover crop effect on microbial properties, it was reported that the conventional tillage (CT) and no-tillage (NT) plots with a ryegrass cover crop enhanced microbial populations (bacterial and fungal) in the upper 2 cm as compare to no-cover soils. The cover crops also increase the enzymatic activity was in upper 0–2 cm depth of soils with cover crop as compared without cover crops (Zablotowicz, *et al*., 2007) [68]. The hairy vetch (*Vicia villosa)* more efficiently increase the microbial biomass N, fluorescent pseudomonads, total and gram negative bacteria in upper 0-2 cm of soil as compared to ryegrass cover crop (Wagner, *et al*., 1995) [62]. Because of higher water content in upper soil layers and retention of borrows due to no till-conditions along with large quantities of crop left over on soil surface helps to increase the number and weight of earthworms in soil (Mele, and Carter, 1999) [44]. Cover crops help to increase the population of bacterial feeders, fungal feeder, plant feeders, omnivores and predator nematodes (DuPont, *et al*., 2009) [18]. Incorporation of cover crops leftovers often increase the bacterial biomass (Ferris, *et al*., 1996) [21].

Being labile and dynamic in nature Microbial biomass representing small percentage of soil organic matter, plays a considerable role in nutrient cycling and environment performance (Mahmood, *et al*., 1997; Wani, *et al*., 2003) [40, 64]. Type of crop or plant cover, cropping history of soils, fertilization and manuring have been found to influence microbial biomass. The positive stimulatory effect of FYM on MBC (microbial biomass carbon) was also recorded

(Bolten *et al*., 1985) [8]. Nevertheless, a smaller increase in MBC with more added FYM levels is not true and consistent (Goyal *et al*., 1995). Impact of diverse cropping systems extensively raised the soil MBC in two long-term fertilizer experiments at Iowa (Moore, *et al*., 2000) [46]. Inclusion of legume crop like greengram, pearl millet–wheat system increased MBC in semi-arid tropics of India (Chander, *et al*., 1997) [9]. Similarly mean bacterial count was observed to be more under soybean–wheat system than maize–wheat or cotton–wheat systems in parts of southern Brazil (Balota, *et al*., 2003) [3]. The wide variability in the microbial population across dissimilar locations, soil type, nutrient management practices, production system, and climatic conditions found to be true and consistent with earlier work (Kumar *et al*., 1982) [32].

Table 1: Commonly grown cover crops in India

Common name	Botanical name	Primary Benefits
Legumes		
Cowpea	*Vigna unguiculata L*	N production and enhance soil fertility
Berseem	*Trifolum alexandrinum L.*	N production and enhance soil fertility
Mustard spp.	*Brassica spp.*	Enhance soil fertility
Non Legumes		
Rye	*Secale cereale L*	Erosion control, N recovery
Wheat	*Triticum aestivum L*	Erosion control and N recovery
Oat	*Avena sativa L*	Erosion control and N recovery
Barley	*Hordeum vulgare L*	Erosion control and N recovery
Sorghum	*Sorghum bicolor L*	Erosion control and N recovery

Table 2: Nitrate-N lost through different treatments

Treatment	Nitrate-N lost (lbs/acre)	
	7-yr Total	7-yr Average
Corn – Soybean	321	46
Corn – Soybean w. Rye	136	20
Difference	185	26

Source: Kapsar *et al*, 2002-2004; *J. Environ. Qual.* 36: 1503-1511

Pest Management

i. Weed suppression

Cover crops can be used as an additional tool for the managing of weed population by exploiting their smothering potential which alter soil micro-environmental conditions, chemical and physical inhibitory effects however they have not been able to outperform weed control via chemical methods (Creamer,*et al*., 1996, 1997; Teasdale, *et al*., 1996, 1998; Price, *et al*., 2006; Yenish, *et al*., 1996; Barnes, *et al*., 1983; Rice, 1984) [11, 10, 59, 55, 49, 67, 4, 50].

Cover crop species, tillage methods and residue produced linearly represents the weed suppression potential by the cover crops (Teasdale and Mohler, 1992) [58]. The cover crops, if managed according to the conservation principles the weed suppression should be better because as the surface residue act as an obstacle in light transmission and daily soil temperature amplitude, will hinder the germination, growth and development of weed plant (Teasdale and Mohler, 1993; Teasdale, *et al*., 1993; Blum *et al*., 1997) [57, 7]. Cover crops can also compete for nutrients such as nitrates after cash crops harvest which will change the nutrient status of the soil also suppresses weeds by reducing the growth of weeds by altering the weed seed (Ditsch, 1992).

ii. Insect and Diseases

By following the conservation principle, crop rotation with cover crops will be helpful in breaking the insect pest life cycles. The incidence of *Rhizoctonia solani* will be reduced by 50 per cent if we incorporate alfalfa in a potato cropping system (Honeycutt, e al., 1996) [27]. The incidence of plant pathogenic nematodes were reduced when cover crops such as cereal rye, which acts as non hosts, were incorporated in various cropping systems (Minton, *et al*., 1986) [45]. In long term experiments, it was concluded that population of soil-borne pathogens was also reduced by incorporating cover crops in crop rotation (Hoorman, *et al*., 2009) [28]. It was also reported in the literature that if cover crops grown in rotation and should be killed early act as trap crop for corn earworm, tarnish bug, and other insects.

Limitations of Cover crops

Although cover crops have many benefits; they can also pose some problems:

i. Water limitations

In rainfed areas, incorporation of cover crops in crop rotation may consume water which should be required for growing the succeeding cash crop. Soil moisture removed by the cover crops may pose a problem in fulfilling the soil moisture requirement of the cash crop during the drought period. The competition between cover crops, as a living mulch or companion crop, and cash crops for the nutrients and moisture limits the adoption of this concept of conservation agriculture unless the living mulches can also be managed by other management techniques that reduce this competition (Teasdale, 1998) [55].

ii. Host to pest

Many insect species, strain of diseases and phytopathogenic nematodes have a large number of alternate hosts during the off season which will result in completing the life cycle of insect and pathogens that helps in vigorous spread of the major pest to the succeeding main crop. Cover crops can also act as an alternate host (Lu, *et al*., 2000) [38].

iii. Length of growing season

Obviously the soil temperature plays an important role in determining the length of the growing season. Where cover crops act as living mulch reduce the soil temperature to several degrees compared to bare soil and polythene mulch that results in delaying the maturity period of the main crop by several days. So growing cover crops is only feasible where the length of growing season supports all the complete phenological stages of growth and expression in time during lien period of main crop (Abdul-Baki, *et al*., 1996; Ashworth and Harrison, 1983) [1, 2]

iv. Additional Costs

Increased cost of cultivation of the cropping system must be kept in mind where cover crops should be included in the systems. Cultivating cover crops requires extra expenditures for the seed and other management practices including labor cost. In no-till systems, special equipments are also required for managing the large quantities of cover crop residues. A shift from a conventional to no-till systems needed new farming machinery like no-tillage seeders, transplanters, mould board plough, mowers, etc. These farm machines also required large tractors. Small and marginal farmers cannot afford the cost of these machineries and secondly, some farmers also have reservation that whether these alternate cropping patterns results in sufficient advantages that justify the large investment made in these systems (Lu, *et al*., 2000) [38].

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