EFFETS COMBINES DU BIOCHAR ET DU COMPOST SUR L'EFFICIENCE D'UTILISATION DE L'EAU ET LE RENDEMENT DU MAÏS AU NORD DU BENIN.

Conference Paper · October 2020

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#OFE2021

Farmer-centric On-Farm Experimentation

Digital Tools for a Scalable Transformative Pathway

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The Conference was sponsored by the OECD Co-operative Research Programme on Sustainable Agricultural Systems, whose financial support made it possible for invited speakers to participate in the Conference either in person or virtually.

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These proceedings are a collation of pre-conference webinars, invited oral presentations and submitted papers and e-presentations presented for #OFE2021. Some contributions are video in nature, others in written format and some authors have provided both for their contribution. For this reason, the proceedings are supported by QR codes instead of DOIs to provide clear links between the various media approaches used within the proceedings.

Color code for the QR code:

General introduction of the conference

15 min live presentation

5 min video e presentation

15 min live webinar

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Editorial

The 1st International Conference on Farmer-centric On-Farm Experimentation Digital tools for a Scalable Transformative Pathway

The #OFE2021 conference "Farmer-centric On-farm Experimentation—Digital Tools for a Scalable Transformative Pathway" was organised by INRAE-#DigitAg and the ISPA OFE-C (International Society of Precision Agriculture, On-Farm Experimentation Community).

#OFE2021 was conducted in a hybrid format from October 13th to 15th in Montpellier (including one day dedicated to a workshop to develop policy propositions) and was preceded by a round of 4 webinars in May 2021 on 4 major themes for OFE:

People and processes

Value creation

Data and analytics

Policy linkages

Most of the 170 participants (40 people in Montpellier and 140 on-line) were researchers but also representatives from farmers' associations, start-ups, NGOs, and policy makers.

The conference achieved widespread geographical representation with 36 countries (54% from Europe, 16% from North America, 8% from South America, 8% from Asia, 8% from Africa and 6% from Oceania).

The conference was structured around invited speakers addressing the 4 above-mentioned themes as well as 4-minutes videos/presentations, made available online (as an alternative to traditional posters), with a selection also presented during plenaries. A total of 80 submissions were selected (30 papers and 50 short presentations) that showcased OFE activities and projects worldwide). This material, additional to that of invited speakers, demonstrated the existence of a very rich and diversified scientific production.

The three best conference papers were awarded by the Scientific Committee.

The present Proceedings were built in an original multimedia format which gathers all the contributions that have been produced for the conference:
pre-conference webinars, contributions of the invited speakers and of researchers who answered the call for papers and videos.

These #OFE2021 Proceedings gather a total of 190 items: 64 papers, 63 video presentations and 63 short video presentations (15 and 4 minutes, respectively, all available on a dedicated YouTube channel). Specific outcomes also include a manifesto for OFE, guidelines for data analytics and policy recommendations to support OFE. A virtual special issue of the Agronomy for Sustainable Development journal is also being produced as a spin-off.

Last, but not least, the organization warmly thanks the Co-operative Research Programme (CRP): Sustainable Agricultural and Food Systems of the Organisation for Economic Co-operation and Development (OECD), Agropolis Foundation, #DigitAg, the Occitanie region, Montpellier University of Excellence (MAK'IT), Occitanum, Agreenium, RMT Modelia and RMT NAEXUS, INRAE (MathNum & AgroEcosystem Departments) for their financial support to the conference.

The co-convenors:
Véronique Bellon-Maurel
Nicolas Tremblay
Simon Cook

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#OFE2021
Farmer-centric On-Farm Experimentation

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Executive Summary

Objectives

The limited presence of mainstream a bottom-up innovation pathways in the agricultural sector hampers the adoption and adaptation of new practices, especially needed to achieve meaningful and lasting change toward improving agri-food systems. Farmer-centric On-Farm Experimentation (OFE) may constitute this privileged pathway to bottom-up innovation. It is a practical and adaptable mechanism to bridge the interests of farmers, researchers and other stakeholders, that has the potential to transform research and innovation in agriculture. It combines the knowledge of farmers and experts, both in formal and informal manners, in a deliberate process of data-supported exploration, embedding research into real-world farm management to create valuable insights that are directly relevant to farm managers.

Change is as much about agricultural innovation systems, policies and our organisations as it is about the technology which can facilitate processes. Change occurs when people evolve in their practices, transformation occurs when changes scale up through networks and organisations. There is a need to better identify to which extent interactions between digital technologies act as enablers of OFE in varied organisational environments that nurture (or impede) transformational change (e.g. for data collection at farm level, analytics, information and knowledge exchange…). The underlying change throughout is in knowledge and shared culture: OFE creates and shares value through processes that bring several groups together in more dynamic business models. As soon as value is created, the issue of IP becomes critical so this topic must also be explained.

Farmer-centric experimentation has great potential to improve the design and adoption of better farm management practices. All stakeholders, including farmers, commercial product and service providers, scientists and policy makers, must seize this opportunity to improve farm practices in terms of precision, efficiency and impact. From smallholders to broadacre farmers, from local to greater scales, well-targeted analytics should be developed and deployed to exploit the valuable data already collected on the farm. However, no critical mass of OFE documentation exists to catalyse activities and enable institutional culture change, with a long tradition now requiring evolution.

The aim of #OFE2021 was to bring together, for the first time, a significant number of specialists, researchers, farmers' representatives, policy-makers, and start-ups to exchange OFE scientific and technical advances and to set the foundation for new routes to encourage the development of OFE enabled by digital tools.

Outcomes

Farmers need little persuasion to engage in OFE: trials and experimentation is, by far, the dominant learning process for farmers globally. This was reiterated during the roundtable.

However, for OFE to scale up and become institutionalised, we need to go beyond the value created for the farmer and create the conditions for OFE to ge¬nerate value for other stakeholders. Is is also critical to equitably share the value created and to recognize how different and varied scientific disciplines can contribute.

Data-rich OFE can be seen both as a way to develop very clear knowledge of the farm potential in order to make accurate propositions (practitioner benefits) and as a way to accumulate data about various agroecosystems to create new knowledge. Impact pathways for OFE contrast markedly with those of conventional research.

Policy, regulation and investments are necessary to support transformation through OFE which is, initially, a local process that engages farmers and others around specific changes on the farm. Currently, initiatives around OFE are happening despite seldom aligned institutional structures and incentives within the agricultural sciences, with funding mechanisms, career paths and norms favouring traditional scientific experimentation (centred around the research scientist). Harnessing the transformational potential of OFE for agricultural sciences and innovation requires more strategic institutional alignment. To scale up, OFE will need nurturing policy, well-designed legislation, and secure investment.

Scaling OFE has implications in the following policy areas:

1. Rural social/community development (process to build social capital amongst farming communities and to recognise its value)
2. Rural tertiary education (increasing levels of farmers and farm advisor skill, despite a worsening demographic profile)
3. Agricultural research policy (how farmer-centric are theories of change?)
4. Supporting growth and diversity in food systems (including farmers in supply chain infrastructure to de-commoditise)
5. Improving resilience in food value chains (trade, biosecurity, market);
6. Data security (IP and data protection legislation)
7. Environmental protection (rewarding farmers who innovate to meet ever more stringent requirements)

Policy development and implementation in line with OFE are essential to translate this new paradigm from fragmented examples into broad scale adoption and investment—a new way of supporting change in farming.

Through the 80 presentations, this conference revealed that there is a lack of analysis on the evaluation of the impacts (both ex-ante and ex-post) of these various policies on OFE initiatives.

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Conclusions

Innovative agroecological practices are advocated by various governments but farmers face constraints to transition because existing pathways are not farmer-centric. Similarly, digital technology has a huge potential to reduce the environmental footprint of agriculture and increase incomes. Yet, the agricultural sector is characterised by the lowest level of digital maturity of all. The rapid adoption of locally adapted sustainable practices will happen only if the innovations stem from a farmer's needs and experience in conjunction with trusted agronomic, social, economic and education science. For both transitions, farmer-centric approaches, as advocated by OFE, are urgently needed.

The conference made it very clear that OFE approaches and applications are highly diverse, which is an asset and a challenge at the same time. To a large extent, this diversity reflects the range of institutional contexts worldwide. This diversity is not transitory and is expected to persist over time. There is a need to coalesce and to communicate the nature of change around the 6 principles of OFE :

1. Farmer-centric
2. Real systems
3. Evidence-driven
4. Expert-enabled
5. Co-learning
6. Scalable - keeping all engaged in this much larger concept

Another need is to move away from plot-based agronomy and develop the "landscape agronomy" that will support the scaling of insights toward innovation ecosystem thinking. Old and new actors acknowledged that this is a real change process.

The conference also provided the opportunity to start fulfilling identified gaps notably:

1. Establish the international visibility of OFE
2. Contribute to international scientific exchange toward the development of OFE methodologies
3. Create a critical mass of scientific information and evidence to nurture public policies related to agricultural innovation systems

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Short-term effects of compost-biochar-based amendments on maize (Zea mays) growth and yield in four agroecological zones of Benin

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e-presentation

Abstract

In Sub-Saharan Africa (SSA), maize (Zea mays L.) production is characterized by low productivity due to the poor availability of external inputs exacerbated by climate variability. In Benin, the on-farm effect of different compost-biochar-based amendments on maize performance was evaluated with maize producers (n = 40). Across sites, fertilization increased grain yields by 90-106% for compost (CP) and terra preta (TP) and by 222% for MF compared to the control. Among the organic amendments, TP1-200 induced the best performance on growth and yield variables and was more stable irrespective of the environment. Thus, substituting MF by TP or complementing half dose of MF with TP may be a cheap strategy to achieve sustainable farming. However, further on-farm experiments facilitated by the development of Digital and Decision Support Tools (DDST) are needed across a broader range of locations in Benin to better understand maize response to compost-biochar-based amendments and farmers and institutional responses relative to this innovation.

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Introduction

Food insecurity is the major constraint facing Sub-Saharan Africa (FAO, 2013) which is sustained by the continuous decline in productivity of major crops, including maize (*Zea mays L.*). This yield decline is mainly due to soil nutrient depletion (Igué et al., 2013) exacerbated by rainfall variation (Pastori et al., 2019). In response to these issues, sustainable land management measures involving improved water productivity have been suggested (Assogba et al., 2017). Among these, the incorporation of compost from household waste has substantially increased crop productivity through the modification of soil physicochemical properties (Mrabet et al., 2011). However, organic fertilizer sources that generally have a C/N ratio below 20 contain a high concentration of nitrogen (Chaves et al., 2007) and the poor management and poor application technique of such compost may cause nutrient losses, greenhouse gas emissions, and reduced productivity (Diogo et al., 2010).

To this end, the solid, porous, environmentally friendly biochar that is derived from the thermal treatment of biomass appears as a solution because of its potential to sequester carbon in the soil and its ability to activate microbial life with a high use of nitrogen (Malinowski et al., 2019). However, this nutrient-poor compound is more effective when activated with organic matter sources (Liu et al., 2014). This combination, which is similar to the so-called terra preta, a blackish, rich soil from Amazonia, has been studied in several maize-based cropping systems worldwide (Agegnehu et al., 2016). The present study seeks to evaluate the effect of various rates of application of biochar-compost based amendments (terra preta) on maize production and to examine how this innovation could be incorporated into local Digital and Decision Support Tools for soil rehabilitation.

Materials and methods

Study sites and farm characteristics

The study was conducted in four agro-ecological zones of Benin,which included Kandi (Zone II, 11°0803 N and 2°5618 E), Bembèrèkè (Zone III, 9°57'39''N and 2°43'30''E), Bantè (Zone V, 8°00' and 8°40' N latitude, 1°30' and 2°17' E longitude) and Zangnanado (Zone VI, located between 7° and 7°30' N latitude and 2°15' and 2°30' E longitude). They are characterized by subhumid (Zagnanado and Bantè) and dry tropical (Kandi, Bembèrèkè) climates. The soils are tropical ferruginous in Kandi and Bembèrèkè (Igué et al., 2017), clayey-sandy, ferruginous-tropical in Banté, and ferralitic and leached tropical ferruginous in Zagnanado (Igué et al., 2013).

Study design and management

A set of on-farm demonstration trials were established in collaboration with 20 farmers across the four agro-ecological zones of Benin during the rainy season of 2019. Each farmer hosted one single, bi-replicated trial with six treatments randomly arranged. The treatments consisted of: : i) Control (Ck), ii) Mineral fertilizer (MF; NPK :150 kg/ha + Urea: 50 kg/ha), iii) Compost from AFVA produced with animal manure at 200 kg/ha (CP1_200), iv) Compost from Toffo produced with household wastes at 200 kg/ha (CP2_200), v) Terra preta (biochar + compost AFVA) at 200 kg/ha (TP1_200) and vi) Terra preta (biochar+compost from Toffo) at 200 kg/ha (TP2_200). The amendments were hill-placed to increase their efficiency (Tovihoudji et al., 2017). On each farmer's field, six contiguous plots in two replicates measuring 4 m x 5 m were delineated and separated by a 1 m alley. Fields were ploughed by farmers, and planting was done under the control of technicians.

Improved and early maturing maize variety EVDT 97 STR W (90 day-maturity) was planted at a spacing of 0.80 m × 0.40 m in all plots and thinned to two plants per hill at 10–14 DAS with a plant density of 62,500 plants/ha.

Participating farmers were identified through extension agents of the ProSOL-GIZ Project based on their experience in maize cultivation, willingness, and consent to participate, and the accessibility of the field. The farmers fully managed their demonstration plots from planting to harvesting, and the role of research technicians was limited to the monitoring of the management practices and the measurements. The sowing, fertilizer application, weeding, thinning and harvest dates were approximately identical across sites and treatments.

Data Collection

Prior to sowing, one composite soil sample (0.2 m depth) was taken using several randomly selected points from the entire experimental field at each farm. This sample reflects the status of the soil before treatment application. They were sent to the Laboratoire des Sciences du Sol, Eaux et Environnement (LSSEE/INRAB, Benin) and standard tests were performed to determine particle size, soil pH (H20, KCl), C and N contents, cation exchange capacity (CEC) and available phosphorus.

Crop parameters measured were plant height and number of leaves (15 days-interval during the growing period), height of spike insertion and crown diameter (at 75 DAS). These variables were collected with a ruler and a caliper respectively on five plants randomly selected and tagged from each plot. Harvest occurred when the plants reached full maturity and grain yield, straw yield, total biomass, and harvest index were determined in all the treatment plots (of 6.72 m^2) and extrapolated to hectare values where relevant.

Data analysis

The collected data were subjected to exploratory analysis to determine the means, and boxplots were constructed. Linear mixed modeling with GenStat Release 12.1 software (VSN International, UK) was used to determine the effect of treatments and sites on the collected variables. Significant differences of means were separated by Tukey's test at 5% level. The stability of yields in relation to the different environments was determined by the curve of the yield of treatments of a replicate as a function of the associated mean yield (Guertal et al., 1994). The coefficient of the regression line was used to assess yield stability by treatment (smaller the slope, the greater the yield stability. The grain yield response of treatments relative to the control was calculated by subtracting the control grain yield from the treatment under consideration.

Results and discussion

Soil and climatic data

The results of the soil analysis in different fields showed low nitrogen content and degraded soils with carbon contents between 0.7 and 1.8%. The soils of the fields in Zangnanado, Bantè, Bembèrèkè and Kandi had sandy, silty, and sandy-silty textures, respectively. Available phosphorus ranged from 19.73 to 43.50 ppm, indicating very poor soil status. Their pHs were moderately acidic ranging between 5.6 - 6 in Bembèrèkè, Zangnanado and Kandi, and weakly acidic in average 6.1-6.5 in Bantè.

The distribution of rainfall was uneven across sites. The peak rainfall was recorded in October, July, August, and September, respectively in Zangnanado (239.4 mm), Bantè (302 mm), Bembèrèkè (256.9 mm) and Kandi (250.3 mm).

Growth parameters

A significant interaction (P<0.05) was observed between sites and treatments for plant height (48 DAS), diameter of plant collar and height of spike insertion (75 DAS). The control plots (Ck) showed the lowest growth performance compared to the fertilized treatments (P<0.05). Under the MF, the plants exhibited the largest diameter at the collar with mean values highest at Kandi (14.1 mm) and smallest at Zangnanado (7.4 mm). These were followed by the TP2_200 treatment (12.1 mm).

The highest spike insertion was recorded in Bantè (0.67 m) followed by Kandi (0.62 m, P<0.05). The MF treatment also gave the highest value (0.68 m, P<0.05), followed by TP1_200 (0.56 m) and TP2_200 (0.55 m). Moreover, the ANOVA test revealed a significant difference for the number of leaves at all dates and sites. The highest number of leaves was observed in the MF treatment (13 leaves), followed by TP1_200 (12 leaves). The different treatments had a positive influence on the maize growth variables evaluated in the different study sites. But, MF significantly influenced all growth variables. Concerning the organic amendments, TP1_200 provided the best performance in height, number of leaves and TP2_200 the best collar diameter. These could be explained by the nutrient composition and availability of these amendments favored by the rainfall condition that prevailed at each site to improve the initial soils characteristics. The range of rainfall obtained could favor the optimal development of maize plants, although it was unevenly distributed per site. Despite this, it was noted that TP1_200 had a consistent effect on the different variables collected in Zagnanado, possibly due to the sandy texture of the soil in this region and its degraded state. Less fertile soils (e.g. sandy soils) are known to respond more quickly to organic amendments compared to silty or clay soils (Glaser and Birk, 2012). The changing behavior of TP1 at 200 kg/ha at the various sites indicated that there are other underlying factors to be revealed. This is in line with the conclusions of Chen et al., (2019) that the effects of biochar will depend on its properties, incorporation methods, rates applied, and, most importantly, soil/site conditions.

Yields and components

The best grain yields were recorded in Kandi (2200 kg/ha) and Bembèrèkè (2000 kg/ha) compared to Bantè (1600 kg/ha) and Zangnanado (1500 kg/ha, Table 1), where numerous heavy rain events were recorded that may have caused significant run-off, drainage, and nutrient leaching. Straw and total biomass yields followed the same trends. The MF and TP1_200 treatments had the highest grain yields (2900 kg and 2000 kg/ha, respectively) compared to the control (900 kg/ha).

Among all the organic amendments, TP1 was most effective. This may be explained by the type of compost used in the formulation of the Terra preta (TP), which derived from animal manure and provided more nutrients (1.66% N; 0,04%P; 0.47%K) and a good C/N ratio (12.2) that were retained by the biochar. It was also shown that the availability of biochar in the TP favored the hydro-physical properties of the soil through its large specific surface area, permeability, and high carbon content (Singh et al., 2019). This may have favored the soil nutritive properties and consequently the crop yield. Despite the higher fertilizer application rates in the MF treatment, yield in MF was similar to TP1-200 at most sites (Table 1).

This may be explained by the hill-placement of organic fertilizers resulting in a more efficient use of water and the applied nutrients (Tovihoudji et al., 2017).

Table 1 | Effects of organic amendments and mineral fertilization on yield and yield components of maize in four agroecological zones of Benin

Factors	Level	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index
Municipality	Zangnanado	1500a	2900a	0.33a
	Bantè	1600a	3200b	0.33a
	Bembèrèkè	2000b	3500b	0.36b
	Kandi	2200b	4200c	0.34ab
	SED	*106.4*	*223.3*	*0.0065*
Treatments	Ck	900a	1800a	0.33ab
	MF	2900c	5200d	0.36c
	CP1_200	1800b	3400b	0.35b
	CP2_200	1600b	3300b	0.33ab
	TP1_200	2000b	4000c	0.32a
	TP2_200	1700b	3200b	0.35c
	SED	*130.5*	*273.8*	*0.0079*
	Site (S)	*<0.001*	*<0.001*	*<0.001*
P-values	*Treatment (T)*	*<0.001*	*<0.001*	*<0.001*
	S x T	*0.614*	*0.729*	*0.492*

Ck = Control. MF = NPK (150kg/ha) + Urea (50kg/ha); CP1-200 = Compost of AFVA (200kg/ha); CP2-200 = Compost of Toffo (200kg/ha); TP1-200 = terra preta of AFVA (200kg/ha); TP2-200 = terra preta of Toffo (200kg/ha). SED = Standard Error of Deviation

Yield stability of maize as affected by treatments in various environments

The MF treatment showed a strong productive capacity in the different environments. The TP1-200 and CP1-200 amendments showed intermediate responses in all environments. However, the analysis of the coefficients of the lines showed that the amendments TP1, TP2 and CP2 generated more stable grain yields than the application of the mineral fertilizer (MF, Figure 1). The use of organic amendments resulted in a very high variation in yield depending on the environment. This is explained by the multitude of environmental factors influencing the mineralization of these amendments, which is much lower than that of the mineral fertilizer. The higher yields observed in the CP1-200 and TP1-200 treatments compared to the other amendments can be explained by the higher availability of nutrients in animal manure than in the household wastes.

The range of environmental and management conditions encountered across the various sites resulted in a high variability of yield responses to the different treatments. The highest responses were observed with the MF treatment, which could be explained by a much higher nutrient use under this treatment than with organic fertilization. However, yield response to MF tended to plateau with increasing yield in the control plots. This reflects the weaker response of this treatment on moderately rich soils than on degraded soils. The organic amendment was much more beneficial on degraded soils than on fertile soils.

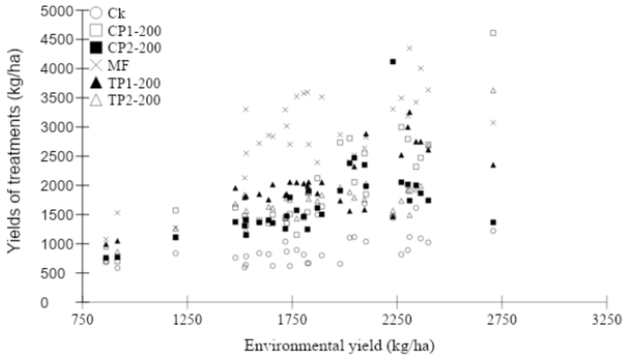

Figure 2 | Stability analysis of maize yield as affected by treatments in various environments in Benin. Ck= Control. MF=NPK (150 kg/ha) + Urea (50 kg/ha); CP1-200= Compost of AFVA (200 kg/ha); CP2-200= Compost of Toffo (200 kg/ha); TP1-200= terra preta of AFVA (200 kg/ha); TP2-200= terra preta of Toffo (200 kg/ha)

Conclusion

Although applying the recommended rate of mineral fertilizer, as currently done by most farmers in the study zones, appeared to give the highest performances, this practice is unlikely to be sustainable in the long term. Among organic amendments TP1_200 induced the best performance on the growth and yield variables. This treatment also showed an average productive capacity with more stable yields among the organic amendments. The range of environmental and management conditions encountered across the sites resulted in a high variability of yields. Yield response to MF tended to decrease more with increasing yields in the control plots than with the organic amendments. Further studies facilitated by the development of Digital and Decision Support Tools are needed across a broader range of locations in Benin to better understand maize response to compost-biochar-based amendments and provide insights to factors that affect farmers performing on-farm experiments.

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