Some aspect of the logical way of studying dinitrogen fixation in an agroforestry context for improving food production

Elijah. M. Akunda
Crop physiologist, Department of Botany,
University of Nairobi,
P. O. Box 30197 Nairobi, Kenya.

Abstract

Dinitrogen fixation in an agroforestry context requires a careful approach which initially require derivation of the methods to be used and careful selection of the priorities of factors which influence the process. Nitrogen element is an important component of protein foods, hence its mechanisms of incorporation in biomass and grain through fixation is vital. The methods used to comprehend its incorporation are crucial to food production.

It is suggested that priority of the factors affecting the basic process of dinitrogen fixation, especially light and water, should be taken into consideration. Logically, a quick assessment of a nitrogen fixer versus a non-fixer should be grown near and far then their assessment done with respect to biomass response. Next phase should then involve how appropriate it would be to design spacing in dinitrogen fixation experiments.

Since dinitrogen fixation research is specific, there is need to clearly state the obejctives. Observations should start on growth components and characters associated with yield and dinitrogen fixation. Growth, nodulation and dinitrogen fixation should involve looking at the dry matter of the tops of plants, nodule number, position, colour, size, shape and weight. In case some competition stress is observed in the initial stages of the study, then such simple parameters of total leaf area, leaf dry weight, specific leaf area and canopy structure should be studied in the second phase. Having accumulated some knowledge about the performance of the system in the early stages, then analysis of yield discerning processes in relation to canopy structure can then be assessed.

Key words
Dinitrogen fixation, agroforestry, biomass, nodulation, experimental methods.

Introduction

The major problem facing developing countries in the tropics and subtropics is the achievement of economic development and improvement of the general welfare of their people through active participation in the development process and in a more equitable sharing of the country's agroforestry potential. In lean, years food situation deteriorates forcing the governments to import food to satisfy shortages in production. Furthermore, these countries have a tendency to increase population and depend on monoculture agricultural systems patterned after production systems of developed countries. This trend has made the food situation unpredictable. Although monoculture is practised, the commonest land use system in these countries for small scale farmers and especially in fragile environments for example, where fertility and aridity are the problems, is that farmers practise agroforestry. The productivity of these agroforestry system have not been assessed. This has mainly been due to lack of research guidelines and technologies.

Although monoculture systems have been imposed on the people of these countries, shortage of agricultural land, and the need to be self sustainable in food and the sustainance of environments has forced the small scale farmers to practise their traditional way of farming whose basis is agroforestry. For these farmers, monoculture systems do not meet the families' needs, nor make optimal use of available labour and financial resources, in contrast to agroforestry which supply more of the family's basic requirements and provide insurance against infavourable conditions. In Kenya, for example, most farmers are mainly interested in agroforestry for subsistence nature. Among the agroforesty land use system is the growing of cereals, legumes and trees.

In addition to this is the animal component. Although this land use system is mainly subsistence, there has been a desire to evolve an agroforestry system of a legume, cereal and animals which can be practised both for commercial purposes to meet other family requirements, in addition to the legume promoting extra nitrogen through nitrogen fixation. A suitable combination of legume-cereal for such an agroforestry potential should incorporate crops and trees that would grow both in high and less potential areas of these countries. In most countries where a greater area is of low potential limit and where population pressure on land has been on the increase, there has been an upsurge in the interest of their governments to develop these areas. The characteristics of trees, agricultural crops which grow in such environment have not been researched upon adequately. Only farmers know the adaptability of these agroforestry system, for example, the crops which are associated with trees in such systems are reasonably free from pests and diseases and fairly tolerant to mild droughts. In Kenya, for example, sorghum is grown in areas with erratic and low rainfall areas generally below 1530m above sea level and area often associated with trees of various kinds scattered randomly.

In addition to sorghum at least a legume, for example, pigeon pea (cajanus cajan) are incorporated in such agroforestry system. Thus, as the population increases and more of the drier areas are brought into agroforestry land use, there has been a need to judiciously select the crops and trees which perform well in these systems.

Although some of the leguminous grain crops are known to be rich in oil, protein, vitamins and minerals, there has been no research to validate their response with respect to these constituents when grown under agroforestry systems. Agroforestry systems contain animal component. An increase or decrease in the protein content of the associated legume is of importance in cases where the protein would be put into animal cake. A lot of foreign exchange is spent in importing animal food ingredients in most developing countries.

The growing of some of the legume grain crops in most agroforestry systems has not been systematic. For example, in Kenya the growing of soybean has been haphazard. Little is known of their agroforestry potential until trials are set to ascertain the variety, time of planting, plant population, tree phenology and management. There is no information on the responses of these crops to fertility manipulation such as inoculation.

Interest in research into improvement of agroforestry based systems which combine legumes which fix nitrogen can be due to several reasons. In addition to provision of nitrogen, as stated, the legume may form a basis for animal feed and hence need into understanding of agrosilvopastoral system. A system in which the grain legume forms a basis for animal feed and at the same time is grown under agroforestry system would require research to look into changes of the soil and protein in relation to season, and agroforestry management. Although some grain legumes may have extraordinary high yielding potential under favourable conditions of moisture, soil fertility and plant protection, there are some major constraints such as poor establishment of the crops in agroforestry systems. The effectivity of indegenous rhizobia is dependent on the tree species, its phenology management and the soil type and hence there would arise a need to research on the appropriate strain and agronomic requirement for effective inoculation. Apart from the appropriate rhizobium strains, plant variety is important in determining the fixation characters and this may limit the expansion of the growing of the crop in combination with trees.

Symbiotic Nitrogen Fixation

At present time, with increasing cost of nitrogenous fertiliser, there is growing interest in the possibility of greater use of legume crops because of their ability to fix atmospheric nitrogen in association with rhizobium in its root nodules.

However, set against this advantage is that there are several factors that affect crop production in agroforestry systems. These include spacement, time of planting, moisture stress, light interception. The environmental factors listed above affect the productivity of the crops in such system by influencing the process of photosynthesis. Thus, the productivity of any crop is dependent upon the CO_2 assimilation capabilities of the crop and the efficiency with which the assimilated carbon is partitioned within the crop.

The process of symbiotic nitrogen fixation is tightly coupled with the process of photosynthesis. Thus, factors that influence photosynthesis such as shading (Lawn and Brun, 1974), high defoliation (Bethlenfalvay *et.al.*, 1978), high plant density and lodging (Hardy and Havelka, 1976), girdling and water stress (Sheoran *et. al.*, 1981) decrease dinitrogen fixation as a consequence of decreased photosynthesis optimum soil water condition for symbiotic nitrogen fixation occur near field capacity (Sprent, 1971), such that periods of water stress induce both structural and physiological changes within the nodules (Sprent, 1976). Root nodules are affected indirectly after a decrease in photosynthesis through water stress (Finn and Brun, 1980).

Most of the effects of environmental factors of light intensity, temperature, soil moisture on legume growth and symbiotic dinitrogen fixation have been extensively studied for legumes growth in sole cropping (Bethlenfalvay and Phillips, 1977; Sprent, 1972; Kitamura *et al.* 1981). There are general reviews of water relations, for example, Begg and Turner (1976); Fischer and Turner (1978); Turner and kramer (1980).

In agroforestry systems, there is naturally competition among others, light, nitrogen, water and space. Competition in agroforestry systems, not only brings in detrimental effects but often moderates the effects of environmental factors such as light water and soil nutrients (Blaser and Brady 1950).

In his review, Donald 1963 suggested in order to obtain the highest possible yield from a crop in association with another, competition for these resources must be reduced to a minimum.

In the case of intercropping, most research has focused on agronomic experiments. Examples of Osiru and Willey (1972) and Willey and Osiru (1972) for mixtures of maize and beans, dwarf sorghum and bean with respect to plant population show that maize mixtures yields were higher by 38% than pure stands. They concluded that this was due to greater utilisation of environmental resources and that higher population in mixtures should be used. In dwarf sorghum mixtures, high yields of up to 50% in mixtures as compared to pure stands were observed. On the other hand Fischer (1979, a, b) carried out competitive studies of productivity and competition of maize - bean and maize- potato mixtures at different plant densities with pure stands. He found that the yields increased only in mixtures when there was ample rainfall and high plant densities, contrary to reductions in yields under low rainfall and density.

It is evident from the above review that intercropping or alley cropping which is a form of agroforestry technology can either increase or lower the yields of the component crops. Many aspects of crop plants physiology has been performed on monoculture systems. For example, Pendieton and Hartwig (1973) reviewed the several aspects of soybean physiology. Several other physiological aspects have been dealt with in other reviews, for example, symbiotic nitrogen fixation photosynthesis (Ognen and Riune 1973) and a comprehensive review of the physiological key processes which influence growth and development (Shibles *et al.* 1975). Nevertheless there is scanty information on the influence of physiological constraints of photosynthesis, water relations, and any yield of promiscuous and non-promiscuous varieties of legume plants in an agroforestry system.

The poor performance of legumes often

noted when legumes are grown in intercrops even when liberally provided with water and nutrients, and attributed to the low photosynthetic potential of their canopy of successive, newly expanded leaves and due to the increasing poor light environment experienced by the developing leaves as the crops become dense require among other effects quantification in the agroforestry system. In order to maximize yields in any derived agroforestry system, there is need to quantitatively analyse growth and yield characters, so that the morpho-physiological factors which limit yield can be identified. In some cases it has been noted that intercrop legumes may fix less nitrogen and thus make greater demand on soil nitrogen than might be expected from analogies with sole crops. Thus growing of the promiscuous and non-promiscuous varieties of legume under various agroforestry systems would require quantitative information on the potential nitrogen benefits of the two types of crop agroforestry.

Although there can be an appropriate rhizobium strain for legume innoculation in various countries, experience shows that innoculation is not suitable for small scale farmers. Among others, the production of innoculants, needs a great care and there is often lack of suitable carrier media. Thus, the use of legume varieties in agroforestry that may not require innoculation would be more suitable for small scale farmers, who may not often be in a position to innoculate the seed before planting. Thus, the general purpose of studies in which the intention is to evaluate an agroforestry land use system with respect to dinitrogen fixation would therefore be (1.) to carry out agronomic experiments, (2.) carry out simple crops physiological experiments in the field to look into yield components and how they come about in agroforestry system and (3.) finally perform detailed work on a productivity process such as photosynthesis, water relations, and dinitrogen fixation so as to answer the specific question on constraints to growth and yield. This would be possible to some extent in an intercrop system but it becomes complex when dealing with an agroforestry system.

Presently there is lack of research methodology in agroforestry system with respect to plant responses under such systems. Problems which arise among others is the time space, the design used and analysis of the results. It is a well established fact that in order to carry out adequate research on tree/crop interactions, a longer period is required.

Tree/Crop Interface

The understanding of the Tree/Crop Interface is fundamental both to the choice of agroforestry designs whether mixed or zonal and their effective management (Huxley, 1986). This should be conducted through simple field layouts, quick and easy assessment methods. The aim should be to come up with research guidelines and protocols which will enable to facilitate the experimental work needed for both investigational adaptive research in alley-cropping and other forms of tree/crop mixtures.

Possible steps in studying the Tree/Crop Interface

Before any measurable attributes are carried out, there is need to have designs which may be direct adaptation of the existing tree/crop association some of the traditional system or derived from the existing designs of the monoculture and polyculture agricultural systems.

In designing this, care should be taken to ensure that several factors such as orientation is given some importance. Also the objectives should be carefully chosen. In Huxley (1983) four different designs for studies of research methodology at the tree/crop interface have been devised. For example, one is a multi-row geometric design of 3 arms each at 120≤ between, planted with *Cassia siamea,* a systematic paralles-row design in which plant population and rectangularity can be tested separately, but only at one orientation (N.W. - S.E.) direction. This is planted with *Grevillea robusta* species and is often side pruned before planting an associated crop mixture. The third design is a two hedgerow geometric designs at 120≤ planted with *Cassia Siamea.* It is possible to have a design of a combination of geometric (120≤) and systematic design of a 3, 2 and 1 row hedges in each area. At ICRAF this last possible design is made of the *psidiuni guajava.* These designs can be used to study crop/tree interface under varying objectives. The designs are robust and utilizes minimum space in contract to convectional designs used in agricultural, and forestry experiments.

Agroforestry systems being complex, there is a great need to have a careful approach as to the right method of investigating the problem. It is common knowledge that the growth and development of plants is function of the genetic potential of the plant and phenotypic potential. Phenotypic influences include both the environmental aspects and management aspects. Before we illustrate our problems with the association of legumes in agroforestry and the likely constraints on the process of nitrogen fixation, let us examine a generalised logical way of tackling any research methodology in agroforestry system.

The likely logical way of solving any plant, responses in an agroforestry system using the designs described above with a view of devising research methods and appropriate agroforestry technologies based on plant responses would be:

1. Logical observations of the previous growth of the wood species in the trials. This enables careful thought-out plan of action of how the experiment may be carried out. Such an approach requires initially an attention to be focussed on some distinct plant growth and development stages in (a) seed germination and seedling, emergence, (b) early plant growth in vegetative stage (c) the maturation of fruit development and fruit ripening stage. There arises various problems of establishment and maintenance of the very regular and complete crop stands needed for such small designs. Thus, this logical approach to the problem enables the researcher to be in a position to know how to overcome them. The observations of the plant association actually growing in the field, and seeing the overall outcome of tree-row orientation on the associated crops throughout one series of growth stages may enable to plan the first approach to sampling and measuring the environmental parameters through which the plants are interacting at these tree/crop interface.

To gain variability of the system, the first trial should involve intensive sampling which for example may be row by row, in some cases, plant by plant. Having gone through such course in one season, the following season using the knowledge gained from the initial sampling, the next step is to couple biological and physical parameters at the same time. This is the right time to select the most important physical parameters; already known to influence productivity in such systems whether from theoretical information or on some systems whether from theoretical information or on some practical information which might have been gained from the initial trial in the first season.

A more logical approach to this would be to examine the available detailed meteorological data for the site if there is any. Simultaneously, careful visual observations should be made on the plant associations in relation to possible effects and interactions on growth and development due to the whole range of climatic factors. This would enable one to select the environmental factors of priority to investigate in the system. From both theoretical and examination of the meteorological data, and knowledge gained from other systems, it is apparent that the most logical environmental physical parameter which should be studied in detail should be the investigation of rainfall distribution and soil water use in such plant associates. Depending on the manpower and money resources, some 'shelter' effects (i.e. wind, humidity and temperature) should be monitored. Otherwise, it is not advisable to study in details. In the subsequent period (phase three) of the investigations, studies on light interception and light distribution can be done similar to the initial plant sampling in the first phase of the trial for each set of climatic variables. A set of climatic variables monitored in a detailed sampling pattern may be modified later as the experience of sampling these parameters grows. Recall that in your designs you may have more than one orientation. In order to simplify the problem it is logical to ignore the opportunities for measuring the effect orientation until you are certain that the methodology being used on one arm is correct. This should lead to full study of orientation effects of the particular set of climatic variables and then proceed to assess the correct methodology to use for tree/crop interface studies for the next climatic variables and so on.

Since the question of physical instruments is very crucial, attempts should be made during the phase of testing the physical (climatic) variables to get in touch with groups of scientists working in such related area. This should lead to a test of a range of much simpler climatic measuring equipment alongside the 'standards'. If such instruments can perform reliably enough for the task, then it will save time when transferring the technology as this can come out as a complete package of the findings of the methods and the appropriate instruments.

In the foregoing paragraphs I have presented the logical steps which may be followed. Let us now give an example of how, in detai,l one of the initial physical parameter of rainfall in the system may be characterised. The first sampling technique for the rainfall distribution (and re-distribution) and soil water use studies at the interfaces have an initial logical plan. Standard rain gauges e.g. standard 5" (metal type) can be set to a transect of sites of the arms of the interfaces arranged across both sites as for example one orientation of the main tree/crop geometric design. One set above soil level at a standard layout. There can be small collecting rain gauges (e.g. plastic) at some distance from the top of the tree canopy parallel to the tree rows in the tree canopy at the interface itself and at the mid-crop distances.

The horizontal distribution of water in the system may be assessed through the phenomenon of gypsum block resistance meters across the one of this instrumental arms. Preferably four depths at each sampling point should be sampled.

Such information should be automated to ensure less time is spent on collection of such data and to minimize the troubling of the area under experimentation through repeated readings. Plant water status can be simply checked using the standard field equipment such as state steady parometer. This instrument allows quick measurements of stomatal conductance, temperature of the leaf, air and transpiration. More simpler methods can only be tested after ensuring that an appropriate technique has been found for sample size and pattern.

Thus in the initial phase of the investigation of the problem there should be an appreciation of the variability in the system of water inputs and soil water use and some careful (but general) observation on shelter and light that eventually lays a firm base for planning the future techniques of investigation to any specific problem. For example, nitrogen fixation in agroforestry system.

Factors likely to influence nitrogen fixation in agroforestry system

In the traditional land use system in tropics, apart from other crop association with trees, there are several examples of trees associated with leguminous crops or the trees may themselves be legumes. A scientist studying such unit of a subsystem of agroforestry is likely to question the influence of the tree association on the process of nitrogen fixation. Nitrogen fixation being very much coupled to the basic process, the most logical way of studying such problem would initially have a priority of the factors which greatly influence this basic productivity process in such system. Although there are several factors which would influence this process, in agroforestry system those of major importance would be light.

Water would be the next factor but it always presents a point of contention in such systems. It is of importance when the associations are of high populations or in arid areas. Thus, this points to first running a quick assessment of how response of the legume which fixes nitrogen and a non-fixer, for example sorghum when grown either close or far away from the trees. This would quickly enable one to determine in the next phase of investigation exactly how appropriate to proceed to design your spacing experiments in the tree/legume association with respect to nitrogen fixation. Plant responses may be evaluated following similar steps outlined for logical studies of the tree/crop interface. This being a specific research problem, there is need to carefully state the objectives precisely. In the initial stage, careful observations should be made on growth components, and characters associated with yield and nitrogen fixation. Growth, nodulation, and nitrogen fixation in such system should involve first of all looking at the dry matter of the top plant, nodules, number, weight per plant and nodule position, colour and size. If any competitive stress can be recognised in the initial stages of the study, then such simple parameters of total leaf area, dry weight, area of individual leaf area, specific leaf area, canopy structure; i.e. leaf rigidity, leaf length, LA1, should be studied in the second phase. Then in the next season, analysis of yield discerning processes in relation to canopy structure can then be assessed, such as plant growth and development, dry matter production relationships between stem weight and number of pods and weight, also relationship between growth parameter and number of pods. It is only after precise information of what is mentioned above has been obtained that a researcher proceeds to study the development of water stress due to cropping pattern and its effects on the detail physiology of the legume. This should involve diurnal, plant water status, photosynthesis of the soil and leaves.

In conclusion, it is apparent that nitrogen fixation in an agroforestry system requires a careful approach which initially require derivation of the methods to be used and careful selection of the priorities of the factors which influence the process initially.

There is currently logical information on this at ICRAF (International Council for Research in Agroforestry). There are programmes which are geared to development of research techniques for studying tree (crop interactions by critically examining what happens at the tree/crop interface. The programmes use various designs aimed at coming up with an appropriate agroforestry systems which can be easily adopted both in high potential and fragile areas of the tropics.

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