Future of Food: Journal on Food, Agriculture and Society

Volume 3 Number 2
Autumn 2015

ISSN-Internet: 2197-411X
OCLC-Nr.: 862804632

Innovative Green Technologies in Agriculture and Food Production & Processing

Publishers

Ökologische Agrarwissenschaften UNI KASSEL

VDW

Future of Food: Journal on Food, Agriculture and Society

Volume 3, Number 2
Autumn 2015

Published 16 December 2015

ISSN Internet	2197 411X
OCLC Number	862804632
ZDB ID	27354544

open access

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Official web page of the journal
www.fofj.org

Social Media of the journal
www.facebook.com/futureoffoodjournal

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Description of the photo: At the Bradford Research Center, Brent Myers and Bill Schlep plant corn for variety testing.This photo illustrates the usage of GPS mapping systems and computers to find the certain seeds in the field.

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Editorial

Innovative Green Technologies in Agriculture and Food Production & Processing

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Dr. Vandana Shiva is a world renowned scholar, activist and practitioner in organic agricultural movement. She is member of the Editorial Board of Future of Food: Journal on Food, Agriculture and Society.

Over the past three decades, I have realised that our current industrial food system is broken. It is responsible for 75% of the ecological destruction of soil, water, biodiversity, and for 50% of the Green House Gases contributing to climate change. Instead of providing health and nourishment, it has become a major source of disease, including cancer, cardiovascular diseases, hypertension, obesity, diabetes, and neurological problems. Both industrial food production and industrial food processing are putting a high burden on the planet's health and human health. We need to shift to truly green technologies that rejuvenate the earth's resources and improve people's well-being. This is a shift from industrial production and processing of food to ecological production and processing, also referred to as artisanal processing. It is a shift from monocultures and uniformity to biodiversity, diversity of economies, and knowledge systems.

In 1984, I began studying the Green Revolution in Punjab as part of the UNU University programme on Peace and Global transformation. The Green Revolution is the misleading name given to a chemical-based agriculture model that was introduced to India in 1965. Following World War II, chemical companies and factories were searching desperately for new markets for synthetic fertilisers made in the explosives factories of the war. But indigenous varieties of crops rejected the artificial fertilisers, so plants were redesigned as dwarf varieties to allow them to take up – and become dependent upon – chemicals. By the mid-1960s, this new seed-chemical package was ready to be exported to countries

ISSN-Internet 2197-411x OLCL 862804632
UniKassel & VDW, Germany- December 2015

in the Global South under the label of the Green Revolution.

The false narrative perpetuated by the Green Revolution is essential to understanding the dominant narrative that has been created around food and agriculture. This narrative credits the Green Revolution with pulling India out of starvation, for which Normal Borlaug – the leading scientist on the project – was awarded the Nobel Peace Prize in 1970. But there was no starvation in India in 1965. Food prices had risen in cities due to a nationwide drought, and the country needed to import food grains. But under a policy to promote chemicals in agriculture, a condition was created by the U.S. government and the World Bank under which food grains would be sent to India by America only if it also imported seeds and chemicals.

There was a huge gap between the Green Revolution's narrative success and the realities in Punjab. Reduced to a land of rice and wheat, Punjab began producing less food and nutrition as a result of industrial agriculture. Once farmers in Punjab grew 41 varieties of wheat, 37 varieties of rice, 4 varieties of maize, 8 varieties of bajra, 16 varieties of sugarcane, 19 varieties of pulses, and 9 varieties of oilseeds. The majority of this diversity was destroyed. In the place of wheat grains with names like Sharbati, Darra, lal Pissi and Malwa, which described the origins and quality of the crops, we find personality-less monocultures named HD 2329, PBW 343 and WH 524: crops infested with pests and diseases, requiring ever-higher doses of pesticides.

While the Green Revolution in Punjab has left behind decertified soils, depleted aquifers, disappearing biodiversity, indebted farmers, and a 'cancer train' that carries the victims of pesticide-related cancer to Rajasthan for free treatment, this non-sustainable model is being exported to the eastern states of India and to Africa. Bill Gates, with his billions of dollars, is blindly pushing chemicals and commercial seeds into Africa through the Alliance For The Green Revolution in Africa. In fact, all world aid routed through policies of the G8 countries is undemocratically imposing a failed model on Africa. Sadly, the true lessons from Punjab's Green Revolution were only learned by those who were destroyed in its wake.

Not only did industrial agriculture destroy biodiversity, and ecosystems, it also created new health problems. Since the Green Revolution and industrial agriculture are based on adapting plants to chemicals, and for breeding for industrial processing, the quality of food degrades. Industrial wheat bred for industrial processing has led to the emergence of gluten allergies. Traditional wheat bred for nutrition do not contribute to gluten allergies. This is why Monsanto took a patent No. EP 0445929 B1 on May 21st, 2003 on an old Indian wheat variety that did not lead to gluten allergies. On January 27th, 2004 the Research Foundation for Science, Technology and Ecology along with Greenpeace and Bharat Krishak Samaha filed a petition at the EPO challenging the patent rights given to Monsanto, leading to the patent being revoked. Today, there is a Second Green Revolution underway: one comprised of GMOs. GMOs, or Genetically Modified Organisms, are genetically engineered crops with genes for toxins introduced into them. Like the original Green Revolution, GMOs claim to 'feed the world'. But the reality is that GMOs do not produce more, they have led to increased chemical use, and they fail to control weeds and pests. Genetic engineering creates an entirely new type of pollution on our planet, negatively impacting plants and animals, human health, and the livelihoods of farmers and local communities. The only beneficiaries of GM crops are corporations, because they sell more toxic chemicals and they also collect royalties on seed. As a matter of fact, corporations' greed and desire to own seeds is the only reason why GMOs are being pushed undemocratically into food and farming systems across the world.

But something is shifting. A new paradigm of truly green technologies is emerging that produce food using less land, less water, less fossil fuels, no agrichemicals, no GMOs. Food is produced by the soil, the seed, the sun, the water, and the farmer, all interacting with one another. Food embodies ecological relationships, and the knowledge and science of the interactions and interconnectedness that produce food is called agroecology.

Food is the web of life – the currency of life, our nourishment, our cells, our blood, our mind, our culture and identity. The contributions of biodiversity, compassion, and the knowledge and intelligence of small farmers feed the world. That is why in spite of priority given to industrial agriculture, even today 70% of the food comes from small farms.

Food is life, and it is created through living processes that sustains life. In agriculture and food production, nature and nature's laws come first. Violating these laws and trespassing on nature's limits of renewal - of seed and soil, water and energy - is a recipe for food insecurity and future famines. While rejuvenating nature's economy, ecological agriculture produces more and better food, and rejuvenates the health and wellbeing of communities. Taking care of the Earth and feeding people go hand in hand.

Feeding the planet raises some of the most fundamental questions of our times. The food question becomes an ethical question about our relationship with the Earth and other species; about whether we have a right to push species to extinction, or deny large members of the human family their right to safe, healthy, and nutritious food. It becomes an ecological question about whether humans will live as members of the Earth community, or will push themselves to extinction by destroying the ecological foundations of agriculture. It becomes a cultural question about our food cultures, our identity, and our sense of place and rootedness.

Feeding people is a knowledge question about whether we continue to think through a destructive, reductionist, mechanist paradigm, seeing seed and soil as dead matter and mere machines to be manipulated and poisoned, or we think of seed and soil as living, self-organising, self-renewing systems that can give us food without the use of chemicals and poisons. It is also a knowledge question about whether we see centuries of farming by peasants as based on knowledge, and farmers as intelligent, or we think of farmers as ignorant just because they may not have been to university.

The food question is also an economic question: about whether the poor eat or go hungry; about whether public taxes go to subsidise an unhealthy and non-sustainable food system; about whether seeds are in the commons or owned through patents by corporations; and about whether food is distributed on principles of justice, fairness and sovereignty, or on the basis of the unfair rules of so called 'free trade'.

Once I realised how misguided, and even false, the dominant system of agriculture was, I decided to do something about it. I dedicated my life to saving seeds and promoting of organic farming and ecological agriculture. Instead of intensifying chemical and capital inputs that were pushing our small farmers into debt, I committed myself to intensifying biodiversity and ecological processes, working with nature, rather than declaring war against her.

Photo credit: Knut-Erik Helle (via flickr™)

Figure 1: Seed bank at Navdanya's Bija Vidyapeeth centre, Dehra Dun

In 1987, I started Navdanya, a movement for saving seeds, protecting biodiversity, and spreading ecological methods in farming. We have helped create 120 community seed banks, which have provided open access seeds to farmers to grow tasty, nutritious crops with no external inputs, thus increasing their own nutrition while getting higher incomes. These seed banks have rescued farmers in times of climate extremes including draughts, floods and cyclones. Beginning with the saving and sharing of seed, we

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Photo credit: Knut-Erik Helle (via flickr™)

Figure 2: Crop diversity at Navdanya's Bija Vidyapeeth farm, Dehra Dun

now share the seeds of the knowledge of agroecology. Through our Earth University we spread the ideas and practices related to living seed, living soil, living food, living economies and living democracies. Through the practice of biodiversity-based, ecological agriculture, we teach how food can be grown in health and abundance, and farming can be done to enhance the fertility of the soil, increase biodiversity, converse water, and reduce Greenhouse Gases that contribute to climate change. My own research and lived experience over the last three decades has taught me that the answer to the food question does not lie in industrial agriculture, but in agroecology and ecological farming. We have evolved criteria of productivity, that better capture health and nutrition and the true costs of agriculture. Our report "Health per Acre" shows that farmers practising biodiversity-based agroecology can produce enough food for two India's, while rejuvenating nature's resources. Our book "Wealth per Acre" shows that the social and ecological externalities of chemical farming in India are $1.2 trillion annually, including the human cost of 300,000 farmers suicides due to the debt trap they are caught in with dependence on high costs seeds and chemicals.

The contest between the two paradigms of food is a contest between two ideas and organising principles. One paradigm is based on the Law of Exploitation and the Law of Domination, beginning with wars and rooted in violence. The second paradigm is embedded in agroecology and living economies and is based on the Law of Return: of giving back to society, small farmers, and the Earth. It embodies the values of sharing and caring, not selfishness and greed. Today, a paradigm shift has become a global survival imperative that cannot wait any longer.

I am delighted to be the member of the editorial board "Future of Food: Journal on Food, Agriculture and Society". As a new international journal, it could gain a considerable readership throughout the period of the last 3 years. Also, the journal has been indexed by many international organizations, universities and academics repository. The journal is based on the policy of open access and no cost on authors. Herewith, we are pleased to publish our Volume 3 Issue 2, on the theme of "Innovative Green Technologies in Agriculture and Food Production & Processing". The selected research papers presented in this volume will provide further insight on innovative solutions on Food processing/ production in regional and global perspectives.

From Subsistence Agriculture to Commercial Enterprise: Community management of green technologies for resilient food production

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Data of the article

First received: 20 July 2015 | Last revision received: 28 October 2015
Accepted: 29 October 2015 | Published online: 16 December 2015
URN: nbn:de:hebis:34-2015092949080

Key words

Private Public Community Partnership; irrigation; governance; market-based agriculture; food security

Abstract

The aim of this paper is to emphasize the capacity and resilience of rural communities in regard to sustainable food security by adopting innovative approaches to irrigation. The shift from subsistence to commercial agriculture is promoted as a means to sustainable development. An analysis of the efficacy of irrigation schemes in Zimbabwe suggests that, in terms of providing sustainable agricultural production, they have neither been cost-effective nor have they provided long-term food security to their beneficiaries. This is certainly true of Shashe Scheme and most others in Beitbridge District. The Shashe Irrigation Scheme project represents a bold attempt at developing a fresh approach to the management of communal land irrigation schemes through a Private Public Community Partnership. The model illustrated represents a paradigm shift from subsistence agriculture to a system based on new technologies, market linkages and community ownership that build resilience and lead to sustainable food security and economic prosperity.

Introduction

Beitbridge district is situated in the south west lowlands of Zimbabwe. It is part of agro-ecological zone five (Vincent & Thomas, 1960) with altitudes averaging about 500 meters above sea level. It is characterised as a semi desert region. Maramani Communal Area is situated in the south west of the district and borders on the Shashe-Limpopo Rivers, the international boundary with South Africa and Botswana.

Zimbabwe's Communal Areas are reserved for Indigenous Zimbabweans where they live under traditional systems of (land) tenure and governance arrangements (Holleman, 1952; Rukuni, 1994). There is very little water inland from the Shashe and Limpopo rivers. Settlements are mainly concentrated near the rivers and scattered villages inland where some water is available from natural pools and springs. In the nineteen 1960s more people were moved into Maramani by the colonial government in order to avail more land for commercial farming.

Boreholes were drilled throughout the hinterland and irrigation schemes were constructed along the Shashe River to cater for the additional settlers. Shashe irrigation scheme (184 hectares) was constructed as part of a governmental plan for the overall development of the area. Shashe as the biggest scheme catered for at least half the villages in the southern section of Maramani while Jalukanga

Citation (APA):
Latham, C.J.K., Palentini, L., Katemaunzanga, M., Ashton, P. (2015). From Subsistence Agriculture to Commercial Enterprise: Community management of green technologies for resilient food production, *Future of Food: Journal on Food, Agriculture and Society*, 3(2), 8-17

and Bili schemes serviced the northern half.

Shashe, Jalukanga and Bili, differ from most other colonial schemes in that the members do not live on the scheme in villages dedicated to this purpose, but are scattered amongst their home villages along the river and hinterland, in not a few cases as far as 16 kilometres away. The influence of this settlement pattern upon the emergence and development of the model described below should not be underestimated in terms of distribution of obligations and the rewards of participating in the scheme.

Shashe Scheme was built and run as a top down government controlled "technocratic" scheme (Bolding, 2004). The scheme was designed to provide livelihood opportunities to approximately ten villages in Maramani. From then until the early nineteen 1980s the scheme was productive, growing crops mainly for local consumption. Support from central and local government dwindled from the nineteen 1970s and almost completely ceased by the early 1980s as collateral damage of the independence war and the resulting lack of funds by the new government. The scheme slowly deteriorated and for all practical purposes it became defunct by the end of the nineteen 1980s. Devastating floods and cyclonic events finally damaged remaining infrastructure so that by the mid-nineties no more than between ten and twenty hectares were being irrigated. A few attempts were made by well meaning but under resourced non-profit partners and the Department of Irrigation to revive the scheme but without success.

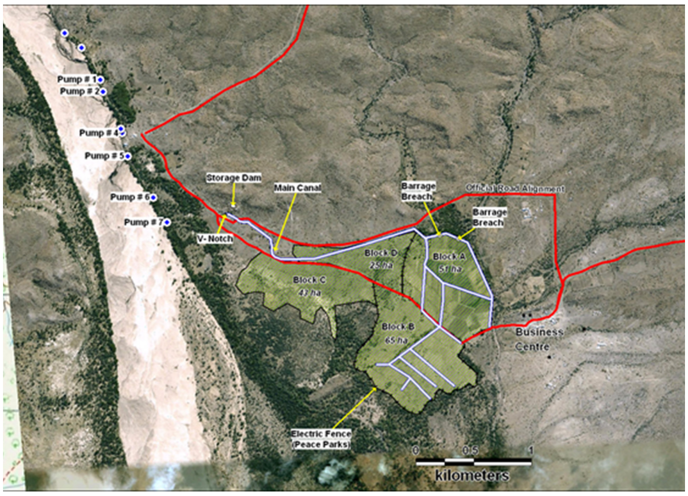

Figure 1: Shashe irrigation scheme superimposed to satellite map of the area.

In 2003, Nottingham Estate, a large-scale commercial citrus farm some forty kilometres from Shashe, promoted a consultation with local plot holders resulted in a proposal submitted by CASS (Centre for Applied Social Science – University of Zimbabwe) to the FAO. The farmers wished for greater jurisdiction and ownership of the scheme (including irrigation infrastructure). They wished to foster the idea of a partnership with commercial institutions or NGOs with a view to raising capital to revamp the scheme. They also proposed a high value marketable crop be introduced and favoured the introduction of oranges.

The notion was expressed that if a new successful model could be developed, it could lead to Shashe being used as a template and training aid for other schemes in the area. A household survey and a start on capacity building were undertaken until the economic meltdown in 2008 meant that FAO funding ceased. By this time, the community had developed a vision of how the scheme might develop. In 2010 CESVI – Italian NGO active in the Southern Lowveld since 1998 having done extensive research in the Maramani area associated with the introduction of the Mapungubwe TFCA (Trans-Frontier Conservation Area) – with EU financial support accepted the challenge of a project for the resuscitation of Shashe scheme. A new model was proposed, which promoted a paradigm shift from the traditional subsistence agriculture to turn the community into a commercial enterprise by linking together: traditional knowledge of the area and its resources; local expertise from existing commercial ventures; market access through the local processing plant; commitment for the implementation of a long term strategy through traditional and local leaderships; and donor funds through the technical support of an NGO. Work commenced on the scheme in 2011.

Literature review

Research indicates that communal area systems of managing irrigation have rested heavily on two persistent models: the "Technocratic" model and the "Local" model. (Bolding (2004) refers to the two models as "factory" and "African" – labels that do not accurately describe their components). Neither model has proved to be sustainable. Analysis reveals essential institutional and economic flaws in both. Thus, the model being introduced at Shashe seeks to create a sustainable system of management through a major paradigm shift involving three interlinked principal ingredients: (i) market viability, (ii) strategic partnerships and (iii) maximum devolved jurisdiction to local level.

Analysis has shown that these schemes generally collapse for the following reasons:

- The "technocratic" model fails because technocrats do not have the capacity to manage down to field level. The transaction costs if properly charged to the scheme (and thus the farmers) are not cost effective. If the government is unwilling or unable to subsidize the scheme, all technical and managerial inputs cease or are curtailed. Without the financial support supplied by Government or NGOs, the scheme's infrastructure deteriorates and collapses. Local level management lacks capacity to manage the financial, institutional, marketing capacity requirements for sustainability (Manzungu & Machiridza, 2005).

- The "local" model fails because technical knowledge is lacking, crops are grown largely for self-provisioning and do not realize sufficient income to provide adequate funds for maintenance and management costs. Local institutions fail to manage adequately as they lack capacity. Insufficient income is generated to levy the farmers and infrastructure collapses after a period of reduced productivity. The caveat to the above is that small schemes have a greater chance of sustainability and micro-schemes (irrigated gardens run by individual families) have a very high level of sustainability.

- Shashe Scheme was built and run as a "technocratic" scheme from about 1960 to the early nineteen 1980s. Because support from central and local government dwindled and almost completely ceased, the scheme collapsed. Since then the scheme has (de facto) been managed by the beneficiary farmers through an elected management committee. Devastating cyclonic events further damaged the infrastructure and it finally collapsed.

Case study

The present model introduced at Shashe (Figure 2) is based on research carried out over a number of years of regional and national level (i.e. Water Research Southern Africa (WARFSA) program) and confirmed by local participative research with and by the Shashe Community. The work undertaken by Mead (Mead, 2001), Cunliffe (Cunliffe, 2004) and Latham (Latham, 1999, 2005) as advisers/ consultants to CESVI, who has been active in the southern Lowveld of Zimbabwe since 1998, contributed to its evolution. Most important of all it incorporates the views and scenarios formed in consultation with the community, local leadership and other stakeholders.

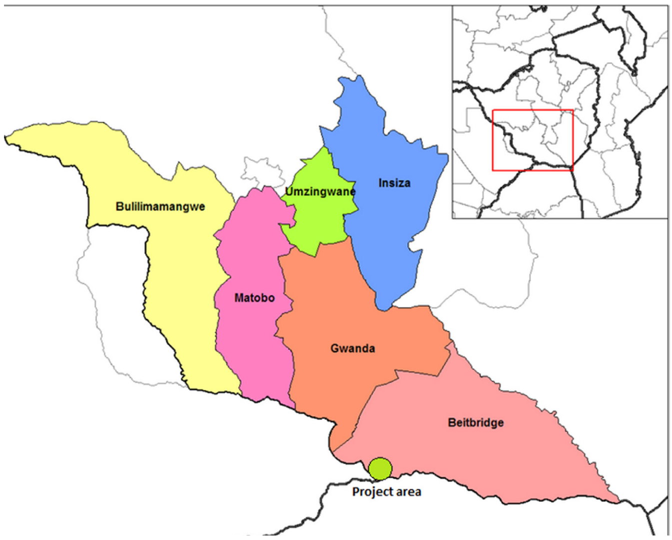

Figure 2: Project area

<u>It includes the following:</u>

- Devolution of "ownership" to beneficiary farmers who form a management organization with constituent representation.

- Considerable institutional development, the acquisition of skills and additional competencies sufficient to manage the complexities of a commercial enterprise. This is a long process that takes time – up to five years – and patient understanding (Murphree, 2004).

- The creation of partnerships with the private sector, focused upon seeking market guarantees, crop loan finance and technical support for economically profitable crops to be grown in

ISSN-Internet 2197-411x OLCL 862804632
UniKassel & VDW, Germany- December 2015

preference or addition to crops grown for food security.

- Support from extension agencies (NGOs, local and central government and private) is confined to assisting the farmers to make the transition to one of commercial sustainability with a food security element or Maize Equivalent Income (MEI) (Osofsky, 2005, p. 42).

Replacement of obsolete technologies (well points and flood irrigation) with a modern and sophisticated irrigation system (submersible pumps and ultra-high center pivots) (Figure 3) designed and modified to fit the needs of the community and the agricultural regime (coexistence of citrus and inter-cropping) . Citrus represents an innovative introduction on a community-managed scheme.

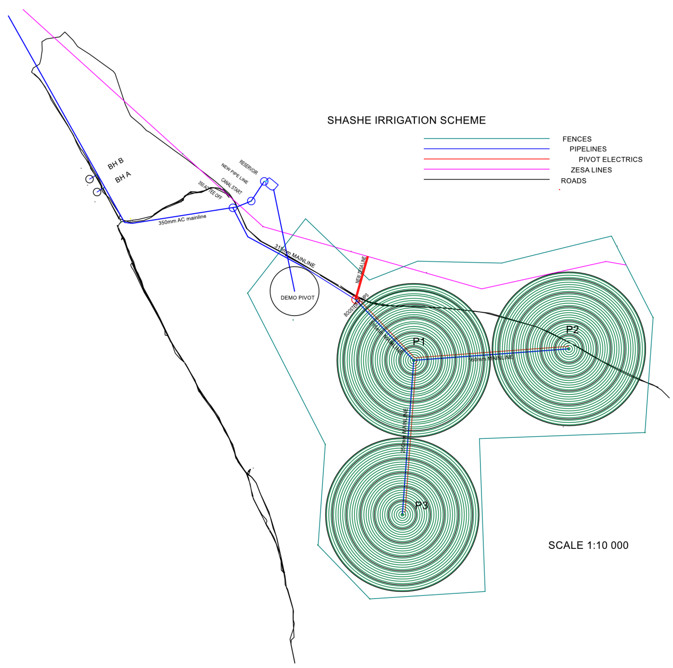

Figure 3: "Shashe Citrus Orchard" installation

The adoption of inter-row cash cropping at the behest of the community, in order to enhance immediate returns of food and funds for development and maintenance, represent a further innovation departing from the traditional citrus culture. In doing this, immediate cash returns are made available by utilising land between the trees, normally remaining uncultivated on citrus monoculture. The 'shift' from subsistence agriculture to a community-based commercial enterprise.

The development of the new model is based on regular and iterative use of systematic, strategic, scenario planning referred to as adaptive management (Jiggins & Roling, 2000; Latham, 1999, 2005; Murphree, 2001).

By goal setting, and regular, iterative self-assessment, farmers are assisted to develop and change perceptions in the light of newly perceived opportunities, technologies and agronomic innovations and to adapt and change their short-term goals while retaining their vision and overall objectives. Facilitators, advisors and techno-bureaucrats are also facilitated to understand perceptions and worldviews other than their own. The new model emerging thus embraces a common worldview and vision that is centred upon rural perceptions of food security ("food crops") as a principal objective, but now married to one of long term commercial sustainability – citrus – ("high value crops") and the investment of acquired income in scheme management and maintenance with individual profits accruing to participating beneficiaries (shareholders). A demonstration/trial plot (Figure 4) or 'mini-farm' started at the outset of the project was and continues to be a useful adjunct to the development and introduction of farming and technological innovations, hands on management, and identification of problems. The rural resource and training centre, offices and workshops situated adjacent to the demonstration plot, makes what the community now calls "The Demo", the nerve centre of the scheme. The creation and maintenance of an on-going learning organisation with the resilience and vision to embrace a partnership between the community and its external partners becomes an essential element of the centre. All activities and practices are viewed as part of an on-going learning process, and help develop a "learning organisation" (Senge, 2006; Senge & Sterman, 1992).

Partners are sensitised to the fact that the scheme is premised on common property management with tenure ("ownership") vested in the community of beneficiaries (Rukuni, 1994). Thus techno-bureaucrats and other resource providing agencies have to understand and adapt their own interventions to the reality that their empowerment and status lies in delivering an innovative, sapient support role, not a directional or authoritarian one. Moreover, man-

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Figure 4: Demonstration plot with 3 ½ year old trees ready for harvesting (June 2015)

agement structures of the scheme are responsible to their constituents and not to outside officials or institutions (NGO officials, Rural District Council, line ministries, etc.) Through lengthy debate and practical trial and error a dynamic institutional framework develops, upon which the organization and management of the scheme can move forward. This includes the formulation of a constitution and by-laws that are applicable, enforceable and enforced in partnership with traditional institutions (courts of headman) and local law enforcement agencies (Police, Environmental Management Authority and Wild Life Management). This answers one of the essential requirements of common property management (Ostrom, 1990).

Hand in hand with the institutional development at Shashe is the task of upgrading the infrastructure. Introduction of the centre pivots and related installations fell to CESVI. It involved some bold decisions such as the sinking of boreholes for submersible pumps deep in the Shashe River bed to replace the unserviceable old well point system, replacing degraded asbestos-cement delivery lines from pumps to field edge and extensive bush clearing and land preparation for three 30 hectare centre pivots that replaced the in-field trapezoidal canals, siphons and flood irrigation system that had been completely destroyed by neglect and cyclonic events.

In addition 22 000 orange trees were supplied by CESVI and planted by the community. Intercropping between the young trees became an established practice. Crops such as seed beans, squash, sweet potatoes, rape (canola) cabbages and maize are cultivated, either on contract for cash, or for basic food requirements or both.

While this activity was underway, the community was also involved in attempts to renovate the two arable blocks known as A and B (see Figure 1). This included work on a breached barrage, construction of a weir and work on canal repairs. Alas, all this demanding work was for nothing. An exceptional flash flood in a minor tributary of the Shashe that is normally diverted by the barrage was breached in several places and wrought havoc over the two blocks, destroying all the gains that had been made. This disaster illustrates the nature of projects such as Shashe, surprise events can never be ruled out.

The Management Committee had to deal with this disaster as well as supervise its members for the urgent need to plant orange trees under the third pivot commissioned by the end of 2014; complete allocation of trees to beneficiaries; negotiate contracts with Agri-businesses for seed bean and crops; tend to existing trees planted in previous years; maintain inter-row crops; attend meetings and workshops (some unrelated to the scheme) as well as maintain their social responsibilities. This daunting array of activities they have managed with commendable

ISSN-Internet 2197-411x OLCL 862804632

energy and maturity. This proves that communities, given the incentives and authority over their own affairs, are generally resilient and responsible. None the less, the learning organisation that is Shashe community, has still to experience their first season of mature trees when they harvest their first major orange crop, transport it to market and receive payment and budget their income against expenses.

A major strategic objective inspiring the colonial and post-colonial policy on irrigation schemes was an attempt to provide food security, to mitigate or avoid having to provide famine relief in the vulnerable low veld districts. This was certainly the case in Maramani. Shashe was designed to help the ten southern villages, Jalukanga and Bili the 10 northern villages. Indeed, this objective went some way to justifying the expense of the primary develop ment of the schemes and the subsequent heavy subsidisation (Bolding, 2004).

We have given an analysis of why these schemes eventually collapsed and the rationale behind developing a new sustainable model. It is necessary to demonstrate that this model when it reaches maturity should once more be capable of providing the food so necessary to augment other livelihood strategies in Maramani and similar environmentally disadvantaged districts. The Shashe case study illuminates this important component of the model's design and purpose. It must be born in mind, that the final concept of the Shashe model was largely influenced by local knowledge, which proved to be generally wiser and more aware of local dynamics and indigenous knowledge systems (IKS) and strategies than some theories and implementing plans brought by development practitioners, technocrats and commercial operators. In particular, their leaders were acutely aware of the community's need for the assurance of food security and for all agricultural plans to include this perceived element so vital to their well-being.

When the CESVI plans for the Shashe Project were being drawn up by the technical and administrative professionals, they logically included all four blocks in the projected citrus orchards. Only after the project was accepted and became operational did serious discussion with the local community ensue. The farmers were adamant that Block A and B be reserved for food crop production (the maize and wheat cycle). They drew attention to a workshop held in 2007 where this arrangement had been agreed. Despite arguments and scenarios presented to them about the advantages of cash crops (as MEI) and particularly citrus they remained obdurate. Wisdom acquired by outsiders may now see the logic behind their stance. No one at that stage (and indeed ever) will be able to guarantee that citrus will, for ever, be the cash crop that it currently appears to be. Bolding (ibid) points out that his extensive research in the Save Valley area (similar to Shashe in climate and livelihood strategies) noted that a constant strategy amongst irrigation farmers was to place food security before economic gain. The time honoured peasant belief in securing enough food before contemplating any adventurous farming innovation holds true. Also, more enlightened thinkers at these early discussions were concerned about the obvious risk of "putting all their eggs in one basket".

In the light of the above, Blocks A and B will remain reserved primarily for food security. It is an unfortunate turn of fate that the efforts to restore them to productivity failed. Nevertheless, it is a firm commitment of the community to bring them back into production.

Findings

In the light of the experience gained at Shashe the following scenario illustrates that the new model being developed may well prove to be the template for success not only at Shashe but for replication (with suitable modifications to fit the needs, aspirations and technical requirements) on other schemes in the area. The figures indicate that not only can food security be enhanced, but the general livelihoods of all the people of Maramani would be significantly improved.

Notional scenario

Maramani has a population of about 4 000 people. Assuming the basic maize requirement per person per annum at 250 kg (Osofsky, 2005, p. 42), the need for feeding Maramani population per annum is 1000000 kg (1000 tons).

Table 1: Shortfall for whole Maramani

@ 5 tons per ha scenario	@ 4 tons per ha scenario
Shashe	
750	600
Shortfall	
1 000 – 750 = 250	1 000 – 600 = 400
Less Jalukanga + Bili	
400	320
Surplus = 150 Tonnes	**Deficit = -80 Tonnes**

Therefore:
If 100 hectares (unutilised Block A & B) are going to be cultivate and assuming two scenarios @:
a. 5 tonnes/hectares = 500 tonnes
b. 4 tonnes/hectares = 400tonnes

Assuming inter-rows cropping can be cultivated under pivot on approximately 50 ha

a. @ 5 tons/ha =250 tonnes
b. @ 4 tons/ha =200 tonnes

By promoting the same model to the other two schemes in the area:

Jalukanga (≃ 60 ha)
a. @ 5 tons/ha = 300 tonnes
b. @ 4 tons/ha = 240 tonnes

Bili (≃ 20ha)
a. @ 5 tons/ha = 100 tonnes
b. @ 4 tons/ha = 80 tonnes

BUT: If Jalukanga and Bili halve their "food security section" and adopt the Shashe model of half food security and half cash crops, they can only reasonably aspire to reap 200 tonnes at 5 tonne per hectare scenario or 150 at 4 tonnes per hectare.

Thus, the Maize Equivalent Income (MEI) must equal or exceed this shortfall and provide sufficient income for repairs, maintenance and management costs and provide a disposable income to the farmers.

Citrus plus intercropping can provide much more than the projected shortfall plus any additional for repairs, maintenance and management costs but only after 5 years, when citrus reaches its commercial viability.

NB: The figures in the above scenario only reflect a single food crop per annum. Irrigation schemes can grow a minimum of 2 crops / p.a. – one for food security (or its maize equivalent) and one MEI crop dedicated to generating cash for repairs, maintenance and management etc. and for farmers' income to be used to supplement food or in good years to be disposable income.

Thus, the new model developed for Shashe is not only economically sound and sustainable but can theoretically also feed the whole of Maramani from the small cluster of Shashe, Jalukanga and Bili.

Our research and conclusions also suggest that increased resilience is achievable by introducing solar power to replace expensive and unreliable grid energy thus promoting environmental conservation and increased profitability of the scheme.

It is clear that these ideas need further research in order to prove the practical benefits, which seem to be self-evident. Perhaps most importantly research should be undertaken to establish the empirically held notion that the trickle-down effect of benefits accruing to farmers and their families on such schemes does in fact reach out into the wider community – and the actual impact of such interventions. If the current programme at Shashe (CESVI/ EU) and the FAO/EU engagement with Jalukanga and Bili are to go ahead for another two to three

ISSN-Internet 2197-411x OLCL 862804632

Figure 5: Shashe beneficiaries at work

years (funding permitting) this final stage of the "Shashe experiment" may well set the pattern for schemes throughout Zimbabwe and beyond, into SADC and the continent. That would certainly be a fulfilment of the vision and mission of those involved, no least the Shashe community itself.

Conclusions

From what we have illustrated in the preceding paragraphs, it becomes clear that managing an irrigation scheme incorporates counterbalancing sets of essential ingredients. There is the need for efficient and effective means of delivering cost effective water to the crops in sufficient quantities and reliability and it is necessary to have effective, appropriate, resilient and adaptable management in place. The Shashe model illustrates the implementation of a programme designed to maximise the benefits of deriving from these primary requirements. State of the art technology, in the form of submersible pumps replaced well points supported by prime movers mounted on the riverbanks. Polyethylene pipes replaced asbestos cement delivery pipes, canals and furrows. Booster pumps and generators (to overcome power outages) insure water delivery. Finally, centre pivots provide water to citrus and inter-row crops with maximum accuracy, efficiency and reliability. Coupled with the introduction of these technologies, novel and untested by the community, has been the introduction of citrus and on a scale both in terms of hectares and lead-time (5 years for its commercial viability) unprecedented in the experience of the farmers.

All these innovations require management. More importantly, they require a sense of ownership by the community. Thus, the development of a management paradigm must have three primary ingredients. First, it must be developed as part of the community's own vision and mission and fit with its worldviews and perception of how best to improve its livelihood strategies in a harsh and unforgiving environment. Second, it must develop in circumstances which allow a conservative and cautious community to adapt to the changes brought about by the technology, the demands of a market driven economy and reliance on outside agencies for support and expertise. Third, and perhaps most important is the powerful imperative of ownership of the scheme being firmly in the hands of the community (This is achieved by the creation of a 'Trust' which incorporates the ownership of the scheme by the community).

From the outset, the facilitators (CESVI and the Beitbridge Rural District Council) employed the methodological tools of scenario modelling and planning linked to adaptive management. Farming at best is an enterprise that has to be able to respond to unforeseen changes in weather, markets, disease and other unexpected events. Adaptive management is thus a natural extension and improvement on normal agricultural cultures. The term was first described as far back as 1999 seeking to balance the conflicting sets of conditions imposed by the clash between economics and ecology (nature is cyclical while industrial systems are linear). Thus adaptive management "is an approach to the management of complex systems based on incremental, experiential learning and decision making, buttressed by active monitoring of and feedback from the effects of outcomes and decisions." (Jiggins & Roling, 2000). While experience and research has proved the efficacy of such a methodology, the caveat is that it is a process. It strengthens resilience, creates a culture of learning and a capacity to use experience blended with new ideas to cope with situations not normally encountered. Ownership and pride in their ability to cope with internal and external challenges is enhanced and management improved. Thus, the gains achieved by adaptive management must be balanced against the reality that the process takes time. Murphree (2004) suggests that at least five years would be a conservative estimate for any large scale innovative programme. It is a view shared by others, including these commentators. In fact, if properly implemented it creates a self- perpetuating system of management or as indicated in the above definition, a "learning organisation" (Senge, 2006).

Acknowledgement

The authors would like to extend their thanks to the European Commission for funding the project, to Cesvi for the continuous support throughout the implementation, to the Beitbridge District Administration and Rural District Council for believing in the idea since its early inception; to Nottingham Estate for the unique and invaluable support, to Schweppes/Beit Bridge Juicing and GIZ for their financial contributions; to the numerous consultants; CASS (Center for Applied Social Sciences – University of Zimbabwe); and last, but not least, to the entire Maramani community and the Shashe Irrigation Scheme beneficiaries and management for their courage, energy and unbelievable efforts throughout the five years of the project. Furthermore, authors wishes to thank the anonymous reviewers for their helpful and critical comments.

Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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ISSN-Internet 2197-411x OLCL 862804632

Influence of pre-plant densities of *Meloidogyne incognita* on growth and root infestation of spinach (*Spinacia oleracea* L.) (Amaranthaceae) – an important dimension towards enhancing crop production

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Data of the article

First received: 13 August 2015 | Last revision received: 11 October 2015
Accepted: 03 November 2015 | Published online: 16 December 2015
URN: nbn:de:hebis:34-2015092949091

Key words

density; *Meloidogyne incognita*; shoot growth; spinach

Abstract

Vegetables represent a main source of micro-nutrients which can improve the health status of malnourished poor in the world. Spinach (*Spinacia oleracea* L.) is a popular leafy vegetable in many countries which is rich with several important micro-nutrients. Thus, consuming Spinach helps to overcome micro-nutrient deficiencies. Pests and pathogens act as major yield constraints in food production. Root-knot nematodes, *Meloidogyne* species, constitute a large group of highly destructive plant pests. Spinach is found to be highly susceptible for these nematode attacks. Though agricultural production has largely benefited from modern technologies and innovations, some important dimensions which can minimize the yield losses have been neglected by most of the growers. Pre-plant or initial nematode density in soil is a crucial biotic factor which is directly responsible for crop losses. Hence, information on pre-plant nematode densities and the corresponding damage is of vital importance to develop successful control procedures to enhance crop production. In the present study, effect of seven initial densities of *M. incognita*, i.e., 156, 312, 625, 1250, 2,500, 5,000 and 10,000 infective juveniles (IJs)/plant (equivalent to 1000cm^3 soil) on the growth and root infestation on potted spinach plants was determined in a screen house. In order to ensure a high accuracy, root infestation was ascertained by the number of galls formed, the percentage galled-length of feeder roots and galled-feeder roots, and egg production, per plant. Fifty days post-inoculation, shoot length and weight, and root length were suppressed at the lowest IJs density. However, the pathogenic effect was pronounced at the highest density at which 43%, 46% and 45% reduction in shoot length and weight, and root length, respectively, was recorded. The highest reduction in root weight (26%) was detected at the second highest density. The Number of galls and percentage galled-length of feeder roots/per plant showed significant progressive increase across the increasing IJs density with the highest mean value of 432.3 and 54%, respectively. The two shoot growth parameters and root length showed significant inverse relationship with the increasing gall formation. Moreover, the shoot and root length were shown to be mutually dependent on each other. Suppression of shoot growth of spinach greatly affects the grower's economy. Hence, control measures are essentially needed to ensure a better production of spinach via reducing the pre-plant density below the level of 0.156 IJs/cm^3.

Citation (APA):
Dammini Premachandra, W.T.S., Gowen, S. R. (2015). Influence of pre-plant densities of *Meloidogyne incognita* on growth and root infestation of spinach (*Spinacia oleracea* L.) (Amaranthaceae) – an important dimension towards enhancing crop production, *Future of Food: Journal on Food, Agriculture and Society*, 3(2), 18-26

Introduction

Spinach (*Spinacia oleracea* L.) (Amaranthaceae) is considered as a nutritionally powerful food which is a good source of dietary potassium, magnesium and of iron as well as several vitamins. It is largely cultivated in the southern wet zone of Sri Lanka on a commercial scale as well as in back-yard gardens. It has been reported that root-knot nematodes, *Meloidogyne* spp. are one of the most common and damaging nematodes on spinach in several countries, limiting production (Potter & Olthof, 1993; Castillo & Jiménez-Díaz, 2003). *Meloidogyne* spp. is among the top major pathogens affecting the global agricultural industry (Sasser & Freckman, 1987; Eisenback & Triantaphyllou, 1991). They cause serious losses in vegetable cultivation, particularly in tropical and sub-tropical regions where environmental conditions favour their growth, survival and distribution. Sikora and Fernandez (2005) reported more than 30% of yield losses in highly susceptible vegetable crops. The life cycle of *Meloidogyne* nematodes constitutes six developmental stages, egg, four juvenile stages and the adult. Second-stage juveniles, hereafter named as infective juveniles (IJs), initiate infestation, via entering the root systems in soil. Once inside the root tissues, they establish permanent feeding sites called giant cells (Hussey & Grundler, 1998), leading to characteristic gall formation. As a result, water and nutrient uptake of the plants is disrupted which ultimately affect the growth and yield (Williamson & Hussey, 1996). However, infestation at the young stage is found to be lethal to host plants. Worldwide, four species, i.e., *Meloidogyne javanica* (Treub), *M. arenaria* (Nealare), *M. incognita* (Kofoid et White) and *M. hapla* (Chitwood) are of great agronomic importance and these species account for at least 90% of total damage caused by this nematode group (Castagnone-Sereno, 2002). *Meloidogyne* species, *M. incognita, M. javanica* and *M. arenaria* are commonly found in tropics, whereas *M. hapla* is more prevalent in temperate countries or at higher altitudes in warmer countries (Eisenback & Triantaphyllou, 1991). In Sri Lanka, altogether six *Meloidogyne* species has been recorded among which *M. incognita* Kofoid and White (Nematoda: Tylenchidae) is predominant, causing severe damage in vegetable cultivation (Ekanayake & Toida 1997; Ekanayake, 2001; Premachandra et al., 2011). It has been reported that *Meloidogyne* spp. are one of the most common and damaging nematodes on spinach in several countries limiting production (Potter & Olthof, 1993; Castillo & Jiménez-Díaz, 2003). In Sri Lanka too, spinach is a highly susceptible crop for *Meloidogyne* nematodes, in particular, *M. incognita* (Ekanayake et al., 1988; Premachandra et al., 2006).

Once *Meloidogyne* nematodes invade a crop field, their control is challenging because of their short generation time, high reproductive capacity and difficulties in identification due to the insidious nature. The damage caused by these nematodes depends on the root penetration of IJs and subsequent development and reproduction within the root tissues (Shahab & Sharma, 2011). Since IJs invade roots in soil, pre-plant density of IJs in soil is the most crucial factor determining the extent of damage (Patel et al., 1996; Khan et al., 2006; Greco & Di Vito 2009; Pang et al., 2009). Low to high densities of IJs in soil cause differential effects on host plants. Previous reports indicated that low IJs densities enhanced the growth and yield (Madamba et al., 1965; Olthof & Potter, 1972), caused serious damage (Barker & Olthof, 1976) and/or had zero effect (Madamba et al., 1965). However, some researchers stated that the growth of a plant is inversely proportional to the initial population density of *Meloidogyne* species (Kinloch, 1982) implying that high densities cause severe growth impairment, high yield reductions or sometimes death of the host plants (Griffin, 1981; Fortnum et al., 1991; Mekete, et al., 2003). However, a mere presence of IJs in soil does not cause crop damage and yield reductions as the IJs density does not reach minimal or threshold density (Schomarker & Been, 2006). It has been reported that the threshold density differs with nematodes species/strain, host plant species/cultivar and the environmental conditions (Barker & Olthof, 1976). When the nematode population exceeds the economic threshold, their control is a difficult task. Hence, information on effects of different initial densities of root-knot nematodes on the growth and infestation of economically important crops are vital to predict crop losses, establish damage thresholds and design effective nematode management programs (Ferris, 1978; Korayem, 2006). In addition, information on the response of plants to different pre-plant IJs provides powerful clues to develop nematode resistant plants and thus serve as cornerstones in resistance breeding programs.

Despite its great importance, information on the degree of damage caused by *Meloidogyne* nematodes on spinach at different pre-plant nematode densities is lacking. This paper elucidates the effect of seven initial densities of IJs of *M. incognita* on the growth and severity of infestation on spinach with the aim of adopting successful management strategies to ensure better production.

Materials and methods

The trials were conducted in a screen house at the Department of Zoology, University of Ruhuna, Matara in southern Sri Lanka. *Meloidogyne incognita* cultures were maintained on spinach plants in outdoor plastic pots (84 cm diameter; 20 cm height) containing steam-sterilized soil (sand 85%, clay 1.28%, silt 11.3% and organic matter 2.8%). The initial inoculum was derived from a single egg mass of *M. incognita*, collected from field-grown spinach plants. Mature egg masses were obtained by teasing off the knotted roots of two month-old plants. Subsequently, the egg masses were set to hatch in glass cavity blocks containing sterile distilled water (SDW) at the ambient temperature, 30° C ±2. Inoculum was prepared by concentrating 24-72 h-old IJs using a mesh sieve with 25 µm pore size. The seeds of spinach cv. "Yodha" obtained from the Department of Agriculture, Matara, Sri Lanka) were sown in plastic pots (capacity 1000 cm^3) containing 1000 cm^3 of steam- sterilized soil (sand 85%, clay 1.28%, silt 11.3% and organic matter 2.8%) and compost mixture (3:1). The pots were arranged in a completely randomised design with five replicates each on benches of the screen house. The seedlings were allowed to grow for four weeks. The temperature prevailed in the screen house during the study period ranged from 28-30º C. At four weeks post-germination, plants were inoculated with IJs at the densities of 156, 312, 625, 1250, 2500, 5000 and 10000 IJs per plant (i.e., per pot) in 15 ml SDW. The plants received only 15 SDW served as untreated controls. At fifty days post-inoculation, the plants were uprooted and the root system was washed gently with tap water to remove adhering soil. Subsequently, length and weight, of both shoots and roots, total number of feeder roots over galled-lateral roots, were recorded. In addition, number of galls and egg masses per root system was recorded. The number of egg-masses per root system was counted on stained roots with Phloxine B. Moreover, the length of all feeder roots and the galled-length of these roots were recorded per plant. After summing the total length and galled-length of the feeder roots separately, an overall percentage of galled-length feeder roots were calculated per plant. Effect on growth by *M. incognita* was evaluated based on the shoot and root length, and shoot and root weight while the damage severity was estimated using percentage infested feeder roots and galled-length of feeder roots and, total number of galls and egg masses, per plant.

Statistical analysis

After confirming the homogeneity of variance between the repeated trails using Brown and Forsythe's test (SAS institute, 1999), the data were combined for the further analysis. The data on shoot length and weight, and root length and weight, the number of galls and egg masses per root system were subjected to $\log_{10}$ transformation while percentage galled-length and infested feeder roots plant with arcsin square root transformed, prior to the analysis. The differences in shoot and root growth parameters between the non-inoculated and inoculated plants were compared using Dunnett's test (SAS institute, 1999). In addition, all the growth and infestation parameters with respect to different IJs densities were compared using one way ANOVA. When the analysis of variance yielded significant F values, means were compared using Tukey's range test. Linear regression analysis was performed to determine the relationship between the growth parameters and gall formation as well as shoot and root growth parameters (SAS institute, 1999). In all analysis, a 0.05 alpha level of significance was used.

Results

At 50-day post-inoculation, shoot length and weight as well as root length of inoculated spinach plants were significantly lower ($P<0.0001$) than those of non-inoculated plants at all the inoculum levels tested (Table 1). However, a significant reduction ($P<0.0001$) in root weight was observed above 156 IJs/plant. Percentage reduction in all growth parameters of inoculated spinach plants increased

ISSN-Internet 2197-411x OLCL 862804632

Figure 1a: Appearance of shoot of spinach plant at the highest nematode density, 10000 IJs/plant

Figure 1b: Appearance of shoot of spinach plant at the zero nematode density

Table 1: Growth parameters of four-week old spinach plants at 50 days post-inoculation with different pre-plant densities of *Meloidogyne incognita* juveniles

Inoculum level (IJs/pot)	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)
0	33.62 a	52.27 a	12.70 a	15.79 a
156	31.03 b	43.76 b	11.53 b	14.97 ab
312	30.84 b	42.16 b	11.49 b	14.21 bc
625	28.14 c	41.05 bc	11.05 b	13.42 cd
1250	25.74 d	38.62 cd	9.80 c	12.59 de
2500	24.70 d	36.57 d	9.23 c	11.95 e
5000	20.87 e	31.38 e	7.98 d	11.71 e
10000	18.70 f	28.12 f	7.04 e	12.47 e

Means followed by the same letter in columns indicate no significant differences (P=0.05, Tukey's Honest significant test, after log transformation: SAS Institute 1999).

progressively with the increasing IJs density level. In comparison to non-inoculated plants, the highest reduction in shoot length and weight was recorded as 43% and 46%, respectively, while root length and weight was reduced by 45% and 25%, respectively. Significant differences among the different Ijs densities were detected with respect to all growth parameters tested (shoot length F=103.09; shoot weight F=8.72; root length F=85.77; root weight F=29.13, df=6,63, P<0.0001). There was no significant decrease in shoot length and root weight at the two lower densities, i.e., 156 and 312 IJs/plant. In addition, shoot weight and root length did not show significant decrease from 156-625 IJs/plant (Table 1). In contrast, at the three higher IJs densities, i.e., 2500, 5000 and 10000 IJs/plant, a significant and progressive reduction in shoot length and weight, as well as root length was observed. Root weight showed a non-significant increase at the highest density, i.e., 10000 IJs/plant, compared to

2500 and 5000 IJs/plant. At the highest density, all the leaves of spinach plant turned into yellow in colour (Figure 1a and1b).

Total number of galls and percentage galled-length of feeder roots showed a significant and progressive increase (galls: F=757.64, df=6,63, P < 0.0001; galled-length F=168.18, df = 6,63, P < 0.0001) with the increasing IJs density (Table 2). The maximum mean number of galls/plant was 432 (±2.17) (Figure 2a and 2b) while the highest galled-length was found as 54% (±1.11)/plant. One Hundred percent of the feeder roots had galls above the IJs density of 1250 IJs/plant. Total number of egg masses on *M. incognita* per plant was significantly and progressively increased (P<0.0001) up to the density level of 5000 IJs/plant, and further increase in IJs density resulted in significant reduction in egg production (Table 2).

Figure 2a: Appearance of root system of spinach plant at the highest nematode density, 10000 IJs/plant

Figure 2b: Appearance of root system of spinach plant at the zero nematode density

Table 2: Root infestation of spinach plants at 50 days post-inoculation with different pre-plant densities of *Meloidogyne incognita*

Inoculum level IJs/pot	Total number of galls/root system	Percentage galled- length of feeder roots	Percentage galled-feeder roots	Total number of egg masses/root system
156	221.20 a	13.71 a	89.18 a	77.00 a
312	249.10 b	18.90 b	94.30 a	88.60 b
625	344.90 c	28.01 c	99.58 b	115.70 c
1250	361.70 d	34.68 d	100.00 b	133.40 d
2500	394.10 e	41.68 e	100.00 b	161.10 e
5000	414.60 f	47.24 f	100.00 b	181.90 g
10000	432.30 g	53.98 g	100.00 b	171.70 f

Means followed by the same letter in columns indicate no significant differences (P=0.05, Tukey's Honest significant test, after log transformation: SAS Institute 1999).

ISSN-Internet 2197-411x OLCL 862804632

Regression analysis showed an inverse linear relationship between gall count and shoot length (F=161.98, R^2=0.70, P<0.0001), shoot weight (F = 107.60, R^2 = 0.61, P<0.0001) and root length (F = 125.31, R^2 = 0.65, P<0.0001). Similar trend was found with the percentage galled-length (shoot length F=247.11, R^2=0.78, P<0.0001; shoot weight F=174.76, R^2=0.72, P<0.0001; root length F=190.95, R^2=0.73, P<0.0001). In addition, shoot growth showed a strong linear relationship (shoot length F=552.89, R^2 = 0.89, P<0.0001; shoot weight F= 263.48, R^2 = 0.79, P < 0.0001) with the root length.

Discussion

The damage caused by root-knot nematodes, *Meloidogyne* species, on various crops depends on species or physiological race and in particular, the magnitude of nematode population densities in soil at the time of planting (Sasanelli, 1994). In order to guarantee a better crop production, plant growers essentially need information on the pre-planting (initial) nematode population densities in soil prior to establishing their crops. Additionally, the response of crops for varying initial IJs densities of *Meloidogyne* nematodes is of crucial importance to apply control measures in advance to minimize the yield losses. The findings of this study showed that the variation in growth and root infestation of spinach plants in response to series of initial population densities of *M. incognita*. The response of growth to different nematode inocula was determined based on four parameters, i.e., shoot and root length and, shoot and root weight. More often root infestation caused by *Meloidogyne* nematodes is assessed in terms of gall index which is a measure of number of galls per root system. However, such a parameter does not provide accurate estimate mainly because of the size of galls varies with the existing nematode densities in the root tissue the plant species that they infested (Eisenback and Triantaphyllou, 1991). Previous investigations reported that the galls produced by *M. incognita* on spinach roots varied in size (Vito et al., 2004). Moreover, Azam et al. (2011) reported that the size of the galls formed by *M. incognita* at lower densities (500 IJs/plant) was smaller than those produced at higher densities, i.e., 1000 and 3000 IJs/plant, on tomato. As such, in the present study, in addition to the gall count, proportion of galled-length of feeder roots and infested feeder roots per plant were determined with respect to each of the seven IJs densities. The findings of this study clearly indicated that *M. incognita* was highly pathogenic to spinach resulting suppression of shoot and root growth even at the lowest IJs density i.e., 156 IJs/plant, i.e., 0.156 IJs/cm^3 soil (Table 1). However, the pathogenic effect was more pronounced (44 %-46 % growth reduction) at the highest IJs density for all the growth parameters, except the root weight. Declined shoot growth greatly affect the marketable value of spinach as it is a leafy vegetable. The reduction in root weight was lower compared to other three growth parameters. The slight elevation of the root weight at the highest IJs density might be caused by the severe root galling making the roots bulky (Barker & Olthof, 1976; Charegani et al., 2012). However, it is clear, that the length of the root is curtailed by 9-46 % implying the retardation of root growth by *M. incognita*. Similar to our findings, previous investigations revealed that *M. incognita* and *M. hapla* significantly reduced the growth of spinach plants (Potter & Olthof, 1974; Pankaj et al., 2001; Vito et al., 2004). Vito et al. (2004) indicated that the tolerant limit of fresh top weight in spinach (cv. Symphony) for *M. incognita* was 0·25 IJs/cm^3 which was bit higher (in this study 0.156 IJs/cm^3) compared to the present study. In addition, the same authors reported that an initial IJs density higher than 32 IJs/cm^3 soil, was lethal to spinach (cv. Symphony). However, such a high IJs density was not included in our trials. The variations in growth could most probably be caused by species/cultivar differences of a particular crop, virulence of species/strains as well as climatic conditions. The three parameters used to evaluate the root infestation clearly showed the severity infestation over different IJs densities of *M. incognita*. In agreement of the findings reported by previous researchers, gall count was found to be increased significantly with the increasing inoculum level (Kankam & Adomako, 2014; Zahid et al., 2001; Mekete et al., 2003). The galled-length of the feeder roots also showed the similar trend (Table 2). At the highest inouclum level, gall number per root system was two-fold from the lowest whereas overall galled-length of feeder roots was four-fold compared to the lowest level implying gall number should not be a sole parameter to estimate the root infestation. Infestation of all the feeder roots of the root system beyond the density level of 1250 IJs/plant confirms the severity of infestation and thus it also serves as a good indicator of root damage. Severe root infestation can partly be caused the reduction of the root length which interrupted the functioning of the root system. The decreased shoot length and weight as well as root length with increasing gall number and galled-length of feeder roots indicated that the reduced top growth could most probably be associated with gall formation. Anwar and Din (1986) reported that *Meloidogyne* infestations lead to decrease the uptake of water and nutrients which in turn cause suppression of the top growth. In addition, our findings revealed that shoot and root length was mutually dependent on each other confirming the reduced top growth with the deceasing root growth (Anwar & Van Gundy, 1993). Apart from that, exploitation of nutrients by the female nematodes in galled-roots could also be caused shoot growth impairment. Moreover, Taylor and Sasser (1978) revealed Meloidogyne infestations induce increased protein synthesis in galls and disruption of growth regulators between the roots and stems resulting in reduced growth. The declined egg production at the highest IJs density might be due to the destruction of tissues (Ferris, 1985). Moreover, Olthof and Potter (1977) reported increased root weight at higher density levels discouraged the nematode reproduction. In agreement with the findings of this study, previous researchers reported lower reproduction potential at higher inoculation levels in spinach infested by *M. incognita* (Vito et al., 2004).

Conclusions

M. incognita caused damaged on spinach plants even at a density level as low as of 0.156 IJs/cm^3 in soil, which might be induced by the warm climatic conditions prevailed in southern Sri Lanka, cultivar susceptibility or high virulence of the nematodes species or their interactive effects. It is of great importance to take steps for not allowing these nematodes to enter the crop as it can cause adverse effects at a low density level. The response of root weight to different nematode densities showed a substantial deviation, compared to other growth parameters. Thus, root weight was not seemed to be a good parameter for such evaluations. However, the two infestation parameters, i.e., proportion of galled-length of feeder roots and infested feeder roots per plant, showed the actual root damage which did not express by the gall number. Altogether, the three infestation parameters clearly reflected the severe root damage which caused the top growth impairment. In addition, continuous monitoring of soil is highly recommended for the presence of IJs and it is essential to keep the IJs density below 0.156 IJs/cm^3 soil. Moreover, in order to have estimates of pre-plant IJs densities, it is of great importance to develop accurate sampling techniques. Further trials are needed for the confirmation of these findings under field conditions.

Acknowledgement

The funding provided by International foundation of Science, Sweden, under the grant No. C-4060-1, is greatly appreciated. We would like to thank the anonymous reviewers for their helpful and critical comments.

Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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Moisture-dependent physical properties of locust bean (*Parkia biglobosa*) seeds

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Data of the article

First received: 13 August 2015 | Last revision received: 06 November 2015
Accepted: 10 November 2015 | Published online: 16 December 2015
URN: nbn:de:hebis:34-2015102649175

Key words

bulk density; locust bean; porosity; production process; static friction

Abstract

Seed moisture content is significant in the handling and processing of seeds. This work therefore determined the physical properties of Locust bean seeds as functions of seed moisture content in the moisture range of 5.9 – 28.2% dry basis. Mohsenin, Stepanoff and ASAE standard methods were used in determining the properties. Increases in seed dimensions vitz length = 10.2±1.0 – 11.3±0.9 mm; width = 8.5±0.8 – 9.1±0.6 mm; surface area = 191.2±24.6 – 208.3±26.3 mm^2; geometric mean diameter = 7.78±0.49 – 8.12±0.03 and arithmetic mean diameter = 8.06±0.56 – 8.34±0.49 mm were recorded. Seed thickness = 5.49±0.43 – 5.26±0.62 mm; sphericity = 0.75±0.04 – 0.71±0.03; true density = 1251.96±55.5 - 1222±62.16 kgm-3 and porosity = 48.4±2.14 – 41.9±3.78 decreased. Static coefficient of friction increased on plywood (0.5±0.02 – 0.6±0.01), glass (0.4±0.05 – 0.5±0.01) and decreased on aluminium (0.5±0.02 – 0.5±0.04). A data of the physical properties of Locust bean; Parkia biglobosa was developed. This is useful for the design and development of equipment necessary for its handling and processing.

Introduction

The Locust bean tree (*Parkia*) (Figure 1), has long been widely recognized as an important indigenous multipurpose fruit tree in many countries of sub-Saharan Africa. It is commonly called the 'African Locust Bean'. In Nigeria, *Parkia biglobosa* is found in the savannah zones with the bulk of it in the Guinea savannah because of its ecological and environmental requirements which are easily met in these areas. Oni et al.(1998) stated that *Parkia biglobosa* was not cultivated in the past, but grew naturally in dotted form in the savannah. It is cultivated nowadays due to its multipurpose uses by transplanting wild ones from the nursery to the field. The seed is the most important part of the tree and a source of a fermented, natural and nutritious condiment that features frequently in the traditional diets of the people of both rural and urban dwellings in at least seventeen West African countries including Nigeria. The locust bean seed is flat, spherical in shape and it is blackish brown in color. It is covered with hard, smooth testa (seed coat) which makes the raw seed very hard and inedible (Booth and Wickens, 1988). During processing, dehulling of the seed is made difficult and laborious (Figure 2a) because of the hardness of the testa (Diawara et al., 2000). Alabi et. al. (2005) reported that the locust bean is rich in lipid, protein, carbohydrate, soluble sugars, ascorbic acid and oil. The oil content is suitable for consumption since it contains very low acid and iodine contents. It has very high saponification value, hence it is useful in

Citation (APA):
Bamgboye, I., Sadiku, O.A. (2015). Moisture-dependent physical properties of locust bean (*Parkia biglobosa*) seeds, *Future of Food: Journal on Food, Agriculture and Society*, 3(2), 27-40

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Figure 1: Locust bean tree (*Parkia biglobosa*)

Photo credit: Adefemi-ola, X.B. and Sadiku, O.A. in Ibadan, Nigeria.

Figure 2a: Seeds dehulling, washing and separation

Photo credit: Adefemi-ola, X.B. and Sadiku, O.A. in Ibadan, Nigeria.

Figure 2b: Main cooking process

ISSN-Internet 2197-411x OLCL 862804632

Photo credit: Adefemi-ola, X.B. and Sadiku, O.A. in Ibadan, Nigeria.

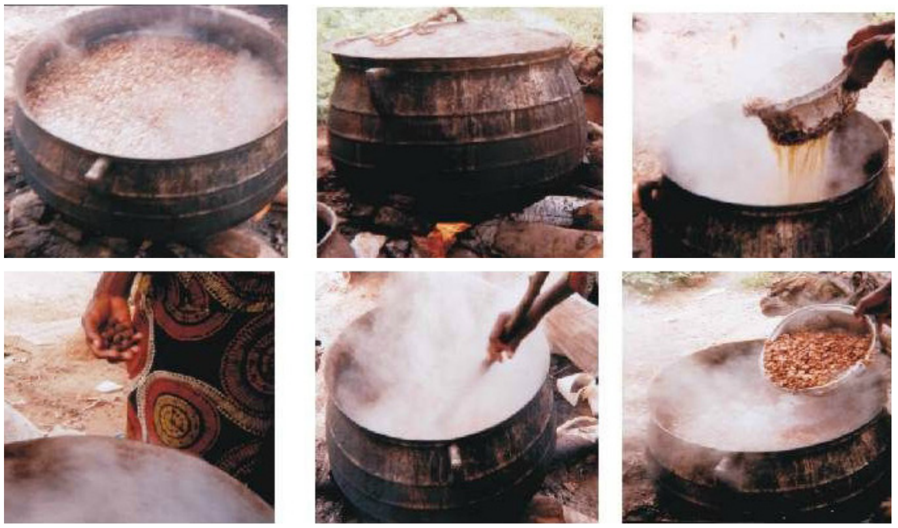

Figure 2c: Parboiling

the soap industry (Diawara et al., 2000). Oni (1997) reported that the locust bean has medicinal benefits which are derived mostly from the regular consumption of the fermented locust bean product.

The production process of locust bean had always been manual and cumbersome, thus requiring mechanization. This necessitates the determination of the physical properties of locust bean seed. Processing locust beans into the fermented product involves: shelling of the pods; sorting the seeds; soaking the seeds in water and drying for pulp removal; soaking and parboiling for de-hulling (removal of seed coat); further parboiling for final stage of fermentation (Figure 2b and 2c) . Frictional properties of agricultural materials are a necessity in predicting the lateral pressure on a retaining wall in storage bins or design of bins and hoppers for gravity flow. Dynamic and static effect of friction of grains on engineering material surfaces (e.g. wood, galvanized metal, glass etc.) are required for the prediction of motion of the material in the design of handling equipment. Bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities. Grain bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. The process of hydration (addition of water) is commonly used in the processing of cereal grain and the seeds of pulses, especially in locust beans processing as earlier stated. As a result of this, a number of important changes in the structure of the raw materials take place in the course of hydration and they are mainly associated with increased water content (Andrejko and Kaminska, 2005). Therefore it is necessary to determine the physical properties of locust bean as a function of seed moisture variation.

The physical properties of different seeds and grains as a function of their moisture content have been determined by researchers such as Altuntas et al. (2005) for fenugreek (*Trigonella foenum-graecum*); Coskuner and Karababa (2007) for coriander (*Coriandrum sativum*); Isik and Izil (2007) for dent corn (*Zea mays var. indentata*); Kiani Deh Kiani et al. (2008) for red bean (*Vigna angularis*); Zewdu and Solomon (2008) for grass pea (*Lathyrus sativus*); Tavakoli et al. (2009) for soybean (*Glycine max*); Shafiee et al. (2009) for dragon's head seed (*Dracocephalum moldavica*) and Razavi and Fathi (2009) for grape (*Vitis vinifera*). Others are Bamgboye and Adejumo, (2010) for roselle seed (*Hibiscus sabdariffa*) and Nalbandi et al. (2010) for Turgenia latifolia.

Materials and methods

Sample collection and preparation

Samples were collected from Saki in the savanna areas of the northern part of Oyo State, Nigeria. The initial moisture content of the dried seeds was determined by the ASAE standard (S 352.2) involving oven-drying method at 103 ± 1 ^{0}C for 72 hours. The samples of other desired moisture content levels (11.1, 16.6, 22 and 28.2 %) were prepared by adding calculated amounts of distilled water using equation 1 (Eq.1) (Mohsenin, 1986).

$$Q = \frac{W_i (m_f - m_i)}{100 - m_f} \quad \text{(Eq.1)}$$

The whole seed bulk was cleaned manually to remove all foreign matter and damaged seeds. All sample lots were stored afterwards in a refrigerator at 5 °C for five days (Akbarpour et al., 2009; Davies, 2010) to allow for uniform distribution of moisture within the seed bulk. For each experiment, the required quantity of seeds was taken out from each sample lot in the refrigerator for two hours to equilibrate with room temperature.

Size and shape

The length (L), width (W) and thickness (T) of each of thirty randomly selected seeds from each moisture level were determined using a vernier caliper with 0.02 mm accuracy (Andrejko and Kaminska, 2005; Zewdu and Solomon, 2008; Nalbandi et al., 2010). The arithmetic mean (Da) and geometric mean (Dg) diameters, surface area (S) and Sphericity (ϕ) were calculated using equations 2,3,4 and 5 respectively (Mohsenin, 1986; Tavakoli, 2009).

$$D_a = \frac{(L + W + T)}{3} \quad \text{(Eq. 2)}$$

$$D_g = (LWT)^{1/3} \quad \text{(Eq. 3)}$$

$$S = \pi D_g^2 \quad \text{(Eq. 4)}$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad \text{(Eq. 5)}$$

Seed mass, seed volume and thousand grain mass

These properties are determined using Mohsenin's (1986) standard methods and replicated five times for each moisture content level. Toluene (C_7H_8) was used as the fluid medium for determining seed volume because it is not readily absorbed by the seeds.

Bulk density, true density and porosity

Bulk and true densities for all the samples are determined by the beaker filling and toluene displacement methods respectively as described by Mohsenin (1986), Ahmadi et al. (2009), Nalbandi et al. (2010) and Sadiku and Bamgboye (2014). Each experiment was replicated five times for each moisture level. Bulk and true densities are calculated using equations 6 and 7 respectively.

$$\rho_t = m/v \quad \text{(Eq. 6)}$$

$$\rho_b = m/v \quad \text{(Eq. 7)}$$

Porosity was determined empirically using the value of bulk and true densities in equation 8. (Heiderbeigi et al., 2008)

$$\varepsilon = ((\rho_t - \rho_b) / \rho_t) \times 100 \quad \text{(Eq. 8)}$$

Static coefficient of friction and angles of repose

The static coefficient of friction (μ) was determined using the tilting surface method on seven surfaces namely plywood, rubber, galvanized sheet, stainless steel, mild steel, aluminum and glass. These test surfaces were placed on a tilting surface one after the other while the experiment was replicated five times for each material surface at each moisture content level. The tilting surface was designed and fabricated for the purpose of this experiment (Nalbandi et al., 2010).

The static angle of repose (θ_s) was measured using a wooden box half full of locust bean seeds mounted on a tilting surface, described by Mohsenin, (1986) and Nalbandi et al. (2010). The dynamic angle of repose (θ_d) was determined using the hollow cylinder method and applying trigonometry rules (Mohsenin, 1986; Razavi et al., 2009) for the calculation as in equation 9.

$$\theta_f = [\tan^{-1} (2H)]/D \quad \text{(Eq. 9)}$$

Coefficient and angle of internal friction, coefficient of mobility and hopper side wall angle

These properties were measured using methods described by Stepanoff (1969) and Irtwange (2000).

ISSN-Internet 2197-411x OLCL 862804632

UniKassel & VDW, Germany- December 2015

Table 1: Variations in physical properties of locust bean with different moisture content

Property	Dimension	Moisture content levels % (d.b) 5.9	11.1	16.6	22	28.2
Length (L)	mm	10.24b±1.02	10.49b±0.73	10.6b±0.85	10.69b±0.64	11.29a±0.85
Width (W)	mm	8.45b±0.83	8.33b±0.78	8.44b±0.79	8.55b±0.79	9.08a±0.56
Thickness (T)	mm	5.49a±0.43	5.11b±0.51	5.14b±0.58	5.2b±0.62	5.26b±0.62
GMD (D_g)	mm	7.78b±0.49	7.61b±0.46	7.69b±0.48	7.73b±0.38	8.12a±0.03
AMD (D_a)	mm	8.06b±0.56	7.97b±0.47	8.06b±0.51	8.16b±0.43	8.34a±0.49
Sphericity (ϕ)		0.75a±0.04	0.72b±0.03	0.72b±0.04	0.72b±0.03	0.71b±0.03
Surface Area (S)	mm^2	191.15b±24.6	182.96b±22.3	186.95b±25.2	191.91b±22.6	208.29a±26.3
Seed mass (M_s)	g	0.24b±0.004	0.25b±0.003	0.25b±0.01	0.26a±0.01	0.26a±0.008
Seed volume (V_s)	mm^3	195.6b±9.39	215.26a±7.56	210.96a±9.10	207.78b±15.0	206.1b±8.56
TGM (M_{tg})	g	247.6c±9.8	263.6b±8.6	275.4b±15.6	277.4a± 6.4	284.2a±4.7

GMD=Geometric mean diameter; AMD = Arithmetic mean diameter; TGM = Thousand grain mass. Values with different letters (a-c) along the same row are statistically significant ($p<0.05$).

The coefficient of internal friction was calculated as:

$$\mu_i = \frac{(w_2 - w_1)}{W} \qquad \text{(Eq. 10)}$$

The angle of internal friction was calculated as:

$$\varphi_i = \tan^{-1} \mu_i \qquad \text{(Eq. 11)}$$

Coefficient of mobility

Coefficient of mobility (m_c) was calculated using the formula given by Stepanoff (1969) and Irtwange (2000).

$$m_c = 1 + 2\mu_i^2 - 2\mu_i \ (1 + \mu_i^2)^{1/2} \qquad \text{(Eq. 12)}$$

Hopper side wall angle (slope)

Stepanoff (1969) stated that the slope angle (β) of the side wall of an hopper must be greater than the angle of internal friction of a material for easy flow of the material and it is calculated using equation 13, which was also used by Irtwange (2000).

$$\beta = 45^o + \varphi_i /2 \qquad \text{(Eq. 13)}$$

The results were analyzed using Analysis of variance (ANOVA) and Duncan multiple range test (DMRT).

Results and discussion

Physical properties

Axial dimensions:

The statistically significant effect of seed moisture content on the length, width and thickness of locust bean seeds are shown in table 1 and table 2 shows the relationship between seed moisture content and the axial dimensions as per the regression equations. Both length and width of locust bean seed increased linearly with increasing seed moisture content in the range of 5.9 - 28.2% (d.b), while a decrease (in a polynomial trend) was recorded in the thickness.

The change in dimensions of locust bean seed, due to increase in moisture content is along its length and width axes. This is due to the filling of capillaries and voids in the seed with moisture, hence there is subsequent swelling of the seed. A similar trend was reported by Mohammad and Reza (2010) with sunflowers (*Helianthus annuus*). It is also due to the internal cell arrangement in the seeds which is in agreement with Nalbandi et al. (2010), on *Turgenia latifolia*. This shows that the shape and size of

Table 2: Equations representing the relationship between seed moisture content and some physical properties of locust bean

Equation	R^2
$L = 0.0418M + 9.9609$	0.889
$W = 0.0273M + 8.1127$	0.657
$T = -0.0019M^2 - 0.0693M + 5.7706$	0.636
$D_a = 0.0021M^2 - 0.0502M + 8.2826$	0.988
$D_g = 0.0024M^2 - 0.0676M + 8.0898$	0.962
$\Phi = -0.0033M^3 + 0.0329M^2 - 0.1038M + 0.824$	0.994
$S = 3.5786M^2 - 17.161M + 204.4$	0.981
$M_s = -9E\text{-}16M^3 - 0.0007M^2 + 0.0093M + 0.232$	0.918
$V_s = 2.1083M^3 - 21.946M^2 + 68.945M + 146.84$	0.961
$M_{tg} = -0.0695M^2 + 3.9273M + 227.64$	0.982
$\mu_{Plywood} = 0.0051M + 0.4449$	0.947
$\mu_{Glass} = 0.0005M^2 + 0.0221M + 0.3099$	0.993
$\mu_{Mild\ steel} = 2E\text{-}05M^4 - 0.0014M^3 + 0.0341M^2 - 0.3314M + 1.552$	1.000
$\mu_{Galvanized\ sheet} = -3E\text{-}05M^3 + 0.0019M^2 - 0.0295M + 0.6226$	0.712
$\mu_{Rubber} = -0.0003M^2 + 0.0156M + 0.3409$	0.782
$\mu_{Aluminium} = 1E - 05M^4 - 0.0007M^3 + 0.0167M^2 - 0.158M + 1.0231$	1.000
$\mu_{Stainless\ steel} = -5E\text{-}05M^3 + 0.0024M^2 - 0.033M + 0.672$	0.999

ISSN-Internet 2197-411x OLCL 862804632

locust bean seeds is altered with increasing seed moisture content. This phenomenon determines the shape and size of screen holes (aperture) in the engineering design of separating or screening devices. Meanwhile, a linear increase in all the three axial dimensions for another locust bean variety (*Parkia filicoidea*) was reported by Sobukola and Onwuka (2010). This means that two varieties of the same seed will behave differently when subjected to moisture acquisition. It shows that they have different internal cell arrangement and will not use the same screening or separating devices. The effects of moisture content on the three axial dimensions were statistically significant ($p<0.05$) (Table 1).

Geometric and Arithmetic mean diameters
The relationship between moisture content of locust beans (*Parkia biglobosa*) seeds and their average diameters are expressed with the second degree polynomial equations (Table 2), although the seed moisture effect on both diameters is statistically significant ($p<0.05$).

The values of both diameters depend on the values and trends of the three seed dimensions. The seed diameters are important in determining the size of screen holes used in the design of separating and size-reduction machines.

Sphericity
The sphericity for most agricultural seeds, as stated by Mohsenin (1986) is in the range 0.32 – 1.00. Though the sphericity for *Parkia biglobosa* seeds decreased from 0.75 to 0.71 as seed moisture increased from 5.9 to 28.2% (d.b), it falls within the standard range and it is relatively high. The higher the sphericity, the higher the tendency for a seed to easily roll on any of its three axes. Therefore, locust bean seeds roll easily on any of their axes because of their high sphericity. But the ability to roll reduces as moisture content of the seed increases. The decrease in sphericity is due to the decrease in the thickness of the seed as the seed increased in length and width. Similar result was reported by Zewdu and Solomon (2008) for Grass pea (*Lathyrus sativus*) and Tekin et al. (2006) for Bambara bean (*Vigna subterranea*). The relationship between moisture content and sphericity is expressed in a polynomial equation of the third degree (Table 2) and the seed moisture effect on it is statistically significant (Table 1) at $p<0.05$.

Surface area
The surface area for *Parkia bioglobosa* seeds significantly increased ($p<0.05$) from 191.1 to 208.2 mm^2 with increasing seed moisture content (5.9 - 28.2% d.b.) in a polynomial (second order) trend (Table 2). A similar result was reported for coriander (*Coriandrum sativum*) seeds by Coskuner and Karababa (2007). On the other hand, Sobukola and Onwuka (2010), reported a linear increase in surface area for *Parkia filicoidea* in response.

Seed mass
The seed mass increased with increase in moisture content in a polynomial (third order) trend. This is

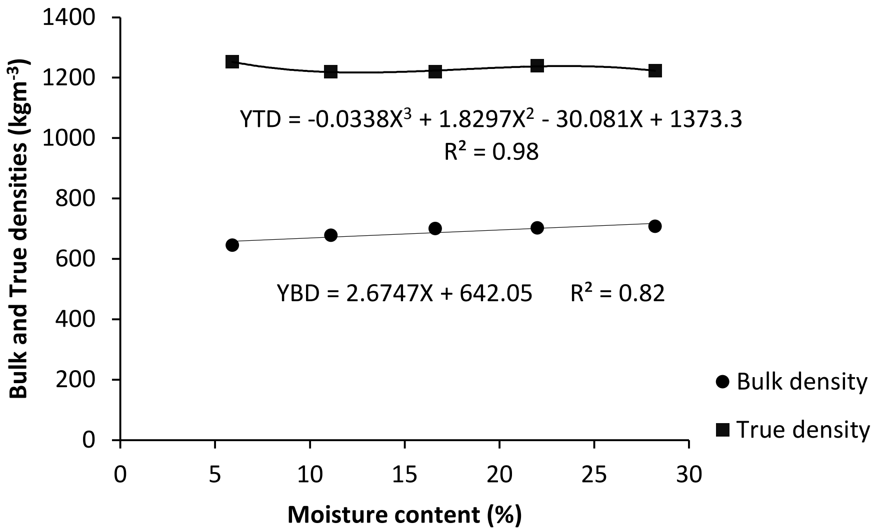

Figure 3: Influence of moisture content on bulk and true densities of locust bean

Table 3: Effect of moisture on porosity, bulk and true densities

MC (%)	BLKD (kgm^{-3})	TRD (kgm^{-3})	Porosity (%)
5.9	644.98c ± 7.92	1251.96a ± 55.50	48.40a ± 2.14
11.1	678.54b ± 9.79	1220.6a ± 40.25	44.36b ± 1.93
16.6	700.28a ± 8.62	1220.6a ± 40.25	42.58b ± 1.64
22	702.48a ± 9.92	1239.22a ± 85.88	43.10b ± 3.71
28.2	708.06a ± 12.05	1222.2a ± 62.16	41.91b ± 3.78

MC= Moisture content, BLKD = Bulk density, TRD = True density. Values in the same column followed by different letters (a-c) are significant ($p<0.05$).

due to the fact that drier seeds take in moisture more rapidly than wet seeds. The faster the colloids in the seed get saturated with water, the slower the rate of water intake. Since the intake of water increases the mass of the seed, there must be a sharp or rapid increase in the seed mass at the very early moisture levels.

Seed volume

Similar to seed mass, seed volume showed a rapid increase at the initial stage when the moisture level increased from 5.9 to 11.1% d.b but gradually decreased as moisture content increased to 28.2% d.b. The relationship between moisture content and seed volume for locust bean (*Parkia biglobosa*) was expressed by a third-degree polynomial equation (Table 2). Seed volume considerations have practical applications in production process such as separation and product loading.

Thousand grain mass (TGM)

Thousand grain mass significantly increased from 247.6 to 284.2 g and showed a second order polynomial relationship with variation in moisture content (Table 2). This is important in the design of conveyors, transport and storage equipment.

Gravimetric properties

Bulk and true densities

Bulk density increased linearly with increasing moisture content of seeds while the true density decreased in a third order polynomial trend (Figure 3). The reason for increase in bulk density was due to mass of seed increasing more rapidly than

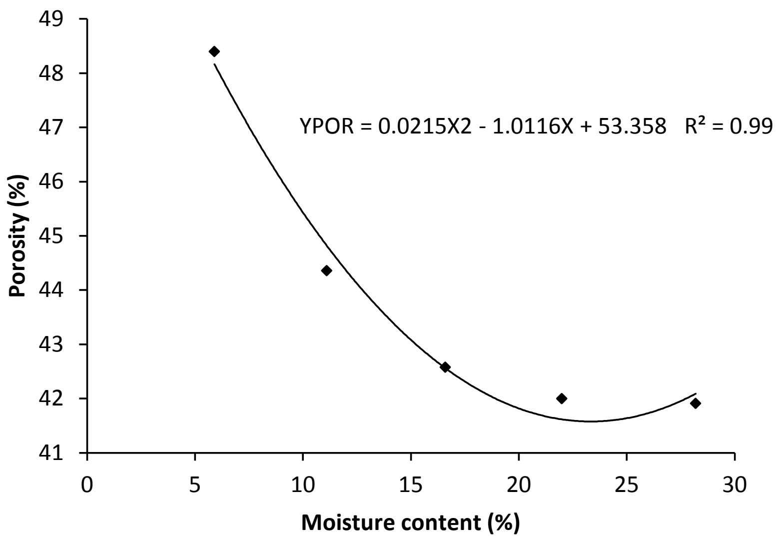

Figure 4: Porosity of locust bean as affected by moisture content

ISSN-Internet 2197-411x OLCL 862804632

the volume of seeds while for true density, the volume of seed bulk increased more rapidly than the mass of the seed bulk. For the true density of locust beans, moisture content had no statistically significant effect but had significant effect on bulk density (Table 3). Similar results were reported by Milani et al. (2007) for Curcubit seeds. Decreases in both bulk and true densities were found for *Parkia filicoidea* by Sobukola and Onwuka (2010). Igbozulike and Aremu (2009) reported an increase in bulk density and a decrease in true density for *Garcinia* kola seeds as seed moisture content increased.

Porosity

Porosity depends on the values of both bulk and true densities (Milani et al., 2007). From Figure 4, the porosity for *Parkia biglobosa* decreased with increasing seed moisture content. In practical terms, the decreasing porosity with increasing seed moisture content means that pore spaces within the bulk of seeds reduced. Also, the seeds became very wet and sticky at high moisture levels thereby filling some of the voids with the water film on the seed surface; therefore porosity decreases. Reduced porosity hinders aeration. Therefore, drying the seeds in wet state will require more energy from the drying fan or blower. A decrease in porosity was reported for *Parkia filicodiea* by Sobukola and Onwuka, (2010) and for beniseed by Tunde-Akintunde and Akintunde (2007). The regression equation expressing the relationship between porosity and moisture content for *parkia biglobosa* is given in Table 2.

Frictional properties

Static coefficient of friction

Table 4 shows the summary of the values of static coefficient of friction of locust bean on seven different structural surfaces. Static coefficient of friction is needed in the choice of structural material for the design of machine components involving the flow of bulk granular materials. Comparing the value of static coefficient of friction at the two endpoints of the moisture range (5.9 and 28.2% d.b.), there was a general increase for all the structural surfaces except aluminum and stainless steel on which a decrease was recorded. The increase in static coefficient of friction was due to increased adhesion between the seeds and the rough surfaces of the test materials while the decrease was due to the smoothness and more polished surfaces of aluminum and stainless steel compared with other test materials. Meanwhile, the effect of seed moisture content on galvanized iron, aluminium and stainless steel was not statistically significant ($p<0.05$). Linear increase in static coefficient of friction for Parkia biglobosa seeds was found on plywood only, while its increases on glass, mild steel galvanized sheet and rubber were in a polynomial trend. Plywood recorded the highest value of static coefficient of friction (0.61), followed by rubber (0.60) at 28.2% moisture content level. Sobukola and Onwuka, (2010) recorded

Table 4: Effect of seed moisture content on static coefficient of friction of locust bean on different material surfaces

	Moisture content (%)				
	5.9	11.1	16.6	22	28.2
Plywood	0.48c ± 0.02	0.50bc ± 0.04	0.53b ± 0.03	0.54b ± 0.03	0.60a ± 0.01
Glass	0.04b ± 0.05	0.050b ± 0.04	0.54a ± 0.03	0.55a ± 0.07	0.54a ± 0.01
Mild steel	0.52a ± 0.04	0.46b ± 0.07	0.55a ± 0.02	0.52a ± 0.009	0.54a ± 0.02
Galvanized iron	0.51a ± 0.04	0.47a ± 0.03	0.51a ± 0.02	0.51a ± 0.04	0.52a ± 0.03
Rubber	0.41d ± 0.04	0.50c ± 0.03	0.56ab ± 0.03	0.51bc ± 0.04	0.60a ± 0.05
Aluminum	0.54a ± 0.02	0.52a ± 0.04	0.56a ± 0.043	0.53a ± 0.06	0.52a ± 0.04
Stainless steel	0.55ab ± 0.03	0.53ab ± 0.05	0.55ab ± 0.04	0.56a ± 0.02	0.50b ± 0.04

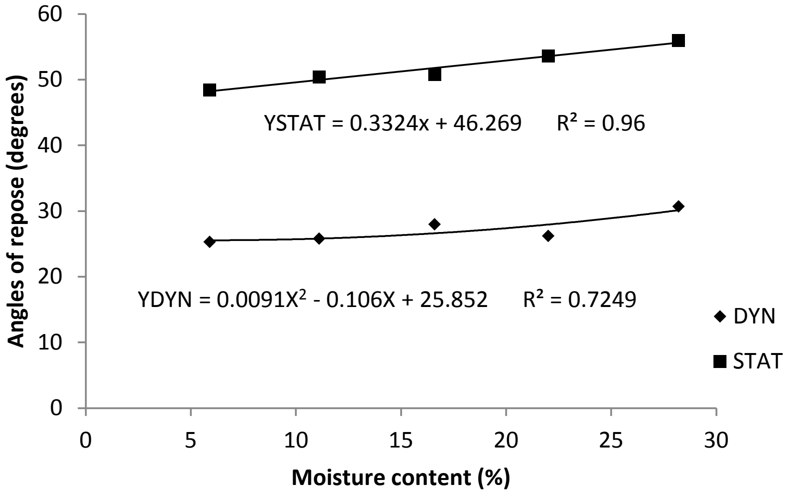

Figure 5: Effects of moisture content on the angles of repose of locust bean

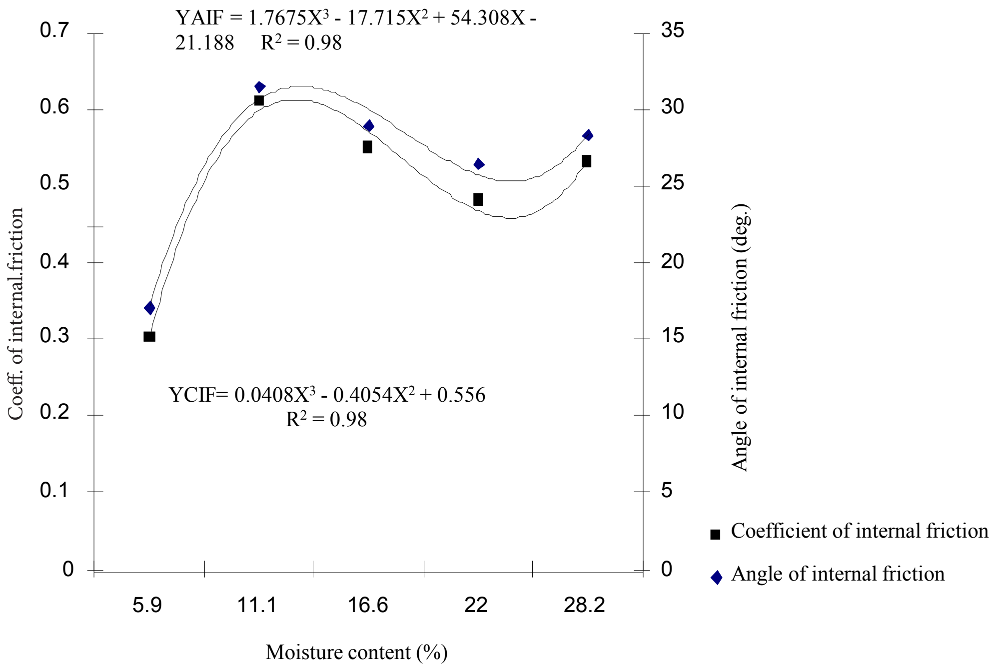

Figure 6: Effect of moisture content on coefficient and angle of internal friction of locust bean

the highest static coefficient of friction for *Parkia filicoidea* on plywood surface (1.00). Equations expressing the relationship between moisture content and static coefficient of friction on the different surfaces for *Parkia biglobosa* are shown in Table 2.

Static and dynamic angles of repose

Mohsenin (1986) stated that the angle of repose determines the maximum angle of a pile of grain in the horizontal plane and it is important in the filling of a flat storage facility when grain is not piled at a uniform depth, but rather is "peaked". Both static and dynamic angles of repose of *Parkia biglobosa* increased with increase in the seed moisture content in the range of 5.9 - 28.2% (d.b). The static angle of repose was higher at each moisture content level than the dynamic angle of repose (Figure 3). The higher the sphericity, the higher the ability of

Table 4: Effect of moisture content on coefficient of mobility and hopper side wall slope

Moisture content %	Coefficient of mobility	Hopper side wall slope / angle (deg.)
5	0.55a ± 0.07	53.5c ± 1.82
11	0.318c ± 0.07	60.81a ± 2.67
16	0.347c ± 0.02	59.46ab ± 0.77
22	0.393b ± 0.03	58.22b ± 1.10
28	0.357bc ± 0.01	59.11d ± 0.48

the seeds to roll over their three axes on material surfaces, hence the lower the angle of repose. Also, the dryer the seeds, the less they stick together and the more easily they slide and roll over one another, and hence a low angle of repose. A reason for high angles of repose is the sticky nature of the seeds at high moisture content. At high moisture levels, the seeds of *Parkia biglobosa* tend to stick to one another because of the presence of excess water films on their surfaces. This hinders their free flow therefore, angle of repose will increase. The relationship between the angles of repose and moisture content is given in Figure 5.

Coefficient and angle of internal friction

Both coefficient and angle of internal friction followed the same pattern of a polynomial increase as moisture content of the seeds increased (Figure 6), with the angle of internal friction higher than the coefficient of internal friction at all moisture content levels. At higher moisture content levels, locust bean seeds stick together, resulting in enhanced stability and less flow ability. This definitely increased the value of coefficient of internal friction, which in turn increased the value of angle of internal friction. The angle and coefficient of internal friction are important in the design of hoppers and flow channels in processing machines and equipment for seeds. Equations for the relationship between moisture and coefficient and angle of internal friction are shown in Table 2.

Coefficient of mobility

The coefficient of mobility for *Parkia biglobosa* seeds decreased (Table 4) from 0.55 to 0.35 with increasing seed moisture content in the range 5.9 - 28.2% (d.b). The decrease in coefficient of mobility was due to the sticky surfaces of the seeds at high moisture content which hindered the freedom of the seeds to move easily. At high moisture levels, the seeds also tend to adhere to the surface on which they are, which constitutes a hindrance to the fluidity of the seeds. The equation representing the relationship between coefficient of mobility and moisture content is expressed in Table 2.

Irtwange, (2000) stated that, 'for easy flow of material, the slope angle of the side wall of hoppers must be greater than the angle of internal friction of the material'. The hopper side wall angle increased, following a similar trend with the angle of internal friction (Table 4). The hopper side wall slope at each moisture content level therefore suggests the angle for which the hopper side walls should be designed for Parkia biglobosa seeds at the specified moisture levels or range. The equation expressing the relationship between moisture and hopper side wall angle for locust bean is shown in Table 2.

Conclusion

The study was carried out to determine the influence of seed moisture content on some engineering properties of locust beans at 5.9, 11.1, 16.6, 22 and 28.2 % (dry basis) moisture levels. Physical, gravimetric, frictional, flow, and mechanical and thermal properties of locust bean and how they relate with moisture content were expressed using regression equations. A property data for the engineering design of necessary machines and equipment for the harvest, post-harvest handling and processing of locust bean was developed. The length and width of locust beans increased but the thickness decreased. The arithmetic and geometric mean diameters which describe the size of locust bean grain increased in a polynomial trend. An increase was obtained for surface area and a decrease was recorded for sphericity of locust bean as moisture content increased. The mass of a thousand locust bean grains also increased linearly. Individual seed mass increased linearly and a polynomial increase in seed volume was obtained. Bulk and true densities increased and decreased respectively. A polynomial decrease was however recorded for porosity.

Static coefficient of friction on plywood, glass, rubber, mild steel and galvanized metal sheet surfaces increased but a decrease was obtained on stainless steel and aluminum surfaces. Both static and dynamic angles of repose recorded a linear increase. The coefficient and angle of internal friction both increased in a polynomial trend and linear increase in both normal and shear stress was obtained under varying loads. Coefficient of mobility showed a linear decrease as the hopper side wall slope (or angle) increased linearly. At each moisture level, it was observed that the hopper side wall slope was higher than the angle of internal friction of the seeds which was necessary for easy flow of the seeds in the design of hoppers and delivery chutes or feeders. It was established that the effect of seed moisture in locust beans was statistically significant ($p<0.05$) on all the properties investigated except true density, static coefficient of friction on galvanized iron and aluminium surfaces. The equations for predicting the behavior of locust bean seeds at any moisture level were generated. With a property data generated from the results, it is therefore possible to design and develop equipment for different locust bean processing stages.

Acknowledgement

Special thanks to Prof. Bamgboye for his excellent support and supervision throughout the research study. Contribution of Adefemi-ola, X.B. to the photography during the research is also acknowledged. Authors wish to thank the anonymous reviewers for their helpful and critical comments.

Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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ISSN-Internet 2197-411x OLCL 862804632

Suppression of root-knot nematode through innovative mustard biofumigation

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Data of the article

First received: 06 September 2015 | Last revision received: 08 November 2015
Accepted: 11 November 2015 | Published online: 16 December 2015
URN: nbn:de:hebis:34-2015102649185

Key words

Biofumigation; Mustard; Root-knot nematode; *Meloidogyne* spp.; Tomato

Abstract

The nematicidal activity of mustard plant against hatching, migration and mortality of the root-knot nematode Meloidogyne javanica was investigated. In vitro test confirmed that mixing the sandy clay soil mixture with mustard as 4% as a biofumigant significantly reduce the percentage of egg hatching at all different incubation periods 24, 48, 72, 96 and 168 h, compared to control treatment (un-amended mixture soil and eggs in free water). Results indicate that the percentage of egg hatching reduction was 88.5, 90, 81.4, 74 and 69.4%, respectively. Mustard mixed with soil as a biofumigant led to high percentage of larval mortality at the different intervals periods in vitro. The percentage of larval mortality was 94, 100, 90.5, 90.5, and 79.4%, respectively compared to control. Laboratory results confirmed that the highest reduction in egg hatching and larval mortality was obtained after incubation period for 48 h. In vivo experiment reveals that the incorporation of the soil pots with mustard at all different doses used 3, 5% (48 h before nematode inoculation, or soil infestation with nematode), and 5% (one week before nematode inoculation or 7% of soil weight) significantly reduces all the nematode parameters compared to plant treated nematode alone. All nematode parameters i.e. the number of galls per root system, gall index, number of egg masses per root system, as well as number of juveniles per 250g soil showed high reduction with mixing the soil pots with mustard at 5% (one week before nematode inoculation), followed by the same treatment for 48h before nematode inoculation. Mustard application, one week before nematode inoculation, reduced the nematode parameters by 97, 64, 97, and 93%, respectively, compared to control. The percent of chemical components i.e. total sugars, total amino acids and total phenols were markedly enhanced compared to positive and negative control. The highest percentage was obtained with mustard at 5% one week before nematode inoculation by 68.7, 57.3 and 45%, respectively. Finally, we have to conclude that this modified technology is an innovative and can be used efficiently to control Root-knot nematode under organic agriculture and Global GAP agricultural systems instead of these carcinogenic nematicides.

Introduction

Root-knot nematodes, Meloidogyne spp. are obligate endo-parasites and very damaging plant pests which are considered to be a limiting factor in crop production and agricultural productivity (Ibrahim, 2011). Most cultivated plant species are susceptible to root-knot nematode infection (Sasser and Carter, 1985). They attack more than 2000 species of plants and almost all cultivated plants such as vegetables, ornamentals. In Egypt, root-knot nematodes, Meloidogyne spp. are becoming serious pests to

Citation (APA):
Salem, M. F., Mahdy, M. E. (2015). Suppression of root-knot nematode through innovative mustard biofumigation, *Future of Food: Journal on Food, Agriculture and Society*, 3(2), 41-50

most vegetable crops, especially tomato plants, and cause severe yield losses in new reclaimed soils, especially the light types and infected plants suffer from vascular damages which disturb water and mineral uptake (Netscher and Sikora, 1990; Abd-Elgawad and Aboul-Eid, 2001; Luc et al., 2005).

Chemical nematicides are considered the most effective method in suppressing and controling root-knot nematodes, but means environmental pollution and is expensive in price (Adegbite and Adesiyan, 2001; Abd-Elgawad, 2008). During the last decades, nematologists worldwide searched for cheaper, safer and eco-friendly alternatives methods i.e. biological and cultural methods to control the plant-parasitic nematodes. Biofumigation and modified biofumigation are a sustainable strategy to manage soil-borne pathogens, nematodes, insects, and weeds instead of methyl bromide in developing countries including Egypt (Salem, 2012; Salem, 2014, Salem et al., 2015). Recently, these harmful nematodes have been controlled using applications of broad-spectrum, synthetic soil fumigants (i.e., methyl bromide, metam sodium, and 1,3-dichloropropene). These synthetic soil fumigants are highly toxic to pests as well as many beneficial soil organisms (Schreiner et al., 2001; Cox, 2006). In addition, many of these conventional soil fumigants exhibit vertebrate toxicity and other damaging environmental effects (Cox, 2006). Together, these negative environmental and human health concerns have driven a search for more benign alternatives (Martin, 2003). Egypt faces this ecological problem. However, many have concerns about the negative impact of synthetic nematicides on the environment and general public health require a re-evaluation of these products. For example, the high use of the soil fumigant methyl bromide and resulting contamination of ground, surface and drinking water in the Netherlands led to a ban on its use in the 1980s. Later, methyl bromide was listed as an ozone depleting compound at the 4th meeting of the Montreal Protocol in Copenhagen (Salem, 2012; Salem et al., 2015).

Brassicaceae produce glucosinolates which are β-D-thioglucosides, distinguished from one another by differences in their organic side chains (R groups). Glucosinolates, classified as aliphatic, aromatic or indole forms, occur in all parts of the plant and degrade via enzymatic hydrolysis. As a result of tissue damage, the relatively non-reactive glucosinolates react with myrosinase, which is stored separately in the cell, to yield nitriles, epithionitriles, thiocyanates and isothiocyanates (ITCs), (Salem et al., 2012a; Salem et al., 2012b). This investigation aimed to use the mustard plant powder as a biofumigant eco-friendly material to suppress and control root-knot nematode, M. javanica on tomato plants under laboratory and greenhouse conditions.

Figure 1: Effect of soil amended with mustard on the percentage of egg hatching and larval mortality of M. javanica under laboratory conditions.

ISSN-Internet 2197-411x OLCL 862804632
UniKassel & VDW, Germany- December 2015

Materials and methods

In Vitro Experiment

This experiment was carried out under laboratory condition in 250 ml conical flasks contains 100g of sandy/clay mixture soil (2:1; v:v) amended with 4 g mustard powder (4%) and covered with 20ml tap water to enhance the decomposing of mustard in soil. The flask has two openings, one of them covered with rubber cover and aluminum foil. A rubber tube was connected from the other pore to another small 50ml conical flask covered with aluminum foil to limit the evaporation (Figure 1). The small flask contain either 500 eggs and/or larvae in 100ml tap water to determine its effect on the percentage of egg hatching and larval mortality at different intervals incubation period 24, 48, 72, 96 and 168 h. Egg hatching and larval mortality was calculated in 50 eggs as well as 50 larvae under stereomicroscope at magnification 100X.

In Vivo Experiment

Mustard (Sinapis nigra) as a powder was used and mixed well with soil pots at three different doses i.e. 3%, 5% (before 48 hr and one week of nematode inoculation) and 7% (w/w). All doses were applied 48h before nematode inoculation, except 5% doses as it applied 48h and one week before nematode inoculation. The mixture of sandy/clay soil amended with mustard powder at different doses was filled into plastic pots (15 cm in diam.). Three weeks-old tomato seedlings (Lycopersicon esculentum Mill cv. GS) were transplanted into pots (one plant/pot).

Pure culture of M. javanica was established from single egg masses on tomato plants under greenhouse conditions at 25±2oC. Nematode species was identified according to the morphological characteristics of the female perineal patterns (Taylor and Sasser, 1978). Root-knot nematode eggs were extracted from heavily galled roots by using 1.5% sodium hypochlorite solution (NaClO) technique as described by Hussey and Barker (1973). Two thousand nematode eggs were pipetting into three holes made around the tomato root zone at the same time of transplanting, except the treatment of 5% one week before nematode inoculation. Each treatment replicated three times and the non-treated plants were served as control. Plants were arranged in a completely randomized block design in the greenhouse at approximately 25±2oC. Plants were watered daily and fertilized weekly with 5 ml of 2 g/l N:P:K (20:20:20).

Two months after nematode inoculation, nematode and growth parameters were recorded. The recorded nematode parameters were: numbers of galls, gall index, number of egg masses/root system as well as number of juveniles in soil pots (Goodey, 1957). Root galling was estimated according to Taylor and Sasser (1978) whereas: 0= no galls or egg mass 1= 1-2 galls or egg mass 2= 3-10 galls or egg mass 3= 11-30 galls or egg mass 4= 31-100 galls or egg mass 5= more than 100 galls or egg mass. Egg-masses were stained prior to counting by dipping the infected roots in phloxine-B solution (0.015%) for 20 minutes as described by Daykin and Hussey (1985).

The determined growth parameters were: shoot and root length (cm), fresh shoot and root weights (g) as well as dry weight (g). Total amino acids (TAA) were determined in dry leaves (Rosen et al., 1957) and total sugars (Dubois et al., (1956).

Gas chromatography/mass spectrometry analysis (GC/Mass)

The mustard plant material, air-dried at room temperature for about one week, was subjected to hydrodistillation for 4h according to the standard method using a Clevenger-type distillation apparatus (Traboulsi et al., 2002). Plant components were determined by gas chromatography (GC) (Hewlett-Packard) coupled to an HP 5871A mass spectrometer detector and equipped with an on column DBI (30 m - 0.20 - 0.05 µm). The temperature programme consisted of an initial temperature of 53ºC, hold 3 min-1, ramp rate 3°C min-1, final temperature 220ºC, hold 65 min-1, column flow rate 0.6 ml d'He/mi constant. The injection temperature was 200ºC with an injection volume of 2 µl/min. The mass spectrometer settings were: electron impact ionization mode with 70 eV electron energy, scan mass range m/z 50–400. Detection temperature was 276ºC using the retention time and peak area as a mean of measure. Components were identified by comparing the GC retention and mass spectra with those reported in the literature. Pure essential oils of commercial origin were kindly supplied by Jean-Marie Bessiere (Ecole Nationale Supérieure de Chimie de Montpellier, France). Each oil was sepa-

Table 4: Major components structure, molecular weight, and concentration of isothiocyanates from Sinapis alba

Major components of Isothiocyanates	Concentration ppm.	Structure of side chain R	Molecular weight
Lucanine 2	14.3	$C_{27}H_{30}O_{16}$	440
12-octadeca dienoic acid,(Z) -2,3-bis(trimethyl silyl) oxy) proplyl ester	12.7	$C_{27}H_{45}O_4S_{I2}$	498
15-Hexa deca methyl-octasiloxane	12.3	$C_{16}H_{50}O_7S_{I8}$	578
13-teradeca methyl-Hepta siloxane	10.4	$C_{14}H_{44}O_6S_{I7}$	504
11-Dodecamethyl-Hexa-siloxane	9.2	$C_{12}H_{38}O_5S_{I6}$	430
15- octadeca trienoic acid,2,3- bis(tri methyl silyl) propyl ester,(z)	8.5	$C_{27}H_{52}O_4S_{I2}$	496
Ethyl isoallocholate	8.4	$C_{26}H_{44}O_5$	436

rated from water with a Pasteur pipette, dried by filtration over anhydrous sodium sulphate and stored at -20°C in a sealed dark bottle until analysis. The Isothiocyanates yield (Table 1) was calculated relative to the mass of dry plant material.

Statistical Analysis: Data were statistically analyzed according to a standard analysis of variance by a one way ANOVA with the software stat graphics (Statistical Graphics. Crop, Rockville, MD), Variance homogeneity for all treatments was confirmed by the Bartlett test. The comparison between means was carried out by Duncan's Multiple Range Test (Duncan, 1955) as given in the figures.

Results

In Vitro Experiment

Laboratory results revealed that the nematode eggs incubated in water and exposed to sandy/

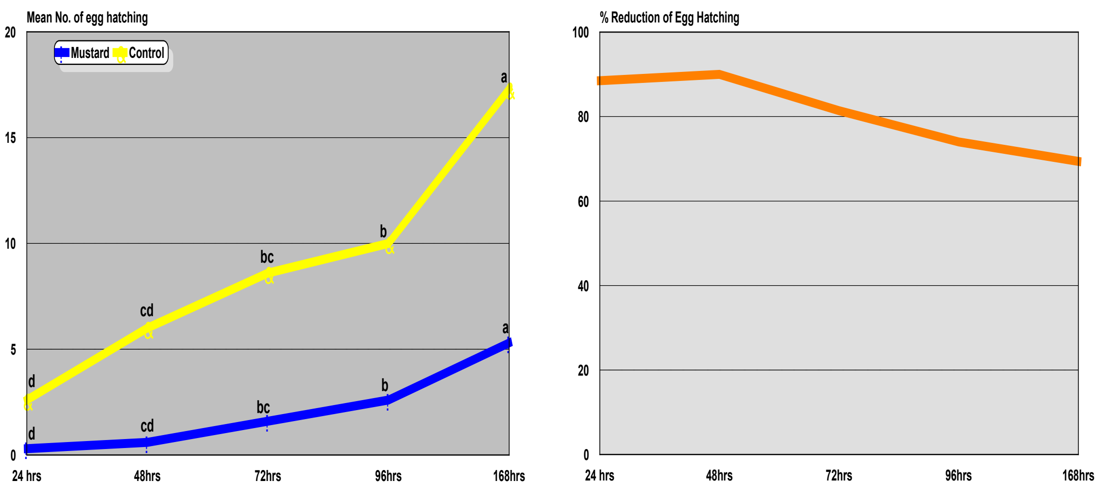

Figure 2: Effect of soil amended with mustard on the mean number (A) and percentage of egg hatching reduction (B) of M. javanica under laboratory condition

ISSN-Internet 2197-411x OLCL 862804632

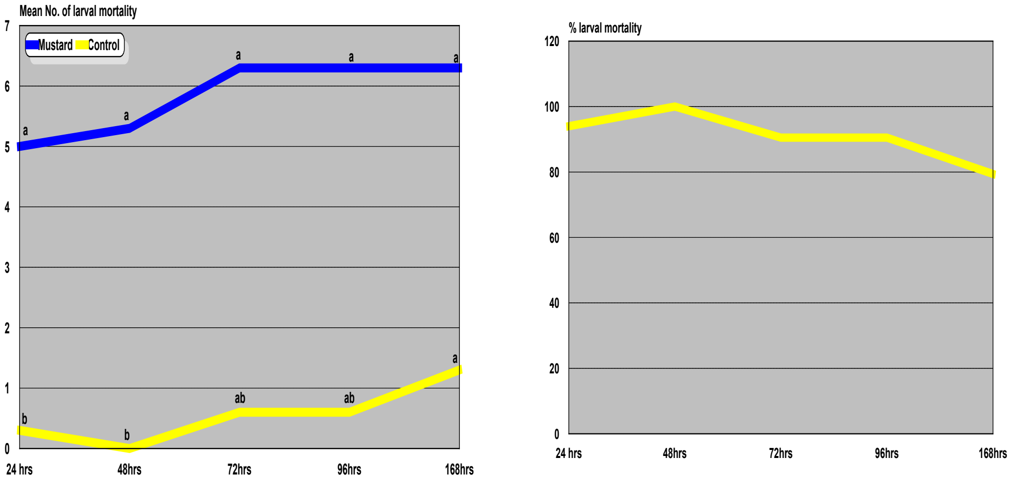

Figure 3:): Effect of soil amended with mustard on the mean number (A) and percentage of larval mortality (B) of M. javanica under laboratory condition

clay soil mixture amended with 4% mustard (Fig. 1) was significantly reduced egg hatching of M. javanica at all intervals incubation period 24, 48, 72, 96 and 168 h, compared to control (Fig. 2A). Results indicate that the percentage of egg hatching reduction was 88.5, 90, 81.4, 74 and 69.4% respectively.

Results observed also that mustard amended with soil as a biofumigant led to high larval mortality at the different intervals incubation periods when compared to control (Fig. 3A). The percentage of larval mortality recorded 94, 100, 90.5, 90.5 and 79.4%, respectively compared to control (Fig. 3B). Laboratory results confirmed that at the incubation period of 48h recorded the highest reduction in egg hatching the highest larval mortality.

In Vivo Experiment

Results of in vivo experiment revealed that the incorporation of soil pots with mustard powder at all different doses 3%, 5% (48 h and one week before nematode inoculation) and 7% of soil weight significantly reduced all related nematode parameters compared to treated plants with nematode alone. All nematode parameters i.e. number of galls/root system, root galling index, number of egg masses/root system as well as number of juveniles/250 g soil showed high reduction with mixing the soil pots with mustard at 5% one week before nematode inoculation followed by 5% before 48h nematode inoculations. The maximum percentage of galls reduction was 96.8 and 96.7%, respectively, whereas the lowest reduction percentage of galls obtained at 7

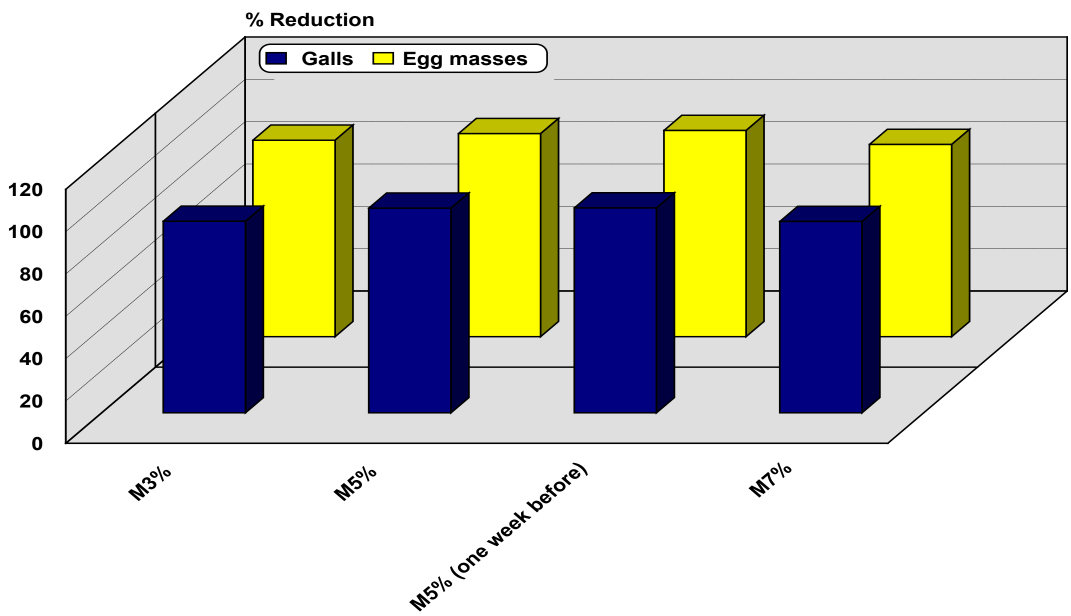

Figure 4: Percentage of galls and egg masses reduction of M. javanica in tomato roots grown in soil amended with mustard at different doses and application time

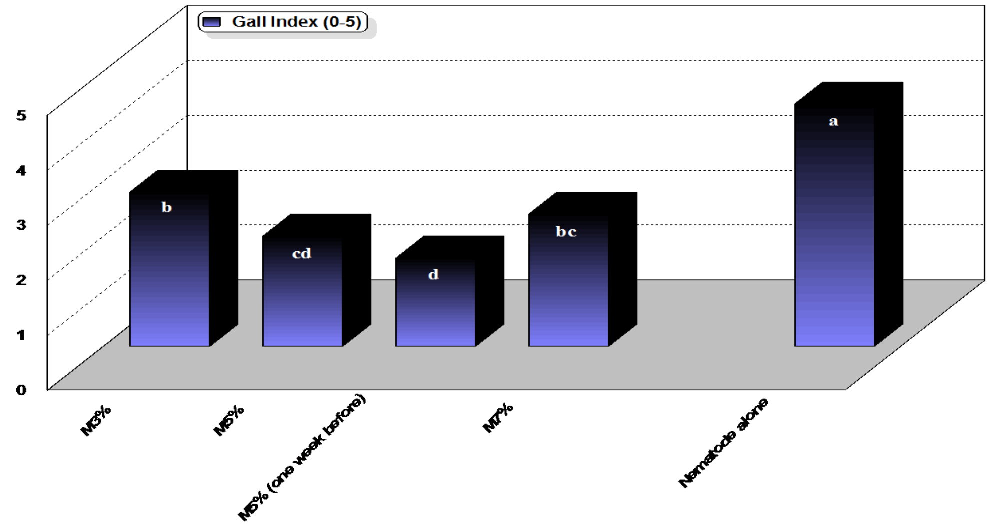

Figure 5: Root galling indices (0-5) of M. javanica as affected by amending soil with mustard at different doses and application time on tomato roots

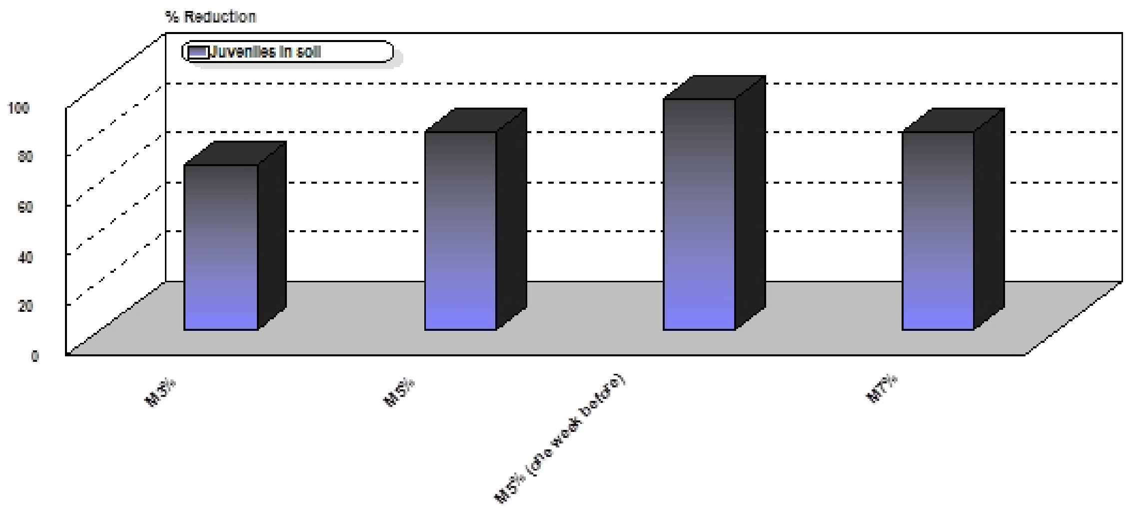

Figure 6: Percentage of reduction of M. javanica larvae in soil amended with mustard at different doses and application time

and 3% by 90.4 and 90.5%, respectively (Fig. 4). Egg masses showed the same trend of results as mixing the soil pots with mustard at 5% either before one week or 48h was the most effective one in reducing the mean number of egg masses. The percentage of reduction recorded 97.4% and 95.9%, respectively (Fig. 4). The lowest effect observed with the application dose 7% followed by 3% by 90.8 and 92.8% respectively. As a result to galls reduction, the root galling indices was significantly reduced at all used doses and application time compared to control (Fig. 5). Soil amended with mustard at all tested doses appeared to have good results in suppression nematode larvae compared to mustard non-treated plants. Application mustard at 5% either before one week or 48hr was the most effective treatment. The percentage of reduction in suppression nematode larvae recorded 93.2 and 80%, respectively (Fig. 6). Application of mustard at 3% was the lowest one by 66.5%.

The chemical components i.e. total sugars, total amino acids and total phenols were enhanced with all doses of mustard applied compared to p treated plants with nematode alone (Fig. 7). Amending the mustard at 5% one week before nematode inoculation with soil pots encouraged the percent of all the chemical com-

ISSN-Internet 2197-411x OLCL 862804632

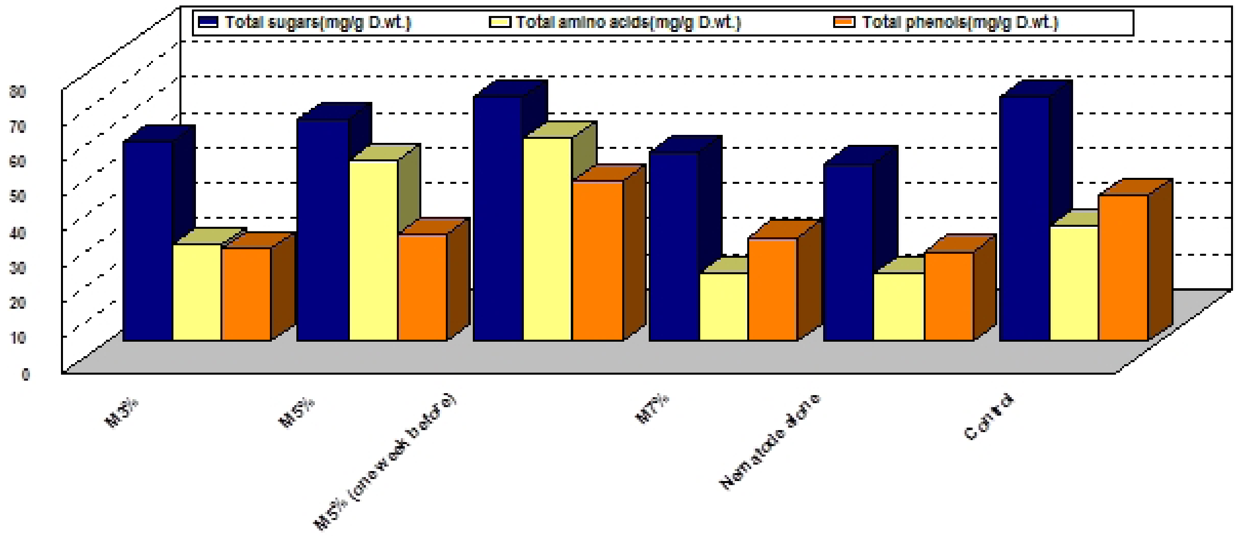

Figure 7: Effect of soil amended with mustard at different doses and application time on the percentage of chemical constituents in tomato plants infected with M. javanica

ponents compared to all the other treatments.

Discussions

The continuous use of chemical nematicides to control Root-knot nematode has considerable environmental impact, and has resulted in the onset of resistance phenomena within some populations of nematode pests. This situation has led to an increased demand for environment friendly products in order to reduce the effects of widespread nematicides utilization in crop protection (Salem, 2012; Salem et al., 2012a; 2012b.). The use of natural products together with chemical nematicides at low dosage in the framework of integrated pest management programs could achieve the aims of reducing costs and limiting the environmental pollution impact on the crops. Several studies using natural products have demonstrated the possibility of their use to control pests and diseases. In the present study, the effects of a natural formulation on isothiocyanates were investigated. Our results reveal that, soil amended with mustard at all tested doses appeared to show good results in suppression nematode larvae compared to mustard non-treated plants. The application of mustard at 5% either before one week or 48hr was the most effective treatment. The formulation (Salem et al., 2012a), used at the dose of 2% emulsion in water, was obtained from vegetable oils of Brassica carinata added to meal obtained from the same species and Arabic gum. The meal contains glycosidic compounds whose enzymatic hydrolysis degradation products (isothiocyanates and nitriles) are well-known for their high cytotoxic activity (Lazzeri et al., 2004; Marciano et al., 2004). In 2013, the experiments reported that under laboratory and field conditions (Personal Communications). This is consistent with glucosinolates, or their toxic breakdown products, acting as antagonists to nematodes (Zasada and Ferris, 2004; Salem et al., 2012b). Second, Root-knot nematode infectivity was greatly affected (greenhouse experiment), and harmed, by the soil-incorporation of mustard, indicating that EPN infectivity was strongly impacted by the addition of mustard plant biomass. Thus, mustard green manure is harmful to Root-knot nematode.

Egyptian governments as well as other developing countries have restricted the use of synthetic soil fumigants such as methyl bromide, metam sodium, and 1, 3-dichloropropene, due to these chemicals' substantial environmental and human health risks (Salem, 2012). These concerns have led to an ongoing search for effective alternatives, such as Brassica and Sinapis mustard species and Sudan grass (Mojtahedi et al., 1993; Salem et al., 2012a; Salem et al., 2012b).

Mustards have been particularly attractive bio-fumigant candidates because of the broad activity of their toxic breakdown products against a range of soil pests (Brown and Morra, 1995; Kirkegaard et al., 1996; Zasada and Ferris, 2004, Salem et al., 2015). Biologically-active compounds are retained in waste-products following conversion of mustard seed to biofuels, forming an inexpensive and likely growing source of these soil amendments (Cohen and Mazzola, 2004). The nematicidal effect of the tested mustard may possibly be attributed to their high contents of certain oxygenated compounds which are characterized by their lipophilic properties that enable them to dissolve the cytoplasmic membrane of nematode cells and their functional groups interfering with the enzyme protein structure (Knoblock et al., 1989; Salem, 2012a; Salem et al., 2015). The present in vitro study found that some of these medicinal plants extract were very effective against one or both nematodes at relatively low concentrations. In vitro assay, isothiocyanates are released through enzymatic degradation of glucosinolates are effective on developmental stages of (RKN), and unaffected medicinal plant extracts on developmental of Meloidogyne. spp shown data. Addition, field applications of promising extracts should be conducted to verify their nematicidal effectiveness.

Biofumigation is the practice of using volatile chemicals released from decomposing plant material to suppress soil pathogens, nematodes, insects and germinating weed seeds. Brassicas are mainly used for biofumigation. The decomposition of the plant tissues in these families releases isothiocyanates which are biocidal. Plants have different profiles of isothiocyanates, and stressing the plants increases the amount of isothiocyanates produced by mustard. Modified or innovative biofumigation technology that firstly described worldwide by (Salem, 2014) has been used as an alternative to methyl bromide and other synthetic pesticides in horticulture and agriculture in general. It has also been used to reclaim soils infested with root-knot nematode. It is eco-friendly and adds organic matter to the soil. There is potential for this technique to be adopted in Egypt by mustard incorporation in soils and compost and horticulture farmers involved in organic farming and as a stored pest management technique. Finally, we are willing to put the recommendation of these results into practice: we should create an effort to educate Egyptian farmers about this modified/innovative biofumigation since most farmers are not aware of this innovative technique. There is a great need for local research into Brassica that can be used for biofumigation. We adopted new and innovative technologies for a modified biofumigation that can suite farmers all over the world even in Africa, Europe, and Asia and taking into consideration the differences in soil type. There is great need also to research on methods of incorporating the biofumigant plants into the soil as well as breeding for Brassica with high isothiocyanates content is an important demand nowadays.

Conclusions

This modified technology of biofumigation would be an innovative and can be used efficiently to control Root-knot nematode under organic agriculture and Global GAP agricultural systems instead of these carcinogenic nematicides.

Acknowledgement

We would like to thank Professor Dr. Ahmed El Sherif, Professor of Nemtology, Faculty of Agriculture, Mansoura University, Egypt. Moreover, a special thanks goese to the Royal Green Technologies, Egypt and Culminations Group, Austria for supporting our research work. We would like to express our thanks to the anonymous reviewers for their helpful and critical comments.

Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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ISSN-Internet 2197-411x OLCL 862804632

UniKassel & VDW, Germany- December 2015

Future of Food: Journal on Food, Agriculture and Society, 3 (2)

By FOFJ Editorial Staff

12th FENS European Nutrition Conference

Today questions on nutrition are attracting a larger audience, as different forms of malnutrition exist in developed as well as in developing countries. Proper nutrition together with adequate physical activity prevents a number of sicknesses. For example, in Europe cardiovascular diseases are the main culprit for the 40% of deaths annually, costing billions of Euros for the European economies. To tackle a wide variety of nutrition-related diseases and present the latest findings, the 12th European Nutrition Conference took place in October 20-23, 2015 in Berlin. The conference's slogan was "Nutrition and health throughout life-cycle – Science for the European consumer". Besides nutritionists, also attending the event were food engineers, doctors, individual researchers, and marketing specialists from food industry, university lecturers and government officials. Taking place simultaneously, the sessions were divided into thematic areas as the number of speakers was high. There were interesting lectures on reducing food waste, the effect of organic food on health, the effect of globalization on sustainable nutrition, importance of spices and herbs in improving public health, mental performance and many other insightful presentations. A special space was provided for industry where food firms could present the usefulness of their products backed up with latest research.

Although the main research findings were coming from European countries, there was a possibility to listen to the experiences of countries from other geographical areas during the poster sessions. It requires much effort and talent to gather people in one event and conduct a conference with a massive audience and speakers. It is testament to the German Nutrition Society and the Organizing Committee of the 12th FENS European Nutrition Conference which conducted such an event on high level. The next FENS Conference will take place in Dublin in 2019.

WHO report - processed meat can cause cancer

Photo credit: giorgio raffaelli (via flickr©)

The recent findings of the World Health Organization (WHO) may now make meat gourmands think twice before consuming their favorite food. According to its statement, increased consumption of processed meat products and red meat raises the chances of getting cancer. Around two ham pieces (50g) a day increase possibility of bowel cancer by 18%. Carcinogenic activity increases due to the additives which extend the expiry date and preparing methods such as fuming and preservation. Sau-

ISSN-Internet 2197-411x OLCL 862804632

sages, bacon, corned beef, canned beef, ham and hot dogs refer to processed meat. Processed meat was put into the Group 1 category meaning that sufficient evidence was found in relation to causing cancer. It stands along with such substances as asbestos, alcohol, tobacco smoke, but they do not have the same level of hazard. The risk of getting lung and other types of cancer because of smoking is much higher than in the case of consuming processed meat.

Experts believe that consumption of processed meat should be discouraged, but in no way it should be eliminated. In the UK, 34,000 deaths a year could be related to diets based on processed meat. Although in comparison to tobacco and alcohol the effect of processed and red meat is not that big, one needs to ensure a proper diet including more fibre, fruits and vegetables coupled with physical activity. The results concerning red meat are tricky. Red meat is meat such as beef, pork, lamb, veal, goat, mutton and horse. During processing and cooking red meat produces certain types of carcinogens. However, it is still unclear whether the way meat is prepared causes cancer or not. The relation between red meat and cancer is loose and has little evidence. However it is advised to reduce its consumption as there is a probability of emergence dangerous chemicals during cooking. Along with decreasing red and processed meat consumption, it is advised to base diets on poultry, fish and beans. It is important to mention that controversy over this topic was even in the panel as out of 22 votes, 7 members decided either to disagree or to abstain.

WHO research is not new to controversy.. A recent report evaluated the impact on human health of glyphosate. According to the International Agency for Research on Cancer (IARC), the world's most popular weedkiller, known as Roundup, might be carcinogenic to humans. Glyphosate is mainly used in large-scale farming to grow corn, soybeans and cotton through spreading on the fields. Due to the increased usage of this pesticide, glyphosate levels in water increased five times in EC/EU. This forced water standards to be reconsidered in the Guidelines for Drinking Water Quality Working Group meeting in Geneva 2004. Controversy over the impact of this pesticide led to debates between skeptics and promoters of Roundup. In discussing advantages and disadvantages of the substance, it is crucial to differentiate between the assumptions whether it could or does cause cancer. On the one hand, the probability that it might cause cancer is based on two types of evidence. First, laboratory studies show that DNA and chromosomes in human cells can be damaged because of this chemical which eventually might cause cancer. Second, exposed to glyphosate rats and mice tend to develop cancerous tumours. On the other hand, large-scale studies show that its effect on human health is not evident as farmers exposed to glyphosate did not have a high cancer rate. It is assured that no danger exists in final food products which use this chemical during its production as glyphosate residues are destroyed during heavy processing. However, gardeners, farmers or children playing on the field where it was spread should be careful. The topic will remain controversial as no strong evidence has been demonstrated through studies of glyphosate on human health. The Guidelines for Drinking Water Quality Working Group meeting in Geneva 2004 decided that it was not necessary to change standards.

ISSN-Internet 2197-411x OLCL 862804632

Future of Food: Journal on Food, Agriculture and Society, 3 (2)

The circular economy and the water-food nexus

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Data of the article

First received: 28 July 2015 | Last revision received: 04 November 2015
Accepted: 07 November 2015 | Published online: 16 December 2015
URN :nbn:de:hebis:34-2015102649198

Key words
water; agriculture; phosphorus; circular economy

Abstract
The global economy is based on a take-make-consume and dispose model where natural resources are turned into products and the waste disposed of instead of being reused as a resource. In the Asia-Pacific region climate change along with rapid population and economic growth is resulting in increased demand for water and food, potentially leading to economic and political instability. Europe has developed policy and technological innovations that can facilitate the transition towards a circular economy where waste becomes a resource. By using existing instruments Europe can transfer its circular economy knowledge and technology to the Asia-Pacific region to increase security of supply of scarce resources. This can help ensure global security, influence climate change negotiations and create jobs in Europe.

Introduction

Since the industrial revolution the total amount of waste has constantly grown as economic growth has been based on a 'take-make-consume and dispose' model (European Commission, 2014). This linear model assumes that resources are abundant, available and cheap to dispose of. In Europe there is a move towards a 'circular economy' that reduces, reuses and recovers resources, which in turn reduces primary resource consumption and greenhouse gas emissions (EEA, 2014, WEF, 2014).

In the Asia-Pacific region rapid urbanization and economic growth has led to environmental degradation and resource scarcity: land for food production has become a fragile resource while three out of four countries currently face water scarcity (LSE Cities, 2014, ABD, 2013). Regarding water and food, accessibility and availability of water resources has historically influenced agricultural production including types of crops grown, crop cycles and irrigation methods adopted. However, this 'water-food nexus' has become vulnerable to changing patterns of water supply from climate change and growing competition for limited water resources, affecting the production of food resources. In addition, the use of fertilizers has increased significantly as demand for food has increased, impacting water quality for natural and human uses (IRENA, 2015). A move towards a circular economy is therefore critical for ensuring economic and social stability in a region that is vital to the world. As such, it is only through closer ties and co-ordination with partners in the Asia-Pacific region that the EU can address major global issues including climate change and resource scarcity. The EU would also gain through job creation and increased economic productivity from producing innovations to further develop the circular economy.

Citation (APA):
Brears, R.C. (2015). The circular economy and the water-food nexus, *Future of Food: Journal on Food, Agriculture and Society*, 3(1), 53-59

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Figure 1: Access to improved water is a big challenge in many parts of the world

Water-food nexus pressures in Asia-Pacific

Water for food production accounts for around 70% of water withdrawals. However, with increases in population growth, urbanisation and economic growth along with changes in diet as prosperity increases, demand for food will increase significantly. For instance, a change in lifestyle and diets in Asia will increase demand for water-intensive products such as meat and dairy products (FAO, 2013). Globally, demand for phosphate as a fertilizer nutrient will rise from 43.8 million tonnes per annum in 2015 to 52.9 million tonnes in 2030 (European Commission, 2013). Currently, Asia accounts for almost 60% of the world's total nutrient use, with China and India consuming around 55% and 29% of Asia's total consumption of fertilizer respectively. Over the next five years, Asia's consumption of fertilizer will increase by around 6% due to changing and interconnected trends including economic and population growth and increased demand for food (PR News Wire, 2014).

Why should the EU help reduce nexus pressures? Addressing environmental degradation, climate change, resource efficiency and water management are key priorities for the EU in the Asia-Pacific region for the following reasons:

Global security:
Increased demand for water and food accompanied by the impact of climate change will affect the supply of natural resources. In many countries this will exacerbate exisiting difficulties including economic weakness, lack of adequate infrastructure and weak governance with potential competition over scarce resources, including water between states (Herman and Treverton, 2009). This will spur the search for new resources and the use of existing resources sustainably and efficiently through new technologies. These challenges provide unprecedented opportunities for the EU to offer its policy-making and technological expertise in ways that can underpin global security and prosperity in a sustainable manner.

Job creation:
At the aggregate EU-wide level, resource productivity in the EU grew by 20% between 2000 and 2011. While some of the increases in efficiency was due to the effects of the recession, if this rate was maintained it would lead to a further 30% increase in efficiency by 2030 and boost GDP by nearly 1%, resulting in an additional 2 million jobs (European Commission, 2014). In addition, if European companies implement waste prevention, eco-design,

ISSN-Internet 2197-411x OLCL 862804632

reuse and other similar measures it could bring net savings of EUR 600 billion while reducing annual greenhouse gas emissions by 2-4% (European Commission 2014). At the same time, the global market for eco-innovation, which is currently worth around EUR 1 trillion per annum is expected to triple by 2030 (European Commission 2015). As such, eco-innovation represents a major opportunity to boost competitiveness and create jobs in European economies (European Commission 2014).

Influence in climate change negotiations:
The EU has set itself the aim of negotiating and implementing a global climate change deal in 2015. To deliver on this, the EU will need to develop co-operation between key countries by encouraging them to commit to a sustainable low-carbon development path. This will include helping them manage their rapid urbanization in a low-carbon, climate resilient and sustainable manner. In addition, if greenhouse gas emissions are to be maintained at a low level that avoids catastrophic climate change, the EU will have to forge alliances with major emitters in areas including long-term business co-operation on low-carbon solutions.

Europe's transition towards the circular economy

In 2014 the European Commission adopted the Communication Paper 'Towards a circular economy: A zero waste programme for Europe' in order to establish a common and coherent EU framework for promoting the circular economy. Transitioning towards the circular economy involves: increasing recycling and preventing the loss of valuable materials, showing how new business models, eco-designs and industrial symbiosis can achieve zero-waste, reduce greenhouse gas emissions while also creating jobs and economic growth (European Commission, 2014). To achieve the circular economy the Communication paper proposes:

Setting up an enabling policy framework:
The European Commission proposes to establish a common and coherent EU framework to promote the circular economy. In particular, the Commission views markets as an important driving force in achieving a circular economy with materials and energy being the principal costs for many companies. However, there are many market barriers to the efficient management of resources. For example, waste prevention, eco-design, and reuse could save nearly 8% of annual turnover for European businesses, while reducing significantly greenhouse gas emissions (European Commission 2014). For this to happen, market barriers that prevent these opportunities from being developed need to be removed. Existing infrastructure, business models and technology all become 'locked-in' to the linear model of take-make-consume and dispose (European Commission, 2014). Companies may lack information, confidence, or capacity to implement circular economy solutions. The financial system is also a barrier. Circular economy companies can fail to raise capital for innovative solutions that increase efficiency or innovative business models that promote circular economy solutions, because they are perceived as being more risky, and so deter traditional investors. Finally, consumer habits may lock-in linear models hindering the development of new circular economy products and services. This happens when prices do not reflect the real costs of resource use to society, and policy does not provide a strong enough signal for the transition towards a circular economy. Utilising evidence of successful products, materials and value chains, the European Commission plans to work with stakeholders to develop an enabling framework that uses smart regulations, market-based instruments, research and innovations, incentives, information exchange and support for voluntary approaches. To implement the circular economy and achieve a 'sustainable industrial renaissance' in Europe, the EU will rely on proactive businesses and consumers with a special focus on small and medium-sized enterprises (SMEs) implementing circular economy solutions.

Designing and innovating for a circular economy:
In circular economy innovations, the goal is to design out waste throughout the value chain, rather than relying on solutions at the end of a product's life. This can be achieved through activities that include: reducing the quantity of materials required to deliver a particular service (also known as lightweighting); reducing the use of energy in production and use phases (efficiency); reducing the use of materials that are hazardous or difficult to recycle in products and production processes (substitution); creating a market for secondary raw materials (also known as recyclates); designing products

that are easier to recycle (eco-design); developing the necessary services for consumers (infrastructure); incentivizing and supporting waste reduction and high-quality separation by consumers (incentives); and facilitating the clustering of activities to prevent by-products from becoming waste (industrial symbiosis) (European Commission 2014).

Unlocking investment in circular economy solutions and harnessing the action of businesses by supporting SMEs:
As businesses are the key actors in a transition towards the circular economy, upstream and downstream decisions need to be better connected, with clear incentives between producers, investors, distributors, consumers and recyclers. In addition to using market mechanisms to ensure the efficient allocation of resources, a functioning secondary materials market needs to be developed. More attention also needs to be paid to enabling entrepreneurs to tap into potential new markets linked to the circular economy. The Commission's Communication Paper itself recommends the EU should encourage investment in circular economy innovations and address barriers to mobilizing more private financing for resource efficiency.

Modernizing waste policy and targets by turning waste into a resource:
Turning waste into a resource is part of 'closing the loop' in the circular economy. Objectives and targets set in European legislation are crucial drivers in improved waste management as they stimulate innovation in recycling and reuse, limit landfilling, reduce losses of resources, and create incentives for behavioural change. The EU has a political commitment to reduce waste generation, to recycle waste into a major, reliable source of raw materials, to recover energy only from non-recyclable materials and eliminate landfilling. For example, garden waste can be treated at composting plants, allowing the nutrients to be recycled as fertilizer (The Danish Government, 2013). The benefit of reducing waste is growth and job creation at relatively no cost, while also enhancing the environment. To boost the economic, social and environmental benefits gained from better management of municipal waste, the Commission proposes to increase reuse and recycling of municipal waste to a minimum of 70% by 2030, ban the landfilling of recyclable waste and biodegradable waste by 2025, and promote the development of markets for high quality secondary raw materials.

Europe, the circular economy and water-food nexus pressures'

Towards a circular economy: A zero waste programme for Europe' and the 2011 'Roadmap to a Resource Efficient Europe' identified the sustainable supply of phosphorous as an important factor affecting sustainability and long-term global food security. The mineral is an essential building block of life and is an irreplaceable part of modern agricultural production in its use as an animal feed and fertilizer. Despite phosphorous resources being abundant globally, there are three issues affecting the availability of supply, both in the EU and globally. First, there are only small reserves of phosphate-bearing rocks in the EU, with only Finland being a small producer. It is estimated that 90% of the world's phosphorous reserves are located in just five countries: China, Morocco, South Africa, Jordan and the United States. This has led to the EU importing 92% of its phosphorous. Second, there has been price volatility – in 2008 prices of phosphorous rose by 700% in just over a year resulting in increased fertilizer and food prices. Third, there is little possibility of reducing non-essential use of phosphorous as its use in animal feed and fertilizer already consumes around 90% of the total mined resource (European Commission 2013). Improving the use of recycled phosphorous in the EU and globally would therefore help safeguard the supply of this critical raw material.

Reducing water-food nexus pressures in the UK

In the United Kingdom (UK), the House of Common's Environmental Audit Committee's 2014 report, 'Growing a circular economy: Ending a throwaway society' stated that in 2012-13 household recycling rates had reached 43% in England, up from 12% in 2000-01. It is estimated that in 2010 the UK economy was 22% 'circular', up from 8% in 2000. Developments in circular economy technologies could mean that by 2030 the UK economy's circularity increases to 27%, leading to a reduction in material consumption of 30 million tonnes a year (House of Commons 2014). Waste policy and regu-

ISSN-Internet 2197-411x OLCL 862804632

lation in England is informed by a 'Waste Hierarchy' where the top priority is waste prevention. This is followed by preparing for re-use, recycling, other types of recovery (including energy recovery) and last of all disposal or landfill. The economic benefits of achieving a circular economy to the UK's GDP could be an increase of GBP 3 billion a year, while businesses could save GBP 23 billion from low/no cost improvements (House of Commons 2014). By implementing EU circular economy and waste reduction initiatives, the UK could save GBP 9 billion a year while adding 50,000 more jobs. In the manufacturing sector, re-manufacturing has the potential to create between GBP 5.6-8 billion per annum and support over 310,000 jobs (House of Commons 2014).

An example from the UK of reducing water-food nexus pressures in the circular economy can be seen in an initiative by Thames Water, the largest water and sewage company in the UK. Thames Water has partnered with Ostra Nutrient Recovery Technologies to launch the UK's first nutrient recover facility at Slough Sewage Treatment Works producing commercial fertilizer from wastewater. Phosphorous and nitrogen concentrated in the facility's wastewater can form a concrete-like substance called struvite which coats pipes and valves, reducing the plants efficiency in treating wastewater – an energy-intensive process resulting in costly maintenance. The plant's nutrient recovery system addresses these issues by converting the struvite into pellets of high-grade fertilizer. The plant is expected to produce 150 tonnes of fertilizer pellets a year for sale to crop-growers as well as gardeners. Economically, the plant will also save GBP 200,000 per annum by avoiding operation and maintenance costs. The important lessons from this example that can be exported to the Asia-Pacific region are that circular economy technologies can: increase efficiency in operations and reduce maintenance costs; increase security of supply of scarce resources, in this case fertilizer for food production; and finally, reduce energy requirements and water use. However, to close the loop it is important to create a viable market for secondary raw material, thus turning waste into a resource.

Tools to transfer circular economy instruments

The EU can use market access tools and innovation funding to expedite the transfer of circular economy knowledge and innovations from Europe to Asia-Pacific. These can help reduce tensions over scarce resources, reduce carbon emissions and support economic growth in Europe.

Market access tools for Green SMEs:

The EU's 'Green Action Plan for Small and Medium-sized Enterprises' provides a framework for how the EU and Member States should enable SMEs to turn environmental challenges into corporate opportunities as part of the transition towards a circular economy. One aspect of the Green Action Plan is to facilitate market access for Green SMEs. Over the period 2008-2014, the EU provided the 'EU Gateway', which was a EU-funded initiative for helping SMEs establish long-lasting business collaborations in difficult markets abroad. In Asia, the programme targeted Japan and Korea. As part of this programme, EU Gateway provided SME participants a one-week in-country business mission along with business support services such as coaching, logistical and financial support. Over the period 2008-2014, 46 business missions were organised to visit Japan and Korea. Of the 1,500 participating companies: 83% found the business mission highly useful to increasing their market understanding; 64% established business collaborations; and 30% saw their revenue grow following the mission (EU Gateway 2014). Building on the success of this programme, the EU has developed the 'EU Business Avenues to South East Asia' program which focuses on the Singapore, Malaysia and Vietnam markets. In 2015, the programme will be conducting business missions to these three countries for European SMEs in the clean technology sector. Particular focus will be given to SMEs focusing on water technology, the environment, renewable energy or energy efficiency, either as a producer of a sub-contractor or as an R&D or engineering company with its own technology.

Horizon 2020 – funding circular economy innovation:

Horizon 2020 is the largest EU's largest ever research and innovation programme, with almost EUR 80 billion of funding available from 2014 to 2020. The purpose of this funding is to take breakthroughs, discoveries and world-firsts from the lab to the market. Horizon 2020's funding will reflect the policy priorities of the Europe 2020 strategy and address major societal concerns shared by citizens of Europe and elsewhere. One of the main societal challenges Horizon 2020 addresses is entitled 'Climate Action, Environment, Resource Efficiency and Raw Materials'. Activities in this challenge are intended to help increase European competitiveness, raw material security and improve wellbeing. At the same time the challenge will help assure environmental integrity, resilience and sustainability with the aim of keeping global warming below 2°C and enabling ecosystems and society to adapt to climate change and other environmental changes. The objectives of the challenge are to achieve a resource and water efficient as well as climate change resilient economy and society; protection and sustainable management of natural resources and ecosystems; and a sustainable supply and use of raw materials for meeting the needs of a rapidly growing global population within the sustainable limits of the planet's natural resources and eco-system. Research and innovation in this challenge will cover: adapting to climate change; protecting the environment and sustainably managing natural resources and ecosystems; ensuring the sustainable supply of raw materials; and enabling a transition towards a green economy through eco-innovation. Through Horizon 2020 funding, breakthroughs in circular economy technologies will be taken to the market, including in the Asia-Pacific region.

Horizon 2020 also calls for the strengthening of international co-operation with China and India, something to be achieved through strategic partnerships. These strategic partnerships will allow countries in the Asia-Pacific region to draw on Europe's experiences and lessons on how circular economy technology and eco-designs can reduce greenhouse gas emissions, increase resource efficiency and reduce water-food nexus pressures by turning waste into resources. Overall, by exporting Horizon 2020 lessons to the Asia-Pacific region the EU will enhance its economic competitiveness by increasing jobs through exports of circular technologies, while improving the security of non-energy raw materials, increasing human wellbeing, fighting climate change and limiting environmental degradation.

Conclusion

In the Asia-Pacific region, population growth, urbanization and economic growth along with changes in diet will increase demand for food significantly. However, water resources in the region are vulnerable to changing patterns of supply and growing competition creating water-food nexus pressures. At the same time, demand for scarce phosphorous supplies will increase. With resource scarcity there is the potential for economic and social instability in Asia-Pacific. In Europe there is a move towards the circular economy where existing resources are reused, repaired, refurbished and recycled. With the European Commission identifying the sustainable supply of phosphorous as an important factor affecting sustainability and long-term global food security, the EU can transfer to the Asia-Pacific region circular economy best practices and technologies to increase security of supply of scarce resources, in this case the recovery of phosphorous for food production. To expedite the transfer of circular economy knowledge and innovations from Europe to Asia-Pacific the EU can use market access tools and innovation funding to not only help reduce tensions over scarce resources in the region but also support economic growth in Europe.

Acknowledgement

This research study was conducted as part of a Visiting Fellowship to the Free University of Berlin's NFG, Asian Perceptions of the EU. I would like to express my thanks to the editorial board for their helpful comments.

Conflict of Interests

The author hereby declares that there is no conflict of interests.

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ISSN-Internet 2197-411x OLCL 862804632

Future of Food: Journal on Food, Agriculture and Society, 3 (2)

Nudging in der Verbraucherpolitik: Ansätze verhaltensbasierter Regulierung

A book review by SEBASTIAN MÜNZ

Authors: Dr. Lucia A. Reisch and Julia Sandrini
Book title: Nudging in der Verbraucherpolitik (125 pages, 34.00 Euro)
Year of publication: 2015
Publisher: Nomos Verlagsgesellschaft Baden-Baden
ISBN: 978-3-8487-1723-1

What is nudging? It is to „influence people into making favourable decisions without having to coerce them" (Jones, Pykett and Whitehead 2013 p. 17). For example hotels that endorse that a certain percentage of guests (75%) reuse their towels, is nudging the current guests into reusing their towels too (Reisch and Sandrini 2015 p. 108). As implied by the title, the authors provide an overview on nudging used in consumer policy making. The book starts with the general classification of nudges and provides a description of the 10 most effective nudges. Since the first chapters are heavily focused on the work of Cass Sunstein, the nudges presented there have a tendency towards political use. Following this classification, the authors explain about the frameworks developed by the Behavioral Insights Team (BIT) of the British government. The first one is the EAST-Framework (Easy, Attractive, Social, Timely) in which the authors provide examples in what to do under each of the four aspects. The second framework is the MINDSPACE checklist. The Authors provide the explanation of the acronym along with more examples on how to use it in practice.

Returning to the basic concept of nudges afterwards, the authors provide a general differentiation in type one and type two nudges. Type one means nudges focused on automated and non-reflected behavior while type two nudges act towards conscious and reflected behavior. This classification is enhanced by adding the category of transparent or non-transparent nudges. The authors provide some examples for this, but unfortunately not all the examples provided correspond to the tables and figures shown in the same chapter and are confusing to the reader. For example, the authors state in table 3 that green footprints that lead to trashcans in a city are type two nudges (conscious). In figure 1 which is just on the next page, the green footprints are listed as type one nudges (unconscious). There seem to be several mix-ups concerning the data in written text and the different tables and figures.

In the next part the authors give examples of institutions using behavioral based regulation. To name a few these are the governments of USA, Canada, Australia, Singapore and the EU. International organisations working with nudges are the OECD, the World Bank and the World Economic Forum. In this chapter the authors provide a large overview on nudging programs and the use of methods like the BIT Frameworks.

In the last chapters three main fields for nudges in consumer policy making are explained and made easily understandable by providing many examples. Those are finances, explaining among others the "KiwiSaver" program in New Zealand, which is a public retirement fund system that is automatically applied when entering working life, but offers several options to the users. Market and legal aspects, laying focus on the use of default settings to make customers pick a certain presented option. Lastly coming down to energy and resources, for example the aforementioned green footsteps that lead to trash cans and therefore reduce littering in urban areas. Those last chapters offers a vast

ISSN-Internet 2197-411x OLCL 862804632

impression on how manifold the use of nudges can be and already is. Especially when concerned with the application for nudges in new fields these already existing and evaluated programs offer a lot of data and help on planning new actions.

In total, the book offers a great overview on nudges in behavioral based regulation and is both an interesting read for the laymen and professionally concerned readers. The last chapters provide easy access to a lot of nudging programs and get into more detail about what is possible with nudging.

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Description of the photo: Expose to Drought Lake Hume in New South Wales, Australia

FOFJ Volume 4. Nr. 3 – Summer 2016

On the theme

"Climate Change Mitigation and Adaptation in Agriculture and Food Systems"

Call for Research Papers, Reports and Analysis, and Book Reviews

Over the last decades it has become increasingly clear that anthropogenic climate change poses an immense threat not only to ecosystems, but also to human societies. Agriculture and food systems are among the sectors that are most affected. Droughts, soli erosion, forest fires, floods, and extreme weather events deeply affect farming and food production. While small-scale farming in the Global South is threatened in its existence in many locales, food production is obstructed world wide through climatic extremes, as California's extreme droughts in 2014/15 have illustrated.

Paradoxically, farming is also a major contributor to greenhouse gas emissions. Overuse of fertilizers, land use change, mechanization, animal husbandry all contribute to climate change.

In December 2015, the international community has gathered again under the United Nations Framework Convention on Climate Change (UNFCCC). The Conference of the Parties 21 (COP21) in Paris has agreed on a binding treaty, a follow-up to the Kyoto Protocol, to reduce greenhouse gas emissions internationally. Beyond the negotiations, one thing is clear: It depends on decisive and encompassing implementations to leave the destructive path to an accelerating climate catastrophe. A host of studies show that under a "business- as-usual"-scenario, live on earth will became unbearable in many locations.

Future of Food: Journal on Food, Agriculture and Society (FOFJ) will devote an issue to the question of Climate Change, Agriculture and Food Production. The journal invites submissions that deal with climate change mitigation and adaptation in farming and food systems.

Topics may include but are not confined to climate-smart agriculture, the water-food-energy-nexus, climate-resilient seeds and water-effective irrigation, the role of international trade and local food systems in mitigation efforts, climate-conscious consumer behaviour (100-miles-diet etc.) and the impact of climate change on global fisheries.

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The Department of Organic Food Quality and Food Culture at the University of Kassel, Germany and the Federation of German Scientists (VDW), Germany