#7646 POTENTIAL PRECISION AGRICULTURE PRACTICES FOR HIGH QUALITY AND EFFICIENT FRUITS AND VEGETABLES PRODUCTION IN WEST AFRICA: A MINI REVIEW

Nicodeme V. Fassinou Hotegni[1], Leocade Azonhoumon, Enoch G. Achigan-Dako
Laboratory of Genetics, Horticulture and Seed Science (GBioS), Faculty of Agronomic Sciences, Abomey-Calavi University, 03 BP 2819 Cotonou, Benin
[1]nicodemef@gmail.com

ABSTRACT

During the last decades, efforts have been made to increase the yield and the quality of major fruits and vegetables but still, farmers mainly those in West African countries are struggling to close the yield gap. Precision agriculture has been reported in most developed countries as a set of tools integrating information and technologies for efficient crop production. Over the decades, scholars have been skeptical about the development and implementation of precision agriculture in West Africa mainly because of the type of agriculture, which is smallholder driven. The present paper aims at grabbing existing precision agriculture technologies in the West Africa to adapt and scale them up in the fruit and vegetable sector. A systematic literature review approach used. Out of the 353 papers pre-selected, 71 scientific papers were finally considered. It came out that there is a lack of research on precision agriculture related to fruits and vegetable crops. The existing technologies have been widely documented for field and cash crops; some technologies were region-specific. Technologies such as seed priming and seed treatment (13% of selected papers) and conservation agriculture (12% of selected papers) are more specific to the semi-arid West Africa whereas site-specific fertilizer management (25% of selected papers) is mostly present in humid West Africa. However, low-cost mechanization (6% of selected papers), fertilizer micro-dosing (21% of selected papers) and precision water management (23% of selected papers) are used throughout the West African region. A multi-steps model is proposed for a wide adoption of these technologies for high quality and efficient fruits and vegetables production in West Africa. New research initiatives need to be undertaken to identify other low-cost technologies such as hand-held sensors which could be used as a decision support tools by smallholders' farmers.

Keywords: Precision horticulture, fruits and vegetables, fertilizer micro-dosing, precision water management, site-specific fertilizer management, West Africa

INTRODUCTION

Fruits and vegetables are the main products highly demanded in West African horticulture (Bouët & Odjo, 2019). The trade of vegetables in West Africa was worth 27.3 US$ million between 2001 and 2005 and rose to 133.7 US$ million between 2011 and 2013 (Badiane et al., 2018). Vegetables grown in West Africa are diverse across countries and are generally categorized based on the harvested parts. Thus, three categories of vegetables are found: leafy vegetables, fruit vegetables, and root vegetables. Most important leafy vegetables in West Africa include *Corchorus olitorus*L., *Solanum macrocarpum*L., *Sesamum radiatum*S., *Amaranthus hybridus*L., *Lactuca sativa*L., *Brassica oleracea*L.), fruit vegetables include *Solanum Lycopersicum* L., *Capsicum annum*L., *Solanum aethiopicum*L., *Phaseolus vulgaris*L., *Cucumis sativus*L.and root vegetables include *Daucus carota*L., *Allium cepa*L., *Allium ampeloprasum*L. (Chagomoka et al., 2015; Houngla et al., 2019; James et al., 2010). Important

exporters of vegetables within West Africa are Niger (71.2%), Ghana (15.2%), and Burkina Faso (11.8%) (Badiane et al., 2018). The West Africa fruits sector is made of commodities such as banana, pineapples, mango, coconut, etc. Fruits and vegetables are not just profitable but they are key components of balanced diets and thus essential to the food security of population in the region. Fruits and vegetables are good sources of dietary fibre which consumption is associated with a lower incidence of cardiovascular diseases and obesity; they are also good sources of vitamins and minerals as well as phytochemicals that serve as antioxidants, phytoestrogens, and anti-inflammatory agents (Alissa & Ferns, 2017; Catarino et al., 2019; Slavin & Lloyd, 2012). Despite efforts of many scientists to improve quality including the yield of horticultural products, farmers still face some problems such as the (i) decline of soil fertility over the years, (ii) high susceptibility of crops to pests and diseases, (iii) low yield along with a low harvest index of many horticultural crops in West Africa, (iv) not efficient irrigation facilities, (v) poor inputs management technologies increasing labour and consequently production cost, and (vi) poor storage facilities (Adebooye et al., 2018; James et al., 2010). These problems constitute a bottleneck to the development of a sustainable horticultural sector in West Africa mainly in the current context characterized by the high interest of young entrepreneurs to agribusiness and mainly to vegetables production. To tackle these problems and incite more people to invest in horticultural sector in West Africa, there is an urgent need to rethink the whole horticultural value chains, mainly the fruits and vegetables farming systems. Sustainable agriculture intensification could be an option to revisit the fruit and vegetable production since it promotes efficient use of inputs (fertilizer, pesticides, water, etc.) (Aune et al., 2017) which will help fruits and vegetables farmers to reduce the huge yield gap. Such agricultural intensification calls for precision agriculture which promotes the timely and efficient execution of farming operations using the optimal rate of input and ensuring its application at the right location in the field (Aune et al., 2017). Indeed, the main objective of precision agriculture is to use information and science-based decision tools to make the best management decisions, achieve the highest possible yield, and reduce the agricultural impact on the environment thereby making it more productive, profitable, and sustainable (Kent Shannon et al., 2018). During the last decade, many scientists engaged some research fitting into the context of precision agriculture for fruits and vegetables production in West Africa and institutions such as the African Plant Nutrition Institute (APNI) based in Benguérir, Morocco has recently started promoting precision agriculture in Africa including, West Africa. Based on the need to develop fruits and vegetables sector in West Africa and tackle the different constraints encountered by stakeholders engaged in this sector, there is a need to capitalise existing technologies, classify them based on the readability to be used. Therefore, the present review aims at grabbing precision agriculture technologies for fruits and vegetables production in West Africa context and proposing a model to scale up these technologies in order to boost fruits and vegetables production. The mini-review is divided into three main sections: (i) definition of precision agriculture in African context, (ii) precision agriculture technologies for fruits and vegetables production in West Africa, and a (iii) way forward for the promotion of precision agriculture in horticultural sector in West Africa.

MATERIALS AND METHODS

A systematic literature approach was used. Google scholar and Scopus were used to find scientific papers related to precision agriculture practices in West Africa. The following key words were used in various combinations: ‘Precision agriculture’, ‘precision horticulture’, ‘vegetables’, ‘fruits’, ‘horticultural crops’, ‘West Africa’, ‘micro-dosing’, ‘drip irrigation’, ‘deficit irrigation’, ‘conservation agriculture’, ‘site-specific management’,‘farming mechanization’, ‘seed priming’ and ‘seed treatment’. A total of 353 papers were found.

Considering criteria such as the study location (which should be within West Africa), the period when the research was conducted (from 1990 -when precision agriculture emerged- to . 2020, and the adaptability of the technology to fruit and vegetable production in West Africa, a total of 71 scientific papers were retained and used in this review.

RESULTS AND DISCUSSION

What is Precision Agriculture and How Can It be Defined in West African Agriculture Context?

The International Society for Precision Agriculture (ISPA) define Precision Agriculture (PA) as: *"a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production"*(*http://www.ispag.org)*. Although complete, this official definition may not always fit in African and mainly West African context where the use of technology in agriculture is still lagging and the management approach is not information-intensive like in developed countries. (Mondal & Basu, 2009) reported that soft precision agriculture technologies are present in West Africa. Technologies such as mineral fertilizer micro-dosing, mechanized sowing, fertilizer application, and weeding, bamboo drip irrigation system based on the principles of precision farming have been used for long and were proven useful for agriculture in West Africa (Agossou et al., 2019; Dubos et al., 2019). So, an adapted definition fitting into the context of West African agriculture is proposed: "*Precision Agriculture is a tool or set of tools which allow farmers to reduce uncertainties by making the right management decisions through the use of the right variety, the right inputs, the right crop management, the right fertilizers, the right application time and dose, the right pest management strategies, to obtain the right product for the right market and at the right tim*e". Based on such definition, many technologies are available and can be classified as precision agriculture practices.

Seed Priming and Treatment

Seed priming is low-cost technology and physiological method to improve pre germinative ability of seeds before sowing. Few scientific papers (13% of selected scientific papers) dealing with seed priming in West Africa were found. (Waqas et al., 2019) reported many seed priming treatments ranging from conventional methods (hydro-priming, osmo-priming, nutrient priming, chemical priming, bio-priming, and priming with plant growth regulators) to advanced methods (nano-priming and priming with physical agents). Priming increased yield by up to 67% in Sudan and 40% in Mali (Aune et al., 2012; Coulibaly et al., 2019). (Harris, 2006) demonstrated that priming reduces time to germination and improved crop establishment, plant vigour, advances flowering and increases yield in regions with very limited rainfall making it a good tool in dry areas in West Africa. A deep description and explanation of this technique can be found in the chapter of (Waqas et al., 2019) entitled "Advances in the Concept and Methods of Seed Priming''. It is important to stress that in seed priming technique, there is a safe limit for soaking time to ensure the seed do not germinate before sowing. In fact, germination prior to sowing could result in a big failure in dryland because very harsh conditions for the new seedling to thrive. Studies have revealed that for many tropical crops the 'safe limits' for soaking seed is around 8h (overnight) (Harris, 2006). Primed seed should be surface dry prior to sowing and sown only when soil is moist enough to allow seed to absorb additional water from the soil and offers conducive soil condition for proper plant establishment (Harris, 2006). A study in Mali revealed that seed priming did not improve yield in area with relatively high rainfall, probably because of high soil moisture

(Coulibaly et al., 2019). The same author reported the use of priming technique in area with erratic rainfall. So, in fruit and vegetable production this technique can be used.

Conservation Agriculture

Few scientific papers (12% of selected papers) dealing with conservation agriculture (CA) were found). The No-till (NT) or minimum tillage system of CA is in line with the principles of PA for it guarantees an efficient use of labour force at sowing. In addition, CA implementation leads to the improvement of soil quality, creating good soil conditions for the success of PA practices. In fact, mulching and crops diversification (legumes, cereals, etc.) have lots of different benefits such as improved total soil nitrogen and soil organic carbon and other biophysical and nutritional qualities (Naab et al., 2017). CA is then a good practice to be considered in sustainable agriculture (Naab et al., 2017; Tittonell & Giller, 2013). Some challenges evolve from CA implementation such as the dearth of crop residue for mulching due to limited yield and the competition for multiple uses and economic value of the crop residue (Giller et al., 2009).

Site-Specific Fertilizer Management, Microdosing, Precision Irrigation and Water Management

Regarding soil fertility, several plant growth simulation models have been developed and proved efficient. In Benin, DSSAT (Decision Support System for Agrotechnology Transfert) has been used to make fertilizer recommendation in different maize production system (Igue et al., 2018; Saïdou et al., 2018). In both studies, DSSAT has been used as decision-support tool which integrated soil and agro-ecological conditions to propose the suitable fertilizer rates. Furthermore, the fertilizer recommendations based on EPIC model (Erosion Productivity Impact Calculator) has been used and authors found that Field Specific Nutrient Management (FSNM) gave higher yield than common local practices in cotton field in Benin (Gandonou & Dillon, 2017; Jones et al., 2003; Williams et al., 1989). However, due to the cost of the technology adoption in Benin (mainly of soil analysis), FSNM is less cost effective than the conventional approach of sole fertilizer rate for every soil unit. In this context, the efforts made by CORAF to avail D4Ag West African database for region-specific seed and fertilizer recommendation needs to be acknowledged and can be viewed at the following website: https://www.coraf.org/2020/09/24/feserwam-a-new-digital-for-agriculture-d4ag-tool-launched/. Fertilizer microdosing has also been listed as proven technologies. The combination of micro-dosing and seed priming greatly increased the crop yield (Aune et al., 2012; Aune et al., 2007). This clearly shows that combining micro-dosing with seed priming result in an additional benefit in semi-arid West Africa. These two practices have high potentiel if used in fruit and vegetables production in West Africa but still studies need to be conducted to validate their effectiveness.

Regarding water management, apart from drip irrigation techniques, an automated irrigation system based on sensors has been developed. One of this type of technology is the chameleon sensor which is place under the soil surface and possesses a solar-powered chameleon reader showing three different colour patterns: blue meaning excess of water, green meaning adequate moisture and red meaning lack of water (Ncube et al., 2018). If the sensing device is connected with the irrigation system, the red colour pattern triggers the watering of the field and stops it as well when soil is humid enough (blue pattern). The use of this kind of technology could significantly reduce need labour force, save water for other uses and spare times for farmer to go for others business or farming practices. Based on information gathered, a model for PA in fruit and vegetable production in West Africa should be based on the crop (fruit and vegetables) physiology, farmer constraints, cost effectiveness, and accessibility of

the technologies. These PA technologies should also be designed taking into account the most preferred quality attributes of the products and farmers should be trained to use them.

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