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Prospects for use of ratoon agriculture in arid and semi-arid regions to achieve sustainable agriculture (Iraq as a model)

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Abstract

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Ratoon farming is one of the most important sustainable farming methods, which can contribute to increasing cultivated areas, especially in dry, semi-dry areas. Ratoon farming means the possibility of harvesting plants more than once from a single crop, and ratoon farming can be applied to specific types of crops when the environmental conditions and varieties are available for this type of farming methods. The most important plant species to which this type of farming is applied are sugar cane, rice, cotton, sorghum and other crops. The ratoon farming method has additional advantages that increase its importance as it achieves some of the goals of sustainable agriculture, in addition to the economic return achieved from using the ratoon farming method, although the second yield achieved from ratoon farming is less than the first yield for most crops grown in this way, but the absence of the cost of the second crop (which includes land preparation, seeds, soil and other crop service operations) and the reduction of labor makes the second yield economically feasible. This type of agriculture, despite its importance, is used in a limited scope, so there is a need to increase investment in ratoon agriculture research to achieve sustainable agriculture and achieve a better economic return for some important crops that respond to ratoon agriculture within the climates of the Republic of Iraq, especially in the central and southern regions.

Keywords: agricultural methods; second harvest; branching; genetic structures

Introduction

The gap between the amount of food production and population growth is constantly increasing, and this gap may shrink or increase depending on the great achievements of scientific research. If there is evidence of this fluctuation in this relationship between the amount of production and the size of the population, as the production of chemical fertilizers achieved a great boom in agricultural production, especially at the beginning of the nineteenth century, which then developed significantly and with it fertilizers and their sources diversified, but that reached another stage in which the gap widened again and then the production of varieties that give a high yield or resistance to disease and insect pests developed and the food gap narrowed again after the introduction of genetically modified varieties (GMO) to agricultural production until some varieties doubled their production to reach 400%, and this scientific achievement achieved a significant decrease in the difference between production and housing size and reduced famine disasters in poor countries despite the existence of some legitimate objections and fears of the use of genetic modification. However, this increase in production may reach a stage that will not be sufficient to feed the world's population, which is increasing in a geometric sequence, unlike the increase in production, which takes a numerical sequence. Therefore, serious consideration must be given to trying to harness all potentials and means to increase production, especially exploiting marginal lands to increase horizontal expansion, and producing high-yielding, good-quality varieties that are more tolerant to environmental stresses and resistant to agricultural pests to achieve vertical increase in production. Also, the farmer or producer's continued use of traditional methods in growing any crop leads to obtaining a similar and close amount of production and revenue in each agricultural season. Therefore, developing modern farming methods that reduce the cost and increase revenues may encourage the farmer to grow this crop (Cheyed and AL-Mohammedi, 2016). Among the most important farming methods that can be promising and have a good economic return is the method of farming using the ratoon method (Ratoon Cropping), which is a type of farming, through which the crop can be harvested more than once from a single crop (Al-Beiruty et al., 2022), where the second crop is allowed to grow from the remains of the previously harvested crop, i.e. it is the regrowth of new plants from the remains of the harvested crop (Stubble Cropping).

Therefore, this study came to shed light on the method of ratoon farming and the most important crops that can be successfully grown using the ratoon farming system, especially in the dry and semi-dry climates of Iraq and countries that are similar to it in this type of climate, and the most important advantages and problems of using the ratoon farming method for these types of crops.

The term ratoon farming

The word ratoon goes back to the Latin word "retonsus", which means "cut" or "retono", which means "return strongly" (Plucknett et al., 1970). The first use of ratoon farming was recorded in the Vedic period in India, as the Atharvaveda book mentions that farmers who grow barley used to cut barley plants many times, and the use of ratoon farming on reeds was also recorded in Chinese history in Fujian Province in 1757 (Sang, 1980 and Acharya, 2002).

In general, ratoon farming is known as harvesting the seeds of the crop more than once for seed crops, or cutting the vegetative parts of the plant after reaching a certain stage and allowing the plant remains (stem bases and root system) to regrow again (Al-Taweel et al., 2020). There are a large number of crops that respond to ratoon farming in the world, but there are a limited number of important economic crops that can be grown in the Iraqi environment, namely white corn, rice, sugarcane and cotton.

Sorghum (*Sorghum bicolor* L. Moench)

Sorghum has a wide ability to grow, adapt, tolerate drought and produce high productivity, even when growth inputs are scarce, and it is more resistant to pests and diseases (Tabri and Zubachtirodin, 2013). Sorghum has a strong and deep root system that has the ability to grow again after harvest (ratoon), so sorghum is very efficient in using nutrients and water so that it can grow and produce even in critical soils (Borghi et al., 2013).

Sorghum is one of the most adaptable crops to ratoon farming in Iraq, which increases the possibility of expanding the cultivation of this crop in all areas where it is grown, as the climatic conditions are suitable for this type of agriculture, as sorghum is grown in two seasons: the first season (spring), most of its varieties are grown during March and early April, and the second season (autumn), which is grown from mid-July to early August, and the harvest date of the first season overlaps with the planting date of the second season, which makes ratoon farming very suitable for this crop (Cheyed and AL-Mohammedi, 2016). Through conducting preliminary research, results were reached indicating the possibility of harvesting sorghum seeds in the spring season and leaving the plant bases without removing them and watering them again to grow and continue until the end of the second autumn season and give a grain yield again without replanting it and the resulting costs of plowing, smoothing, preparing the land and seeding, which makes it a method with high economic feasibility (Jassam et al., 2016), and more environmentally friendly and supports sustainable agriculture. Here, we must differentiate between mowing for fodder purposes and harvesting the crop for the purpose of obtaining seeds, as the latter is what is intended (El-Fahdawi et al., 2019a). A number of important studies were conducted in Iraq on the response of sorghum to ratoon cultivation, and their results were summarized as follows:

1 – Sorghum ratoon is characterized by an increase in the number of its branches and an increase in the volume of green matter (Al-Beiruty et al., 2022), which necessitates a review of the fertilizer recommendation adopted in the production of sorghum grown by the ratoon method compared to that resulting from direct seed planting, so a number of separate studies were conducted to determine the fertilizer needs of this type of cultivation, which showed that sorghum ratoon plants responded more to increased levels of ni-

trogen and potassium fertilizer (Cheyed et al., 2014; Cheyed and AL-Mohammedi, 2016);

2 – The yield of the main crop was significantly higher than the yield of the ratoon crop for forage varieties such as Kafir and Buhuth-70, while the seed varieties showed a great convergence in ratoon cultivation with those grown using seeds directly as a comparative treatment, especially the Enqaz variety and to a lesser extent the Rabeh variety (Al-Beiruty et al., 2022 and El-Fahdawi et al., 2019b and Al-Taweel et al., 2020);

3 – What distinguishes the seed varieties of sorghum in Iraq is that their plants are approximately 150–200 cm in height, while the forage varieties generally exceed 2 m in height;

4 – Another advantage of sorghum ratoon is that it remains in the field for approximately 28 days (Cheyed and AL-Mohammedi, 2016). This gives a greater opportunity to prepare for winter cultivation, or to cultivate green manure crops to improve soil properties for winter cultivation;

5 – Since the initial results indicated that the root system of sorghum ratoon plants is larger compared to seed-grown plants, water consumption and the effect of water stress on ratoon plants were studied, and it was noted that they consume more, and planting and irrigation dates as additional factors in testing the ratoon cultivation method are less water-consuming due to their early maturity and are also more tolerant of water stress compared to plants grown directly by seeds (El-Fahdawi et al., 2019 a, b);

6 – Lower concentrations of toxic hydrocyanic acid (HCN) in sorghum ratoon compared to plants resulting from the traditional cultivation method (seed cultivation), which makes it better as a green fodder provided earlier than if animals were fed green fodder resulting from traditional cultivation (Al-Beiruty et al., 2020);

7 – Sorghum ratoon grains contain a higher percentage of starch, protein and tannin, but a lower oil content (Zhou et al., 2022).

Sugar cane (*Saccharum officinarum*)

It is believed that the original home of sugar cane is southern China, Guinea and India, then it spread to the Arab countries and then to Andalusia, and its economic importance was recognized since the fifteenth century, which caused its spread and cultivation in Europe and then to the countries of the world, since then sugar cane has become the main and largest source of sugar in the world. Sucrose produced from sugar cane constitutes 86% of the world's production (OECD-FAO, 2021). However, its cultivation in Iraq did not receive the required attention until a specialized factory for sugar production was established in Al-Majar district in 1965, and it reached commercial production in 1971.

Sugar cane stalks represent the important economic part of the plant, which is harvested fresh, so it needs to be processed as soon as possible after harvest. It is treated immediately to reduce the conversion of sucrose to reducing sugars inside the sugarcane stalk to increase sugar production. The center of sugarcane emergence is in the tropics and requires a warm temperate climate above 20 °C, which provides an effective cumulative temperature that meets the requirements for the normal growth and development of sugarcane. Non-optimal germination temperatures, which are too low or too high, may lead to reduced growth and yield of ratoon cane (Kumar et al., 2022). The root system can regrow sugarcane and the activity of ratoon plants in each cycle depends on the strength of the root system, the activity of the shoots and the food reserve in it, as well as the appropriate environmental conditions (Pissolato et al., 2021). The root system in ratoon plants produces 1–8 new shoots after each harvest cycle, and in Brazil, sugarcane production cycles last for 4–5 years (Singh et al., 2015). Although ratoon cultivation is undoubtedly an economical, simple and easy way to improve the efficiency of sugarcane production, however, in general, the production of ratoon decreases with age.

In general, the germination process of ratoon sugarcane buds depends on the hormonal system during bud germination in ratoon crops. The higher the content of abscisic acid (ABA) and gibberellic acid (GA3) and the lower the content of auxin (IAA), the greater the ability of buds to germinate (Bashir et al., 2012). It was observed that auxin and ethephon (IAA and CTK) played an important role in the germination and growth of sugarcane lateral buds (Qiu et al., 2018). The root system plays an important and decisive factor in the production of ratoon sugarcane plants after the first harvest. Newly planted sugarcane plants first need to grow the root system, especially the perennial roots, which requires a relatively longer growth period and a higher effective cumulative temperature. As a result, newly planted sugarcane does not use light and heat sources efficiently at this stage. Ratoon sugarcane requires only 89,040,000 calories per ton of sugarcane production, while newly planted sugarcane requires 204,550,000 calories per ton (Sehtiya et al., 1992). They believe that irrigated ratoon crop requires only 295 days to mature compared to 482 days for plant cane (Hunsigi et al., 1998).

Ratoon cultivation is an ancient method of sugarcane propagation, which historical manuscripts in China indicate that this type of cultivation method was documented in 1757, in eastern China, in Fujian Province (Xu et al., 2021), where the basal buds that are found below the ground surface after harvest are stimulated to grow and produce new branches that are stimulated as a result of the removal of the apical dominance imposed by the main branches that were harvested in the first harvest. This type of agriculture reduces the cost of cultivation by eliminating the cost of planting and buying seeds in the next season and some other practices such as land preparation and irrigation. Ratoon cultivation leads to early maturity by at least a month for sugarcane harvested in the next season compared to direct seed planting, which gives more time to complete post-harvest operations and prepare for subsequent planting and better utilization of the land or field. It also maintains the purity of new improved varieties as well as genetically modified plants for a longer period of time because they remain in the field for more than one generation. However, other studies have shown that sugarcane yield decreases by 20% in the second harvest and the decrease increases to 40% in different areas of sugarcane cultivation in China and India. The reasons for the decrease in ratoon yield can be summarized in the following points (Shrivastava et al., 1982 and Shrivastava et al., 2000):

1 – Poor crop management;
2 – Difference in genetic structures and the presence of genetic structures less responsive to ratoon cultivation;
3 – Increased risk of diseases, especially mildew and red mold, and insect infestation due to the remains of dead harvested stems, which provide a suitable environment for the recovery of these pests;
4 – Unsuitable environmental conditions for the growth and production of the second crop (ratoon plants), as temperatures drop during the second harvest, which reduces production. The optimum temperature for branching is 33.3–34.4 C (Mathur and Haider, 1940), so winter harvesting of the crop negatively affects branching in ratoon plants. If the flowering process coincides with April, branching is abundant, but the number of dead branches is low (Parthasarthy and Rao, 1954).

This deterioration in the ratoon yield can be prevented or mitigated by following the following measures (Anonymous, 1992; Sundara et al., 1996):

1 – Proper management of sugarcane that takes into account the growing ratoon plants and their fertilizer requirements, as the special fertilization program led to an increase in the average weight of the cane by 62–75%;
2 – Selection of appropriate and early genetic compositions that are compatible with the ratoon farming method, as extensive studies were conducted in India to produce sugarcane varieties that are compatible with ratoon farming such as CoPant 90223, CoS 95255, CoS 94270 and CoSe 92423 as excellent varieties in sugarcane harvest (Sinha et al., 2016);
3 – Following integrated control programs that prevent the spread of agricultural pests that include weeds, diseases and insects;

One of the benefits of the ratoon cultivation of sugarcane is that it matures early by about a month and a half in the season. Early maturity increases the effective sugar collection period, which increases sugar production in ratoon plants. The benefit of cultivating short-growing-season genotypes is providing high-quality fodder for livestock.

From all of the above, ratoon crop reduces production costs and benefits growth by saving energy through reducing inputs and using residual fertilizer and moisture.

Indirect selection of genotypes with strong resistance to diseases and insect pests, drought tolerance and high yield also increases the ability of the selected materials for sugarcane breeding to reproduce (Ferraris et al., 1993; Chapman 1998). It is also believed that the ability of sugarcane to regrow after harvest (ratoon cultivation) is mainly determined by four important factors, which are:

1 – Root system characteristics;
2 – Total number of shoots;
3 – Number of growing stems;
4 – Productivity of sugarcane emerging stems. Good performance in the above four aspects in sugarcane and ratoon sugarcane plants is essential for selecting cultivars that respond to ratoon cultivation. In general, if there is an increasing number of effective stems formed by the lower buds of the main stems, and there is an increasing total number of effective stems on the main stems, the cultivar is likely to have strong reproductive ability and is suitable for ratoon cultivation (Qin et al., 2017).

Rice (*Oryza sativa*)

The history of using the ratoon method for rice crop dates back to 1800 years in China, and the development of ratoon rice has been repeated significantly and continuously and has achieved a large return in yield compared to its early origins (Xu et al., 1988). The same is the case in East Asian countries, and with the continuous innovation of agricultural technology, the importance of ratoon rice cultivation is increasing. Rice is considered one of the important strategic cash crops in Iraq and comes second after wheat as a basic component of the Iraqi food table. Despite its important economic position in Iraq, its production is very low and does not achieve self-sufficiency, as Iraq imports approximately half of its needs of this crop due to the small areas planted with it, especially after Iraq's shares of Tigris and Euphrates water decreased due to the water policies of the upstream countries, and because it is a crop, that depends mainly on the irrigation agriculture system. Therefore, the production of this important crop must be developed in various possible ways, and this can only be achieved by introducing and applying modern agricultural technologies instead of old patterns.

Rice is a crop that responds to ratoon cultivation, as its dormant shoots can re-sprout and produce grains after the main rice season harvest (Fei et al., 2021). Ratoon cultivation of rice increases the yield per unit area, thus reducing the area allocated for rice cultivation (Lin, 2019). It also promotes the sustainable development of ratoon rice and contributes to food security. There are two commonly used methods for harvesting ratoon rice: manual harvesting and mechanical harvesting (Lin, 2019). In the early stage of rice ratoon cultivation, the artificial harvesting method with high sectoral regeneration was mainly used to increase the number of sufficient inflorescences of rice ratoon by obtaining more axillary buds (Xu et al., 2018). In general, studies have shown that mechanical harvesting gives a higher yield of rice ratoon than manual harvesting, and the success of mechanical harvesting depends on the characteristics of the cultivated variety, planting date, cutting height, water availability, fertilization program, and the quality of those fertilizers (Torres et al., 2020; Zhang et al., 2021; Wang et al., 2021; Yang et al., 2022). The use of the ratoon cultivation method achieves seven reductions (reduction in seeds, labor, time, water, fertilizers, medicines, and rice field management) and two increases (increase in rice quality and price) (Yuan et al., 2019; Huang et al., 2020). What contributed to the expansion of the use of rice rotary cultivation by farmers is the low high production costs, by exceeding the cost of secondary cultivation and the accompanying use of mechanization for the purpose of plowing, smoothing and preparing the land for cultivation, in addition to a sharp reduction in labor, which was achieved as a result of the use of rotary cultivation and the expansion of artificial harvesting (Lin, 2019). Moreover, conducting such research would enhance the area of brown rice cultivation and improve food security.

Cotton (*Gossypium hirsutum* L.)

Cotton is grown in all regions of Iraq and is an important cash crop with multiple uses that provides high revenues to the producing country and ranks first among fiber crops, in addition to providing job opportunities for many workers. Cotton cultivation was spread in Iraq in 1921 by introducing American varieties (Cocorolite, Acala and Carrots), who's production developed after many studies were conducted on them to develop their production in various places on the map of Iraq.

The low productivity of sustainable agricultural systems is the main constraint to the future growth of sustainable agriculture, in addition to the increasing demand for global food and other products due to population growth. To overcome the constraints and simulate the widespread adoption of sustainable agriculture, a wide range of varieties is required that meet the requirements of sustainable agriculture and the usual production requirements, knowing that the application of sustainable agriculture is unstable due to the continued climate changes (Mohammed, 2014). Cotton production faces challenges represented by high costs with multiple management inputs and materials including seeds, pesticides and fertilizers. Production costs can be reduced and profits increased by developing effective crop management strategies, including permanent cotton cultivation (Zhang et al., 2022a). Cotton is one of the most widespread and needed natural fiber crops in the textile industry (Zhang et al., 2022b). High-yielding varieties, especially genetically modified cotton varieties, are the backbone of production for this cotton crop, as they are resistant to pests that have destroyed old varieties, especially the bollworm. This progress has also contributed to reducing the use of chemical pesticides and contributing to supporting the ecological balance (Silva et al., 2008; Wan et al., 2017). Cotton is grown in a wide range of environmental conditions, as it can be grown in arid and semi-arid areas, in saline lands, and even in clay soils. Breeding cotton varieties that are resistant to multiple stresses is of great and far-reaching importance (Wang, 2007; Migicovsky and Myles, 2017). The high potential of cotton to regenerate and regrow after the first harvest has been indicated since the end of the eighteenth century (1786), in Georgia (Seabrook, 1844). The use of cotton ratoon was recommended in Peru in 1961 to harvest more than one crop of second-generation seeds (Stroman, 1961). In tropical cotton producing areas, cotton ratoon is one of the most economical ways to utilize the high-quality, low-cost cotton fiber and seed products produced by planting high-yielding hybrids (Zhang et al., 2022a).

Both perennial and annual cotton varieties can be grown permanently in greenhouses or frost-free areas, and fertilizers must be provided sufficiently to continue cotton ratoon production cycles to avoid low production. Studies have indicated that perennial varieties respond better to ratoon cultivation, which may last for three years, compared to single-season varieties (Chen et al., 2010 a, b; Zhang et al., 2020 a, b).

Komala et al. (2018 a,b) indicated that perennial varieties are distinguished from single-season varieties by three main features:

1 – The root system is large for perennial varieties, which gives higher efficiency in absorbing water and nutrients and shortens the vegetative growth period;

2 – Reduced stem height and increased number of fruitful branches;

3 – Unlimited growth and production of inflorescences and a long growth period, which is reflected in increased yield;

There is considerable evidence that failure to control pests effectively can have a severe impact on the perennial cotton crop (Flint et al., 1980). Although perennial cotton has declined due to the many problems, it is exposed to and the high management requirements, some countries have even banned its cultivation (Plucknett et al., 1970; Morris, 1973). Second-season (ratoon) cotton cultivation, which is associated with increased first-season yields, can be used in areas where closed-season legislation is in place and has great potential for cotton production. In general, there are a number of studies that have been conducted to achieve a high cotton ratoon yield resulting from new branches. The results of these studies (Azevedo et al., 2000; Chen et al., 2010a; Khader and Prakash, 2014; Vukicevich et al., 2016) concluded with important recommendations to achieve this goal, which are:

1 – Pruning or cutting the main stems and the appropriate pruning height for the old branches at the end of the first harvest season, and the best cutting height is 15 cm above the soil surface (Macharia, 2013);

2 – A fertilization system that is proportional to the number of new branches produced in the second fruiting cycle of cotton ratoon, which is preferable to start at the time of pruning;

3 – Pest control and regulation of plant hormonal growth in accordance with the cultivated variety and the prevailing environmental conditions (Sachs and Zilkah, 1985);

A noteworthy study by Zhang et al. (2022 b) grafted annual (non-perennial) cotton onto perennial species with strong stress resistance in subtropical frost-free regions, which achieved significant results in terms of yield and quality in cotton ratoon cultivation. Seasonal cotton grafted onto perennial species as rootstocks and grown in this way can undergo more growth cycles than conventional grafted crops. Using wild cotton as rootstock for grafting annual cotton species can expand the geographic range of seed production (Zhou, 2016). This measure is of high economic significance for cotton ratoon cultivation in frost-free regions (Zhang et al., 2020a, 2022a). Therefore, breeding male-sterile cotton varieties with strong survival and cold tolerance during winter, and utilizing ratoon cultivation to maintain their male sterility for the production of cotton hybrid seeds, which can reduce the current production cost of hybrid seeds (Zhang et al., 2015a; Zhou, 2016).

Cotton varieties in Iraq have been improved to suit the prevailing environment and achieve higher yields by other methods, including the selection method by beehive (Mohammed, 2014), and selection under the influence of water stress (Al-Khirllah and Mohammed, 2015).

There is a need to increase investment in plant breeding and improvement research to find perennial cotton varieties that are compatible with environmental variables and respond to ratoon cotton cultivation, and this can be achieved from two main directions:

First: Breeding efforts should focus on stabilizing the multi-year ratoon cotton crop and determining the adaptability of the variety and appropriate planting arrangements for local conditions;

Second: Suitable male sterile cotton strains should be selected or bred for cotton ratoon cultivation in the environment of production areas.

Despite the success of cotton ratoon cultivation in some countries such as Brazil, China and India, due to the lack of local studies for this type of commercial production within Iraq, we cannot predict that ratoon cultivation of cotton can have good future prospects.

Conclusions

Although ratoon cultivation of some important strategic crops has been known since ancient times, and it is an important method that achieves the goals of sustainable agriculture and has good economic feasibility, its application is still limited, and may be due to the scarcity of studies on it in many countries and the lack of sufficient information among farmers about ratoon cultivation and its advantages, which makes them more likely to fear failure in using the ratoon cultivation method. This paper sheds light on the most important crops that can be grown in arid, semi-arid areas (Iraq as a model) and the advantages and problems that may hinder the application of ratoon cultivation in such environments. This makes expanding the study of the ratoon cultivation pattern of great importance.

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