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Research and Development for a Modern Horticulture in the Groundnut Basin of Senegal

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This research is part of the "Programme d'appui au Programme National d'Investissement en Agriculture du Sénégal"(PAPSEN), a program funded by the Italian Ministry of Foreign Affairs, as a result of a collaboration among the Ministère de l'Agriculture et de l'Equipement Rural du Sénégal, the Italian Cooperation and the Israeli Cooperation. The main objective of the program is to strengthen food safety and food security in Senegal, through the sustainable development of rural areas and the promotion of innovative agricultural systems.
PAPSEN is composed of two regional programs: one in the Central Senegal, aimed at the development of vegetable production in the Regions of Thiès, Djourbel and Fatick and another in Casamance, focused on rice cropping systems in the Regions of Sédhiou and Kolda.
One of the main activities within PAPSEN Centre is the rehabilitation of approximately 400 ha of small or medium-scale farms with low-pressure drip irrigation systems based on the Israeli model TIPA (Techno-Agriculture Innovation for Poverty Alleviation). Through the collaboration with the Institut Sénégalais de Recherches Agricoles (ISRA) this research aims at a preliminary assessment on the adaptability of new potential crops and cultivars, using more sustainable agronomic techniques for the water and soil fertility management. The following paper presents the approach used in the definition of the methodology, xpected results and future development.

Introduction

Horticulture is a potential economic development vector for Senegal: in recent years, a high population growth in urban areas (2.5% per year) has led to an increasing demand of vegetables on the domestic market (CIDA, 2005). In the decade 2001-2011, available national data show that the overall production for the main vegetable crops (e.g. onion, tomato, cabbage) increased from 286,000 tons to around 640,000 tons, with an average annual growth rate of 7%. Moreover, vegetables and tubers account for 13.5% of the food budget and are the basis of the Senegalese diet, along with cereals (mostly rice) and bread (FAO, 2014).
Since 2005, exports have also increased in terms of value, with an average annual growth rate of 16.3% and a peak of 70% from 2010 to 2011, demonstrating an increasing interest for off-seasonal vegetable production among international trading partners (ANSD, 2011). Although positive, these results are still not enough to achieve national self-sufficiency for the most requested horticultural products such as potatoes, onions and tomatoes, and also with regard to business export opportunities for other horticultural products. In fact, thanks to its geographical position and the experience gained by its producers, Senegal has an enormous potential in exporting on sub-regional and international markets (APIX, 2007).

The production is still concentrated in a few areas, where water resources are easily available (as for the Senegal River Valley, along the northern border of the country) or the climate is mitigated by the proximity to the sea (coastal belt of Niayes) (Touré *et al.*, 2005; FRAO, 2003; Fall *et al.*, 2001; De Bon *et al.*, 1997). Nonetheless, there is an ongoing rapid shift of the production areas towards the neighbourhoods of big cities such as Dakar and Saint-Louis and to the southern regions of the country, where water reserves allow longer production cycles during the dry season, as a direct effect of the higher rainfall (Broutin *et al.* 2005).

In the Groundnut Basin, where 60% of the active rural population lives, climate change is leading to rainy seasons with an increasingly erratic inter-annual rainfall distribution and short rainfall events of higher intensity (Konté, 2010). Consequently, there is a drastic reduction in the productivity of the traditional rain-fed crops (groundnut, millet, sorghum, etc.), associated with a decrease in peanuts rentability on the international markets, caused by the liberalization policies implemented by the central government (Oya, 2008). As a possibility to grow high-value products all year round through irrigation, horticulture could become an interesting alternative activity for the rural population of these regions, hitherto regarded as marginal areas, not only ensuring a stronger food security, but also representing a substantial source of income (Olasantan, 2011). Nonetheless, the official available data on irrigated horticulture in Senegal show that in 1997 only 35% of horticultural farms were irrigated, representing 11.5% of all irrigated areas (FAO, 2005).

Moreover, there are other constraints affecting this sector: from poor access to agricultural production inputs (seeds, fertilizers, pesticides, energy and land, agricultural machinery), to the lack of training and again for the commercialization of the product, due to inadequate methods and facilities for storage, packaging and processing (Ndiaye, 2012; AICS, 2011; Wade 2009). The way towards a greater diversification and modernization of the sector passes certainly from a better marketing organization, but also from the production planning in the field and a better management of natural resources, especially water.

A necessary step towards this intensification is to have well-adapted cultivars, in terms of quantity and quality of seeds, giving high yields and with suitable characteristics for the needs of a specific market. In particular, for horticultural crops the Senegalese public research sector has been overtaken by the private research of some international seed companies, due to the lack of state investments (Stads *et al.* 2011; Fall *et al.*, 2010).The national *Centre pour le Développement de l'Horticulture* (CDH), established in 1972, has conducted an excellent work on varietal selection, first on the most economically important crops such as potato, tomato, onion and cabbage and more recently on some traditional African crops (ISRA et al. 2005). In recent years, though, it has become very difficult for the centre to regularly conduct genetic improvement activities and evaluation tests on the adaptability of newly selected or introduced varieties.

Material and Methods

In an attempt to identify new vegetables cultivars for the most economically important vegetable crops and to develop possible new crops, an experimental field with drip-irrigation is being installed at the *Centre National de Recherches Agronomiques* (CNRA) of Bambey, in the Region of Djourbel.

A multi-variety trial on seven (7) different vegetable crops, chosen as the most important for the local development, takes place in two years during three different growing seasons: a cool dry season, a hot dry season and a rainy season (*hivernage*). During each potential growing season, five (5) cultivars or landraces for each species, three (3) of which already cultivated in Senegal and two (2) of newly introduction, are tested in three different repetitions, following a randomized split-plot experimental design. In addition, three (3) new crops, represented each by two (2) landraces, are tested to evaluate their adaptability to the agro-ecological area of the PAPSEN Program. For the second year, trials are taking place on the same site, but the species

are arranged differently, not to return on the same plots. The total area involved by the experimentation amounts to about 1,4 ha, divided into 12 irrigated plots, each equipped with an independently manageable drip irrigation system.
The morphological characterization and agronomic evaluation of all the compared species/cultivars aims at rationally establish the best performing cultivars and their suitable seasonality; on this purpose, a list of descriptors IPGRI/Bioversity International has been preliminary selected for each species to allow an on-field evaluation of their adaptability and productivity, but also a qualitative comparison for those characteristics necessary to meet local and international commercial standards. In addition, some panel tests involving local farmers and researchers are organized and accompanied by specific chemical and physical analysis, for the evaluation of the main organoleptic characteristics of the different cultivars.
In parallel, a research experiment on the use of biochar as a soil amendment in vegetable cropping is carried out by two different experimentation activities using tomato (*Solanum lycopersicum* L.) as a test crop, in order to verify its effectiveness in increasing soil water retention and on the improvement of soil fertility management.
A first trial consists in three different applications of biochar per hectare (no biochar, 15 t/ha, 30 t/ha) under two different irrigation regimes (100% and 65% restitution of water consumption) for a period of three years. The experimental design is a randomized split plot with three (3) repetitions for each water regime giving six (6) main blocks divided into three (3) sub-plots of about 80 m^2 each, representing the three levels of biochar. Afterwards, another two-year activity aims at assessing the possible reduction in the use of fertilizers due to the biochar effect, testing three different levels of fertilization (100%, 75% and 50% of doses recommended by the national research centre) on the most productive combination out-coming from the previous experiment. The design is a randomized block with 3 repetitions for each dose of fertilizer. Considering two cultivars of tomato, there are totally 18 plots of 48 m^2 each.
To optimize the efficiency of drip irrigation systems, a simplified water balance model for the determination of an appropriate water scheduling on a daily scale is also developed, through the simulation of the crop-soil water demand based on the crop cycle length and few easily measurable meteorological parameters (minimum and maximum air temperature values on a five-days series). A model set up to estimate the water demand of semi-arid crops (WINETROP) can be easily adapted to this specific purpose.
The crop actual evapotranspiration, representing the soil-crop-atmosphere water loss, can be calculated through the algorithm ETc = ETo x Kc, where ETo is the reference evapotranspiration on the site and Kc the crop coefficient, varying for each crop according to the different phenological stages. Appropriately initialized with soil characteristics, the model compares ETo values estimated from two different equations (Penman CIMIS and Hargeaves Samani) together with the historical climate datasets. Weather data to estimate evapotranspiration are provided by a weather station. Outputs are then validated by checking if the estimated irrigation volumes actually result in an optimal plant water status for the plots at 100% water restitution and whether there is a reduction in water stress, as an effect of biochar, in plots where only 65% of theoretical water requirements are reinstated. Adjustments on the Kc coefficient values as established by the FAO are also possible, according to the real crop sowing/transplanting date and cycle length, through repeated measurements on soil moisture and on plant water status at different crop stages.

Results and Discussion

A preliminary analysis based on the collection of national and regional statistical data concerning the production (yields and surfaces) and the marketing of vegetables in Senegal was initially necessary in order to ensure adequate technical support for the definition of the objectives and methodology for the proposed research. The species chosen for the investigation are: cabbage

(*Brassica oleracea* var. *capitata* L.), onion (*Allium cepa* L.), eggplant (*Solanum melongena* L.), melon (*Cucumis melo* L.), tomato (*Solanum lycopersicum* L.), pepper and hot pepper (*Capsicum* spp. L.).
An investigation on the most common cultivars from those selected over the years by the national research institutes to the ones currently commercialized by private seed companies within the region was carried out for the detection of some interesting varieties for the purposes of the trial, in consideration of their suitable growing conditions, as well as the common cropping techniques, but also of their demand on domestic and international markets or their role in the culinary tradition. A parallel study for the identification of some landraces/cultivars whose introduction could lead to an improvement in the productivity or to the diversification of the market supply in terms of commercial types was also conducted. Three new possible crops were selected as of possible interest: lentil (*Lens culinaris* Medik.), "barattiere" and "carosello" (*Cucumis melo* var. *chate* (Hasselq.) Filov). For a comparison with the Senegalese realities, a survey with local stakeholders was organized to identify all the varieties commonly available for farmers and key seeds suppliers (private companies, research institutions, producers' organizations, international partners, etc.). This step allowed to collect information about traditional crop calendars, fertility and pest management and to analyze the preferences and constraints of the actors involved in the horticultural sector at various levels. Particular attention was given to verify the on-site availability of biochar production companies, together with the material characteristics and the distance from the experimental site, in order to minimize transport costs. Finally, the most suitable cropping techniques have been chosen coherently with the suggestions received by local researchers from CDH and LNRPV (*Laboratoire National de Recherche sur les Productions Végétales*).
Following this preliminary study, a research plan was defined, for the organization and development of all the experimental field trials, together with the estimation of needs in terms of personnel, materials, field equipment and laboratory instrumentation for the analysis of specific parameters. A first collection of the main environmental parameters of the site has also been done to get the baseline for a correct evaluation of the agronomic results, that will be further integrated with data deriving from the installation of a weather control station.

Conclusions and Outlook

Within the PAPSEN Program this activity could favour an improvement in the horticultural sector by giving an assessment of the induced effects of biochar application on the physic, chemical and microbiological soil characteristics in a sahelian environment, together with its impact on tomato production as well as on water and fertilizers use efficiency. Through the development of a simplified water balance model to establish water requirements for some major vegetable crops, advices to farmers on localized scale could be sent using smartphones applications or web platforms. An evaluation of the productivity of several vegetable crops under drip irrigation and the definition of profitable agronomical practices accessible to small-scale farmers could represent possible solutions to the major agro-ecological and socio-economical production constraints, whilst allowing to cover non-exploited commercial windows or promoting a better product position on export markets. In the end, diversifying vegetables and legumes availability represents an opportunity to improve the local food supply.

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