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Integrating biotechnology into the polyfarm concept

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The polyfarm concept aims at strengthening traditional and appropriate farming technologies within the local agro-economic, cultural and socio-economic constraints of rural small farming. Different modules can be grouped together to suit the needs of the farmer. The polyfarm can serve as a demonstration and training facility to make rural farmers aware of the existence of biotechnologically-enhanced crops, their benefits and potential for use by resource-poor farmers. Enhanced soybean and maize are planted together with the conventional crop to demonstrate that these crops can improve yields, cut costs, reduce spraying and save time for the small-scale farmers.

Introduction

One of the problems facing resource-poor agriculture is the often-unsustainable use of natural resources due to farming management systems practised by small-scale farmers. A common problem in most extensive rural farming systems is the lack of stability in fodder flow production. Livestock enterprises within the communal grazing scenario have both forage quantity and quality constraints, which seriously restrict animal production, particularly in the dry season.

The introduction of alternative forage options (indigenous and exotic annual and perennial grasses, legumes and other crops) into existing livestock production systems will assist in the development and implementation of sustainable farming management practices.

The Polyfarm Concept

To address constraints currently faced by resource-poor farmers in South Africa, a demonstration unit, based on small-scale farming enterprises, was developed at the ARC–Range and Forage Institute. The aim of the polyfarm (referring to mixed farming systems) was to develop a 'shop window' for farmers, demonstrating different crop cultivation practices with the potential to be integrated into livestock (fowls, sheep, goat and milk production) enterprises. The polyfarm was conceptualised by researchers of the ARC–RFI, namely D Swart and B Mappledoram as well as C Kok of the ARC–Vegetable and Ornamental Plant Institute.

The design of the facilities and the agricultural inputs are based on low-input, resource-friendly production systems. For example, enclosures and shelters for animals were built from materials easily accessible to rural farmers. Fertilisation and establishment practices, as well as the crops used, are in accordance with methods traditionally used by these farmers. The integration of different types of livestock introduced other variables in the polyfarm, such as the use of animal manure for soil fertility improvement in the arable cropping component, with corresponding improvement in crop production.

The polyfarm demonstration unit (Figure 1) was mainly developed for training purposes of farmers, extension staff, students and school children. Farmers are confronted with alternative cropping systems and shown how to integrate this with various livestock enterprises to increase their income from farming activities. Students and school children are made aware that farming could be a profitable career, considering that most rural children leave their farming community for more prosperous careers in urban areas. Several modules present the opportunity to be implemented at their home or on the school premises. When collaborating with the rural farming communities, their suggestions could also be implemented and tested, provided that it is based on acceptable and sustainable integrated land-use practices.

Description of polyfarm demonstration modules

Module 1: veld

Veld grazing is an excellent and also the cheapest source of feed for the livestock and game population of South Africa. Natural pastures on farms are one of the country's most important agricultural resources and form the basis for the country's production of animals and animal products; the welfare of the population is linked to the natural grazing and its condition (Tainton 1999).

The polyfarm is situated in the Sourish Mixed Bushveld Veldtype of South Africa (Acocks 1988). The demonstration

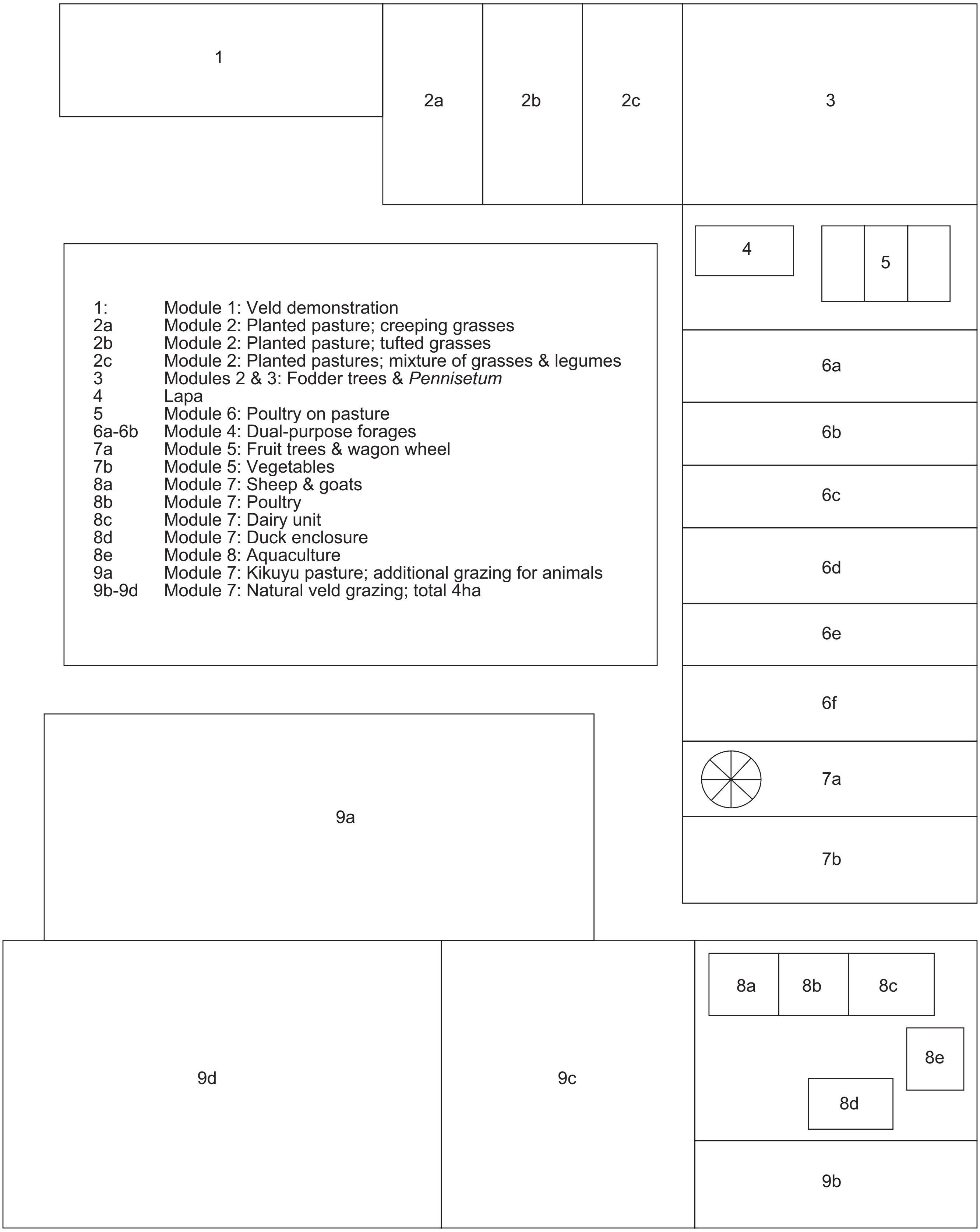

Figure 1: Sketch of polyfarm layout

module consists of small blocks of 30m^2, which aims to demonstrate the impact of different management strategies on the natural vegetation. The treatments include the following:

- Burning — annual, biannual and triennial burning. This demonstrates the influence of different burning regimes on the vegetation.
- Cutting — annual, biannual and triennial cutting. These treatments show the influence of different defoliation regimes on the vegetation and on the survival and vigour of the species within this veldtype.
- Continuous cutting to a height of 5cm to simulate the influence of over-grazing on vegetation.
- A block with no treatment is also included to demonstrate the consequences of under-utilisation of vegetation.
- The above-mentioned treatments are duplicated and treated with effective micro-organisms.

The potential of Effective Micro-organisms (EM) in agriculture and environmental management systems is significant. EM technology has shown beneficial effects on many aspects of the environment, agricultural crops and animal husbandry. EM leads to the improvement of the nutritional status and the physical, chemical and microbiological properties of soil. The need to use often harmful chemicals and pesticides to improve crop production can be avoided if EM is properly implemented. The same principle holds for animal husbandry. It assists the farmer to maintain an eco-friendly farming system, minimising the harmful effect on natural cycles (Correa 2001). EM includes four important micro-organisms, namely lactic acid bacteria, photosynthetic bacteria, actinomyces and yeast. The mixture does not contain any genetically modified organism (Sangakkara 2001).

Since the technology is safe, effective and environmentally friendly and accessible to farmers in both developed and developing countries, effective micro-organisms can be tested and evaluated in the polyfarm.

Module 2: planted pastures for animal production

This module illustrates the use of planted pastures for sheep, goat and milk production to be used as grazing or standing hay:

- Two creeping grasses (*Pennisetum clandestinum* and *Cynodon nlemfuensis*).
- Two tufted grasses (*Panicum maximum* and *Digitaria eriantha).*
- Grass and legume mixtures (*Chloris gayana* and *Cenchrus ciliaris* in mixtures with indigenous summer and winter legumes).
- Dwarf and giant *Pennisetum* species express the genetic variability within a genus.

Module 3: multi-purpose fodder trees

The fodder tree and shrub species included in this module demonstrate the potential use of leaves and small branches for forage production and the branches for firewood and fencing material. Trees and shrubs cultivated in this unit are adapted to high rainfall as well as to drier conditions and include *Desmanthus virgatus, Faidherbia albida* and *Leucaena pallida, L. diversifolia, L. leucocephala* and *L. lanceolata.*

Module 4: dual purpose forages

Dual-purpose forage species supply food for animal production as well as for human consumption. Agricultural practices such as intercropping and rotational cropping are well illustrated with dual-purpose forage in this module. The aim of intercropping (where two or more forage crops are planted in alternate rows) is to use land optimally, whereby climatic and edaphic growth requirements for each crop differ, resulting in no or little interspecies competition. Research has shown that increased crop diversity also enhances integrated pest management, saving input cost for small-scale farmers (Päts *et al*. 1997). Rotational cropping systems (where different crops are cultivated over two growing seasons on the same land) are used to ensure land intensification with the advantage of a reduction in the use of environmentally harmful agrochemicals since it can be successfully managed as a low-input or organic farming system (Griffith 1997). Both these cropping systems play a significant important role in controlling weed populations, limiting the use of herbicides.

Three annual dual-purpose legumes e.g. cowpeas (*Vigna unguiculata*), soybean (*Glycine max*) and lablab (*Lablab purpureus*) were planted in separate blocks for the summer period. These species are also used to demonstrate the advantages of intercropping with maize (*Zea mays*). Ryegrass (*Lolium multiflorum*) and an annual *Trifolium* sp. will be established in rotation during the winter period, providing forage for late winter/spring grazing.

Module 5: vegetable and fruit production

For vegetable production, the wagon wheel irrigation system, designed by G Alberts (1995), was put into practice. The layout is in the form of a wagon wheel; with the drum (210 litres) representing the centre of the wheel and the cut polyethylene pipes the spikes. Water (household or rain water) is added to the drum at least three times a week, depending on the area to be watered. Water is led out of the drum via a tap into the pipes to form a dripper line. Holes, burned into the pipes, are each fitted with a piece of nylon to prevent clogging. Vegetables are planted near the wetting area, spaced according to their growth habits e.g. maize close to the drum, followed by tomatoes, cabbage, sweet potatoes, pumpkin and other crops that require growing space for their vines. Crops are rotated every season.

The production of vegetables such as cabbage, carrots, beetroot and spinach will be compared on a piece of land that was fertilised in the past using animal manure and water from the aqua-culture unit as an alternative to the use of inorganic fertiliser. Soil samples are taken yearly to determine the effect on soil properties.

For fruit production, peach trees are cultivated in an intercropping system with various annual and perennial fodder crops. This cropping system demonstrates how livestock can be successfully integrated into tree crop systems, providing valuable income-generating products (New Agriculturist 1999).

Module 6: poultry on pastures

This module was designed to determine whether highly nutritious pastures could improve production of African-bred poultry. An indigenous poultry race, the Venda, was chosen for its good broodiness and mothering characteristics for raising village chickens. Both eggs and meat production are possible under low input with minimum supplementary feed (Honeyborne 1999). The following are demonstrated:

- a free-range system on kikuyu (*Pennisetum clandestinum*)
- a free-range system on white clover (*Trifolium repens*)
- feeding entirely on a commercially-mixed poultry feed.

Although the free-range systems feed exclusively on the pastures during the growing season, they are fed with commercial feed during off-season periods.

Module 7: animal production

This module demonstrates simple designs for a kraal (sheep and/or goats), a poultry enclosure, a dairy unit and an enclosure for muscovy ducks. The enclosures can be built with inexpensive materials such as poplar branches and reeds (Figure 2). Branches from the fodder trees can be used to create a feeding structure for supplementary feeding purposes.

The sheep and goats graze the surrounding veld during the day and are kept in the enclosure during the night. During dry summer spells and winter periods, available planted pastures within the polyfarm are grazed. Muscovy ducks and naked necks, known for their adaptability under a free-range system particularly for keeping the enclosure area free from insects (Erasmus 1999) are free to graze within the enclosure and an adjacent veld area. The number of progeny is recorded and either kept or sold.

Module 8: aquaculture

A dam with a capacity of 45 000 litres (15m X 3m x 1m) was built. A 500µm thick ultraviolet resistant plastic was used as isolation material to prevent water seepage. The dam was stocked with 150 tilapia and/or barbel and fed with a commercial fish food. Tilapia are top feeders, whilst barbel are bottom feeders, thus competition for food is minimal (Erasmus 1999). Previous to feeding with commercial fish food, a poultry unit was operating above the dam. The aim was to sustain the fish population by feeding on poultry manure droppings. The poultry unit, however, was discontinued until larger units can be built to ascertain an acceptable fish to poultry ratio.

Figure 2: The kraal for sheep and/or goats, a poultry enclosure and the dairy unit are built with inexpensive materials such as poplar branches and reeds

Biotechnology in an African Perspective

Malnutrition — the lack of sufficient calories and nutrients to lead healthy, productive lives — is widespread in Africa (Council for Biotechnology Information 2003a, 2003b). It is estimated that 40 to 50 percent of the southern African population is malnourished every year and that the region is worse off nutritionally today than it was 30 years ago (Somerville 2002).

According to the United Nations, farmers will need at least to double their production over the next 25 years to satisfy these appetites (State of World Population 2001). Annual increases in agricultural yields in recent years are holding at just 1.3 percent a year — less than half of the gains of 30 years ago. An additional 1.62 billion hectares will need to come under the plough by 2050 to feed the population if there are no increases in farm productivity (Council for Biotechnology Information 2003a, 2003b). The area is more than twice that of the continental United States.

Lagging productivity on small farms is the chief reason why 30% of children in Africa are still chronically malnourished. For Africa, more than any other region, the problem of inadequate food consumption stems directly from an unsolved farm production problem (Paarlberg 2001).

Plant biotechnology, a process combining genetic information and production techniques, is used to develop useful and beneficial plants (Council for Biotechnology Information 2003a, 2003b), is not the single solution for feeding a growing population. But it is a tool that can help grow more food in a sustainable way, which does not deplete existing farmland or force remaining wilderness areas to undergo cultivation.

Biotechnologically enhanced crops include soybean, cotton, maize, potato, squash and tomatoes.

Most of these crops have been improved in one or more of the following ways (Council for Biotechnology Information 2003a, 2003b):

- **Herbicide tolerant** crops are tolerant to certain herbicides that are effective against harmful weeds but have no effect on the crop. Globally, about three-quarters of the genetically modified crops planted in 2002 were herbicide tolerant (James 2002a).
- **Pest resistant** crops usually contain a gene from *Bacillus thuringiensis* (*Bt*), a naturally occurring soil bacterium that expresses a protein that is toxic to the young larvae of some insects, e.g. the European maize borer and bollworm.
- **Virus resistant** crops are protected from plant viruses by a variety of strategies.
- **Stacked trait** crops combine these and other traits.

A review of the impact of agricultural biotechnology on biodiversity (Ammann 2003) concluded that to conserve or enhance agricultural biodiversity, gene transfer technology provides the potential to introduce desired characteristics, such as drought resistance, improved nutrition or improved production efficiency. Further, the use of herbicide resistant crops could have a great impact towards the adoption of reduced tillage or no-till practices, due to the lower level of weed control required. Since the decrease in natural biodiversity is linked to habitat destruction (most severe under subsistence agriculture), the advantage of GM crops is threefold: increased yields, reduction in use of broad-spectrum insecticides and reduction in tillage with herbicide tolerant crops. Conventional breeding and selection methods are used to select crops that are adapted to local climates, farming practices and cultural preference, presenting as much risk to crop genetic diversity as GM crops.

Biotechnology is the most rapidly adopted technology in agricultural history due to the social and economic benefits the crops offer farmers and society, particularly the 5 million resource-poor farmers in developing countries. However, modern biotechnology research is focused on by US and European transnational companies and, in general, as biotechnology development programs are not oriented to small-scale farmers in developing countries, it is very likely that the global industrialisation of agriculture will widen the gap between large- and small-scale producers (Spijkers 1996).

The use of GM crops in Africa is still very limited. Bananas (Qaim 2000) are grown in Kenya and cotton (Council for Biotechnology Information 2003a, 2003b), maize, soybean and potatoes (Manning 2000) are planted commercially in South Africa.

The Polyfarm and Biotechnology

The need to produce more food is particularly urgent in developing countries, home of nearly all the world's hungry today as well as nearly all the rapid population growth. As a result, nearly all of the projected increase in world food demand will also take place in developing countries (World Food Prospects 1999).

To cope with the environmental challenges of the future, plants are needed that can withstand adverse conditions and biotic stresses. The authors believe that developing GM technologies — and their application — could make an important contribution to future consumption demands.

The polyfarm can serve as a demonstration and training facility to make farmers, extension personnel, students and other visitors aware of the existence of biotechnologically-enhanced crops, their benefits and potential for use by resource-poor farmers.

It is envisaged to use enhanced soybean and maize as part of the Dual Purpose Forages Module, where the genetically modified crop and the conventional crop are planted together to demonstrate that the farmer can improve yields, cut costs, reduce spraying and save time for the small-scale farmers (James 2002b).

Tissue culture, micropropagation and other advanced biotechnological techniques will not at present be incorporated into the polyfarm due to lack of facilities and lack of capacity for the training of rural farmers.

Conclusion

Biotech crops can significantly alter the lives of resource-poor farmers, limiting the time they must spend in the field and help to alleviate poverty. The polyfarm can serve as a shop window to make rural farmers aware of genetically modified crops, the role they play in improving their income and productivity on farm.

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