ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS

Journal of Agronomy

ISSN 1812-5379
DOI: 10.3923/ja.2019.49.54

Mini Review
Dryland Farming and the Agronomic Management of Crops in Arid Environments

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Abstract

Farming plays and will continue to play a pre-dominant role in food production and the sustainability of the world's population. Objective of this mini review was to describe the dry land farming and its importance and also to outline the future growth prospects of this type of agriculture. Dryland management practices over time have undergone continuous evolution and in this mini-review it is synthetically explained. They are essential and over time they have become more active but alone are not sufficient to promote increased crop production in arid environments. The conventional approach which involves in establishing drought tolerant cultivars through breeding has not yet been able to solve the problem. The world of scientific research to increase production in drought environments in recent years is moving in two up-and-coming areas: (1) The use of Plant Growth Promoting Rhizobacteria (PGPR) and (2) The use of water-saving superabsorbent polymer (SAP), both of these opportunities in these last year seem to give great chances for success.

Key words: Dryland, rainfed farming, growth promoting rhizobacteria, superabsorbent polymers, drought tolerant cultivars

Citation: Lovelli Stella, 2019. Dryland farming and the agronomic management of crops in arid environments. J. Agron., 18: 49-54.

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The world's population needs a vast amount of food, about 60% more food is required to feed 9.5 billion people[1,2] in 2050. The continual increase in the world's population coupled with rising consumption, especially in emerging countries, highlights the urgent need to produce more food to meet the growing demand[3]. In other words, it is necessary to provide more food but in a sustainable manner (sustainable intensification). Farming plays and will continue to play a pre-dominant role in food production and the sustainability of the world's population. Innovation in the agricultural sector is crucial to achieve the Millennium Development Goals to eradicate hunger and poverty globally. The growth of the farming must be almost like a new green revolution, in fact, a doubling of food production is required for the next 20-30 years, in particular in sub-saharan Africa and partly in southeast Asia, where malnutrition and food demand growth are very prevalent. However, it should be pointed out that, in contrast to these needs, the cultivated areas are currently being reduced due to cementation, desertification, erosion, salinization, change of use and increasingly give up of marginal land[4]. No economic sector consumes so much water as agriculture with an estimate of 1300 m^3 per person per year. Some analysis scenarios show how about 7100 km^3 of water per year are consumed to produce food, of which 5500 km^3 per year under dry cultivation and 1600 km^3 per year in irrigated agriculture[5]. There is a further significant increase in the amount of water needed to produce food in 2050, from 8500-11000 km^3 per year depending on how much the farming systems will improve in dry and irrigation cultivation.

Climate change could further undermine efforts to mobilize water resources for the primary sector, due to reductions observed in precipitation at the lowest tropical latitudes. Some experts predict a further decline in rainfall and an intensification of extreme events[6,7]. Currently irrigated water withdrawals already cause stress situations in many of the irrigation districts in the world. In other words, a water crisis is already facing the world with very few possibilities that irrigation surfaces can further expand on a large scale. This situation accentuates the need for water management in dry crop systems not only to ensure the water needed for food production but also to develop resilience to deal with future risks and uncertainties related to water use. Water availability varies considerably from region to region and water competition can become very severe in areas where natural precipitation is reduced (arid and semi-arid). Therefore, the current situation and future scenarios lead to looking with renewed interest to dryland farming, which refers to growing crops entirely under rainfed conditions. Rainfed agriculture and dryland farming are terms often used as synonyms, but this is a mistake, both exclude irrigation, but by omitting this aspect they are different profoundly[8]. Dryland farming is a particular form of rainfed agriculture which characterizes the arid and semi-arid regions in which annual rainfall is about 20-35% of potential evapotranspiration. Rainfed systems, although they include dryland farming can also include crop systems in which annual rainfall can even or only at a high level equate the potential evapotranspiration[8]. Rainfed agriculture and dryland farming have in common the characteristic of excluding both irrigations, but the last emphasizes water conservation, sustainable crop yields, limited fertilizer and other inputs and wind and water erosion constraints[9]. Drylands cover 41% of the global terrestrial area[10]. Dry farming uses natural water intake, that is, water from precipitations that infiltrates the soil and forms a useful water reserve in the root zone (the so-called green water resource). Dry farming will play a crucial and dominant role in providing food and livelihoods for an increasing world population and it also represents a tremendous potential untapped for the upgrading of agriculture, for this reason undoubtedly requires more investment, so, this review was established to study the dry land farming and its importance and future growth prospects.

MODERN DRYLAND MANAGEMENT PRACTICES AND CHANGE OF THE CONCEPT OF DRYLAND FARMING

Dryland management practices over time have undergone continuous evolution, a complete description, although not recent, being that provided by an Italian agronomist named Cavazza[11], which stated that for dryland agriculture is meant “Agriculture where the most rational use of available water resources is practiced, so to cultivate a surface as wide as possible in optimum conditions of crop water supply".

The primary objectives of dryland farming, which apply to crops are:

- Encourage the accumulation of water resources from natural resources in the soil
- Reduce unnecessary and non-productive water losses
- Use genotypes and crop management aimed at the best water use[8]

Dryland farming provides a suitable hydraulic arrangement of the soil, both in flat and sloping conditions since only adequate water regeneration tends to favor water infiltration into the ground and reduce leakage by surface runoff. Then, all agronomic techniques are used to increase the permeability and penetration of water in the soil[10].

Traditional management practices for dryland farming is, undoubtedly, soil tillage that, as is known, increase water accumulation in soil, reduce evaporation from the soil, eliminate weeds and weed transpiration, minimize soil creep and consequent evaporation. Even a simple plowing contributes to increasing the accumulation of water in the soil, improves the depth to which the roots grow, improves the root density and contributes to decreasing the surface runoff, in other words, helps to increase the useful rain and allows best subsequent exploitation of water[12,13]. Among the modern agronomic techniques of dryland farming, there is the use of windbreaks that is the real barrier, customarily positioned perpendicular to that of the dominant winds and consisting of trees or hedges (live windbreaks) or inert material (artificial windbreaks)[14]. In semi-arid climatic conditions, where dryland farming is applied, windbreak action is considered crucial for the active effect of reduction of the crop evapotranspiration. In fact, in the case of windy conditions, the crop water use grows because the layers of moist air are removed continuously, which would otherwise tend to settle on the evaporating surfaces, decreasing the gradient between vegetation and atmosphere[15]. There is a significant reduction in water consumption and more efficient use of water in the presence of windbreaks. It is, therefore, necessary to increase its presence in agriculture always in the sustainable management of the water resource. The technique of mulching, in particular with plastic film, which has become quite common in the cultivation of horticultural crops has a noticeable effect on the microclimate of crops and in particular on evapotranspiration. It dramatically reduces evaporation from the soil with a substantial reduction in water requirements[16].

This technique, however, in addition to lower the evaporation losses from bare soil, contributes significantly to create a growth environment more favorable to plant development. Increased water availability for the plant, a different thermal regime of the soil, better growth of the root system due to non-tillage on the row, conservation of the structural characteristics of the soil due to non-treading in the mulching soil and absence of weed competition are the main reasons for the lushest vegetative growth of mulch crops[17]. As far as weeds control is concerned, one of the prerogatives of the weeds is to adapt more rapidly to crop by changes in water availability and agronomic management. The presence of weeds significantly reduces the availability of water to the cultivated species. Therefore, useful weeds control, especially in non-irrigated areas, is indispensable to maximize the production and water use efficiency[18,19].

Crop management plays a crucial role in reducing crop water consumption. Correctly, the timing of the sowing time must be carried out taking into account both the biological characteristics of the species and the environmental rain performance of the environment. If the needs of temperature, soil humidity at the time of sowing, plant germination and subsequent phases are consistent with the climatic trend of the area, the maximum exploitation of natural water resources is obtained. Moreover, the adoption of early and timely planting periods allows for a significant reduction in water use thanks to the possibility of intercepting a higher number of rainy events. Finally, as far as the transplanting species are concerned, this plant technique allows for the cultivation to remain in the field for a shorter period than the direct sowing, allowing in this case also a considerable water saving. The containment of soil water losses is also achieved through targeted interventions on the vegetation, i.e., optimizing planting density[10]. At least two are the main criteria for choosing the most suitable crop to be cultivated under dryland farming: (1) The crop cycle and (2) Crop attitude to maintain the productivity and water use efficiency in limiting water conditions. It is crucial to utilize crops that are drought tolerant and that fit the precipitation patterns[8]. Knowing the impact of water stress on the growth, development and yield crops is an essential aspect of the crop choice. There are plants able to control the internal redistribution of water in stressful situations, by accumulation in the underground organs and succulent plants in particular overhead tissues. There have been remarkable advances in soil-plant-atmosphere water studies, but these studies have almost always been applied in the field, both to facilitate the choice of the species to be cultivated in arid cultivation and to address their cultivation. Much more useful from this point of view is to know the phenological phases of greater stress sensitivity (in which to intervene with possible supplemental irrigations), the yield response to the irrigation, the irrigation scheduling and the relationship between the crop yield and the water use efficiency[20,21]. Last but not least, it is not neglected to use software, including those developed by FAO and open source on the network as the latest AQUACROP[22].

FUTURE PERSPECTIVES

In case of water scarcity conditions, selection of crop is crucial to maintain productivity. As far as this aspect is concerned in arid environments, the conventional approach which consists in establishing, through breeding, cultivars tolerant drought conditions has not yet been able to solve the problem, it can also lead to improvements but in a time horizon too broad[23]. One should focus on an approach that is

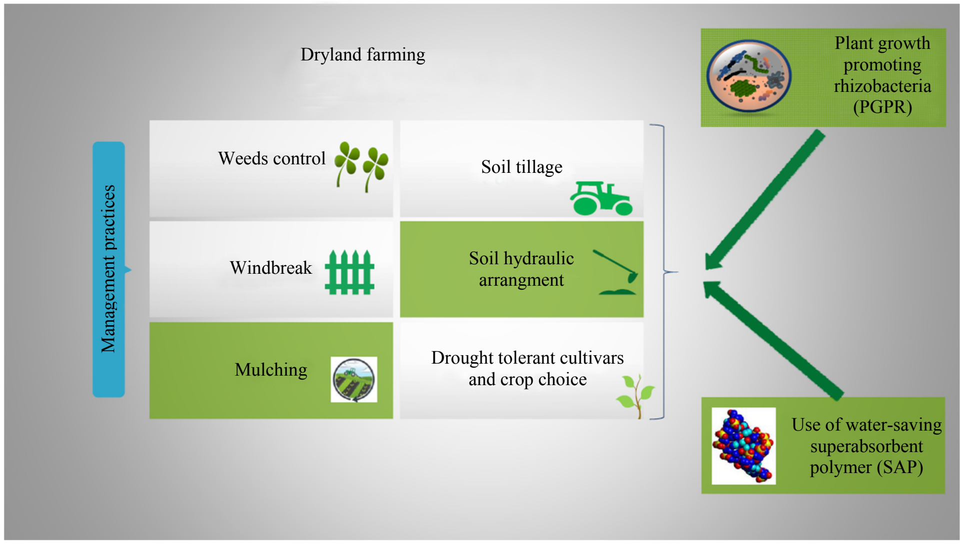

Fig. 1: Overview of agronomic management techniques in dryland farming and future options to improve them

more of a multidisciplinary type, giving the necessary space to soil science[24] and especially soil microbiology (Fig. 1).

In particular, the use of rhizobacteria that is Plant Growth Promoting Rhizobacteria (PGPR), which co-exist with the roots of cultivated plants can make the most efficient and timely solutions. These microbial species are organized into a real defined microbial community of rhizosphere. By analogy with the microbial populating the intestinal tract of vertebrates, including humans, the rhizosphere microbiota can cooperate with the plant in removing mineral elements from the soil and protecting the roots from potential pests. Intuitively, the rhizosphere microbial is, therefore, an unobserved reserve of bio-fertilizers and bio-pesticides. Recent developments in genomic sequencing techniques and computer analysis tools have allowed scientists to make enormous advances in this field. For this reason, many research groups have been focusing on the study of improving microbial-mediated crop production performance over the years and in particular, the physiological and molecular mechanisms underlying root-microbial symbiosis[25,26]. These research approached are geared to exploit the rhizosphere macrobiotics to enhance crop tolerance to adapt agronomic practices and crop yield in arid conditions[23,27]. In this case, the needs of specific crops, such as mineral nutrition and plant protection treatments, could be covered by microbial interventions aimed at addressing the deficiencies of a particular type of soil. These practices could be inoculation of bacterial strains or other microorganisms and selection of plant cultivars capable of "Recruiting" the microbiota most suitable for a particular soil type. It is interesting to point out how these concepts, increasingly rooted in the academic world are also brewing in the business world. In several countries, increasing attention is being paid to microbial applications in agriculture. However, it is good to point out that the enthusiasm for innovative products needs to be accompanied by research aimed at explaining the medium and long-term effect on the environment and specific rules regulating its use. The microbiota that proliferates in the soil-root interface can be one of the winning cards for the sustainable development of dryland farming, but for this objective, the work undertaken has just begun[23]. The use of water–saving superabsorbent polymer (SAP) represents an innovative technology for agriculture in semiarid and arid areas (Fig. 1). Several studies have shown the role of SAP application in improving physical properties of the soil (porosity, structure, water holding capacity[28-31] and for relieving drought effects on crops)[31-33]. These polymers when are buried they retain large quantities of water and nutrients, which are released as required by the plants. Three classes of superabsorbent polymer that are generally used: natural, semi-synthetic and synthetic polymers[34]. Some of them are macromolecular completely biodegradable and biocompatible[33,35]. Now, these superabsorbent polymers have been little used by farmers because of the high costs, but in recent years a synthetic polyacrylamide with potassium salt base produced in China has reached decidedly acceptable costs (5 US$ kg^{-1})[34]. For this reason, the application of SAP is a valid example of effective innovation for farming in arid and semi-arid areas and has the potential to become a popular practice of water saving technology for farmers in many areas of the world[34]. Furthermore, this technology can be used when using irrigation deficit techniques, since the use of these polymers (SAPS) also allows the irrigation intervals to be extended[36] and to reduce the irrigation water amount[33]. There are great expectations from this area of research, but still few studies on the physiological and molecular mechanisms that explain how the application of SAPs increases crop drought tolerance. There are, however, some important aspects to be investigated further, such as the impact and long-term evolution of SAPs, especially those that are not biodegradable.

CONCLUSION

This review confirms that innovation in the agricultural sector is crucial to eradicate hunger and poverty globally. To conclude the use of Plant Growth Promoting Rhizobacteria (PGPR) and water-saving superabsorbent polymer (SAP) represents an excellent opportunity to stabilize and increase crop yields in dryland farming.

SIGNIFICANCE STATEMENT

This mini-review describes the modern agronomic techniques of crop management in dry climate environments, with a specific reference to those innovative techniques that will probably allow increasing the productivity of crop systems in arid areas in the immediate future. This mini-review will help the researchers to uncover the critical areas of study to solve the actual problems of crop management in drought areas.

ACKNOWLEDGMENTS

This research was carried out in the framework of the project 'Smart Basilicata' (Contract no. 6386-3, 20 July 2016). Smart Basilicata was approved by the Italian Ministry of Education, University and Research (Notice MIUR no. 84/Ric 2012, PON 2007-2013 of 2 March 2012) and was funded with the Cohesion Fund 2007-2013 of the Basilicata Regional authority.

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