

## Review

### A Review of Advantages, Disadvantages and Challenges of Crop Rotations

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**C**ROP rotation is the most important cropping system can help to minimize the application of fertilizers and herbicides, thereby decreased food contamination with agrochemical residue and increase structure of soil microbial communities. Furthermore, among other benefits, additional benefits also can be gained such as high land use efficiency, superior yield stability, well distributing of labor contribution over the growing season by the way which allows for more choice when deciding on change one practice or more, larger variety of produce, less dependence on storage, greater market opportunities by making a balance in the crop production. Recently, many researches showed that crop rotation is a foundational component of sustainability and long-term profitability without any requirements to additional financial investments. Finally, crop rotation can be recommended in many regions as valuable practices for refining sustainability and long term profitability.

**Keywords:** Sequential-cropping, Mono-cropping, Crop rotation, Crop sequences.

#### Summary

This review compiled the global research from the past few years on one of the most important agronomic practices, which is crop sequence (crop rotation). Rotations have a great potential in maximize crop yield production of unit area without any requirements to increase financial investments (Stanger et al., 2008 and Sexton, 2016). Rotation is the most important and effective plans in managing equipment, labor availability, market variability and climate changes. Over time, crop rotations could occurred some benefits, for example increasing level of soil organic matter, thereby enhancing soil quality, reduce soil degradation and rapid going to depletion and advance soil physiochemical composition.

Generally, while rotations are a foundational element of sustainability and long-term profitability, in the same time adopting crop rotation is a complex practice, it is must be adaptable to local conditions and challenges. Also, considerable attention must be looked at natural systems as a model to mimic always needs to improve. Although a corn-soybean rotation is well known and the widespread rotation in many areas, but it is not continuously the dominant or the optimum option. A good rotation program should be productive, minimize nutrient loss, cover the

soil, provide resilience against natural constrains, and each crop should offer some benefits to the following crop.

Crop rotation could also help to minimize the application of fertilizers and herbicides, thereby decreased food contamination with agrochemical residue and increase structure of soil microbial communities. Additional benefits also can be gained such as high land use efficiency, superior yield stability, well distributing of labor contribution over the growing season by the way which allows for more choice when deciding on change one practice or more, larger variety of produce, less dependence on storage, greater market opportunities by making a balance in the crop production and well soil and water uses (Edwards, 1995). Additionally, allelopathy effect which is defined by the annihilation of plant growth of specific plant species by another species. Auto toxicity is one of allelopathic categories that happen when chemical components released from a crop root, disturb the same crop species and may be extended to other plant species.

Crop rotation is not new technique, earlier, introduction of the "Norfolk Rotation" (Barley-Clover/ryegrass-Wheat-Turnips) by Sir Charles Townshend in England played a large role in nearly tripling England's agriculture output in the

1700s in a sustainable manner. This technology also has introduced a lot of improvement provided food and also provides required employment for England's Industrial Revolution.

Recently, many researches, showed that crop rotation is a foundational component of sustainability and long-term profitability without any requirements to additional financial investments (Stanger et al., 2008 and Sexton, 2016). Furthermore, obvious effects of crop rotation were also discovered on soil mineral status, and (N) mineralization (Carpenter-Boggs et al., 2000); increase the efficiency of nutrients use (Tanaka et al., 2005); mitigating the effects of limited nutrient availability (Brozyna et al., 2013); asset in building soil organic matter due to large amount of crop residue; which was left in the soil after harvest (Adiku et al., 2009 and Sexton et al., 2012, 2014); the impact on the structure of microbial communities which are highly respond to host plant; soil characteristics and climatic conditions (Garbeva et al., 2004; Berg & Smalla, 2009; Lehman et al., 2015 and Benitez et al., 2017) and protecting the soil against erosion, deciding whether, sowing crop in a rotation or as a monoculture is partially depended on many variables such as commodity markets, disease and insect pest's present and available labour and equipment's in the time of crop seeding or crop harvesting.

### **Introduction**

Among others agronomic practices crop rotations (Crop sequences), are valuable practices can be recommended in many regions for refining sustainability and long term profitability. Crop rotation is an idea of growing different types of crops in a series or as successive seasons, rotating may vary from 2 or 3 years or extended to long time. Dependence on the fact that, different crops are differed in their requirements, whereas crop rotation is contains legumes and non-leguminous plants, thus this is a good idea for improving soil productivity because you can sure that you do not over use soil health and make it more efficiently utilized and enabling to be preserved. Occasionally, crop rotation is may be the better choice or the dominant option must be followed for maintain production systems. There are several benefits can be gained by using crop rotation, including improved nutrient cycling, soil tilth, and soil physical properties; enhanced weed

control, and resulting higher yield, as compared to following a monoculture under identical conditions.

Research on the influence of long-term crop rotation, not only confirmed that, the crop rotations is a best way for managing crop residue, but also is the master key of sustainability and profitability, it is can proved some advantages, which can be subjected in the following topics:

- Crop sequence can help maximize crop yield production of the unit area without any requirements to increase financial investments.
- Crop rotation is an important technique in elimination insects, more breaks in disease cycles and fewer herbicide-resistant weed species. Food and Agriculture Organization (FAO, 2002), recognizes crop rotation as one of the most important methods of integrated pest management (IPM). It is an ecofriendly method of crop production that aims to reduce the use of chemical pesticides and herbicides in agriculture.
- Soil organic matter tended to increase as the result of following crop rotation than monoculture system, then led to better soil structure, reduce soil degradation and rapid going to depletion and advance soil physiochemical composition and soil health.
- Rotating crops is an important practice could mitigate the effect climate changes and market variability.
- Whenever, crop rotation can include forage crops, hence the livestock help to increase the soil nutrients with manure.

Over the last few years, some researchers have also discovered that, although, there are many advantages, also there is some disadvantages, but these are very low as compared to its benefits, for example:

- Sometimes less profitability may be accompanying with the following of crop rotations, when you are forced to reduce the area cultivated with the most profitable crop.
- Sometimes crop flexibility may be decreased, for example selecting a complex crop rotation,

hence the chance to add alternative crops decreased.

- Some rotations can have a high initial outlay, involves input of much money to buy different seeds of the different crops species to be sown, alongside more money expended in field preparation. The success, however, for each crop type is not guaranteed and one can end up incurring a loss of harvest.

Indication of the global research on the role of managing agronomic practices in developing and sustainable agricultural production systems, can arguably that the relationship between soils, crops and management practices is a complex relationships. In the light of global water crisis particularly in arid and semiarid regions, especially in the case of planting a water voracious crops, or crops consume much nutrients from the soil during the growing season, this is led to rapid depletion the soil fertility (Higgs et al., 1976; Mannering & Griffith, 1981; Dick et al., 1986; Peterson & Varvel, 1989 a and 1989 b; Higgs et al., 1990; Raimbault & Vyn, 1991; Bullock, 1992; Copeland et al., 1993; Karlen et al., 1994; Varvel, 1994; Riedell et al., 1998; Varvel, 2000; Garbeva et al., 2004; Tanaka et al., 2005; Karlen et al., 2006; Kaye et al., 2007; Bremer et al., 2008; Adiku et al., 2009; Berg & Smalla, 2009; Seeley, 2012; Brozyna et al., 2013; Sexton et al., 2014; Lehman et al., 2015; Sexton, 2016 and Benitez et al., 2017).

#### *Designing a rotation*

While crop rotation can have many advantages and disadvantages, adopting the most compatible and effective rotation for a specific field is linked with number of variables and many factors that must be considered including socio-economic factors that fit with the small holder farming systems; soil preparation which are needed and available equipment's; the current disease and spread insect pests. While rotating a corn-soybean is the most common practice among many farmers in many areas, but it is not always is the best choice. Although it may be rotated Corn-Soybean rotation most traded among many farmers in many areas, may not always be the best choice. Walter et al. (2009), reported that, growing maize in prolonged rotations that include forage legumes may be a more favorable practice than growing maize in monoculture system or 2-yr rotation with soybean.

Thus before decision, need sufficiently addressed to cover the principle aims of crop rotation and also, to avoid counter productive expected, if producers adopt in appropriate technologies. Therefore, attaining the most suitable rotation is complicated, as one management practice may have negative implications on other practices, for example, reducing tillage intensity without use of a sustainable rotation can increase the risk of plant diseases.

#### *Advantages and disadvantages of crop rotations*

##### *Rotations and plant disease and insect management*

Rotation is a very valuable and an effective tool for breaking disease cycles, chiefly when the pathogens have a chance with crop rotation included host crop or invisible in crop residue or soil when you follow no-tillage program or conserving tillage (Beck, 2003 and Pedersen & Lauer, 2004). The early experiments of Karlen et al. (1994), registered that crop rotations offer the best way to combat weeds, interrupt insect and better control disease cycles. Crop rotation able to reduce the level of inoculum present by introducing resistant varieties or which are not host crops. When planting impervious crop (non-host), the pathogen could not able to complete their cycle life and causes infection, then inoculum gradually die, and accordingly the level of inoculum decreased and become unable to causes infection. Contrary, when narrow host plant is continuously sown, the pathogen is able to live; complete life cycle and reproduce, thus, inoculum gradually increased, and consequently the level of inoculums will progressively increase.

Furthermore, there are some diseases, such as seedling damping off (*Pythium* spp.) and root rots (*Rhizoctonia solani* and *Fusarium* spp.), that can be managed only by combining the rotation, with additional methods might suggested, such as using appropriate seed treatments, delaying seeding, and installing tile drainage. On the other hand, some diseases such as Stewart's wilt and common rust of corn do not rely on overwintering in soil or crop residue and are not affected by crop rotation.

Conclude from the previous presentation that the crop rotation is one of the most important management approaches able to overcome some insect pests (Anderson, 2008). Crop sequences are most effective practice able to eliminate that

feed on a narrow range of crops, and that laid eggs or larvae in the soil. For example rootworm in corn, wireworms, white grubs, and some cutworms is an insect that has traditionally been controlled by following crop sequence (Teetes & Pendleton, 1999). Kaye et al. (2007), found that crop rotations also has an indirect control insect and disease cycle, through better weed control, and able to restrain and stop their progress.

#### *Rotations and weed management*

Rotation can have large impacts on weed distributions, pressure and turn off long life cycle. Rotations provide a good opportunity to rotate the use different types of herbicides and choosing chemistries which have a different mode of actions, over sequential years. Thus, overcome undesirable weeds and decreasing the ability of weed resistance. Liebman & Dyck, (1993), registered that crop rotation (temporal change) plans can decrease weed population, tolerability and biomass production. Furthermore, adding another crop may help further manage weeds (Cavigelli et al., 2013). A good rotation program should be productive, minimize risk of weed developing, and offer pliability against more growing weeds, e. g., annual summer weeds may not be able to successfully sprout under winter crops such as wheat or they are cut before completely formation seeds in the time of wheat are harvested. In addition, grown very similar crops for two years in a row and then skipped for four or more years (e. g., corn-corn soybean- soybean-wheat-wheat), allowing for the use of herbicides with long residuals in the first year of each crop while maintaining a long period (four years) where the land is rotated to other crops (Beck, 2003).

Inoculation rotations with forage crops (grass or broad-leaved forage) in long-term rotations can help to reduce weeds population and also can assist to control perennial and annual weeds as long as the forage stand is healthy and vigorous. Weed control is improved quantity and quality of forage, when harvesting forage crop as hay or silage, the seeds of weeds are not yet formed and often are not valuable component and can be ignored.

Similarly, an advantage can be gained by a rotation between warm- and cool-season crops, where each cycle is held for two seasons (two warm-season crops followed by two cool-season crops), holding the given pattern for two years

disrupts weed life cycles such that the weed seeds have to survive for three years (Anderson, 2008).

Finally, can conclude that crop rotation helps to decrease the growth of weeds, which received or not received herbicides, as compared to monocropping system, thus, adopting crop rotation is a way for reducing and eliminating weeds is an acceptable method for reducing the use of pesticides and decreasing the total costs.

#### *Rotations and soil structure and microbial communities*

Several studies at different agro-ecological zone indicated that soil physiochemical parameters (properties), included infiltration, bulk density, aggregate stability, water capacity, soluble cations, anions, EC, and available nutrients as well as biological composition can improve through the use of irregular crops with taproots and fibrous roots, through the formation of humus from decomposing plant residues after harvest. Such system allows for many options when deciding on tillage practices, for example no-till or reduced tillage systems (Raimbault & Vyn, 1991; Campbell & Zentner, 1993; Bremer et al., 2008 and Snapp et al., 2010). A long-term field experiment evaluating different four-year rotation sequences was established, in this experiments consider combinations of small grains, legumes and oil-seed crops, results indicated that, rotation-sequence-specific benefits at both the soil and plant level in greater soil carbon accumulation, C:N ratio improvement and soil aggregate stability (Benitez et al., 2017). When the rotation includes forages legume crops, particularly alfalfa, marginal advantage to following crops decreases after the alfalfa stand in soil is three years old.

Rotating crops also had significant effect on microbial communities. Several studies registered that, overtime, crop rotation can improve soil biological composition. It is well known that microbial societies are associated with many factors, among these host plant identity and genetics, soil characteristics and climatic conditions. Microbial species are respond to plants and are directly influenced by the root's architecture as well as the chemical characteristics of root exudates (Garbeva et al., 2004; Berg & Smalla, 2009; Lehman et al., 2015 and Benitez et al., 2017). Early time, Johnson et al. (1992), reported that crop rotations

enhanced mycorrhizal associations with plants establish. Additionally, in crop rotating with a high C/N ratio (corn, small grains) with low carbon to nitrogen ratio crops (soybeans) helps construct a wide-ranging population of soil micro-organisms. Such effect on soil micro-organism groups along with development in soil tillage can lead to more steady soil structure and minimized the ability of soil erosion.

So, crop rotation helps receiving a good soil structure (alternatively shallow and deep rooting roots), high organic matter, good water distribution in root zone, particularly in combination with maintenance tillage, rising yield productivity.

#### *Rotations and soil nutrient status and availability*

Recently, the majority of literature indicates that, crop rotation is a foundational element of sustainability and long-term profitability without any needs to additional financial investments (Stanger et al., 2008 and Sexton, 2016). Additionally, appropriate crop rotation based on information of soil health is an important tool for assessing soil nutrients balance, crop nutrient requirements, and remains soil enriched or at least preventing it from running out speedily (Chuan, 2013 and Paul et al., 2014).

According to the fact that, the response to fertilizer inputs is differentiated by crop species and segregated as the soils native fertility is variances, then application of fertilizer is not always means that an increasing in crop yield must be occurred; a part of added fertilizers may be not absorbed by crops and mostly are remained in soil in different form (available or fixed) or may be lost through volatilizing in the environment or leaching to underground water. Hence, adopting satisfactory crop rotations program can able to improve soil productivity, eliminating the constraints, sustaining food security and satisfying economic yield without or with minimum risk in environment pollution (Zingore et al., 2007, Hossain et al., 2008, Snapp et al., 2010; Zingore et al., 2011; Zhang et al., 2012 and Tittonell & Giller, 2013).

Although, rotations has notable effects on soil nutrients content, essentially related to nitrogen-fixating (Carpenter-Boggs et al., 2000), several researchers have concluded that there are others effects outside that, which can be clarified by soil

mineral contents (Wright, 1990; Bullock, 1992 and Copeland & Crookston, 1992); improved soil structure (Raimbault & Vyn, 1991); improve nutrient use efficiency (Karlen et al., 1994 and Tanaka et al., 2005); increased soil organic matter contents, as a result of large amount of crop residue was left in the soil after harvest (Campbell & Zentner, 1993; Bremer et al., 2008; Adiku et al., 2009; Ali et al., 2010; Zhang et al., 2012 and Sexton et al., 2014); also crop rotation can have substantial positive influence on plant nutrients uptake and mitigating the effects of limited nutrient availability of N, P, K and Ca for cereal crops (Bolton et al., 1976; Higgs et al., 1976; Welch, 1976; Copeland & Crookston, 1992; Riedell et al., 1998; Brozyna et al., 2013 and Abdul Quddus et al., 2017). Marginal benefit also can be gained in managing the production of crop residues by adopting crop rotation system as compared with monoculture, when high biomass and crop residue were formed (such as corn) are recommended to sequence with crops that produce more subtle residue similar soybean.

Also, increasing the availability of most nutrients through appropriate crop rotation means fewer fertilizer uses, lower costs paid and higher farmer returns. Adding legumes to a rotation, alike soybean or alfalfa have a great possibility to increase fixer nitrogen rate (N-fixing), and then (N) available for succeeding crops will be increased (Peterson & Varvel, 1989 a; Raimbault & Vyn, 1991; Carpenter-Boggs et al., 2000 and Mallarino & Rueber, 2006). Furthermore, deep-rooted legume crops, such as alfalfa, forage deep residual soil (N) and consequently increase soil N availability to succeeding shallow-rooted crops (Mathers et al., 1975 and Karlen et al., 1994). Many researchers also concluded that, the influences of crop rotation on soil mineral status, particularly "nitrogen credit" for example, corn succeeding soybean is may be due to soybean roots and root exudates increasing the pool of easily mineralized organic- N (Wright, 1990; Copeland & Crookston, 1992 and Murrell, 2011), crop rotation can also play a major role in minimizing the potential risk of nitrate leaching to soil surface and underground water by enhancing soil (N) availability, thus the application of fertilizer (N) will be decreased. Additionally, the rate of (N) conversion from organic- N to mineral-N were influence by modifying soil moisture, soil temperature, pH, plant residue, decomposing process and tillage practices (Sisti et al., 2004 and Murrell, 2011).

*Rotations and water use*

Crop rotations are long-term plans, over time, rotations can improved soil structure (infiltration, bulk density, aggregate stability and water capacity), Horst & Hardter (1994), reported that crop rotation also, can increase soil water-holding capacity as well as developing macro pores in the soil promotes new root growth in consecutive crops. Moreover, Raimbault & Vyn (1991); stated that, improve root function and nutrient use efficiency (Copeland et al., 1993; Karlen et al., 1994 and Tanaka et al., 2005). Additionally, cropping system is more frequently with water-use, for example cropping system has highly water-use *viz.*, corn, soybean and alfalfa, whereas barley, winter wheat, field peas and canola are low water-use crops. Due to, increasing the efficiency of crop rotations on water-use, crop rooting depth should be considered. Crops with deep extensive root systems that grow late into the season (e. g., sunflower and alfalfa) are likely to leave less reserve moisture than shallower-rooted, earlier maturing crops (e. g., peas, flax and lentils). Similarly, an advantage can be gained by a rotation; the large amount of residue from high vigor crops such as corn is an asset in building soil organic matter, then improving soil physical properties, which are reflected in decreasing soil water loss and protecting the soil from erosion.

Researchers conducted by many author shows that, different crops has different critical periods for water stress throughout the growing season. For example, wheat partially escapes drought-stress by flowering early and completing its cycle life earlier in the growing season than either corn or soybeans. Soybean flowering is spread over several weeks so that it can better avoid the effects of drought. Whereas, corn flowers and sets seed are at one point in time and does this during the warmest part of the season, when evaporative demand (water use) is at its peak. High temperatures and drought stress can reduce corn kernel set by decreasing pollen viability and delaying silking. Thus, seeding varieties of different time of maturities, the length of the pollination period for the farm can be expanded few weeks. Christian et al. (2012), reported that, rotation included or not included legumes can improve water infiltration (between 70 and 238%), soil moisture and crop productivity. Therefore, adopting a suitable rotations be able to distributing the critical water-use periods across the growing season, by this way crop rotation

could mitigated the harmful effects of drought and increased water use efficiency (Roder et al., 1989; Varvel, 1994; Al-Kaisi et al., 2003 and Tanaka et al., 2005).

*Rotations and crop yield potential and yield diversity*

Yield gaps are poverty traps; and following crop rotations can increase soil productivity by improving soil conditions and reducing weed inhabitants and insect populations, even under conventional tillage programs. Additionally, rotations help producers use conservation tillage successfully (Roth, 1996).

In addition, rotation also have considerable positive influence on yield potential (Peterson & Varvel, 1989 b), when compared with monoculture system and presented the greatest opportunity for increasing productivity from the current average and maximizing farmer incomes (Snapp et al., 2003; Mallarino & Rueber, 2006; Snyder & Bruulsema, 2007; Snapp et al., 2010; Murrell, 2011 and Yousaf, 2016). Also, notable increment was registered in grain yield of maize grown in rotation; amounted (10 to 17%) as compared to continues sowing system (Mannerling & Griffith, 1981; Dick et al., 1986 and Higgs et al., 1990).

Adopting a good rotation can help producers escape from serious problems associated with the confliction between seeding and harvest times of different crops (i. e., trying to seed one crop when harvesting another or harvesting more than one crop at a time). Also information on market prices, which is changed with time, it is important to protect farmers from realizing potential losses. Also, crop rotations improved yield quality parameters (Kaye et al., 2007) and reduced the variability (Varvel, 2000).

*Rotations and allelopathy*

Allelopathy is the overpowering plant growth of a definite plant species by another plant species. In the same subject, auto toxicity occurs is a specific plant type, when chemical compounds released from root, such as corn, had a harmful effect on the same crop, if it was the succeeding. Several studies indicated that auto toxicity had conflicted effect that delaying corn seed sprouting and early season growth. While, it is not thought to be a primary cause of yield disadvantages in case of corn succeeding corn, this is may be probably a contributing factor (Elmore & Abendroth, 2007).

Designing most suitable crop rotations is important to avoid any conflicts between the present crop and the following crop. Producers need to look at rotations as one tool for optimizing long-term profitability and reducing risk. Practically, achieving these goals is complicated, as one management practice may have negative implications on other practices.

#### *Rotations and flexibility and risk management*

Flexibility means adapting rotation, which can be able to change, to achieve the fewer disadvantages and higher advantages. Also, adopting suitable rotation, this is highly linked to market forces and prices by regulating it slightly. If market prices are satisfactory for cereals, you may accept cereal rotation, e. g. wheat, corn, sorghum and barley. If prices for legumes are good, you can alternate to beans, and peas. If forage seed prices are good, you might extend your forage seed crop for one year. Although, adapting flexible crop rotations depends on market and a good price, but these might be likely to change by the time from product to sell, unless we have hedged them in.

Adopting appropriate crop rotations is a complex practice; due to it is a combination of art and science. For any given state, there will be a range of rotations that are suitable. Within this range, there are rotations and tillage practices that reduce or increase risks.

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#### أستعراض المزايا والعيوب والتحديات لنظام تناوب المحاصيل

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تناوب المحاصيل أو تعاقب المحاصيل من أهم الممارسات الزراعية التي تساعد على التقليل من استخدام الأسمدة ومبيدات الحشائش، وبالتالي تؤدي إلى انخفاض تلوث الغذاء ببقايا الكيماويات الزراعية وزيادة المحتوى الميكروبي للتربة. وعلاوة على ذلك، من بين المزايا الأخرى العديدة التي يمكن جنيها من استخدام نظام مناسب للتعاقب المحصولي زيادة كفاءة استخدام الأرض، ثبات واستقرار التفوق في الإنتاج المحصولي، الانتظام في توزيع العمالة (عناصر العمل) طوال موسم النمو في المزرعة بما يسمح بالاستغلال الكامل لعنصر العمل مع إمكانية وضع الأولويات لتنفيذ بعض العمليات عن غيرها، التنوع في الإنتاج، تقليل الاعتماد على التخزين، تقليل مخاطر تقلب الأسعار بالسوق عن طريق العمل على إيجاد توازن في الإنتاج. في الآونة الأخيرة، اثبتت العديد من الدراسات أن تناوب المحاصيل أحد المكونات الأساسية للاستدامة والربحية طويلة الأجل دون الحاجة إلى إضافية استثمارات مالية. وأخيراً يمكن الوصية بإتباع نظام تناوب المحاصيل في مناطق كثيرة لتحسين الاستدامة والربحية طويلة الأجل.