SUSTAINABLE HORTICULTURE IN CROP PRODUCTION THROUGH INTERCROPPING: A SYNTHESIS

Bijendra K. Singh, Raj Pandey, Rajaneesh Singh and Hari Baksh
Department of Horticulture, T.D.P.G. College, Jaunpur- 222 002
simpalbk1987@gmail.com

ABSTRACT: Sustainable agriculture seeks to at least use nature as the model for designing agricultural systems. Since nature integrates her plants and animals into diverse landscape a major tenet of sustainable agriculture is efficiency and lack of waste products in nature. When domestication of crops replaced hunting and gathering of food, landscape changed accordingly. Producing a limited selection of crop plants and animals, human kind has substantially reduced the level of biological diversity over much of the earth. Intercropping is the cultivation of two or more crops at the same time in the same field. Its advantages are risk minimization, increased income and food security, reduction of soil erosion and pest and disease control. This paper discusses the practice of intercropping in horticultural crop production to promote sustainability. To achieve all these, however, some minimum level of farmer's education, field-market linking infrastructure, and favorable government policies to encourage and stabilize vegetable production are required. Under this scenario, technological innovation can act as a catalyst to expand vegetable production. The enhanced management capability of vegetable growing farmers would then enable them to actively participate in the economic development process of the whole economy.

Keywords:Sustainable, horticultural, diversity, stability and crop.

Intercropping is the cultivation of two or more crops at the same time in the same field. Sustainable horticulture seeks to at least use nature as the model for designing agricultural systems. Due to the fact that nature integrates her plants and animals into diverse landscape, a major tenet of sustainable horticulture is efficiency and there are no waste products in nature. When hunting and gathering were replaced by domestication of crops landscape also changed. The level of biological diversity over much of the earth has been substantially reduced when human kind produces a limited selection of crop plants and animals. When two or more crops are growing together, each should have adequate space to maximize cooperation and reduce competition between them. This is accomplished by the following factors namely: spatial arrangement, plant density, maturity dates of the crops grown, plant architecture.

The spatial arrangements are:

1. Row intercropping – Growing two or more crops together at the same time with at least one crop planted in rows.
2. Strip intercropping – Growing two or more crops together in strips wide enough to separate crop production using machines, but close enough to interact.
3. Mixed cropping – Growing two or more crops together in no distinct row arrangement.
4. Relay intercropping – Plant a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

Planning intercrop with staggered maturity dates or developmental periods utilize variations in peak resource demands for nutrients, water and sunlight. Plant architecture allows one intercrop to capture sunlight that would not otherwise be available to others. This is important to growth and yield of cereal and legume crops. It measures the advantages of using intercropping systems on combined yields of both crops. It provides a standardized basis for comparing systems under different situations and crop combinations.

Planning should involve selection of crop species, appropriate cultivars, water availability, plant populations, spacing and labour requirements throughout the season, tillage requirements and predicted profitability of inter crops, timely planting, proper fertilization, pest and disease control.The first round of the Green Revolution in the 1970s and 1980s in Asia focused on cereals and neglected other food crops, such as legumes and vegetables, which had traditionally been an integral part of the cereal-based system. Growing evidence points to slowed productivity growth and increasing degradation of the resource base of these systems. While advances in cereal production have supplied ample carbohydrate, micronutrient deficiency has surfaced more prominently as a result of the neglect of micronutrient rich foods. There is a relationship between horticultural production and overall socioeconomic development. Horticulture encourages agricultural business development in the rural economy, and generates employment and income. Growers learn to manage multiple cropping systems and deliver quality outputs on time by fulfilling contractual arrangements and dealing with sophisticated marketing systems. The management skills needed for successful horticulture are the very skills required for socioeconomic development to take off. These skills enable farmers to run other kinds of businesses. Horticultural production improves availability of micronutrient rich foods. Consumption of sufficient micronutrients improves health, learning capability, and working capacity of the population. All these factors enhance working efficiency, thus facilitate and stimulate socioeconomic development (Figure 1).

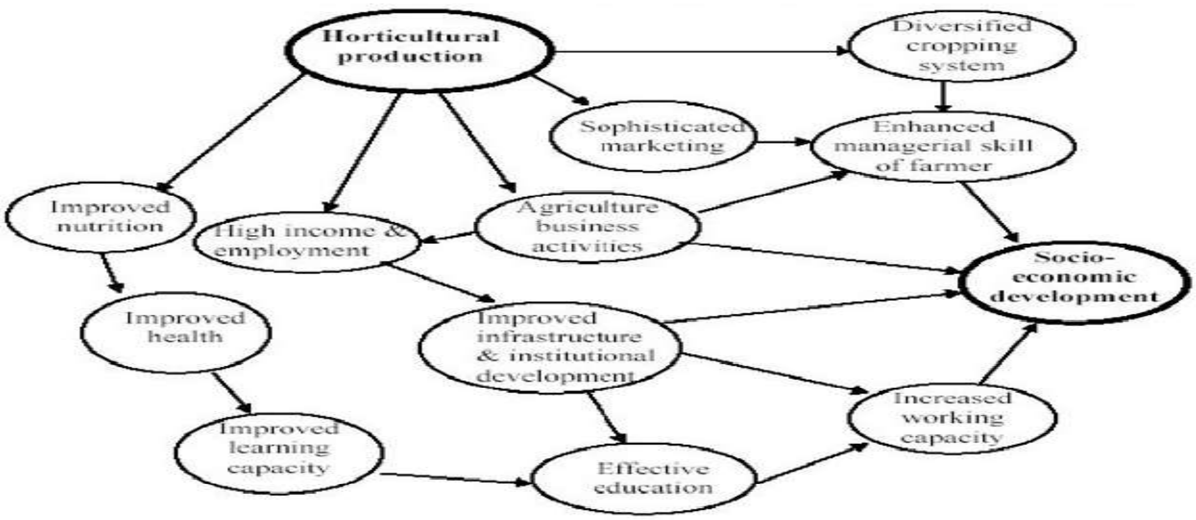

Figure 1. Horticultural production and socioeconomic development

Sustainable farming applies agricultural systems and practices which aim to maintain or enhance the health of the natural resource base within the constraints of the market based production system. In this framework this publication examines some of the benefits and challenges of sustainable horticulture. Horticultural activities inevitably have some impact on the natural resources harnessed for the production of fruit, vegetables and other products. As awareness of sustainability issues increases, horticultural industries are becoming increasingly concerned with maintaining and protecting their resource base and the wider environment. Some past and some current production systems have failed to address the impact they have on the environment resulting in the degradation of the natural resource base on both a local and landscape scale.

Figure 2. Our horticultural industries provide fruit and vegetables to local and export markets.

Impacts that need addressing include salinity, raised water tables, soil erosion and degradation, residues of persistent pesticides and off-site impacts of nutrients. Positive action is needed now to protect, restore and enhance the natural resources our horticulture and horticulture industries depend upon. As horticultural industries develop a better understanding of their production systems, growers are increasingly adopting best practice management approaches that aim to market a regular supply of safe, quality foodstuffs at reasonable cost to consumers whilst preserving the productivity of the landscape (Figure 2). To ensure the horticultural industries are sustainable, management strategies need to encapsulate practices that minimise impacts on the environment. Approaches such as Environmental Management Systems are being developed to facilitate the adoption of sustainable practices into the farm management system. Some of the key elements of farm management and the sustainability issues relating to them are discussed in the following pages.

Advantages of intercropping: There has been anincrease in grower interest in using intercroppingsince it could reduce management inputs that resultin sustainable systems more efficiently using an evenpotentially replenishing natural resources used duringcrop production for long term management offarmland. The advantagesof intercropping are risk minimization, effective use ofavailable resources, efficient use of labour, increasedcrop productivity, erosion control and food security (Owuor *et al*,2002). There is reduction of insect/mitepest populations due to the diversity of crops grownand reduction of plant diseases because the distancebetween plants of the same species is increased dueto the planting of other crops between them,alteration of more beneficial insects especially whenflowering crops are included in the cropping system,increase of total farm production and profitability andreduction of weed population through allelopathy andefficient crop production.

Crop rotation and intercropping: Crop rotation resulted in emerged weeddensities in test crops that were lower in comparisonto mono-crop systems. In a good number of casesseed density of weeds in crop rotation was lowercompared to monocultures of component crops. Inintercropping systems where a main crop wasintersown with a “smother” crop species, weedsbiomass in the intercrop was lower in many cases. When intercrops were composed oftwo or more main crops, weed biomass in theintercrop was lower than in all of the component sole crops.The success of rotation systems for weedsuppression appears to be based on the use of cropsequences that create varying patterns of resourcecompetition, allelopathic interference, soil disturbanceand mechanical damage to provide a stable andfrequently inhospitable environment that prevents theproliferation of a particular weed species. Intercropsmay demonstrate weed control advantages over solecrops in two ways. First, greater crop yield and lessweed growth may be achieved if intercrops are moreeffective than sole crops in usurping resources fromweeds or suppressing weed growth throughallelopathy. For weed suppression to occur in crop rotation andintercropping three areas need to be researched onnamely.

1. There must be continued attention to thestudy of weed population dynamics andcrop-weed interference in crop rotationand intercropping systems. Moreinformation is required on the effects ofdiversification of cropping systems onweed longevity, weed seedlingemergence, weed seed production anddormancy, agents of weed mortality,differential resource consumption bycrops and weeds and allelopathicinteractions.

2.There needs to be systematicmanipulation of specific components ofrotation and intercropping systems toisolate and improve those elements (e.g.inter row cultivation, choice of cropgenotype) or combinations of elementsthat may be especially important forweed control.

3. The weed-related impacts of combiningcrop rotation and intercropping strategiesshould be accessed through careful study of complex farming systems andthe design and testing of new integrated approaches.

Intercropping and soil fertility: One importantreason for intercropping is the improvement andmaintenance of fertility. An example of this is when acereal crop or tuber crop is intercropped withlegumes (beans, peas, ground nuts). After theintercrop is harvested, decaying roots and fallenleaves provide nitrogen and other nutrients for thenext crop, legumes also fix nitrogen. Thenutrients in the crop residues can then be recycledwhen manure is used to fertilize crops. Waterlosses, soil erosion and leaching of nutrients are alsoreduced in intercropping systems due to theimproved structure and better soil cover. Inintercropping, nitrogen fixation by the legume is notsufficient to maintain soil fertility. If chemical fertilizersare applied, it is not necessary to use nitrogenfertilizer on the cereal crop. Fertilizers are moreefficiently used in an intercropping system, due to theincreased amount of humus and the different rootingsystems of the crops as well as differences in theamount of nutrients taken up (Rehman *et al.,* 2006,Rukazambuga *et al.,*2001 and Sakala *et al.*, 2000).

DIFFERENT INTERCROPPING SYSTEMS

Fruit crops: In India fruitcrops are usually intercropped with annual crops. Forexample, bananas areintercropped with potato which has led to goodreturns (Ahmed *et al.*, 2008). Mustard has also beenintercropped with bananas in India. Other fruit treeshave also been intercropped. For example, in anintercrop between citrus mandarin seedlings andcucumber there was a high yield of cucumber fruitand minimal interference in the growth of citrusseedlings possibly due to the low growing nature of the latter.

Vegetable crops: In an intercrop system betweencereals, beans and peas, there has been increasedyield presumably by the transfer of biologically fixednitrogen from the roots of legume to the root zone ofthe companion crop (Akyempong *et al.*, 1999 and Gold *etal.*, 1999.Vegetables such ascabbage, cucumber, radish, snap bean, and broccoliare intercropped into double rows of field maizeplanted on raised soil beds. Intercropping twovegetables with different architecture and nutritionalvalue such as beet and okra, pepper and onion. Some factors that will influence ornot whether two crops can be successfullyintercropped include plant height,the size of the leaves and the orientation anddistribution of these leaves in the plant canopy(Sogbedji *et al.,*2006). For vegetable crops intercropping system to besuccessful in a geographical location effectivecultural practice must be determined, with respect toplant population. In the intercropping system of southern peaand sweet corn the reduction in component crop lightintercepted by southern pea and sweet corn ascompared to light intercepted by the monocropsystem of those crops probably contributed to thereduction in their respective yields. Combinations such as carrot-cabbage, lettuce-cabbage,carrot-garlic, tomato-beans, sweet potato-pumpkin,maize-tomato, tomato-beans, sweet potato-pumpkinand maize-sugarcane have been successful in India.The advantages of the sweet potato-maize-banana intercrop are a diversification of cropsand more efficient use of land. The permanent soilcover by the sweet potato reduces weed costs andsoil erosion.

WHAT IS SUSTAINABLE HORTICULTURE

Sustainability was defined as “meeting the needs oftoday without compromising the ability of future generations to meet their needs.” Wenow hear about sustainable forestry, sustainable buildings, and sustainable developmentalong with sustainable horticulture, an indication that the negative impacts of humanactivity on the global systems we rely upon are being recognized and addressed.While ecological issues such as soil erosion, water scarcity, and air pollution arewell-publicized, many barriers to sustainability are social, economic, and political overpopulation, global competition, low commodity prices, shrinking numbers of farms.These are all “people” problems rather than agronomic or horticultural problems.Sustainability is commonly defined as being economically viable,environmentally sound, and socially acceptable (or just). Put another way, sustainability depends on the 3 E ecology, economics, and equity. It is sometimes described as a“three legged stool,” with economic, ecological, and social legs. When all three legs arestrong and equal, the stool is stable. If a leg is weak or short, the stool wants to tip over.These ideas easily transfer to sustainable horticulture, where the farmer works to optimizeand balance all three legs.

Principles of sustainable horticulture: No widely accepted standards exist for sustainable horticulture, in contrast toorganic or integrated fruit production. However, attempts have been made to articulateuniversal principles by which systems can be monitored and evaluated. For example, theNatural Step program, developed in Sweden, identifies four system conditions forsustainability that are used to evaluate current operating procedures and system design,and changes are made to help the system better comply with all four conditions. Sustainable horticulture should be considered a direction rather than a threshold.We can determine if a farm is becoming more sustainable relatively easily, for example,if it reduces soil erosion, increases reliance on bio-control, or obtains a greater amount ofN nutrition from legumes instead of purchased fertilizer. However, it is more difficult tovalidate that a farm is “sustainable”, implying it has crossed a threshold much like acertified organic farm has done.

Measuring sustainable horticulture: There are no widely accepted protocols for judging the sustainability of a farm oragricultural system. Tools exist to assess specific parts of a system, using directmeasures such as soil organic matter, soil erosion, water quality, profitability, energy use,and wildlife numbers, as well as indirect measures or models such as the soil lossequation, pesticide toxicity indices, trends in farm size and ownership, and carbonsequestration models. Such long-term comparison studies are very useful in understanding whatsustainability parameters are likely to be substantially impacted by management choices.But farms can vary greatly in their performance even when growing the same crops in thesame environment. So surveys of farm practices and impact can be as important ascontrolled long-term studies on one site if we are to have a real-world understanding offarm management choices and sustainability outcomes.

SUSTAINABLE FRUIT PRODUCTION

The impetus for thinking about sustainable fruit production came from challengeswith pest management, particularly the use of insecticides that left a persistent legacy(e.g. lead arsenate), induced new pest outbreaks, or resulted in pesticide resistance. Fruit production faces a whole range of sustainability issues today, spanning allthe economic, environmental, and social dimensions mentioned above. For growers ofall crops, economic sustainability must be addressed in the short-term or their operationwill fail in an unsubsidized system. Environmental issues around pesticides, water use and quality, energy,biodiversity, and air (e.g. methyl bromide) all relate to sustainability, but often on alonger time frame than economics. And social sustainability encompasses worker safetyand other labor issues, the health-imparting benefits of fruit in the diet, urbanization andland use changes, and food security.

Integrated fruit production: Integrated production is an umbrella concept intended to address sustainabilityissues in horticulture, emphasizing economic and environmental aspects. In the 1970s, anIntegrated Production (IP) framework was developed by the International Organizationfor Biological and Integrated Control of Noxious Animals and Plants (IOBC) as anoutgrowth of its pioneering work on biological control and integrated pest management(IPM). The IOBC members recognized that adoption of IPM would be more successfulwhen considered in the context of the entire farming system, and thus the IntegratedProduction concept was launched.Thiswas one of the first attempts to delineate the specifics of sustainable fruit production.

Rise of organic fruit production: As mentioned above, organic farming is one approach to increasing sustainabilityin horticulture that is market-driven and growing rapidly. The origins of organic farmingcome from a focus on improving organic matter in the soil in order to grow healthy plantsthat can resist pests and diseases, and that provide maximum health to the people andanimals that eat them. One guiding principle is the use of natural materials for cropproduction and the avoidance of synthetic materials (e.g. fertilizers, pesticides). Organic certification programs can more easily determine if a grower has or has not useda particular material than they can verify that a farm is ‘working with natural systems.’As a result, much of the focus of organic certification has been on determining whatmaterials are allowed for use on organic farms. Sustainable horticulture generally doesnot share this focus, although IFP programs often do exclude or restrict the use of certainmore toxic or disruptive pesticides.

Comparing system sustainability: Various studies have compared the performance and impacts of fruit productionsystems to understand how well they achieve sustainability goals. Reganold *et al.* (2001)compared conventional, integrated, and organic apple production in side by side plots. The integrated and organic had the best soil quality, while theorganic had the lowest environmental impact based on a pesticide rating system. Treegrowth and fruit yields were similar across all systems, as were production costs.However, the authors estimated that the organic system would need a 12% price premiumto match the financial breakeven point in the conventional system (Glover *et al.,* 2002).

Stolze *et al.* (2000) reviewed the environmental performance of various farmingsystems in Europe. They made a qualitative rating, based on the scientific literature, forthe ecosystem, soil, ground and surface water, climate and air, farm input and output, andquality of produced food. They also compared energy use in organic andconventional production, looking at both energy per hectare and energy per ton ofproduct. While organic apple used 90% of conventional apple on a per hectare basis, it used 123% of conventional on per ton of product basis due to the lower yields.Organic growers often spray more frequently andconduct more tractor operations for weed control. At the same time, consumers arebecoming more aware of the distance that food travels from farm to store. Locally grownfoods require the least fossil fuel for transport and are more sustainable from an energypoint of view. Finally, while all organic growers must comply with a specific set of standards,they can vary substantially in the sustainability of their system, as do growers in most anycategory. The Food Alliance requires a score of 75% ofavailable points for soil and water conservation, integrated pest management, fair andsafe working conditions, and biodiversity, along with continuing improvement, whileusing no genetically-modified organisms or any of the prohibited pesticides (FoodAlliance, 2006).

Sustainable vegetation management: Vegetation management is a critical component of sustainable horticultural management, particularly in its contribution to biodiversity, protection of soils and management of water tables. Vegetation management should be considered on a whole farm scale when planning the layout of the farm and on a paddock scale when planning which crops to grow. Benefits include the provision of habitat for birds and other pest control agents, wind protection for crops, and associated reduction in irrigation demand. Farmers also need to consider how the property fits into the surrounding landscape when designing the farm layout. Trees also have a positive hydrological effect on a landscape scale by drawing water up from the subsoil and/or water table which will help protect arable land from the disastrous effect of rising water tables and increased salinity.

Sustainable water management: A healthy river system is essential for a healthy environment and a productive agricultural sector. This has necessitated the introduction of a range of water reform regulations over recent years. It is recognized that rivers need to have sufficient flow for the ecological processes in the catchment and to provide water of suitable quality for domestic use and irrigators. Horticulture must compete for water with other needs such as town water supplies, industrial uses, environmental flows and recreational uses. Over-irrigation and poor management of drainage water leads to major changes to the hydrological characteristics of the catchment and can have detrimental effects on other producers and the environment many miles downstream. A well planned and managed irrigation and drainage system should achieve a healthy vigorous crop with very little run-off above the natural level, only small losses to the water table and minimum discharge of salt, fertilizer, pesticides and organic matter into the river system. Horticultural producers can improve their use of water by developing a better understanding of the interaction between the crops and the soils in which they grow and an increased knowledge of the fate of water applied. Irrigation efficiency increases with increasing precision of water delivery. Flood irrigation is generally least efficient. High pressure, high volume sprinkler systems covering wide areas are considerably less efficient than micro sprinklers or dripper systems which target the root zone of the crop.

Sustainable soil management: A primary goal of sustainable horticulture is to protect and enhance soil health. No farming system can be sustained unless the soil has suitable fertility, structure, water holding capacity, drainage capacity and sufficient depth. Topsoil forms very slowly and is, in terms of the human life cycle, irreplaceable. Growers should protect their land from soil loss due to erosion by wind or water and to more closely monitor the chemical and physical condition of the soil so that tillage and fertilizer practices can be better managed.

Erosion controls: Erosion control begins at the farm planning level. Some areas are simply too erosion prone to sustain horticultural activity. Incorporation of windbreaks into farm plans will slow wind velocity, and reduce soil loss due to wind erosion. When planting windbreaks the mature size and shape of the windbreak needs to be considered. A combination of tall and low growing species may be needed. Information on suitable species for different areas and needs is available from a number of sources, and checking local experience is a good indicator. Mulching under tree crops can also be used to protect soil against erosion by water or wind, as well as adding valuable organic matter to the soil. Restricting vehicle movements when the soil is wet also reduces the likelihood of soil compaction.

Organic matter: Organic matter and the humus it breaks down to are vital to sustaining the productive life of the soil. Humus helps bind soil particles into aggregates and improves soil structure. In turn this improves aeration and drainage, as well-structured soils allow water and air to pass through the soil more easily. Generally crops with dense fibrous roots are more useful than those which have fewer fleshier deep roots. Inter-row cover crops in orchards can also be mown and put into the crop row to supply leaf matter to the crop row litter. Incorporation of green manure crops can provide short-term increases in organic matter as well as protection for the soil during a fallow. Bulky organic manures can increase organic matter but frequent and heavy applications are needed. Where this activity is a fundamental part of the enterprise (such as with organic production) it can be worthwhile but applications are generally energy intensive. Crop residues can be another good source of organic matter, provided their retention is compatible with the good crop hygiene essential for disease management. Pest and disease guides will indicate where crop hygiene is an issue.

Nutrient management: The challenge in managing crop nutrition is to supply the nutrient levels required at the right time to meet crop demands while preventing on-site soil degradation and minimising off-site movement of nutrients. The most basic approach is to use indicative fertilizer programs that can be obtained for most crops. Some have been derived from experimentation on crop responses whilst others are derived by calculating the amount of nutrients expected to be exported from the field in the form of product, pruning and leaching.Typically, soil and tissue tests are made once or twice a year. In some crops growers gain further information by using sap testing which provides a very immediate picture of the plant's nutrient status.Applications need to be made in small amounts at the right times in the crop cycle. Crop calendars provide this information for most horticultural crops. For example some forms of nitrogen fertilizer are much less acidifying than others and should be the preferred choices.

Sustainable pest management: Having achieved sustainable production by maintaining water and soil health, the challenge then is to protect this production from the threat of various pests. To do this sustainably requires a balanced approach that maximises the use of natural control agents and minimises pesticide use when controlling insects, diseases and weeds. Integrated pest management programs are available to achieve this aim, and are under constant development for a wide range of cropping situations. Integrated pest management (IPM) uses a combination of biological, physical, cultural, genetic and chemical control methods to manage weeds, insects and diseases. IPM requires growers to have a thorough understanding of crop growth stages, the lifecycle of pests and the conditions most favourable to the development of pest populations. Monitoring of crops and pests, either by direct observation, trapping with pheromones or other baits, or monitoring of seasonal conditions allows growers to predict the arrival of a harmful pest population or event and take action to prevent economic effects on crops.

Weed management: Weeds impact on productivity and on biodiversity. Good weed management benefits both agricultural production and the conservation and enhancement of natural resources. Integrated weed management combines management strategies such as fertilizer use, groundcover retention, cultivation, biological control and herbicide use. Such an approach can dramatically reduce the reliance on herbicide use, limit weed establishment and simultaneously encourage desirable plant species. In perennial horticulture, weed management, once a matter of routine spraying or ploughing, is now part of total orchard floor management. In general growers can use a combination of non-tillage methods such as mowing, selective herbicide application, cover crops and mulching for a healthy and protected orchard floor.

Cover crops: The benefits of cover crops for erosion control and as part of the weed management plan in sustainable horticulture have already been discussed. Cover crops can also improve the habitat for beneficial insects by providing shelter and nectar for food. Leguminous cover crops can increase fixation of atmospheric nitrogen. Cover crops should be selected with overall crop management in mind. For example tall growing vigorous cover crops may be well suited to inter-row plantings in annual vegetable crops while low growing, shade tolerant species are often most suitable for orchards of trees.

Insect management: Integrated pest management has replaced older approaches to pest control based on routine calendar spraying or spraying pests on sight. Biological control agents are important components of modern pest management systems. These are predators, parasites or disease agents which help control key pest insects. If too much spraying of the pest kills these biological control agents, then the key pest may rebound in even higher numbers, leading to a treadmill of spraying. Biological agents also often control a range of other minor pests to the extent they are not a problem. If inappropriate spraying kills them, the minor pests may become major problems. Mites and scales are good examples of this induced pest syndrome. Some biological control agents are available commercially so they can be introduced to crops at strategic times. Their use is often much more effective if applied in response to specific stages in the pest life cycle and changes in the season. Wasp parasites for control of some scale insects and mealy bugs and predatory mite for control of spider mites are examples of commercially available biological control agents.

Disease control: A good starting point for sustainable disease control is the use of plant varieties that are resistant or tolerant to troublesome diseases such as Fusarium in tomatoes canker in stonefruit, and Panama disease in bananas. Many horticultural tree crops utilize rootstocks that are resistant to key soil borne diseases or pests. In cases such as citrus and avocados the bud-wood can potentially be infected with diseases and accreditation schemes are available to ensure the grafting material is free of disease. Ensuring planting material is from accredited nurseries utilizing good quality resistant rootstocks are an important fundamental step to sustainable production. Vegetable breeders are constantly developing new varieties with disease resistance. Disease control strategies have been developed in a range of crops that use weather data to predict high-risk conditions and allow growers to apply fungicides when and where they are most effective. Another essential aspect of sustainable disease management is to avoid resistance to the pesticides used. Modern disease programs clearly spell out rotation strategies using different groups of pesticides to reduce the risk of resistance developing. Finally cultural control by good crop hygiene (the removal of crop residues which can be a disease reservoir) is another essential element of sustainable disease management.

CONCLUSION

Due to ever increasing human population especiallyin Africa leading diminishing land sizes, intercropping,with its advantages of risk minimization, reduction ofsoil erosion, increased food security should bepracticed. Most crops can now be intercropped including fruit trees and therefore farmers with smallpieces of land should no longer worry. Howeverresearch still need to be carried particularly withrespect to row orientations and light interception andthe economic benefits as more horticultural crops areintercropped.Sustainable horticulture builds on the long-standing desire of farmers to ensure their land remains productive into the future. It also addresses the community’s expectations and concerns for safe food and for environmental protection.Sustainable horticultural systems can be achieved by appropriate planning and by building on the general Best Practice Management approach increasingly employed by modern horticultural enterprises to achieve a holistic approach to their farming system.

The issues for a sustainable horticultural system, outlined in the preceding pages are to:

1.Protect and enhance existing native vegetation for greater biodiversity and security of the rural environment at large.

2.Manage the use of scarce water resources to ensure greatest efficiency, productivity and protection of surrounding catchments and waterways from salt, soil, fertilisers and chemicals carried in run-off water.

3.Manage for healthy soils through protection from degradation and loss by erosion, organic matter depletion and unbalanced and inappropriate fertilizer usage.

4.Manage the impact of pest and diseases while minimising the usage of chemicals and maximising profitability over the short and long term.

Public interest in sustainability is growing in many countries today. As horticulture is critical to world food supply and is linked to numerous environmental andsocial issues, consumers are increasingly aware of and interested in the sustainabilitydimensions of the food they buy.

However, interest in more sustainablefruit systems is growing in developing countries as well, as governments andcommunities seek alternatives to the problems caused by some input-intensive productionsystems. Also, our reference point changes over time. In some areas, the distinction is blurringbetween the progressive edge of conventional and the codified organic.While many sustainability indicators are available for pieces of the agriculturalsystem, widely accepted methods to quantify improvements in agricultural sustainabilityhave not yet been deployed. The ultimate impact fromchanges in fruit production will be the sustainability impact per unit area times the areainfluenced. Future challenges such as climate change and peak oil will test these systems innew ways, with local likely to become a more important sustainability attribute.

REFERENCES

[1]Akyeapong, E., Hitimana, L. and Munyemana, P. C. 1999. Multistrata Agroforestry with beans, bananas and*Grevilla rubusta* in the highlands of Burundi, *Expt. Agric.,* 35 Pp. 357-369.

[2]Food Alliance. 2006. Food Alliance web site http://www.foodalliance.org/Glover,J., Hinman, H., Reganold, J.and Andrews, P. 2002. A cost of production analysisof conventional vs. integrated vs. organic apple production systems. XB1041,*Agricultural Research Center*, Washington State University, Pullman, WA, pp. 88.

[3]Gold, C.S., Karamura, E.B., Kiggunda, A. and Baganda, F.A. 1999. Geographic shifts in highland banana(Musa group A A A-E). Production in Uganda. *Afric. Crop. Sc. Jnl.,* 10(**2**): 20-25.

[4]Hassanali, A., Herren, H., Zeyaur, Khan, R. and John, A., Pickett and Christine, M.W. 2008. IntegratedPest Management: The push-pull approach forcontrolling insect pests and Weeds of cereals and itspotential for other agricultural systems including animalhusbandry.Philos Trans R Soc.*Lond B Biol.Sci.*, 363(**1491**): 611-621.

[5]Ndungu, K.W., Kifuko, M.N. and Okatebo Jr. 2003. Producing fortified compost from crop residues. In:Scvala, E. N., Omare, M. N. and Woomer, P. L(eds).Organic Resource Management in Kenya.Perspectives and Guidelines: *Forum for Organic Resource Management and Agricultural Technologies,*Nairobi, Pp. 71-79

[6]Owuor, C., Tenywa, J.S., Muwanga, S., Woomer, P.L. and Esele, P. 2002. Performance of a sorghum-legumeintercrops in response to row levels of nitrogen.Program and extended abstracts. *The Forum on Horticulture Resource Husbandry*, Nairobi, 5: 542-544.

[6]Rahman, M., Rahman, M.H., Haque, M.E. and Naber, K. S. 2006. Banana-based intercropping system inNorthern port of Bougladesh. *J. Agron*., 5(**2**): 228-231.

[7]Reganold, J.P., Glover, J.D., Andrews, P.K. and Hinman, H.R. 2001. Sustainability ofthree apple production systems. *Nature,* 4(**10**):926-929.

[8]Rukazambuga, N., Gold, C.S., Gowen, S.and Ragama, P. 2001. The influence of crop management on banana weevil (*Cosmopolites sordidus*) populations and yieldof highland cooking banana in Uganda. *Bulletin of Entomological Research*, 9(**2**): 413-421.

[9]Sakala, W.D., Cadisch, G. and Giller, K.E. 2000. Interactions between residues of maize and pigeonpea and mineral N fertilizer during decomposition andN mineralization. Soil *Biology and Biochemistry,* 3(**2**):699-706.

[10]Sogbedji, J.M., Van, H.M., Melkonian, J.R.R. andSchindelbeck, R.R. 2006. Evaluation of the P. N. M.model for simulating drain flow nitrate-N concentrationunder manure fertilized maize plant and soil, 28(**2**): 343-360.

[11]Stolze, M., Piorr, A., Haring, A. and Dabbert, S.2000. The Environmental Impacts ofFarming in Europe. *University of Hohenheim,* Stuttgart. Pp. 127

[12]Yuri, J. A., V. Lepe, C. Moggia, R. Bastias, I. Quilamapu, and L. Bertschinger. 2004.Sunburn on apples. Obst und Weinbau 140(8):7-10.