Recent Research in Science and Technology 2017, 9: 18-24
doi: 10.25081/rrst.2017.9.3358
http://updatepublishing.com/journal/index.php/rrst/

ISSN: 2076-5061

REVIEW ARTICLE

SOIL FERTILITY MANAGEMENT, A TOOL FOR SUSTAINABLE DISEASE AND WEED CONTROL IN SUB-SAHARAN AFRICA: A REVIEW

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ABSTRACT

Agro-ecosystem health is built on habitat manipulation and fertility enhancement. Similarly, plant nutrient levels altered by fertilization practices can expose crop plants to pests. In addition, diseases, weeds and other pests are principal agricultural losses all over the world. This is particularly devastating particularly in the developing nations of Sub-Saharan Africa, especially Nigeria. Reduction in these losses will not only improve agricultural production but will enhance food security and economic well-being of society. Sole use of synthetic chemicals is economically not a viable option and does not encourage environmental sustainability while land expansion is equally elusive due to urbanization and different forms of development and not environmentally friendly. The most viable and practicable option is integration of different fertility management alternatives that could produce crops on a sustainable basis while ensuring the safety and sustainability of the environment. Integrated Soil Fertility Management (ISFM) has proved to be a promising approach to fertility management and sustainable environment. It could be adopted as it provides the needed nutrients for plants, reduce weeds and disease incidences while safeguarding the environment.

INTRODUCTION

Population is increasing all over the world and is expected to rise to over nine billion (9b) by 2050 and even higher by 2100 [1, 2]. This calls for increased crop production to carter for these population and even the increasing livestock that may be required to carter for the protein requirement of the ever increasing population at least by 50% [2, 3]. Of tremendous importance is the production of food grains and vegetables that could be consumed and processed for livestock feeds. The sub-Saharan Africa threatened by myriad of soil and other environmental problems have great potential to increase agricultural productivity through integrating scientific and local know-how [4]. Achieving this objective requires increased land for production and effective and sustainable fertility management, disease and weed control. However, expansion of land for agricultural production may seem elusive due to industrialization, urbanization; expansion in infrastructure like roads and railways, education and health centers. Furthermore, land expansion may translate in to deforestation with negative consequences on the environment. Similarly, disease and weed have been managed effectively in modern agriculture to a large extent through use of modern technologies particularly the use of pesticides. However, rising cost of global energy with consequences in chemical costs and appearance of resistance against chemicals by pests and diseases compounds the problem [5, 6]. In addition, the agro-ecosystem is also threatened by the use of these chemicals and therefore questions productivity and sustainability of soils. Negative consequences of agro-chemicals to agro-ecosystems have severally been reported [7, 8]. In addition, several herbicides have been reported to have influence on micronutrient availability [9, 10]. This is particularly important in the Sub-Saharan African continent with dynamic unpredictable and disequilibrial climate [11, 12]. Similarly, with changing climate, Africa remains one of the vulnerable continent with substantial number of its inhabitants dependent on agriculture for survival [13]. Thus, the most viable option is agro-ecosystem management through habitat manipulation, good and effective fertility management [14]. Intensive year round cultivation with effective fertility management and minimum use of agrochemicals could ensure sustainable environment and optimum yield.

In narrow perspective, soil fertility is the capacity of the soil to supply plant nutrients in the right amounts, time and proportions. However, broadly it is a complex term relating to the chemical, physical and biological soil attributes and processes in relation to environmental and crop condition. It is therefore governed by both internal and external factors. While internal factors are genetic and

Received 07 October 2017; Accepted 18 December 2017

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cannot be manipulated on the field, the external are subject to manipulation to an extent. These includes climatic factors; precipitation. temperature solar radiation and relative humidity, edaphic factors; soil moisture, soil temperature soil mineral matter, soil organic matter and soil reaction, biotic factors; plants e. g competitive weeds and crop plants, symbiotic bacteria, animals eg earthworms, small and large animals, physiographic; geologic ie parent material, topography, anthropic-management. Thus, soil fertility is only a factor in the productivity of soils. Although fertility is only a factor in soil productivity, it has been shown to be the most limiting factor particularly in rainfed agricultural systems [15]. Importantly is the fact that nutrient imbalance, loss of soil carbon and biodiversity have been identified as some of the threat to soil function [16]. Nutritionally balanced plants have highest resistance and tolerance to pest, diseases and even weed infestation and the susceptibility of the plants to these increases as the nutrient concentrations deviate from the optimum [17].

At global scale fertility problems varied in relation to country's development and environmental conditions. And, in developed countries there are many problems from over production as well as environmental issues [18]. Contrary to this, in the developing world, agricultural production is constrained by low soil nutrients reserves, low organic matter contents and adverse soil conditions of aluminum toxicity, soil acidity, and phosphorus, ammonium and potassium fixation, poor soil structure and dense sub-surface layers, poor drainage and low water holding capacity [18]. Apart from these constraints, the tropical savanna soils are further constrained by low micronutrient levels as a consequence of low organic matter levels arising from their predominantly sandy nature and relatively low rainfall and high temperatures [19, 20, 21], and the use of primary nutrient elements as synthetic fertilizers on continuous basis compound the problems. In both scenarios the soils and crop plants are exposed to incidences of diseases and pest infestations [22].

Disease and weed damage to crops

Yield losses are incurred both on the farm (pre-harvest) and after harvest (post-harvest). The sources of the losses are diverse and multifaceted [23, 24]. The losses could be due negative effects of either biotic or abiotic factors. Global losses have been estimated to be within 35-70 % [25]. Out of these, a substantial percentage of the losses are due to pests comprising of animal pests, birds, rodents, slug and snails, mites, insects and nematodes; plant pathogens: bacteria, fungi, viruses and chromista, and weeds with losses of 34, 18, and 16 % for weeds, animal pests and microbial diseases respectively [25]. Losses due to weeds depend on crop type, cropping system, location and species of weeds [23]. Global potential crop losses due to pests and diseases was estimated to be 40.3, 37.4, 31.2, 28.8 and 28.2 % for potatoes, rice maize, cotton and wheat respectively [25]. High losses particularly in the staple cereals could further endanger the threat of food security in the region. Potential losses due to weed was estimated at 34 % while animal and pathogens were estimated at 18 and 16 % respectively [25]. Reduction of nutrient availability, uptake, distribution and utilization by crops are consequences of plant diseases, thus limits improved production efficiency and crop quality [26, 27]. Disease development occurs as a consequential interaction of susceptible hosts, virulent pathogen and a favorable environment [28]. Importantly also, is the fact that global warming and changing climate increase disease incidence with rise in temperature. Temperature rise by a unit increased severity of terminal disease development [29]. It was reported that in every 1 °C rise above 30 °C for maize crop under stressed condition, there is an accompanied 1.7 % reduction in yield [30]. Strategized agro-system manipulations through habitat modification and fertility management have been identified as a key factor in not only reducing the negative effects of diseases and pests but also produce optimum yield. In addition, sustainability of the environment is ensured and current threat to nutrient imbalances is curtailed [31, 16]. Agroforestry, crop rotation, mulching, green manuring and use of organic manures, mineral fertilizers, and integrated soil fertility management have apart from enhancing soil fertility reduced yield losses due crop diseases and pests.

Fertility management, diseases and weed control

Agroforestry

Agroforestry has been an important element in agricultural production due not only to its high productivity compared to monocultural systems but due to its complementarity in resource capture through deeper roots accessing both water and nutrients and recycling through leaf fall [31, 32, 33]. Carbon sequestration, biodiversity conservation and soil enrichment are also benefits of agroforestry system [34]. 7 kg $Nkg^{-1}yr^{-1}$ have been reported as nitrogen release from litter fall [35]. Apart from nutrient recycling, pest can be regulated by agroforestry through providing sources of adult food (e. g flowers) site for mating [36], thus reducing the negative effects of pests. It has also been identified long before now as one of the most effective means of nematodes control, parasitic fungi, many other pests and diseases in all agricultural systems particularly in tropical Africa [37]. In addition, although most agroforestry system reduces crop yield, there is always a give and take relationship with environmental sustainability [38].

Mulching

Mulch has successfully been used not only to improve and sustain soil fertility but also reduce pests, disease and weed infestation. It has also been a good moderator of the agro-ecology. Mulches, apart from regulating nutrient levels, it had been shown to hamper weed emergence particularly at the beginning of season [39, 40]. Polyethylene mulch have been reported to effectively control *phythopthora infestans* in tomato, in fact, more effectively compared to use of fungicides [41]. Similarly, *pythopthora infestans* in leaf infection was drastically reduced through increased systemic resistance by *arbuscular mycorrhizal* fungi [42]. Nemades (*Pratylenchs penetrans*) in apple plantation were successfully reduced by the use of Newspaper mulch [43]. In a study of alternative weed control using allelopathic effect of natural benzoxazinoids from rye mulch, and the use of rye mulch to control weed reduce herbicide use and enhance soil health was confirmed [44], thus reducing the negative effects of herbicide on the agro-ecosystem. Generally, crop pests are effectively reduced naturally through mulches [42, 43].

Green Manuring/Cover crops and use of organic manures

Green manuring is a method of soil fertility restoration in which fresh plant material either in situ or brought from a long distance is turned under to maintain soil carbon pool [45]. There are different sources of green manure crops; grain legumes or perennial woody multipurpose legume

trees [45]. The grain legumes include but not restricted to pigean pea (*Cajanus cajan*), green gram (*Vigna radiata*), Soybean (*Glycine max*), groundnut (*Arachis hypogea*) common beans (*Phaseolus Vulgaris*) [46]. The woody perennial legume trees include Kassod tree (Cassia siamea), Subabul tree (*Leucaena leucocephala*), Glicidia tree (*Glinicidia sepium*). The use of green manuring in soil fertility restoration and maintenance has been reported in Asia [45], and researches have confirmed its multiple advantages [47-45]. Green manuring improves fertility through increasing microbial activities and increase the nutrient supplying capacity of soils. It moderates soil structure; reduce soil erosion, control weeds and soil borne diseases [50, 47, 51, 49, 52, 53]. Bacterial and Fungal infections, pathogenic effects of nematodes have also been proved to be remedied by green manuring [48, 54-61]. Similar to green manuring, organic manures have been proved to improve soil fertility, reduce disease incidence, control weed and sustain the environment [62, 63].

Mineral fertilizers

Mineral or synthetic fertilizers have profound effects on germination, growth and yield of crops and reduction in pests and diseases [64, 65]. In a study effect of inorganic fertilizer on aphids' abundance, [66] reported variable effects of mineral fertilizer on mites and aphids' population on selected crops and indicated increased infestation in response to mineral fertilization. However, good fertilizer management provides competitive advantage to growing crops, reduces weed interference and competition [67] and thus, have direct impact on weed control strategies [64-69].

Crop rotation

The cultivation of different crops with different characteristics on the same field for successive years and following a previously established sequence is referred to as crop rotation [70, 71]. Effective pests and disease control have severally been achieved from rotation of crop combination [72]. The crops used in rotation system depend on geographical location, climate and soil type [70, 73]. Crop rotation is practiced in both developed and developing economies of the world; however, differ in emphasis in terms of objectives. In conventional crop rotation, emphasis is on the control of stubborn weeds, diseases and pests while in dryland systems of agriculture, the emphasis is on water conservation, minimization of salinity and soil fertility improvement [70]. However, both are usually achieved with proper rotational sequence of crops [70, 67] suggested integration of enhanced soil fertility management through use of mineral fertilizers, cover crops, green manures, mulching, compost and rotations and enhanced pest regulation through crop diversity, good cultural practices, pesticides and habitat modification for a healthy crop and agro-ecosystem. Crop rotation is the fulcrum of all sustainable farming systems and gives the most effective and efficient indirect method of controlling or minimizing weeds, diseases and pest problems while maintaining and sustaining soil fertility [70, 71]. Lower pest pressure has been reported in several literatures and this has been attributed to rotation and is mediated by improved soil fertility [70-78].

Plant nutrition, disease and pests control

Plant nutrition is one of the most effective strategies of controlling diseases in an agricultural setting. The use pesticides in controlling pests have severally been questioned due to environmental sustainability and safety [79]. Pesticides; fungicides (toxic to fungus), insecticides (toxic to insects), nematicides (toxic to nematodes), and weedicides (toxic to weed) when applied to the environment upset the ecological balance and destroy micro-flora and fauna [80]. Fertilization or soil manipulation to influence nutrient availability and control diseases has severally been reported in many excellent reviews [81-86, 65]. Sound defense mechanism of crop plants with balanced nutrition due adequate supply of plant nutrients has been shown to be an insurance to weed, pests and disease control [79]. Susceptibility of the host to various pathogens is directly a function of the strength of the host; the plant system and the environment [87]. Nutritionally balanced plants exhibit high defense system and since multiplication, penetration and distribution of the different disease causal pathogens is through weaker cell walls, the chances of infection or damage is substantially reduced [79]. In a study of the effects of N and K mineral fertilizer application on levels of severity of disease caused by parasites, [66, 65] indicated that high nitrogen levels reduced the severity of facultative parasites while high potassium levels reduced the severity of both obligate and facultative parasites [66]. In another study of nutrient fertilization on disease incidence, [88] indicated that depending on the form, time and method of fertilizer N applied, 168 of 1, 180 sampled decreased disease incidence due to fertilizer N application. Similarly, potassium supplies reduced disease incidence by 12 % of the total cases [88]. The same thing applies to the other secondary and micronutrients [88]. Compost has been shown to be used effectively to achieve reduce disease infestation in different crops [89]. [64, 65] further reported that the incidence of *Erysiphe graminis* (powdery mildew in Barley/Wheat crop by 95 % using 1:1 ratio soil: compost mix was reduced. Similarly, pea germination was significantly facilitated by soaking the seed in compost extract [64, 65, 89]. In a field infested by *Rhizactonia* spp, the infestation was reduced by 80 % in which highest compost rates of 72 ton/acre) were applied, 40 % where intermediate rates were applied and highest grain yield was achieved with plot with highest compost rates [81]. Similar results were achieved in controlling *phythoptora* sp in pepper (89). Clover tiredness and increased yield in Alfalfa was also achieved using compost [81]. Disease suppression was apart from other factors linked to soil fertility levels and nature of the soil itself and adding compost into the soil induces disease resistance in many plants [90, 91]. Earlier, [29] has indicated that the ability of a crop to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and biological soil attributes and any form of farm practices causes nutrition imbalances can lower pests and disease resistance [92]

In a review on defense system of plants against diseases as affected by primary and secondary nutrient elements, [79] indicated that the susceptibility of plants to diseases of fungus, Bacteria, viral and other soil-borne diseases can directly be linked to balance fertilization and nutrition of plants. Nutrients move within the cells to the apoplast through leakage of thinner and weaker cell walls and fungal spore's germination is often facilitated by these weaker leakages when there is K deficiency [79]. Imbalances of nutrients particularly of nitrogen, potassium and calcium in the plant system expose them to attack by fungal diseases [79]. This is similar in bacterial, viral and other soil-borne diseases where nutrient imbalances exist [79]. Thus, although disease resistance of plants is

genetically controlled, its susceptibility to diseases is directly associated with imbalances in nutritional status of plants [66, 65, 90]. Different studies [65, 90, 93] indicated that providing nutrient sufficiency remains the principal component of full expression of genetic resistance. Crop sequence/rotation, organic amendments, soil pH adjustments, tillage and irrigation management influences weed and disease control through nutrient interactions [79, 93, 94]. The entire essential nutrient element in one way or the other influence the incidence or severity of some diseases [64, 65, 90, 93, 94].

Integrated soil fertility management (ISFM)

Global intensification of agriculture with use of high yielding crop varieties (HYV), excessive use of mineral fertilizers and pesticides after the World War II and land expansion was said to be the root course of soil degradation and pest's resistance [73, 95, 96, 97, 98, 99, 100, 101, 102]. Agrochemicals generally have undesirable effects on the environment; bio magnification, long half-lives, destruction of non-target organisms and eutrophication of adjacent fields [73, 100-102]. Environmental manipulation through fertility management could moderate the interaction of the host plant, the pathogens and the environment as well as reduce weeds, pests and disease incidences, thus safe guarding the ecosystem [47, 79, 80, 84, 89, 90, 91, 98, 102, 103]. Integrated soil fertility management has proved to be an effective technology in many countries due to its use of local materials and cultural practices [104-109] and has effectively improved soil fertility and reduced weed and diseases infestation [106-109]. However, level of genetic resistance, nutrient availability relative to plant requirements, form and stability of nutrient applied or available, rate, time and method of nutrient applied, nutrient ratios and associated ions as well as integrating fertilization with other cultural practices are imperative in sustainable soil management. It is envisaged that in future more biodiverse agricultural systems may be more productive than the monocultures [73, 109].

CONCLUSION

Holistic approach is required to sustainably produce crops and safeguard the ecosystem due to the complexity of various interacting factors. Competing demands of resources made it pertinent to have a rethink on sustainability of both production and the environment particularly with global geometric increase in population in which the African continent is said to be most affected on its negative consequences. Improved high crop yielding varieties (HYV), pesticides and heavy doses of mineral fertilizers have been advocated and used for increased crop production globally including Nigeria. However, small farm holding farming systems dominant in Africa with the poor resource base of the farmer and negative consequences of using both heavy doses of mineral fertilizers and pesticides where feasible put the sustainability of both production and environment into question. Integrated soil fertility management which recognizes the use of improved germplasm, mineral fertilizers, organic materials sourced in cognizance of the local environment and management practices may be a viable option for controlling weed and diseases as well as sustaining fertility, environment and production of crops.

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