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Measures to achieve a stable farming system in sustainable agriculture – a short review

Introduction

The rapid increases in human population and exploitative use of non-renewable resources have worsened food shortages (Amini et al., 2012; Esfandiary et al., 2012; Soleymani et al., 2012a–b; Shahrajabian et al., 2017, 2018; Ogbaji et al., 2018; Soleymani, Shahrajabian, 2018; Yong et al., 2018). In the context of improving the global food situation, chemical fertilisers play a dominant role (Yazdpour et al., 2012; Shahrajabian, Soleymani, 2017a–b). Most scientists believe that increasing yield per ha is a major way for increasing crops yield (Soleymani et al., 2016; Soleymani, Shahrajabian, 2017; Yong et al., 2017). Due to high costs and poor accessibility of inorganic fertilisers to resource-poor farmers, other inputs are oftentimes proposed as alternatives (Abedi et al., 2010; Shahri et al., 2011; Soleymani, Shahrajabian, 2012a; Shahrajabian et al., 2013). It is believed that much of deficient plant nutrients could be supplied to soils through organic matters while small shortage are made up with mineral fertilisers (Oluleye, Akinrinde, 2010; Ogbaji et al., 2013).

In forage production, considering chemical position of forage crop is important (Rezaeifard et al., 2010). Farmyard manure (FYM) contains very small amount of major nutrients and involves transportation. But, it maintains the soil physical and chemical condition and improves the overall ecological balance of the crop production system. FYM reduces the external inputs and can on self-regulating ecosystem process.

The aim of this research is to review intercropping, its importance and comparison of fertilisers, organic manures, and green manures.

Intercropping

Intercropping is known as a practice, which can improve the utilisation of available resources and cause yield advantages and increases yield stability compared to sole

cropping (Soleymani et al., 2011e; Soleymani, Shahrajabian, 2012a). It is a sustainable practice used in many developed and developing countries and an essential element of agricultural sustainability (Singh et al., 2010). In intercropping system, there is normally one main crop and one or more added crops, with the main crop being of primary importance for food and forage production. The most important aim and advantage of intercropping is to produce a higher yield on a given piece of land by appropriate use of the available growth resources that may not be utilised by each single crop grown alone. There are different types of intercropping but the most important types are, row intercropping, strip intercropping, mixed intercropping and relay intercropping. Intercropping system may lead to soil conservation, improvement of soil fertility, and improvement of forage quality, reduction of pest and diseases.

The intercropping systems are old and widespread applications in low-input agricultural systems, and they were common for many countries before the modernisation of agriculture. There are both direct and indirect facilitative interactions of intercropping systems. Intercropping systems can cause more effective use of resources by providing symbiotic nitrogen from legumes or making available inorganic phosphorus fixed in soil because of lowering of pH via nitrogen fixing legumes. Also, more efficient water usage in intercropping systems was suggested by numerous researchers. Intercropping practices are the most productive when intercrops of different growth period are used so that their maximum requirements for growth resources occur at different times. They are the best way of introducing more biodiversity into agro-ecosystems and results have shown that increased crop diversity may increase the number of ecosystem service provided. These practices are the best way to ecological balance, more utilisation of resources, increase in the quantity and quality of agricultural products and significant reduction of damage and loss by pests, diseases and weeds. On the basis of multiple advantages of intercropping especially in the terms of sustainable agriculture and organic farming, it is clear that intercropping is more reasonable than sole cropping systems.

The agricultural use of a living cover crop during a crop growth cycle (relay intercropping) may help to preserve biodiversity, increase soil organic matter content and carbon sequestration and provide nutrient recycling (Shili-Touzi et al., 2010). Leguminous as a cover crops are extensively used in the tropics for soil conservation in plantation crops, maintaining it fertility. These plants have good potential for replacing many unwanted weeds (Olorynmaiye, 2010). For example, in potato and corn intercropping, Land Equivalent Ration (LER) reached 1.58 (Ebwongu et al., 2001). Bekele and Sommartya (2006) noticed that in intercropping of potato with garlic LER was more than one. According to Dua et al. (2005) the intercropping treatments increased yield as compared to sole-cropping. LER was higher than one in the intercropping of potato and pinto bean (Nasrollahzadeh Asl et al., 2009). Ghanbari et al. (2010) reported that

land equivalent ration values were higher in all intercropping systems with different planting ration of maize-cowpea which indicated the yield advantage of intercropping over sole cropping maize. Bilalis et al. (2005) reported that in the maize-bean intercrop system, LER values were statistically higher than in maize-cowpea.

The intercropping shows the beneficial effect on the quality and quantity of growth of crop plants. For example, Soleymani et al. (2012c) reported that in Iran there has been a rapid increase of fertiliser application in recent years to achieve high yields. Mix cropping legumes with cereal and grasses species were used for enhance nutrition value, supply energy and protein on both crops. This mixture offers a sustainable alternative to maintain efficient farming systems with reduced environmental impacts. The studies showed that intercropping causes yield advantage and better nutrition uptake. For suitable ways to animal's grazing were intercropping of berseem clover and forage corn in low input farming system and nitrate accumulation in clover.

The intensive cropping system, heavy input technology, environmental degradation and other related problems again encouraged to use green manuring in plant nutrient supply system. Residue burning accompanied with usage of triticale as a green manure was the best choice to achieve high quality. For obtaining the most fresh forage yield and biological yield of forage corn, triticale plantation can be replaced by barley cultivation. Four weeks of residue retention accompanied by using of barley as green manure led to the highest yield and yield components of forage corn. That is why, the green manuring is an age-old practice used for supplying nitrogen to crop plants.

Fertiliser

Low-input farming systems such as arable organic farming, often have limited access to nitrogen and decreased the productivity of these systems (Marsalis et al., 2010; Soleymani et al., 2010, 2011e, 2012a; Soleymani, Shahrajabian, 2012b; Abdollahi et al., 2018). The minimal or no fertiliser input causes serious nutrient depletion, which coupled with the low fertility status of soil is the major limiting factor to crop production. Increasing nitrogen supply enhances both growth of shoot and root of plants (Shahrajabian et al., 2011; Soleymani, Shahrajabian, 2011).

To optimise plant production and minimise production cost needed is supplemental nitrogen application (Ahmadi Moghaddam et al., 2010; Kayan, 2010; Soleymani et al., 2013). Inadequate amount of nutrient availability can show deficiency symptom and influence on the quality and quantity of yield of crops. In most commercially available fertilisers, the concentrations of active ingredients rapidly decreased due to chemical, photochemical and biological degradation, volatilisation, leaching, adsorption or immobilisation in soil (Broumand et al., 2010; Xiong et al., 2010).

Farmers often intercrop on soils without adequate knowledge of the right quality of fertilisers to be applied. By human activity nitrate found naturally at moderate

concentrations in many environments often rises to dangerous level. For example, nitrogen fertilisers affect yield and nutritive value of corn (Marsalis et al., 2010). Combined organic and inorganic fertilisation enhances organic matter in soil and increases yield of sweet maize (Efthimiadou et al., 2010). However, the application of excessive amounts of nitrogen can cause the accumulation of toxic levels of nitrate (NO_3^-) in plants (Gulmezoglu et al., 2010; Khoshkharam et al., 2010; Soleymani, Shahrajabian, 2013). Nitrate toxicity in forage plants can cause chronic or acute stress in livestock.

Manure

Organic farming, which evolved in the 1980s, is one way to solve the current farming problems. In this method, manure and green manure is used instead of chemical fertilisers (Soleymani et al., 2011b–d; 2012b). Because of this substitution, the food and environment become safer. Manures are very variable products, often difficult to apply accurately and release nutrients in the soil at a desirable rate. Some studies have shown that farmyard manure applied alone or in combination with inorganic fertilisers was effective in maintaining soil fertility under continuous cultivation. Applying farm manure increased cation exchange capacity (CEC), organic carbon and water holding capacity of the soil and nutrient availability. For example, a dairy manure is an excellent source of nitrogen for crops and can easily fulfil the nitrogen requirement. To get satisfactory results well-composted manure must be used, because it is usually free of weed seeds and has a better nutrient balance. Barmaki et al. (2008) reported that the yields of potato plots in which manure was used were 0.4 kg m^{-2} higher than in plots that receive only chemical fertilisers. It has been noted that application of organic manure has a more lasting beneficial residual effect that can remain significant up to four seasons when compared with inorganic fertilisers whose residual benefit do not last beyond season (Babaji et al., 2010). Liu et al. (2010) reported that sheep manure had no significant effect on rice's characteristics. Long term application of NPK and pig manure together with straw return to field produced highest rice grain yield. Future of agriculture lies in the development of organic based fertilisers.

FYM improves plants production better than mineral fertilisers as the crop is not capable of optimising single application of inorganic fertilisers but prefers slow continuous release of nutrient that is possible with the use of organic manure.

Green manure

Symbiotic N_2 fixation (SNF) in legumes is a fundamental process for maintaining soil fertility continued productivity of organic cropping systems (Singh et al., 2010). It is very often used in inter-row crops. One of the benefits of this kind of crop is having high potential of extrapolation. Cultivation of legumes together with non-legume

plants is a common practice in the world. Mixture of annual legumes and cereals is intensively cultivated in the world as a forage. Recently increasing interest of intercropping as an attempt to substantiate functional biodiversity for agriculture and reduce chemical inputs use was observed. For example, Sulc et al. (1993) concluded that ryegrass-alfalfa mixtures cultivate in North-Central USA can provide a good forage.

The typical organic production is characterised by extended rotations involving leguminous crop green manure and organic amendments utilisation (Soleymani et al., 2011a–b; Soleymani, Shahrajabian, 2012c). Canali et al. (2010) noted that supply of nitrogen from the soil, which consist of nitrogen mineralised from organic soil matter and crop residue is an important and variable contributor of nitrogen to potato crop production. Without organic farming, food security will be hampered (Sarker, Itohara, 2010). Legumes are often grown for incorporation into soil as a green manure providing benefits such as off-season soil cover, stimulated soil biological activity and improved plant nutrition (Soleymani et al., 2011c). Most interest has been attached to the legume's ability to furnish subsequent crops with readily available nitrogen (N). Some plants used for the production of green manure can significantly increase in yield of crops (Singh et al., 2010).

Conclusion

Sustainable agriculture means a shift from monoculture to intercropping. In other words, intercropping means the agricultural cultivation of two or more crops in the same space and at the same time. Sustainable farming also means self-sustaining, low-input and energy-efficient agricultural systems. Biodiversity is the main key and strategy for sustainable agriculture. Application of organic and synthetic fertilisers to soil would provide multiple benefits for improvement of soil chemical, physical and biological properties leading to improved crop yield. Integrated use of synthetic and organic fertilisers leads to development of sustainable crop production. Also, this may improve the efficiency of synthetic fertilisers and reduce their usage. Integrated use of organic and synthetic fertilisers is a good method to improve crop productivity and sustain soil quality and fertility. In sustainable agricultural system, fertilisers, livestock manure and cover crops are important parameters in productive agricultural systems to have stable food.

Conflict of interest

The authors declare no conflict of interest related to this article.

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Środki służące do uzyskania stabilnego systemu rolnego w zrównoważonym rolnictwie – krótki przegląd

Streszczenie

Zrównoważony system rolny jest najlepszym sposobem na zaspokojenie potrzeb dzisiejszych i przyszłych pokoleń. W systemie tym wielkość plonu wzrasta wraz z zastosowaniem upraw międzyrzędowych, poprzez wyższy współczynnik wzrostu roślin, redukcję nasion chwastów, ograniczenie ilości szkodników i chorób oraz bardziej efektywne wykorzystanie zasobów. Uprawa międzyrzędowa jest jednym z najważniejszych sposobów zwiększenia różnorodności w ekosystemie rolniczym. Systemy międzyplonowe mogą być bar-

dziej stabilnymi systemami praktyk rolniczych niż uprawy monokulturowe. Najważniejszymi zaletami uprawy międzyrzędowej są: zwiększenie produkcji rolnej i większe wykorzystanie zasobów środowiska. Zintegrowane stosowanie nawozów syntetycznych i organicznych może również prowadzić do rozwoju zrównoważonej produkcji roślinnej. Metoda ta poprawia wydajność działania nawozów chemicznych i jednocześnie ogranicza ich stosowanie. Zielony nawóz z roślin strączkowych, takich jak: koniczyna, lucerna i inne, które są bogatym źródłem azotu uwalnianego w glebie, jest w stanie zmniejszyć znacząco zapotrzebowanie na azot syntetyczny. Tego rodzaju biologiczne wiązanie azotu odgrywa bardzo ważną rolę w zrównoważonych systemach rolniczych. W zrównoważonym systemie rolnym nawozy, odchody zwierzęce i rośliny uprawne oraz chwasty są ważnymi parametrami dla zapewnienia stabilnej produkcji żywności.

Key words: intercropping, chemical fertiliser, manure, sustainable agriculture, stable system

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