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ROLE OF CROP ROTATION IN SOIL HEALTH

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ABSTRACT

Increasing concern about the need to provide high-quality food with minimum environmental impact has led to a new interest in crop rotations as a tool to maintain sustainable crop production. We review the role of rotations in the development and preservation of soil structure. After first introducing the types of rotations in current practice and their impact on yield, we assess how soil and crop management in rotations determines soil structure, and in turn how soil structure influences crop growth and yield. We also briefly consider how soil structure might contribute to other beneficial effects of rotations, namely nutrient cycling and disease suppression. Emphasis is given to the influence of crop choice and, where relevant, interaction with tillage system and avoidance of compaction in the improvement and maintenance of soil structure. Crop rotations profoundly modify the soil environment. The sequence of crops in rotation not only influences the removal of nutrients from a soil, but also the return of crop residues, the development and distribution of bio pores and the dynamics of microbial communities. These processes contribute to the development of soil structure.

Key words: Crop Rotation, Soil health and Different Crops, Nutrients etc.

INTRODUCTION

Crop rotation is the practice of growing a series of different types of crops in the same area across a sequence of growing seasons. This practice reduces the reliance of crops on one set of nutrients, pest and weed pressure, along with the probability of developing resistant pests and weeds. Growing the same crop in the same place for many years in a row, known as monocropping, gradually depletes the soil of certain nutrients and selects for both a highly competitive pest and weed community. Without balancing nutrient use and diversifying pest and weed communities, the productivity of monocultures is highly dependent on external inputs that may be harmful to the soil's fertility. Conversely, a well-designed crop rotation can

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reduce the need for synthetic fertilizers and herbicides by better using ecosystem services from a diverse set of crops. Additionally, crop rotations can improve soil structure and organic matter, which reduces erosion and increases farm system resilience.

History:

Agriculturalists have long recognized that suitable rotations such as planting spring crops for livestock in place of grains for human consumption make it possible to restore or to maintain productive soils. Ancient Near Eastern farmers practiced crop rotation in 6000 BC without understanding the chemistry, alternately unknowingly, this was the start of a practice that would soon benefit many farmers.

Two-field systems:

Under a two-field rotation, half the land was planted in a year, while the other half lay fallow. Then, in the next year, the two fields were reversed. In China both the two-field and three-field system had been used since the Eastern Zhou period. From the times of Charlemagne (died 814), farmers in Europe transitioned from a two-field crop rotation to a three-field crop rotation.

Three-field systems:

From the end of the Middle Ages until the 20th century, Europe's farmers practiced a three-field rotation, where available lands were divided into three sections. One section was planted in the autumn with rye or winter wheat, followed by spring oats or barley; the second section grew crops such as peas, lentils, or beans; and the third field was left fallow. The three fields were rotated in this manner so that every three years, one of the fields would rest and lie fallow. Under the two-field system, if one has a total of 600 acres (2.4 km^2) of fertile land, one would only plant 300 acres. Under the new three-field rotation system, one would plant (and therefore harvest) 400 acres. But the additional crops had a more significant effect than mere quantitative productivity. Since the spring crops were mostly legumes, they increased the overall nutrition of the people of Northern Europe.

Four-field rotations:

Farmers in the region of Waasland (in present-day northern Belgium) pioneered a four-field rotation in the early 16th century, and the British agriculturist Charles Townshend (1674–1738) popularised this system in the 18th century. The sequence of four crops (wheat, turnips, barley and clover), included a fodder crop and a grazing crop, allowing livestock to be bred year-round. The four-field crop rotation became a key development in the British Agricultural Revolution. The rotation between arable and ley is sometimes

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called ley farming.

Modern developments:

George Washington Carver (1860s–1943) studied crop-rotation methods in the United States, teaching southern farmers to rotate soil-depleting crops like cotton with soil-enriching crops like peanuts and peas. In the Green Revolution of the mid-20th century the traditional practice of crop rotation gave way in some parts of the world to the practice of supplementing the chemical inputs to the soil through topdressing with fertilizers, adding (for example) ammonium nitrate or urea and restoring soil pH with lime. Such practices aimed to increase yields, to prepare soil for specialist crops, and to reduce waste and inefficiency by simplifying planting, harvesting, and irrigation.

Crop choice:

A preliminary assessment of crop interrelationships can be found in how each crop:

1. contributes to soil organic matter (SOM) content
2. provides for pest management
3. manages deficient or excess nutrients
4. how it contributes to or controls for soil erosion
5. interbreeds with other crops to produce hybrid offspring, and
6. impacts surrounding food webs and field ecosystems

Crop choice is often related to the goal the farmer is looking to achieve with the rotation, which could be weed management, increasing available nitrogen in the soil, controlling for erosion, or increasing soil structure and biomass, to name a few. When discussing crop rotations, crops are classified in different ways depending on what quality is being assessed: by family, by nutrient needs/benefits, and/or by profitability (i.e. cash crop versus cover crop). For example, giving adequate attention to plant family is essential to mitigating pests and pathogens. However, many farmers have success managing rotations by planning sequencing and cover crops around desirable cash crops. The following is a simplified classification based on crop quality and purpose.

Row crops:

Many crops which are critical for the market, like vegetables, are row crops (that is, grown in tight rows). While often the most profitable for farmers, these crops are more taxing on the soil. Row crops typically have low biomass and shallow roots: this means the plant contributes low residue to the surrounding soil and has limited effects on structure. With much of the soil around the plant exposed to

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disruption by rainfall and traffic, fields with row crops experience faster break down of organic matter by microbes, leaving fewer nutrients for future plants. In short, while these crops may be profitable for the farm, they are nutrient depleting. Crop rotation practices exist to strike a balance between short-term profitability and long-term productivity.

Legumes:

A great advantage of crop rotation comes from the interrelationship of nitrogen-fixing crops with nitrogen-demanding crops. Legumes, like alfalfa and clover, collect available nitrogen from the atmosphere and store it in nodules on their root structure. When the plant is harvested, the biomass of uncollected roots breaks down, making the stored nitrogen available to future crops. In addition, legumes have heavy tap roots that burrow deep into the ground, lifting soil for better tilt and absorption of water.

Grasses and cereals:

Cereal and grasses are frequent cover crops because of the many advantages they supply to soil quality and structure. The dense and far-reaching root systems give ample structure to surrounding soil and provide significant biomass for soil organic matter. Grasses and cereals are key in weed management as they compete with undesired plants for soil space and nutrients.

Green manure:

Green manure is a crop that is mixed into the soil. Both nitrogen-fixing legumes and nutrient scavengers, like grasses, can be used as green manure. Green manure of legumes is an excellent source of nitrogen, especially for organic systems; however, legume biomass does not contribute to lasting soil organic matter like grasses do.

Planning a rotation:

There are numerous factors that must be taken into consideration when planning a crop rotation. Planning an effective rotation requires weighing fixed and fluctuating production circumstances: market, farm size, labor supply, climate, soil type, growing practices, etc. Moreover, a crop rotation must consider in what condition one crop will leave the soil for the succeeding crop and how one crop can be seeded with another crop. For example, a nitrogen-fixing crop, like a legume, should always precede nitrogen depleting one; similarly, a low residue crop (i.e. a crop with low biomass) should be offset with a high biomass cover crop,

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like a mixture of grasses and legumes. There is no limit to the number of crops that can be used in a rotation, or the amount of time a rotation takes to complete. Decisions about rotations are made years prior, seasons prior, or even at the last minute when an opportunity to increase profits or soil quality presents itself.

Soil organic matter:

The use of different species in rotation allows for increased soil organic matter (SOM), greater soil structure, and improvement of the chemical and biological soil environment for crops. With more SOM, water infiltration and retention improves, providing increased drought tolerance and decreased erosion.

Soil organic matter is a mix of decaying material from biomass with active microorganisms. Crop rotation, by nature, increases exposure to biomass from sod, green manure, and various other plant debris. The reduced need for intensive tillage under crop rotation allows biomass aggregation to lead to greater nutrient retention and utilization, decreasing the need for added nutrients. With tillage, disruption and oxidation of soil creates a less conducive environment for diversity and proliferation of microorganisms in the soil. These microorganisms are what make nutrients available to plants. So, where "active" soil organic matter is a key to productive soil, soil with low microbial activity provides significantly fewer nutrients to plants; this is true even though the quantity of biomass left in the soil may be the same. Soil microorganisms also decrease pathogen and pest activity through competition. In addition, plants produce root exudates and other chemicals which manipulate their soil environment as well as their weed environment. Thus rotation allows increased yields from nutrient availability but also alleviation of allelopathy and competitive weed environments.

Carbon sequestration:

Studies have shown that crop rotations greatly increase soil organic carbon (SOC) content, the main constituent of soil organic matter. Carbon, along with hydrogen and oxygen, is a macronutrient for plants. Highly diverse rotations spanning long periods of time have shown to be even more effective in increasing SOC, while soil disturbances (e.g. from tillage) are responsible for exponential decline in SOC levels. In Brazil, conversion to no-till methods combined with intensive crop rotations has been shown an SOC sequestration rate of 0.41 tonnes per hectare per year. In addition to enhancing crop productivity, sequestration of atmospheric carbon has great implications in reducing rates of climate change by removing carbon dioxide from the air.

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Nitrogen fixing:

Rotating crops adds nutrients to the soil. Legumes, plants of the family Fabaceae, for instance, have nodules on their roots which contain nitrogen-fixing bacteria called rhizobia. During a process called nodulation, the rhizobia bacteria use nutrients and water provided by the plant to convert atmospheric nitrogen into ammonia, which is then converted into an organic compound that the plant can use as its nitrogen source. It therefore makes good sense agriculturally to alternate them with cereals (family Poaceae) and other plants that require nitrates. How much nitrogen made available to the plants depends on factors such as the kind of legume, the effectiveness of rhizobia bacteria, soil conditions, and the availability of elements necessary for plant food.

Pathogen and pest control:

Crop rotation is also used to control pests and diseases that can become established in the soil over time. The changing of crops in a sequence decreases the population level of pests by (1) interrupting pest life cycles and (2) interrupting pest habitat. Plants within the same taxonomic family tend to have similar pests and pathogens. By regularly changing crops and keeping the soil occupied by cover crops instead of lying fallow, pest cycles can be broken or limited, especially cycles that benefit from overwintering in residue. For example, root-knot nematode is a serious problem for some plants in warm climates and sandy soils, where it slowly builds up to high levels in the soil, and can severely damage plant productivity by cutting off circulation from the plant roots. Growing a crop that is not a host for root-knot nematode for one season greatly reduces the level of the nematode in the soil, thus making it possible to grow a susceptible crop the following season without needing soil fumigation. This principle is of particular use in organic farming, where pest control must be achieved without synthetic pesticides.

Weed management:

Integrating certain crops, especially cover crops, into crop rotations is of particular value to weed management. These crops crowd out weeds through competition. In addition, the sod and compost from cover crops and green manure slows the growth of what weeds are still able to make it through the soil, giving the crops further competitive advantage. By slowing the growth and proliferation of weeds while cover crops are cultivated, farmers greatly reduce the presence of weeds for future crops, including shallow rooted and row crops, which are less resistant to weeds. Cover crops are, therefore, considered conservation

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crops because they protect otherwise fallow land from becoming overrun with weeds. This system has advantages over other common practices for weeds management, such as tillage. Tillage is meant to inhibit growth of weeds by overturning the soil; however, this has a countering effect of exposing weed seeds that may have gotten buried and burying valuable crop seeds. Under crop rotation, the number of viable seeds in the soil is reduced through the reduction of the weed population.

In addition to their negative impact on crop quality and yield, weeds can slow down the harvesting process. Weeds make farmers less efficient when harvesting, because weeds like bindweeds, and knotgrass, can become tangled in the equipment, resulting in a stop-and-go type of harvest.

Benefits of Crop Rotation:

1. Enhance Soil Structure:

Plant growth can be inhibited by soil compaction, which is when the pores in soil are pressed so tightly together that they leave little room for water and nutrients to reach a plant's root, killing the plant. Soil compaction can be caused by walking on top of the soil or using heavy farming equipment across it. Crop rotation improves soil's physical texture by rotating different plants whose roots reach various soil depths instead of leaving the soil in its compressed state. Poor soil structure will result in hormonal signals being sent to slow down the growth of a plant's shoot even if they can physically access water and nutrients. This survival-like mechanism is the soil's response to preservation so more nutrients can infiltrate the soil. If crop rotation isn't implemented, the plant can still suffer regardless.

2. Boost Soil Fertility:

Continuous planting can decrease vital nutrients in the soil. Crop rotation can revitalize soil by putting some of those lost nutrients back into the ground. For instance, certain crops can increase potassium levels in the soil, which can then be used by peas or corn (which require higher levels of potassium to grow). Manure can also be used to improve soil fertility and bacterial diversity levels by enriching soil better than inorganic fertilizer. Microorganisms like fungi and earthworms increase in the soil after manure application. These organisms assist the nutrient cycle process, which can be given to plants for increased yield.

3. Prevent Soil Erosion:

Nature is unpredictable and heavy rainfall or wind can erode the top layer of soil, impacting crops. Crop rotation with cereal rye, oats, and certain strains of wheat protects topsoil and almost acts as a blanket for

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crops. These cover crops also provide roots to the soil so they can continue to gain nutrients for optimal conditions. Plants like vetch, rye, and clover can also be used as cover crops. Plants like vetch, rye, and clover can also be used as cover crops. Soil erosion tends to happen in places like the Midwest where farming is common. Research shows that 60 percent of eroded soil washes away into streams, lakes, and rivers, increasing the chance for further pollution?

4. Decrease Pollution:

Crop rotation allows plants to receive optimal nutrients from the soil, which can result in a reduction in fertilizer use – especially if crops are able to effectively utilize the nutrients in and around them. More nutrients in the plant mean less in streams and lakes.

5. Prevents the Concentration of Pests and Diseases:

Crop rotation is useful to prevent plants succumbing from pests and diseases. Pests and diseases can live in the soil, which is why changing the crops each season can deter them. Certain plants are resistant to pathogens called non-host plants that could be used to assist in limiting the spread of diseases and pests.

6. Reduces Weed Growth:

It's no secret that weeds can wreak havoc on a plant's life cycle. If you don't have access to a self-driving robot that shoots lasers, farmers can look to herbicides to destroy weeds. One way to reduce the number of weeds (without farm robots) is by creating less-than-desirable conditions for the weeds through crop rotation. Crop rotation creates a constantly changing environment so weeds have very little time to adapt to the new conditions. Weeds are opportunistic and seek to steal nutrients from crops and plants. Over time, weeds have become adaptable as some survive with minimal water. Crop rotation allows plenty of crops to grow, and creates less space for weeds to inhabit the soil.

7. Raises Crop Yield:

Honestly, this could be the No. 1 listing in this section. Yield is everything. As a farmer, if you don't have adequate yield, you probably aren't staying in this job for long. Crop rotation leads to more yield and profitability. Mono-cropping involves using a field for one type of crop every single year, which can increase pollution and depletes the soil of nutrients. Ditching this practice in favor of crop rotation can create a better return on investment.

One study found a 29 percent improved corn yield compared to continuous cropping when done in a two-

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year rotation. This yield increased to 48 percent during a four-year crop rotation with the use of a legume cover crop in the winter season for one of the four years. Implementing crop rotation can positively affect farmers' bottom lines, especially during turbulent times as many family farms continue to struggle financially and take on unsustainable levels of debt.

8. Lower Production Costs and Crop Variety:

Food costs are rising due to a variety of external pressures. One of the many crop rotation benefits includes decreased input costs. Crop rotation leads to better soils, fewer weeds, and lower pathogens. According to one survey, farmers who used crop diversity with three or four crops for a period of ten years said they had higher profits and crop yields.

CONCLUSION

Crop rotation is a valuable tool for improving soil health, increasing crop productivity, and reducing the need for chemical inputs. Crop rotation improves soil health by gradually changing the sorts of crops that are produced in an area. Because different crops require different amounts of nutrients and have different root systems, this helps minimize nutrient depletion and encourages nutrient cycling.

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