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A Review on Factors Affecting Drying Process of Pistachio and Their Impact on Product's Quality

K.A. Abbas (Corresponding author)
Department of Food Technology, Faculty of Food Science and Technology
Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
Tel: 60-3-8946-8534 E-mail: ali_kassim@hotmail.com

A. M. Saleh
Department of Mechanical Engineering, University of Technology, Iraq
Tel: 964-790-136-9589 E-mail: adel196150@yahoo.com

Ola Lasekan
Department of Food Technology, Faculty of Food Science and Technology
Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
Tel: 603-8946-8535 E-mail: Lasekan@food.upm.edu.my

Sahar K. Khalil
Faculty of political Sciences, University of Al-nahrain, Iraq
Tel: 964-770-873-9943 E-mail: ali_kassim@hotmail.com

Abstract

This review is focusing on the parameters affecting the quality of pistachio during hot-air drying process. Accordingly, the various common existing processing methods are reviewed extensively using the current literature to investigate the latest developments in this regard. The findings revealed that both of the type of method used as well as the parameters controlling the drying rate, have different impacts on final product's quality.

The study concluded that the sun drying method has the best final quality as well as to lowest energy cost. This study provides a guide for the food technologist to the select the optimum method by which the best quality can be produced and minimum energy can be spent.

Keywords: Drying process, Pistachio nut, Quality

1. Introduction

Pistachio nut (Pistacia vera L.) is one of the popular tree nuts in the world. Due to its high nutritional value and split shell, pistachio is an increasingly important nut crop consumed raw, roasted or salted (Rosengarten, 2004). Most pistachio production occurs in countries with warm arid climate (Kashani Nejad, *et al.,* 2007). Iran, United States, Turkey, Italy and Syria are principal pistachio production countries. Pistachio nuts are grown mainly for export in these countries (F.A.O., 2007).

Pistachios are served principally as salted nuts. A large percentage of pistachios are marketed in the shell for snack food. Non split, filled nuts are used for processing (Kashani Nejad, *et al.,* 2007). The food industry uses pistachios for cakes, biscuits, candies, ice cream, chocolate, and pistachio butter. It is also used as the main ingredient of many desserts. Pistachio nuts contain 25% protein (mainly essential amino acids), 16% carbohydrate (mainly sucrose) and 55% oil (80% unsaturated fatty acids) (Rosengarten, 2004). A one-ounce serving of pistachio contains more than 10% of the daily value for dietary fiber, vitamin B-6, thiamin, magnesium, phosphorus and copper (Herber *et al.,* 2008).

The pistachio is a semi dry stone fruit consisting of a single kernel enclosed in a thin, bony shell, which is surrounded by the hull (Fig. 1). The pistachio nutmeat typically develops at least a month before maturity and harvest, where the enlarged nut pushes on the surrounding shell to cause a natural split. Once pistachio nuts are harvested, the hulls should be removed within a short period of time to avoid shell staining and drying (Fig. 2) (Avanzato and Vassallo, 2008).

Drying is one of the conservative methods of agricultural products and also a complex process involving heat and mass transfer between the surface of the product, its surrounding medium, and also within the product.

Drying is an important operation in pistachio processing (Aktas and Polat, 2007). During the drying process, nuts can undergo reactions that cause degradation of quality, because of the odd colors and flavors formed. The major oxidative reactions in dried foods are due to peroxidation of lipids. In comparison with other food products, studies on the drying of pistachio nuts are very limited (Kashani Nejad *et al.,* 2007). Accordingly, more research should be done in parallel with the increasing demand of such crop worldwide. The outcomes of these researches may be therefore necessary to design and simulate accurate drying systems. This, however, requires knowledge of nut properties as thin-layer drying characteristics under different drying conditions. In the light of above, this work has been justified to review some factors such as Aw, moisture content, airflow and layer thickness affect on drying and quality of pistachio nuts and the existing methods which are broadly used in drying.

2. Factors affecting on drying rate

2.1 Aw

The water activity (Aw) of food describes the energy state of water in the food, and hence, it's potential to act as a solvent and participate in chemical/ biochemical reactions and growth of microorganisms. It is an important property that is used to predict the stability and safety of food with respect to microbial growth, rates of deteriorative reactions and chemical/physical properties (Anthony and Fontana, 2000). There is a risk of aflatoxin contamination in pistachio (Magan and Aldred, 2007). Therefore correct use of drying process can eliminate this risk. The most effective preventative control is to dry pistachio nuts to an Aw of 0.82 for short-term or 0.70 for long-term storage to prevent mold growth and aflatoxin contamination. At 25˚C, these critical Aw values translate to moisture contents of approximately 10 and 5–7%, respectively (F.A.O, 2001).

2.2 Moisture content

Drying to appropriate moisture content (4-6% wet basis (w.b.)) is an important factor insuring good quality. Drying affects the constituents of pistachio but its influence is less than blanching and roasting. Unsaturated fatty acids are more susceptible to changes during processing. Studies have shown that there is little or no effect of drying temperature on pistachio quality as measured by percent closed shell edible nuts or percent loose kernels in a sample (Thompson, 2005).

Rafiee *et al.* (2009) reported that there is a decrease in moisture content of pistachio nuts from 56-57% to 5-6% during drying process. Drying conditions affect the quality of dried pistachio nuts, therefore, this calls for an accurate description of the drying trend to the process. They suggest that using FEM (Finite Element Method) can properly predict the moisture content distribution inside the pistachio nut from which the moisture gradient as well as stress can be calculated.

Aktas and Polat (2007) predicted the moisture content of the product at any time of the drying process with high ability between drying air temperatures of 40 and 60˚C and initial moisture content of 32 and 38% (w.b.). While the effects of the drying air temperature, pistachio cultivar (variety) and the initial moisture content of pistachios on the Aw of dried samples were found as significant ($P < 0.05$), interaction among the drying temperature, initial moisture content and cultivar was found as in significant.

To design suitable dryer in order to dry pistachio perfectly, and to keep goods in a good situation, it is considered to have adjusting equilibrium moisture curve. These curves are very important information, which are used in solving equivalent mass and energy transfer for designing a dryer system. Moisture content is important to predict the shelf life. Pahlevan zadeh and Jafarian (2002) studied these curves in temperature of 15 and 35˚C for pistachio kernel and unhulled pistachio (whole). By using the experimental data, the adsorption and desorption isotherm curves of pistachio have been presented and also by using them the net isosteric heat of sorption was obtained.

2.3 Air flow

Air is used in drying, aeration and storage systems of biological materials. In drying, air carries heat to and moisture from the product, while in aeration, air cools the product by carrying away the heat. Moisture removal or cooling, in these cases, cannot be achieved if air is not forced through the material. When air is forced through a layer of agricultural bulk materials, resistance to the flow, the so called pressure drop, develops as a result of energy lost through friction and turbulence. The prediction of airflow resistance, which is fundamental to the design of efficient drying and aeration systems, has been studied for the past 70 years. Fan selection for drying and aeration systems requires knowledge of how much airflow resistance will be developed in a particular bed of grain. Drying, aeration and storage are key stages in pistachio nuts production. In pistachio nut dryers, forced air is necessary to provide the heat of vaporization of moisture and remove the moisture from the nuts. The most important preventive method after harvesting is to prevent further growth of the molds and toxin production. Thus, pistachio nut should be dried properly and uniformly as soon as possible after harvesting and stored in an appropriate condition. To optimally design the forced ventilation systems for drying and cooling the stored bulk, the resistance to airflow through bulk pistachio nut is an essential parameter and must be estimated to a reasonable accuracy (Kashani Nejad, 2009).

Kashani nejad and Tabil (2009) were determined resistance to airflow of bulk pistachio nuts (Ohadi variety). They found the pressure drop through the bulk pistachio nuts increased with an increase in airflow rate, bed depth, moisture content and bulk density. An increase in the moisture content range of 4.08–38.40% (w.b.) resulted in about 55% increase in pressure drop.

Gazor *et al* (2005b) reported that if the air velocity is increased from 1.5 to 2.5 m/s, drying time reduces about 10 percent. Changes in temperature and air velocity have no significant effects on protein and fat content of pistachios, but if temperature reaches 90°C, peroxide value will increase to 0.55meq/kg, which is still within the permissible limit for processed pistachios.

2.4Layer thickness

Kashani nejad *et al.* (2007) determined the thin-layer drying characteristics of Ohadi cultivar pistachio, and they found the best model (Page model) for describing the drying behavior of the pistachio cultivar. The drying air temperature had the greatest effect and air velocity and relative humidity had a small effect on the drying kinetics of pistachio nuts. Table 1 show Mathematical Models Applied to the Drying Curves.

2.5 Temperature

Drying temperature affects the sensory attributes of pistachio nuts. Its roasted flavor increases during high temperatures drying (116-138ºC). On the other hand changes in temperature, air velocity and pistachio layer thickness plays important role in pistachio drying process. Gazor *et al.,* (2003) investigated changes of drying rate for *Kalehghouchi* variety of pistachio. Findings indicated that, Increasing the temperature from 75°C to 90°C reduced the drying time by more than 50 percent, increased the drying rate and better roasted flavor in pistachio. Drying temperature does not have any effect on appearance of dried pistachios. But increasing the air velocity at high temperatures can reduce the drying time by about 25 percent. And moreover increasing layer thickness of product caused increase in drying time, but amount of dried product increased considerably.

There is a difference between drying and roasting that must be consider during drying. According to literature review drying is less than 100°C but roasting is more than 100 °C even to 200°C. In pistachio, the characteristic aroma, and texture are developed during roasting, which the crucial step in the pistachio nut is processing as in the case of other nuts and coffee processing. Roasting is also one of the effective physical methods to reduce aflatoxins content in pistachio nuts (Yazdanpanah, 2005).

3. Existing methods of drying of pistachio nuts

Post harvest processing is very important to pistachio quality. When pistachios transfer at the processing plant (Terminal), the following processes are conducted(Nakhaei Nejad, 2007):

1) dehulling, to remove hull from nuts.

2) trash and blank separation, to remove blank pistachios and trashes such as small branches, remaining shells and leaves.

3) stick tight (unpeeled) separation, to remove unpeeled and unripe nuts.

4) washing, which involves spraying water at high pressures on the pistachios to clean the nuts; 5) drying, to decrease moisture content of pistachios to 4-6%.

In practice pistachio are dried using the following methods:

3.1 Sun drying

Pistachio nuts were spread out in a thin layer 2 to 3 cm thick on a concrete floor under the sun for 2 days at an average temperature of 26.5 º C and average relative humidity of (RH) of 18%.

Fig. 4 depicts this Method.

Owing to lack of sufficient preservation methods, the producers open out to dry the nuts in thin layers on the grounds. Although this method has a good final product quality, however exposed to negative climatic and environmental conditions which are heavy solar radiation, wind, rain, storm, dew and snow. Additionally, the drying process in the open air can be exposed to the worst contamination by dirt, dust and environmental pollution. Some harmful organisms and insects can grow in the organic structure of the dried product and the dry products can be damaged and decomposed during storage due to insufficient or non-uniform drying. If the farmers in a shiny region want to use this method, the principal of GMP (good manufacturing practice) and HACCP (hazard analysis critical control points) must be considered.

3.2 Solar drying

One of the conventional drying methods which is used is solar-assisted drying process and can be defined as a drying process when the heat required for drying of crops is supplied from the sun. Sun drying of solid products comprises the conventional part of the solar energy applications and has the advantage of small or negligible installation and energy costs. Accordingly, drying process can also be performed using solar energy as well as other renewable energy sources or non-renewable energy sources. On the other hand, solar drying can be widely applied in the preservation of industrial agricultural products such as pistachio, hazelnut and walnut to reduce their moisture contents and to prevent the quality from deterioration within a period of time regarded as the safe storage period. Additionally, it is applied in the villages and cities where solar radiation is abundant enough to be dried the crops and also farmers and customers try to decrease their energy expenses in drying agricultural products. After harvesting, the pistachios are mostly spread on the ground and generally dried in the open sun. Hence, both the producers spend a lot of money to recover the quality of dried pistachio otherwise the quality of the products will lower than expected. Therefore, drying of pistachios becomes increasingly important. It is suggested to improve the drying conditions using solar-assisted convection dryer, to decrease the drying time, and to increase the quality of dried products by means of faster transportation of moisture than open sun drying(Midilli, 2000 and Midilli 2003b).

Midilli and kucuk (2003a) were carried out the energy analyses of the drying process of shelled and unshelled pistachios using a solar drying cabinet (Fig. 5). They found the shelled and unshelled pistachios are sufficiently dried in the ranges between 40 and 60 °C (200 and 808 w/m of the solar radiation) at 1.23 m/ s of drying air velocity in 6 h.

Ghazanfari *et al.*, (2003) were designed a thin-layer forced air solar dryer to study the feasibility of drying pistachio nuts. The maximum temperature in the solar collector reached 56°C, which was 20°C above the ambient temperature. The required drying time was 36 h. During the first day of drying the moisture content dropped to about 21% (wb). The final moisture content of the dried nuts was 6% wb, which was 1% below the recommended storage moisture. They mentioned that In general, the quality of solar dried nuts was better than the conventional heated air due to slower drying rates (Ghazanfari *et al.*, 2003).

In solar drying of agricultural grains, the rate of water removal depends on the stage of dryness of the grains. A large quantity of water could be removed during initial stage of drying with large volume of fresh air. The diffusion of moisture within the material is the limiting factor and higher temperature is more expedient in removing moisture. Drying rate is highly and positively correlated with amount of solar radiation and vapor pressure deficit, but highly and negatively correlated with density and initial moisture content of the hay (Ghazanfari *et al.*, 2003).

3.3 Bin drying

Samples dried in a batch bin dryer (Fig. 6) for about 8 hours at an average drying temperature of 65±2ºC. Fig. 6 depicts this process.

3.4 Vertical continuous drying

Pistachio nuts dried in a vertical continuous dryer (Fig. 8) for about 10 hours. Drying temperatures for the first (top) and second stage (bottom) were 45º and 40ºC, respectively.

3.5 Vertical cylindrical drying

Pistachio nuts dry in a vertical cylindrical dryer (Fig. 9) at a drying temperature of 55±2ºC for 8 hours.

3.6 Funnel cylindrical drying

Samples dry in a funnel cylindrical dryer (Figure 10), which was equipped with some perforated funnels to adjust the movement and holding time of pistachio nuts in the dryer. The dryer was operated at a temperature of 80ºC for 5.5 hours.

3.7 Continuous mobile and steady tray dryer

The dryer was operated at a temperature of 70ºC for 5 hours.

3.8 Batch drum dryer

The dryer was operated at a temperature of 70ºC for 4 hours (Fig.12).

3.9 Continuous belt conveyor dryer

In this dryer, hot air blows in bottom and moisture content decrease to 10-12% in 2.5-3 hours.

4. Quality changes during drying

Midilli (2001) was determined the drying behavior and conditions of shelled and unshelled pistachio samples using both solar assisted and open sun drying. It was deduced that the shelled and unshelled pistachio samples in the solar assisted forced convection dryer were perfectly dried at temperatures of 50 $\pm$ 10 ºC in the time period of 6 hours. Whereas, the samples in the open sun drying were not sufficiently dried at temperatures of 28 $\pm$ 4 ºC in the same time period. Hence, it is suggested that the pistachio samples with approximately 29.0 per cent of moisture are dried in the solar assisted convection dryer at 50 $\pm$ 10 ºC of temperature in the time period of approximately 6 hours in order to protect from the negative climatic and environmental effects. However, it is not desirable to dry the pistachio samples in the open sun because of greater drying time, dirt, dust and harmful insects.

Ghazanfari *et al.* (2003) reported that the quality of solar dried nuts was better than the conventional heated air due to slower drying rates. Quality evaluation of the nuts indicated that a properly managed solar drying system could be a suitable alternative for drying pistachio nuts. Since the temperatures of fossil fuel-based dryers are not precisely controlled, a portion of the dried nuts are discolored, burned, or exposed to various toxic fumes. The maximum recommended temperature for heated air drying of pistachio nuts is 55°C. Higher temperatures besides being uneconomical, cause cracks in the kernels, escape of volatile aromatic compounds, case hardening of the kernels, and reduction of storage life and germination. These damages have also been reported for other agricultural products.

Gazor et al (2005a) were studied influence of temperature and thickness of product layer on drying time in batch dryers. Results showed that the temperature and product thickness have significant effects on drying time. Pistachio appearance (color and shape) has no change in the experiments. Different temperatures have significant effects on dried pistachio flavor. The results indicated that at two temperature levels, pattern of moisture content variation in layers were significantly different. Hence use of agitators in dryers with pistachio thickness above 10 cm is advisable. With the consideration of suitable moisture for storage and pistachio quality, enough time recommended to dry each variety.

Kashani Nejad *et a.l*, (2002) reported that sun drying and bin drying resulted in higher split shell percent on pistachio nuts than other drying methods. The different drying methods did not have any significant influence on the free fatty acids, peroxide value and thiobarbituric acid of lipids in pistachio nuts. Significant differences were found in firmness of pistachio nuts dried using various methods. The lower is the moisture content of pistachio; the higher is its firmness. The higher firmness of nuts dried in vertical cylindrical dryer was due to their lower moisture content (2.427%) and the lower firmness of nuts dried in bin dryer was due to their higher moisture content (3.272%) than those dried with other methods. Few significant differences were observed in sweetness scores and panelists detected slightly higher sweetness in nuts dried in the funnel cylindrical dryer and slightly lower in samples dried in vertical continuous dryer. they detected a few differences in roasted flavor of pistachio nuts. Also, differences in shell appearance of nuts dried with various methods were significant. The nuts dried in the funnel cylindrical dryer got the highest score and those dried in vertical continuous dryer got the lowest score. Shell appearance is one of the most important factors in pricing of raw pistachio for export. Shell staining as an appearance quality defect should be minimized by avoiding delays in harvesting and delays between harvest and hull removal. The cause of shell staining is not yet known, but the high content of phenolic compounds in the hull may be a factor. Significant differences were found in split shell of nuts dried using various methods. Split shell of pistachio nuts is also another important factor affecting price. They reported, the bin drying method produced pistachio nuts with the best quality.

Rostami and Midamadiha (2004) were evaluated the effect of various dryers (batch wagon, cylindrical dryers, continuous funnel cylindrical and Vertical continuous dryers). Results showed that drying nuts up to 4-6% moisture level increased nut splitting to 1.21mm in batch cylindrical dryer and decreased it to 1.07mm in Vertical continuous dryer. Continuous cylindrical dryer caused the highest heat injury percent but it was the lowest in batch cylindrical dryer. Sun drying resulted in the best uniformity, but outlet pistachio nuts of batch cylindrical dryer had the least uniformity. According to drying curves, for the first, second and third three hours of drying, 8.5, 15.1 and 38.5 minutes were required to decrease 1% of pistachio moisture content, respectively. Fuel consumption was the highest for drying up to 4-6% moisture level and the lowest for drying up to 10-12% (w.b.) moisture level in batch wagon dryer. Drying nuts up to 4-6% (w.b.) moisture level in continuous cylindrical dryer resulted in the best kernel color. Drying method and outlet pistachio moisture content of dryers didn't have any significant influence on shelf life, texture and rancidity in pistachio nuts. Drying also didn't cause splitting in pistachio nuts. Table 2 summarize characteristics of these dryers:

5. Symbols

a Dimensionless drying constant

b Parameter of the present model (h^{-1})

k Constant of drying velocity (h^{-1})

MR Dimensionless moisture ratio

n Dimensionless drying constant, number of constant

t Time (h)

6. Conclusion

The parameters of drying rate in general are: Aw, moisture content, air flow, layer thickness, temperature and relative humidity. These parameters as well as the type of method used are affecting the quality of final product.

Among methods of drying, although sun drying has a good final product quality, however exposed to negative climatic and environmental conditions. The dryers consuming fossil fuels or electricity are not also completely appropriate for the farmers because of expense in terms of investment and energy costs, and the skilled personnel needed for operation and maintenance. Among fossil based dryers, bin dryer is the best (Kashaninejad et al, 2002). According to Rostami and mirdamadiha (2004) various dryers (batch wagon, cylindrical dryers, continuous funnel cylindrical and Vertical continuous dryers) and outlet pistachio moisture content of dryers didn't have any significant influence on shelf life, texture and rancidity in pistachio nuts. Shell appearance and split shell significantly are affected by drying methods (Kashaninejad et al, 2002). Also different temperature affect on flavor (Gazor, 2005a). In order to prevent from these dramatic conditions and to perform the drying process of pistachio nut efficiently; the conventional drying processes, which are assisted by renewable energy sources, should be introduced to the producers. From literature, it is clear that the performance of a solar dryer also depends largely on the prevailing ambient conditions. As a result, the chosen drying process should also include some other factors such as customer convenience or preference, shipping costs, maintenance of product, transportation and storage.

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Table 1. Mathematical Models Applied to the Drying Curves

Model No.	Model Name	Model
1	Lewis	MR* = exp(-kt)
2	Page	$MR = \exp(- kt^n)$
3	Modified Page	$MR = \exp(-(kt)^n)$
4	Henderson and Pabis	MR =a exp(-kt)
5	Logarithmic	MR =a exp(-kt) + c
6	Two-term	MR =a exp(- k0t) + b exp(- k1t)
7	Two-term exponential	MR =a exp(- kt) + (1 - a) exp(- kat)
8	Wang and Singh	$MR = 1+at+bt^2$

Source: Midilli and Kucuk, 2002

Table 2. Some characteristics of four types of dryers (Rostami and Mirdamadiha, 2004)

Dryer	**Batch wagon**	**Vertical continuous**	**Cylindrical dryers**	**Continuous funnel cylindrical**
Depth	25cm	30cm	1.5m	20cm
Air temperature	60-65	70-75, 60-65 for 2 dryer	50-55, 55-60 60-65,70-75 For 4 dryer	60-65
Capacity (kg)	338	10000	10000	376
Temperature control possibility	Yes	Yes	Yes	Yes
Agitation possibility	Yes by labor	Yes	Yes	No
Air flow changing possibility	No	No	No	No

Figure 1. Fresh pistachio

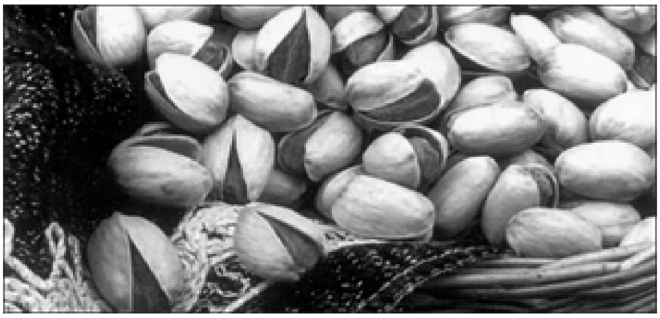

Figure 2. Dry pistachio

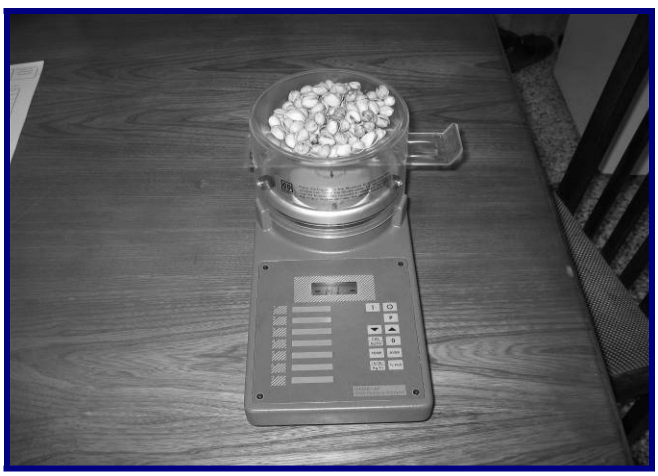

Figure 3. Rapid moisture content tester in processing plant

Figure 4. Sun drying of pistachio nut

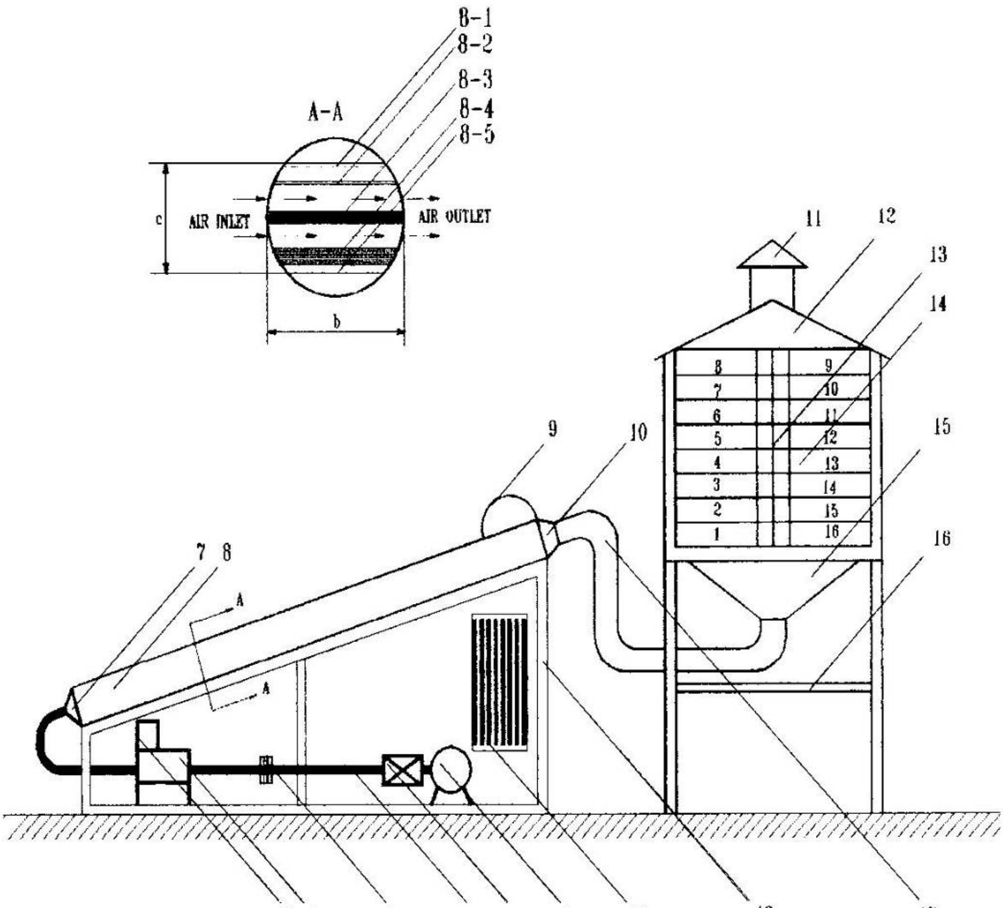

Figure 5. Solar-assisted drying cupboard (Midilli and kucuk, 2003)

1. Fan, 2. Valve, 3. Connection pipe, 4. Orifice, 5. Auxiliary Heater, 6. Temperature controller, 7. Inlet of solar air collector, 8. Solar air collector, 8-1. Glass cover, 8-2. Glass cover, 8-3. Absorber plate, 8-4. Insulation, 8-5. Wood cover, 9. Pyranometer*, 10. Outlet of solar Air collector, 11. Chimney, 12. Outlet of drying cupboard, 13. Inter section, 14. Shelves, 15. Inlet of Drying cupboard, 16. Support of drying cupboard, 17. Flexible connection pipe, 18. Support of solar air Collector, 19. Manometer.

*A pyranometer used to measure broadband solar irradiance on a planar surface and is a sensor that is designed to measure the solar radiation flux density (in watts per metre square) from a field of view of 180 degrees.

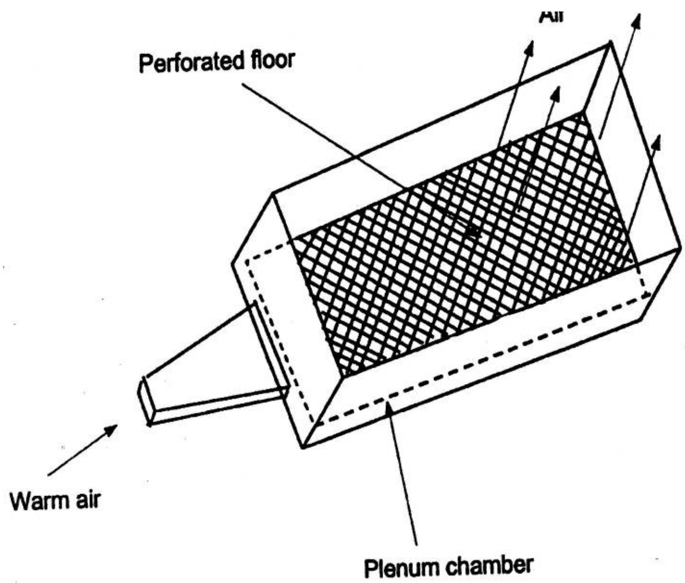

Figure 6. Bin dryer(Kashani Neja d, 2002)

Figure 7. Wagon Bin dryer

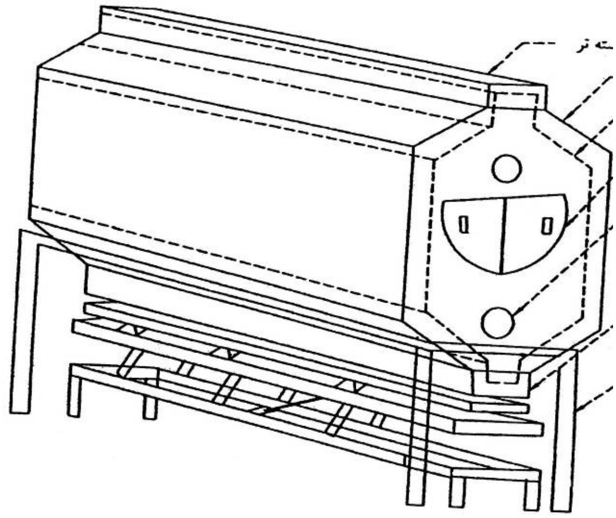

Figure 8. Vertical continuous or cross flow dryer (Rostami and Mirdamadiha, 2004)

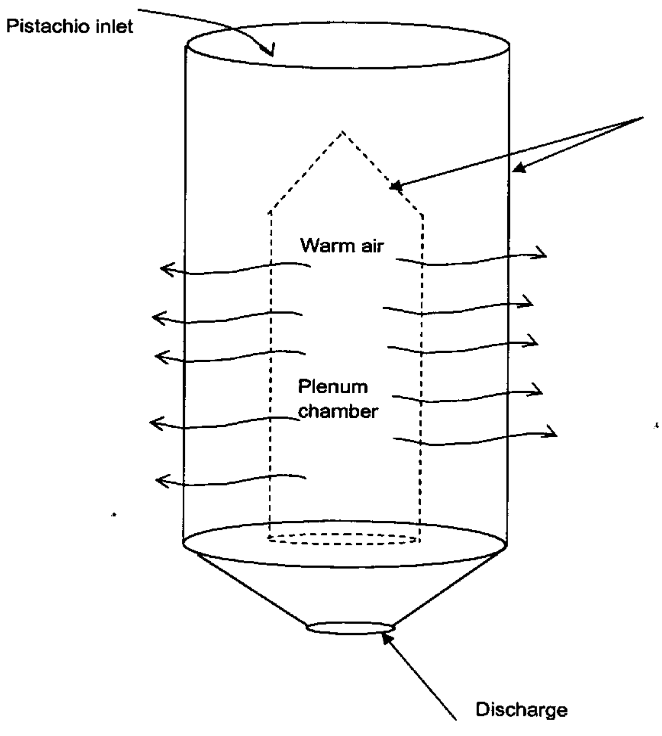

Figure 9. Vertical cylindrical or column dryer (Kashani Nejad, 2002)

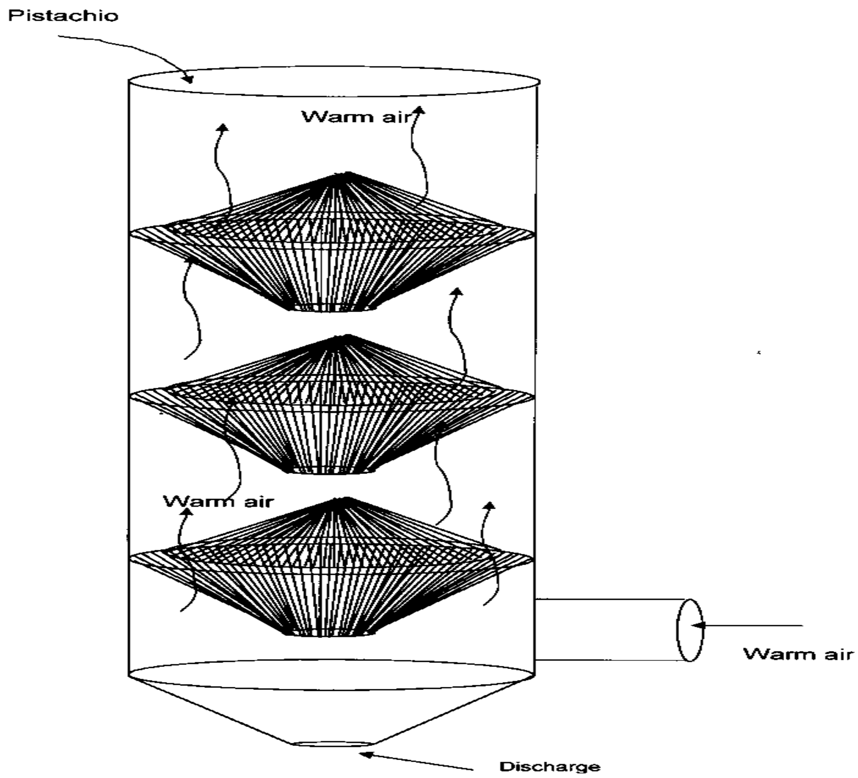

Figure 10. Vertical funnel dryer(Kashani Nejad, 2002)

Figure 11. Continuous mobile and steady tray dryer

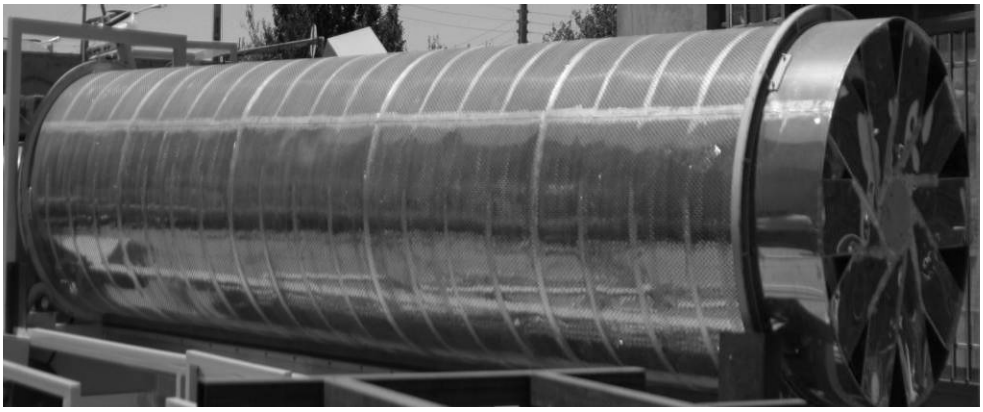

Figure 12. Batch drum dryer

Figure 13. Continuous belt dryer

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Mineral Nitrogen and Microbial Biomass Dynamics under Different Acid Soil Management Practices for Maize Production

Richard N. Onwonga (Correponding author)
Department of Land Resource Management and Agricultural Technology
University of Nairobi. P.O. Box 29053-00625, Nairobi, Kenya
Tel: 254-725-828-254 E-mail: onwongarichard@yahoo.com

Joyce J. Lelei
Department of Crops, Horticulture and Soil Science
Egerton University, P.O. Box 536, Njoro, Kenya

Benson B. Mochoge
Department of Agriculture Resource Management, Kenyatta University
P.O. Box 43844, Nairobi, Kenya

Abstract

Field and laboratory incubation studies were conducted to determine the effect of different acid soil management practices; liming (L), combined N and P fertilizers (NP), and goat manure (M) application, for maize production on the dynamics of mineral N, microbial biomass nitrogen (MBN) and microbial biomass carbon (MBC). A randomised complete block design with a 2^3 factorial arrangement replicated thrice was used. The factors, each at two levels, were: NP fertilizers applied as triple superphosphate (0 and 75 kg ha^{-1}), and urea (0 and 50 kg ha^{-1}), L (0 and 2.5 t ha^{-1}) and M (0 and 5 t ha^{-1}) giving a total of eight treatments; L, M, NP, LM, LNP, MNP, LMNP and C (control). Soil samples for determination of mineral N, MBC and MBN were collected from the 0-15 and 15-30 cm depths at seedling, tasselling, and maturity stages of maize growth and after 0, 15, 30, 60, 120 and 240 days of laboratory incubation of soils obtained from the same field.

The NP treatment had significantly ($P< 0.5$) higher levels of mineral N in both depths at all stages of maize growth, followed by MNP and LMNP. The net mineralized N (μgN/g dry soil) for the incubated soil followed the order LMNP, MNP, LM, M, L, LNP, C and NP for the two depths. The MNP, LMNP and M treatments had significantly higher MBC and MBN for both field and incubated soils. The correlations between mineral N and MBN were positive but non-significant at seedling and maturity stages of maize growth in the 0-15 cm depth and at seedling and tasselling stages in the 15-30 cm depth. The correlations between MBN and Mineral N for both depths and sampling periods were positive and significant for the incubated soils, The maize grain yield increases (%) above control were 43, 36.4, 31.1, 25.3, 21.9, 13.7 and 3.0 for LMNP, MNP, NP, M, LNP, LM and L treatments, respectively.

Application of LMNP and MNP treatments enhanced mineral N, MBC and MBN and concomitantly soil quality and productivity as gauged from the improved maize yields in the respective treatments. Combining manure, lime and chemical fertilizers and /or manure and chemical fertilizers is thus a promising alternative to developing a more sustainable acid soil management strategy for increased maize production in Molo district, Kenya.

Keywords: Acid soils, Inorganic fertilizers, Lime, Manure, Microbial Carbon, Microbial nitrogen, Mineral nitrogen, Kenya

1. Introduction

Soil degradation occurs due to nutrient depletion, soil structure deterioration, acidification and sub-optimal addition of organic and inorganic fertilizer to soil. Acidification of soil results in loss of exchangeable Ca^{2+} and Mg^{2+}, a decrease in effective cation exchange capacity, and an increase in exchangeable Al^{3+} (Graham *et al.*, 2002). An adverse effect of soil acidification is decreased water and nutrient retention capacity of soils and reduced biotic activity (Kinraide, 2003).

Such adverse soil condition can lead to decline in soil quality and crop yields. Numerous properties characterizing the status of soil microbial biomass, activity and nutrient content have been suggested as indicators of soil quality (Doran and Parkin, 1994). Although microbial biomass only forms a small fraction of soil organic matter, it contributes to agricultural sustainability because its high turnover rate is responsible for nutrient release and therefore promotes plant uptake (Smith *et al.*, 1993).

Soil organic matter is thus an important component of soil quality and productivity. Nevertheless, its measurement alone does not adequately reflect changes in soil quality and nutrient status (Mathers *et al.*, 2000; Chen *et al.*, 2004). Measurements of biologically active fractions of organic matter, such as microbial biomass carbon (MBC) and nitrogen (MBN), and potential C and N mineralization better reflects changes in soil quality and productivity that alter nutrient dynamics (Hole *et al.*, 2005). Because it is living, the microbial biomass responds much more quickly to changing soil conditions, particularly decrease or increase in plant or animal residues, than does soil organic matter as a whole. Measurable changes in microbial biomass would thus reflect changes in soil fertility due, for example, to changes in the total pool of soil organic matter (Brookes, 1995; El-Ghamry *et al.*, 2001).

The soil microbial biomass (MBC and MBN) is the active component of the soil organic pool playing an important role in nutrient cycling and plant nutrition and functioning of different ecosystems. It is responsible for organic matter decomposition thus affecting soil nutrient content and, consequently, primary productivity in most biogeochemical processes in terrestrial ecosystems (Gregorich *et al.*, 2000; Haney *et al.*, 2001). Applying organic amendments to soil not only increases the total organic carbon content and its different fractions but also has a series of effects on microbial proliferation and activity (Tejada *et al.*, 2006; Ros *et al.*, 2003). Soil microbial biomass is undoubtedly a valuable tool for understanding and predicting changes in soil fertility management and associated soil conditions such as nutrient dynamics and soil reaction (Sharma *et al.*, 2004; Yougun *et al.*, 2007). It has assumed greater significance and increasing interest in its determination (Azam *et al.*, 2003).

Knowledge of mineral N, MBC and MBN dynamics is particularly critical in the management of acid soils, to reverse declining soil organic matter content and restore soil fertility. There is hitherto a dearth of literature on the effects of various acid soil management practices for maize production on soil mineral N and soil microbial biomass dynamics for Molo district of the central Rift valley province, Kenya. Most of the studies that have been carried out in the district (Lelei *et al.*, 2006; Cheruyoit *et al.*, 2003) have mainly focused on the effects of soil amendments on nutrient availability, soil pH changes and maize performance.

The aim of the current study was therefore to determine the effect of different acid soil management practices for maize production on the dynamics of mineral N, MBN and MBC and maize yield.

2. Materials and methods

2.1 Site description

The field study was conducted at the Kenya Agricultural Research Institute field station located 5 km from Molo Town in Molo District. The site ($0^0 12^1$S, $35^0 41^1$E) is at an elevation of 2500m with a gently undulating slope (0-5%). The rainfall distribution is bimodal in nature with the long rains occurring from March to July/August and short rains from September/October to December. The annual rainfall and mean temperature during the experimental period were 1450 mm and 17.5^0C, respectively. The soils are acidic, well drained, deep, dark reddish brown with a mollic A horizon, and are classified as mollic Andosols (FAO/UNESCO, 1990). The measured initial characteristics of the top soil were 1.74% organic carbon, 0.18% total N, 3.20 ppm available P (Mehlich), pH (H_2O) of 4.87 and clay texture.

2.2 Experimental design, treatments and statistical analysis

A randomized complete block design (RCBD) with a 2^3 factorial arrangement replicated thrice was used. The factors, each at two levels, were: combined N and P fertilizers (NP) applied as triple superphosphate (0 and 75 kg ha^{-1}) and urea (0 and 50 kg ha^{-1}), lime (L, 0 and 2.5 t ha^{-1}) applied as $CaCO_3$, and goat manure (M, 0 and 5 t ha^{-1}) giving a total of eight treatments; C (control, with no soil amendment applied), L, M, NP, LM, LNP, MNP and LMNP. The manure (1.2%N) and Urea (46%) supplied 60 and 23 kg N ha^{-1}, respectively. The calculated amounts of N supplied (kg N ha^{-1}) by the different combinations were; LM (60), LNP (23), MNP (93), LMNP (93). These amounts were higher than the current farmer practices. Farmers use soluble but acid forming Diammonium phosphate (DAP; 18%N) fertilizer in small amounts of 20-30 kg ha^{-1} against the recommended rate of 60 kg N ha^{-1} (FURP, 1994, Lelei *et al.*,2006).

Soil samples for the incubation study, conducted at the Egerton University soil science laboratories, were obtained from the experimental site. The soil were sampled at 0-15 and 15-30 cm soil depths dug out from two profile pits, and mixed thoroughly according to the respective depths to get one composite sample for each depth. Eight soil samples (2 kg each) obtained from each composite sample, were treated similarly as for the field study. The samples were, incubated, in triplicate, in polythene bags in the laboratory at room temperature (25^0C) and moisture adjusted to field capacity.

The results obtained were subjected to analysis of variance (ANOVA) using SPSS version 11.00 (SPSS. 2003). The means were separated at 0.5% least significant level (LSD). Correlation analysis, to generate correlation coefficients, was done to determine the relationships between mineral N and MBC and MBN. The correlation coefficients were computed using the Pearson's correlation coefficient.

2.3 Agronomic Practices

Prior to the experiment, the field had been under a two month weedy fallow and had maize stubble from the previous crop. Land was prepared manually, using hand hoes, followed by secondary cultivation which involved raking and levelling of the seedbed. The maize stubble was removed manually before application of treatments. Lime and goat Manure were applied two weeks (immediately after secondary cultivation) prior to planting of maize (hybrid 614, eight months maturity period) through broadcasting and banding, respectively and thoroughly mixed with soil. Triple superphosphate (TSP) fertilizer was applied per hill and mixed well with soil at planting of maize while urea was top-dressed along maize rows one month after planting. Three maize seeds were sown at each planting hole at a spacing of 60 x 75 cm in all plots each measuring 4 x 4.5 m. Four weeks after planting the seedlings were thinned to two per hill, thereby retaining the recommended population of 44,444 maize plants/ha. Aladrin dust (25%) and dipterex were used to control cutworms and stalk borers, respectively. Weeds were regularly controlled by hand weeding.

2.4 Soil sampling and analysis

Soil sampling: Soil samples for mineral N, MBC and MBN determination were obtained from the 0-15 and 15-30 cm depths before maize sowing (initial sampling) and at maize; seedling (Zadoks stage 25), tasselling (Zadoks stage 65), and maturity (Zadoks stage 98-99) stages of maize growth (Zadoks *et al.*, 1974) at random between the plants within a row in every plot. Four auguring were done in every plot and the soil bulked together according to the respective depths to get one composite sample for each depth. For the incubation experiment, soil sampling, for mineral N, MBN and MBC analysis was done at 0, 15, 30, 60, 120 and 240 days of incubation.

Soil analysis: Soil microbial biomass C (MBC) and N (MBN) were determined by the chloroform-fumigation extraction method (Joergensen, 1996). Field-moist soils were fumigated with ethanol-free chloroform for 24 h. Both fumigated and non-fumigated soils were extracted with 0.5 M K_2SO_4 (for MBC and MBN) by shaking for 30 minutes. MBC was determined by a heated sulfuric acid dichromate digestion, and MBN was analyzed in a persulfate digestion of the extracts and measured total N using a modification of the micro-Kjeldahl method. The factors used to convert the extracted organic C and N to MBC and MBN were 0.38 and 0.45 respectively (Brookes *et al.*, 1985; Vance *et al.*, 1987). Inorganic N (NH^+_4–N and NO_3^-- N) was extracted with 2M KCl and determined by colorimetrical methods (Okalebo *et al.*, 2002).

3. Results and discussion

3.1 Mineral N at the different stages of maize growth

The initial (background N) mineral N measured, prior to maize sowing, in the 0-15 and 15-30 cm depths was 49 and 34 μgN/g dry soil, respectively. There was a marked decline in mineral-N across sampling times in all treatments and depths with progression of maize growth (Table 1). NP and MNP treatment had significantly ($P<0.5$) higher levels of total mineral N (0-30 cm depth) than the other treatments at all stages of maize growth (Table1). Mineral-N was significantly higher in the treatments containing NP, MNP, LM and LMNP at maize maturity.

The high mineral-N measured during the initial soil sampling could be attributed to the flush of nitrates formed at the onset of the main rains. Nitrate frequently accumulates in tropical soils during the onset of the rains following a dry season (Scherer *et al.*, 1992). The observed declines in mineral N in the soil profile with sampling time (Table 1) could be due to increased crop uptake during development. Hybrid 614, a long maturing maize variety is a high responsive hybrid with a high nutrient requirement. Tsai et el. (2009) reported that the amount of N taken up varied with hybrids and was higher in high responsive hybrids. Sangoi *et al.* (2001) similarly reported that older hybrids took up more N and presented higher values of shoot dry matter at flowering. Kamoni *et al.* (2000) had also found that N is taken up by maize throughout the growing season with maximum uptake 10 days before tasselling to 25 to 30 days after tasselling. The sudden increase in mineral N for NP treatment at seedling stage was as a direct result of the top dressed urea (Tejada *et al.*, 2008).

The significantly higher mineral N in NP and MNP treatments (0-30cm depth) than LM, LNP and LMNP at all stages of maize growth is directly attributable to the direct N supply from the fertilizer applied and subsequent manure mineralization. Bending *et al.* (2002) had also found that organic materials applied alone or in combination with inorganic fertilizer gave greater residual soil fertility in terms of increase in organic carbon content and the available N. Magill and Alber (2000) reported that immobilization can occur upon organic fertilization of the soil depending on the carbon-nitrogen ratio of the substrate. The low mineral N in LMNP could be due to increased competition for nutrient uptake between plant and microorganisms. Although organic amendments can provide available nutrients for plants, the coupling of carbon and nutrient transformation during organic matter decomposition strongly interacts with plant nutrient uptake, leading to a competition for nutrients between soil microorganisms and plants (Kaye and Hart, 1997).

The decrease in mineral N with depth is attributable to better substrate supply in the upper soil depth than the sub-soil and the rhizosphere effect. This observation is in agreement with Young and Ritz (2000) and Kladivko (2001) who reported that soil microbial biomass (SMB) as well as mineralization of carbon and nitrogen tended to be greater in the upper layers of the soil and decrease with depth. Yong-Liang *et al.* (2001) reported that there exists a relative nitrogen accumulation in the rhizosphere. Mineralization of rhizodeposition provides a possibility for `recycling´ organically bound nutrients such as N and P (Marschner *et al.*, 2003).

3.2 MBC and MBN during maize growth as affected by treatment application

There were variations in soil MBN and MBC with progression of plant growth in all treatments and depths except for the C and L treatments where the variations were minimal and insignificant (Table 2). MBN and MBC were high at the initial sampling stage in the 0-15 cm (23.90, 18.30) and 15-30cm (146.90, 116.80), depth respectively (Table 2). The MBN and MBC declined slightly at tasselling but increased substantially towards maturity. The treatments MNP, LMNP and M had significantly ($P<0.05$) higher MBN and MBC than the rest of the treatments at all sampling depths and maize growth stages (Table 2). This could be due to enhanced soil conditions and availability of substrates with application of the soil amendments and probably due to the positive interaction between M, NP and L. Compared against the control treatment, the M treatment had the highest (47.8 to 51.2%) MBN across sampling times and depths. MBN was found to be much lower on average when compared against control treatment across depths and sampling times especially in treatments where the NP fertilizer; LNP (16.4-31.08%), MNP (2.64-37.96%), LMNP (20.34-48.52%) was applied.

The fluctuations in microbial N and C pool (Table 2) with progression of maize growth could be due to frequent environmental changes in the soil which would have had an impact on soil moisture status and temperature. These changes could have continually affected the activities of microbes and uptake of nutrients by the maize crop. According to Poudel *et al.* (2002) soil microbial properties are influenced by variations in soil moisture, temperature, crop type and nutrient supply as well as immediate farming practices, such as fertilization and cultivation. Differences between the sampling dates could also be responsible for the observed fluctuations in microbial biomass. This assertion is in agreement with that one of Cerny *et al.* (2003) who had found wide fluctuations in MBC and MBN across seasons with decreases coinciding with periods of high plant N demand and vice versa.

Minimal fluctuations of MBN and MBC in the C and L treatments suggests low microbial turnover due to soil acidity and insufficient time for neutralization of soil acidity by lime. Liu *et al.* (2004) had reported that acid soils limit microbial growth. However, most experiments in which pH has been manipulated by either acid or lime addition have been relatively short term, and so the soil microbial biomass (SMB) may not have had time to adjust to the radically altered conditions (Wheeler *et al.*, 1997; Curtin *et al.*, 1998). In many soils, lime application has the consequence of solubilizing organic matter. This enhances the availability of organic nitrogen to the plant by facilitating the action of microbiota on soil organic matter decomposition. So any observed short-term microbial responses may be due to this increased release as opposed to a direct effect of pH on the microbes themselves (Curtin *et al.*, 1998).

Decline in MBN and MBC with depth is attributable to the declining organic substrates with increase in depth. Organic matter supports most micro-organisms in terms of energy and protoplasmic build up. Girvan *et al.* (2003) and Hole *et al.* (2005) states that the size of MBC is regulated by substrate availability necessary for providing energy for the maintenance of microbes. Kirchner *et al.* (1993) had also observed that microbial populations and activities were greater in the 0-7.5 cm than 7.5-30 cm zone and found the differences between the depths to be statistically significant ($P<0.01$) for all enzymes, fungal populations and levels of available N.

The high MBN at seedling stage could be due to high rhizosphere activities resulting from initial stages of crop take off and low crop demand. The micro-organisms reimmobilize N that is mineralized leading to high MBN. These results are in agreement to those of Bremner and Van Kessel (1992) who found high levels of microbial biomass at planting of crops compared to the rest of the season and attributed the same to increases of microbial biomass during periods of low crop demand that reduced loss of N and other nutrients in soil.

Low MBN at tasseling for all treatments and depths is an indication of enhanced N uptake by the plant thus limiting mineral N supply to microbial biomass. Kamoni *et al.* (2000) had reported that maize got most nutrients from the soil at about 10 days before tasselling to 25-30 days after tasselling. Garcia and Rice (1994) had also observed a decrease in MBN accompanied with a transitory decline in inorganic N which was assimilated by actively growing plant roots. The increase in MBN at harvest therefore reflects reduced uptake of mineral N by the maize crop due to cessation of crop growth. This is in addition to immobilization of N into microbial biomass and turnover of root biomass into the soil pool. According to Groffman *et al.* (1993), N that is returned to the soil at the end of the growing season is conserved by microbial immobilization.

The observed increase in MBC at harvest (Table 3) is due to the substrates in form of sloughed root cells, root exudates and leaf fall produced during maize growth. Franzluebbers *et al.* (1995) found that MBC responded to addition of C substrates from rhizodeposition during the growing season and crop residues at harvest. El-Ghamry *et al.* (2001) and Tejada *et al.* (2006); observed maximum levels of microbial biomass later in the growing season and attributed this to C addition from plant roots.

The high microbial biomass C and N levels in treatments; M, MNP and LMNP is attributable to microbial proliferation. Cropping systems that increase inputs of carbon through green manures, cropping sequences or animal wastes have been shown to have more microbes and greater microbial activity than that found in systems that utilize only fertilizer inputs (Buchanan, 1990). Fauci and Dick (1994) reported that soil amended with beef manure had significantly higher MBC, MBN and soil enzyme activities than inorganic N treatments. It is a well known fact that soil organic C strongly affects the amount and activity of soil microbial biomass (Francisco *et al.*, 2005).

3.3 Incubation study

3.3.1 Mineral N in soil during incubation

Mineral N increased with progression of the incubation period for all depths although significantly lower in the 15-30cm depth. A lag phase was observed in N mineralization in the first 15 days of incubation in the C treatment at the 0-15 and 15-30 cm depths (Figures 1 and 2), whereas for the other treatments mineral N accumulation began immediately. The treatments; LNP (0-15 cm depth), NP, LNP, and M (15-30cm depth) registered a gradual increase in mineral N during the first 15 days with the remaining treatments showing a steep increase in mineral N within the same period (Figure 1 and 2). Between day 15 and 30, rapid N mineralization was realized but tipped off towards the 240 days of incubation (Figure 1 and 2).

For the LMNP, MNP, LM and L treatments, there were sharp increases in mineral N up to the 30th day. The NP treated samples, however, showed a different pattern of mineralization with respect to other treatments. From the onset of incubation to the end, N mineralization increased gradually in all depths with mineralization rates of 0.9 and 0.8 μg N/g dry soil/day for the 0-15 and 15-30 cm depths, respectively. The total N mineralized (0-30 cm depth, μgN/g dry soil) during the incubation period followed the order: LMNP (720.3), MNP (620.8) LM (602.2), M (562.9), L (564.7), LNP (530.5), C (524.4) and NP (423), with treatments LMNP, MNP, LM and M registering significantly ($P<0.5$) higher total mineralized N.

The gradient decrease in mineral N with depth for all treatments would be due to decreasing organic matter with depth. Similar trends had also been observed by Lelei *et al.* (2006) who had attributed the decline in organic matter reduction with depth increase. Drissner *et al.* (2007) and Venkateswarlu *et al.* (2007) had also observed increased microbial biomass carbon in the upper soil layer and attributed the same to increased availability of substrate carbon that stimulated microbial growth.

The lag period observed in the C treatments during the first two weeks could be attributed to the soil acidity leading to lack of N mineralization stimulation. According to De Boer and Kowalchuk (2001), growth of nitrifying bacteria populations is strongly reduced in acidic soils hence low nitrifying potential of the soil. The effect of acidity on nitrification is through the toxic effect of active aluminium ions which inhibit microbial activity and consequently N mineralization (Graham *et al.* 2002; Sierra, 2006).

3.3.2 Microbial biomass during incubation

The trends in MBN and MBC for both depths could distinctly be grouped into three categories; NP and C treatments, slight fluctuation in microbial biomass realized up to the 240 day, LM and LNP treatments gradual increase up to the 60th day followed by slight decrease towards the 240 days of incubation and L, M and LMNP treatments showing sharp and significant ($P<0.5$) increases up to the 60th day followed by a slight decrease towards the 240 days of incubation (Figures 3, 4, 5 and 6).

The observed trend of treatments in the levels of MBN and MBC during incubation points out the importance of adding organic substrates (manure) to the soil and equally the amelioration of soil pH through liming. The addition of manure to the soil stimulated growth and activity of the microbial community simultaneously, while in the control and NP treatments changes in biomass size did not occur at the same time as changes in activity with resultant suppressed mineralization (Barkle *et al.*, 2001).

The declining levels in MBN and MBC for all treatments and depths towards the 240 days of incubation (Figures 3, 4, 5 and 6) may be attributed to low microbial turnover in incubated soils possibly as a result of regulated temperatures and limited carbon supply. Organic substrate and moisture usually declines with incubation period while temperatures increase resulting in reduced microbial activities. Venkateswarlu *et al.* (2007) had found a decline in microbial biomass during N mineralization in laboratory incubation while Drissner *et al.* (2007) reported that MBC size was regulated by substrate and water availability and temperature.

The significantly low mineral N in the control and NP treatments could also suggest a limitation in decomposable compounds other than N in these treatments (most likely C), resulting in nutrient supplies too low to sustain microbial cell synthesis and high activity levels. According to Liu, (2005) organic amendments could improve soil physical properties (soil moisture and structural stability), and consequently benefit soil microbial mediated processes.

3.4 Correlation coefficients

Correlation analysis was done to determine the relationships (correlation coefficients) between mineral N and MBC and MBN in the field and incubated soil and between field and incubated soil.

Field: The correlations coefficients between mineral N and MBN were positive but non-significant at seedling and maturity stages of maize growth in the 0-15 cm depth and at seedling and tasselling in the 15-30 cm depth (Table 3), whereas the correlation between mineral N and MBC were positive and non significant at maturity in the 0-15 cm depth (Table 4) and at seedling and maturity in the 15-30 cm soil depth (Table 4). The correlation coefficients between MBN and MBC was positive and significant at all sampling periods in the 0-15 cm depth and at tasselling in the 15-30 cm depth (Table 3).

Incubated soils: In the incubated soils, there were positive and significant correlations between MBN and Mineral N for both the 0-15 and 15-30 cm soil depths at all sampling periods (Table 4). The correlation between mineral N and MBC was positive at all sampling periods (Table 4) but only significant at 120 and 240 days of incubation in the 0-15 cm depth and at all sampling times in the 15-30 cm depth. The correlation coefficients between MBN and MBC were positive at all sampling times and depths (Table 4).

Field vs. incubated soils: The Correlation coefficients in respect of mineral N, MBC and MBN between field and incubated soil (Table 4) were; positive and significant for MBC, at all sampling periods in the 0-15 cm depth with MBN being positive only in the 15-30cm depth at tasselling vs. 180 (date of incubation corresponding to maize tasseling stage) days of incubation. Mineral N was negative and non-significantly correlated at all depths and sampling periods.

The positive correlations between mineral N and MBN for the field soils at seedling and maturity stages of maize growth reflect low crop demand for N at these growth stages. Booth *et al.* (2005) assembled data on soil characteristics, gross and net N mineralization rates from 100 studies conducted in forest, grassland, and agricultural system. They found that across a wide range of ecosystems, gross and net N mineralization rates were positively correlated with MBN. Positive correlation between MBN and N mineralization has also been reported by other workers (Fisk and Schmidt, 1995; Merila *et al.*, 2002). The negative correlation between N and MBN at tasseling could be due to the high N demand and uptake by the maize crop. It also indicates that immobilization rates increase with microbial biomass and activity. According to Sano *et al.* (2006), this partly provides the evidence for the hypothesis that N cycling and microbial functional diversity is related.

The positive correlations between MBN and mineral N; MBC and mineral N; and MBN and MBC during incubation is attributable to the fact that the dynamics of N in soil could be closely linked to C which exists in organic compounds and heterotrophic microbial biomass, which utilize organic C for energy. This assertion is consistent with previously reported studies (Arunachalam and Arunachalam, 2000; Sharma *et al.*, 2004; Wright *et al.*, 2005) who found a significant positive relationship between MBN, MBC and mineral N in incubated conditions.

The positive and significant correlations observed in laboratory and field studies with respect to MBC in the 0-15 cm depth for the corresponding maize growth stage and incubation sampling periods, is a reflection of the similarity in mineralization pattern. The negative correlations between field and mineral N, however, points to the dynamic nature of mineral N. Processes such as plant uptake, leaching, immobilization and denitrification determine the availability of mineral N (Scherer *et al.*, 1992) to field crops. The correlation coefficients for MBN were positive but non-significant, except at tasseling, in the 0-15 cm depth. This could be due to plant uptake coupled with decline in substrate.

3.5 Effect of treatments on maize yield

Average maize grain yield ranged from 3067 to 4387 kg/ha across the treatments with LMNP giving the highest yield followed by MNP, NP and M treatments. Grain yield increases above control were 31.1, 25.3, 36.4, 3.0, 21.9, 13.7, and 43 % for NP, M, MNP, L, LNP, LM and LMNP treatments, respectively (Figure 7).

There were significant increases in maize grain yield with application of NP fertilizers and manure. This may be attributed to the readily available N and P nutrients supplied by the fertilizers applied. This is in addition to manure's effectiveness in acidity regulation and binding of exchangeable Al in this acid soil. Tejada *et al.* (2006) reported that manure is a good fertilizer on soil that requires P and N to produce high yields. This is attributed to manure's slow release of plant nutrients and contents of N and P. The control treatment had the lowest maize yields probably because of reduced nitrification rates and fixation of P in the acid soil that rendered N and P unavailable hence limited uptake by the maize crop and consequently poor performance. Low yields could also be attributed to Al saturation. Yamoah *et al.* (1996) attributed 44 % reduction in maize yield to Al saturation in acid soils. Maize grain yields increases over control across treatments followed a similar trend as in mineral N and microbial biomass (Figures 1, 2, 3, 4, 5 and 6). The treatments to which M was applied had higher microbial biomass, mineral N and maize yields thus underscoring the importance of soil microbial biomass in nutrient cycling and plant nutrition.

4. Conclusions

Results from the present study have demonstrated that the acid soil management practices applied for maize production had a profound influence on mineral N and microbial biomass. The substrate and nutrient limitation of microbial biomass (MBN and MBC) and their central role in nutrient cycling in acid soils could be enhanced through application of soil amendments. Our data suggest that LMNP, MNP and M treatments were more effective in enhancing soil microbial biomass, mineral N and consequently enhanced maize yields. Overall, the effectiveness of the imposed treatments in acid soil management were in the order of MNP, LMNP, LM, NP, LNP and L. The acid soils of Molo thus need manure in combination with NP fertilizer and lime to improve their physicochemical and biological properties and consequently their productivity. In light of the findings of the current study, it is evident that combining organic amendments (5 t ha^{-1} of manure and 2.5 t h^{-1} of limes) with chemical fertilizer (60 kg ha^{-1} of TSP and 50 kg ha^{-1} of Urea) would be a promising alternative in developing more sustainable acid soil management strategy.

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Table 1. Mineral N (μgN/g dry soil) in soil at the different stages of maize growth (means of 3 observations)

Treatment	Depth(cm)	Seedling	tasselling	Maturity
C	0-15	20.51 (2.90)	16.70 (1.24)	9.38 (2.40)
	15-30	14.20 (1.00)	12.20 (3.36)	9.90 (2.00)
	Total	**34.71**^{cd}	**28.90**^{b}	**19.28**^{cd}
L	0-15	19.50 (2.20)	15.90 (2.26)	7.80 (2.40)
	15-30	24.48 (3.40)	15.80 (4.20)	6.20 (0.80)
	Total	**43.98**^{bc}	**31.70**^{bc}	**14.00**^{e}
M	0-15	16.42 (0.62)	13.70 (2.96)	8.60 (2.23)
	15-30	21.43 (2.30)	12.60 (1.18)	9.20 (1.68)
	Total	**37.85**^{cd}	**26.30**^{c}	**17.80**^{de}
NP	0-15	36.95 (6.50)	22.80 (1.87)	13.50 (4.60)
	15-30	29.60 (2.36)	18.90 (1.23)	12.50 (3.80)
	Total	**66.55**^{a}	**41.70**^{a}	**26.00**^{b}
LNP	0-15	25.65 (1.40)	20.60 (0.98)	16.28 (1.26)
	15-30	16.33 (1.18)	14.80 (2.60)	8.60 (1.42)
	Total	**41.98**^{bc}	**35.40**^{ab}	**24.88**^{bc}
MNP	0-15	28.74 (1.00)	23.60 (0.89)	18.58 (2.00)
	15-30	19.39 (2.36)	17.80 (4.20)	13.60 (1.68)
	Total	**48.13**^{b}	**41.40**^{a}	**32.18**^{a}
LM	0-15	15.39 (0.62)	12.70 (1.00)	12.60 (2.28)
	15-30	17.35 (1.28)	14.30 (0.58)	11.60 (1.62)
	Total	**32.74**^{d}	**27.00**^{c}	**24.20**^{bc}
LMNP	0-15	22.58 (2.24)	18.80 (1.47)	12.30 (2.30)
	15-30	18.40 (2.00)	14.20 (1.26)	9.80 (1.50)
	Total	**40.98**^{bcd}	**33.00**^{bc}	**22.10**^{cb}

Means in a column for the different treatments followed by the same letter are not significantly different according to the LSD mean separation procedure. Figures in parenthesis are standard deviations

Table 2. MBN (μgN/g dry soil) and MBC (μgC/g dry soil) at the different stages of maize growth (means of 3 observations)

Treat-ment	Depth (cm)	MBN			MBC		
		Stages of maize growth			Stages of maize growth		
		Seedling	Tasselling	Maturity	Seedling	Tasselling	Maturity
C	0-15	28.00 (1.65)	18.30 (1.56)	23.50 (1.65)	179.20 (2.46)	131.70 (2.00)	183.50 (1.63)
	15-30	18.40 (6.92)	12.60 (1.24)	15.20 (2.24)	130.70 (1.98)	106.20 (1.38)	140.10 (2.40)
L	0-15	29.80 (1.18)	20.90 (2.68)	26.20 (1.13)	202.60 (1.13)	156.80 (1.12)	214.50 (3.23)
	15-30	21.90 (2.60)	15.10 (2.32)	16.40 (2.50)	160.30 (2.50)	128.50 (2.56)	156.20 (1.00)
M	0-15	53.84 (2.24)	37.80 (4.21)	45.00 (3.20)	382.30 (1.49)	290.70 (3.38)	382.80 (2.00)
	15-30	19.40 (3.12)	16.40 (0.98)	17.40 (4.80)	242.50 (2.68)	208.40 (4.56)	231.30 (4.64)
NP	0-15	50.02 (2.16)	31.70 (2.40)	40.51 (3.64)	260.20 (3.21)	190.30 (1.46)	272.70 (1.98)
	15-30	38.40 (1.16)	15.70 (3.62)	15.40 (2.81)	238.20 (4.16)	119.10 (1.72)	123.50 (1.30)
LM	0-15	40.06 (2.42)	25.50 (1.12)	35.53 (0.98)	260.40 (2.34)	181.10 (3.64)	280.70 (2.92)
	15-30	26.70 (1.60)	17.40 (1.12)	25.90 (1.21)	210.70 (6.20)	142.80 (2.81)	225.20 (2.46)
LNP	0-15	35.40 (2.24)	21.90 (1.00)	31.90 (0.50)	248.10 (3.84)	164.30 (4.63)	268.50 (2.52)
	15-30	26.70 (3.25)	15.40 (0.98)	21.20 (2.80)	208.70 (4.23)	126.50 (2.23)	210.30 (3.36)
MNP	0-15	41.40 (1.00)	29.50 (2.60)	36.70 (1.16)	388.90 (1.18)	298.20 (1.12)	396.10 (4.28)
	15-30	18.90 (1.12)	16.40 (1.26)	16.80 (2.21)	246.70 (1.53)	225.30 (1.73)	238.30 (2.60)
LMNP	0-15	54.40 (3.63)	34.90 (1.35)	42.20 (2.30)	402.20 (1.64)	268.30 (3.26)	388.60 (2.28)
	15-30	23.10 (1.20)	19.90 (2.45)	19.40 (1.80)	282.10 (2.38)	256.80 (1.38)	267.60 (2.00)

Figures in parenthesis are standard deviations

Table 3. Correlations coefficients of mineral N, MBC and MBN for the field and incubation studies

Parameter	Soil depth	Maize growth stages			Incubation period (days)		
		seedling	tasseling	maturity	30	120	240
Min N vs. MBN	0-15 cm	0.133	-0.199	0.129	0.888**	.899**	0.884**
	15-30 cm	0.691	0.036	-0.034	0.825*	.947**	0.953**
Min N vs. MBC	0-15 cm	-0.356	-0.529	0.065	0.595	0.763*	0.783*
	15-30 cm	0.196	-0.391	0.008	0.896**	0.824*	0.873**
MBN vs. MBC	0-15 cm	0.805*	0.851**	0.841**	0.829*	0.927**	0.947**
	15-30 cm	0.239	0.769*	0.530	0.866**	0.946**	0.957**

Key:* - correlation significant at 0.05 level (2 tailed) ** - correlation significant at 0.01 level (2 tailed)

Table 4. Correlation coefficient of mineral N, MBN and MBN for the field and incubated soil

Parameter	Soil depth	Seedling vs.60 days of incubation	Tasseling vs. 180 days of incubation	Maturity vs. 240 days of incubation
Mineral N	0-15 cm	-0.618	-0.447	-0.072
	15-30 cm	-0.575	-0.424	-0.219
MBN	0-15 cm	0.486	0.516	0.557
	15-30 cm	-0.147	0.794*	0.631
MBC	0-15 cm	0.712*	0.750*	0.780*
	15-30 cm	0.465	0.678	0.815*

*correlation significant at 0.05 level (2 tailed) ** - correlation significant at 0.01 level (2 tailed)

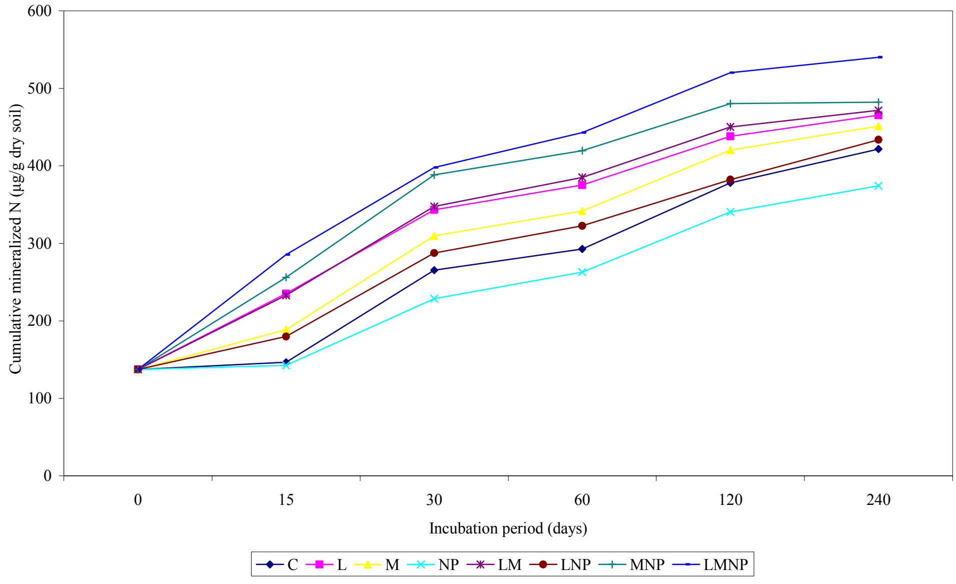

Figure 1. Cummulative mineral N (µg/ g dry soil) at the 0-15 cm depth

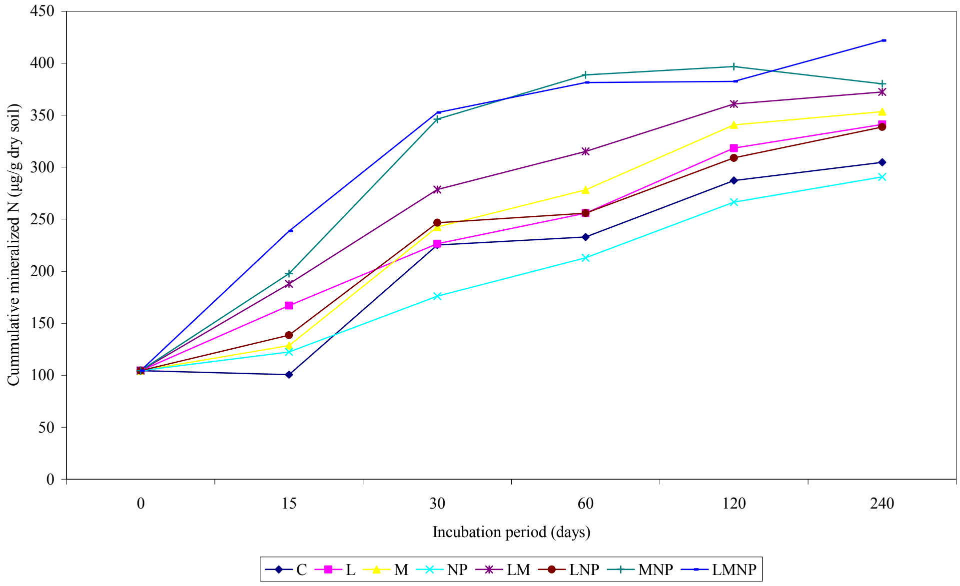

Figure 2. Cummulative Mineral N (µg g dry soil) at the 15-30 cm depth

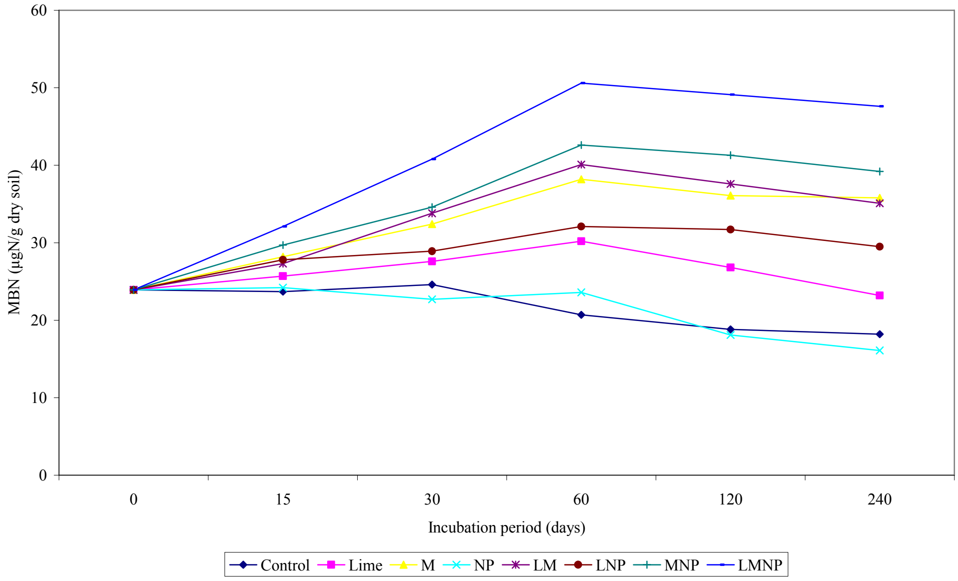

Figure 3. MBN (µg N/ g dry soil) at the 0-15 cm soil depth

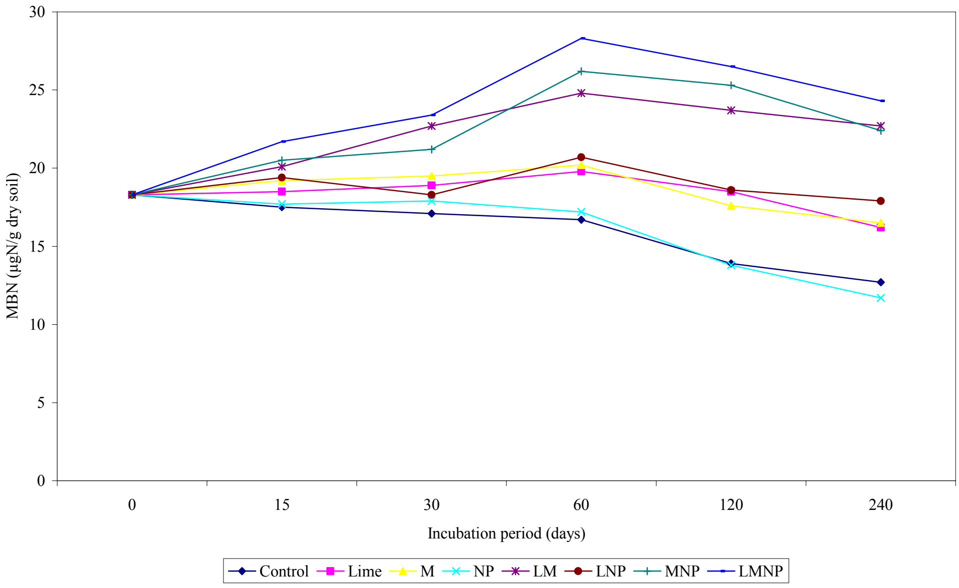

Figure 4. MBN (µg N/ g dry soil) at the 15-30 cm soil depth

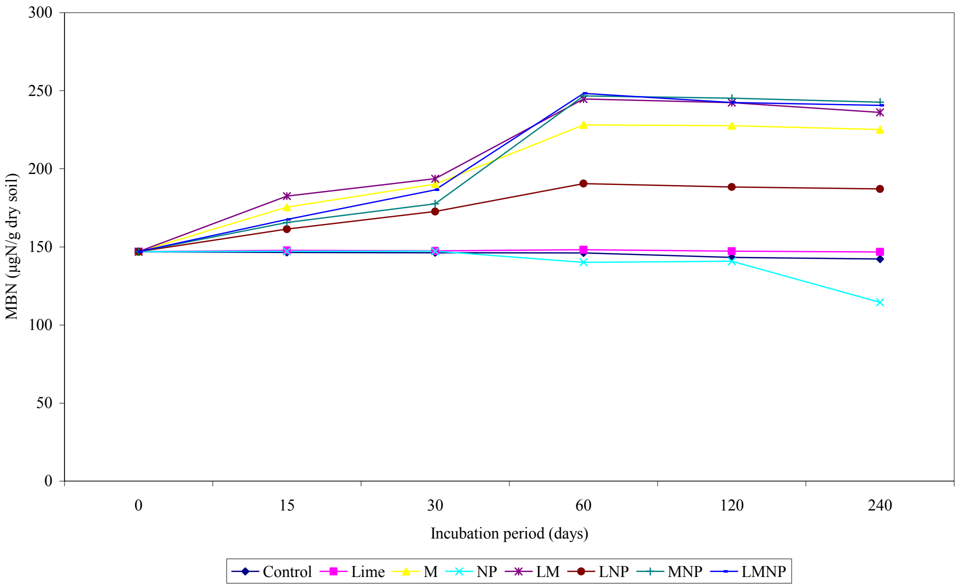

Figure 5. MBC (µg C/ g dry soil) at the 0-15 cm soil depth

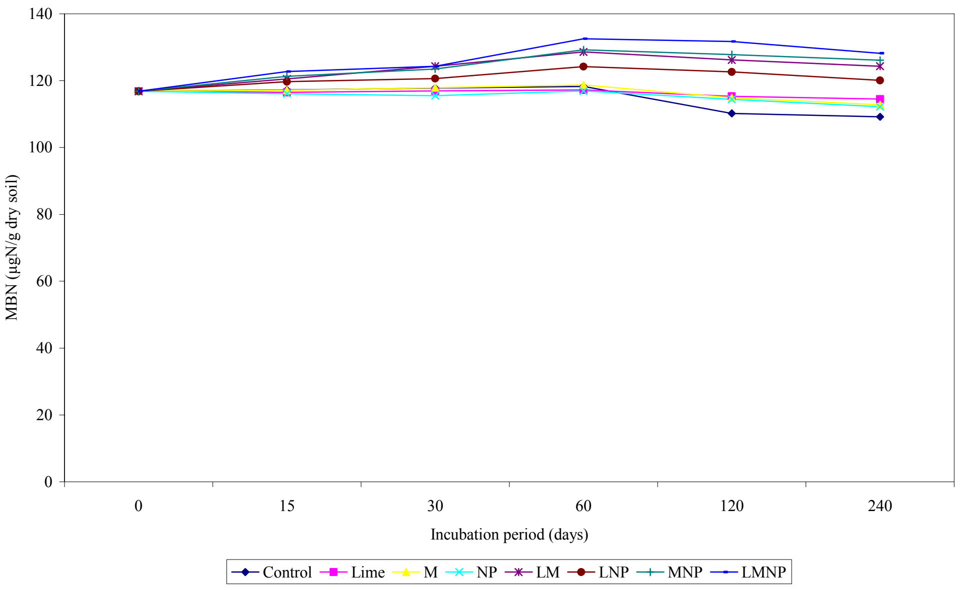

Figure 6. MBC (µg C/ g dry soil) at the 15-30 cm soil depth

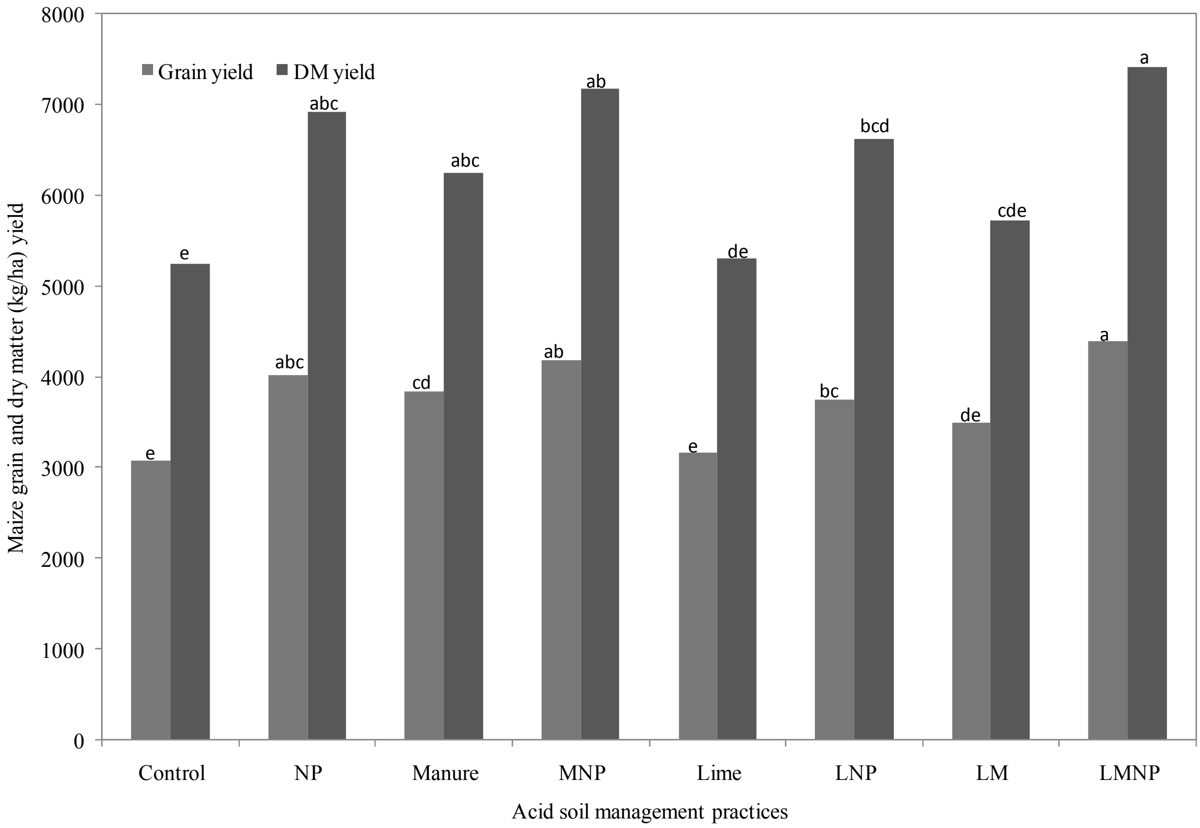

Figure 7. Means of maize grain and DM yield (kg/ha) as affected by the different treatments (means of 3 observations) Means of maize yield for each soil amendement followed by the same letter are not significantly different according to LSD mean separation procedure, P < 0.05

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Assessment of Plant Species Diversity at Pasir Tengkorak Forest Reserve, Langkawi Island, Malaysia

M.S. Abdul Hayat, Kamziah Abd Kudus (Corresponding author)
I. Faridah-Hanum, A.G. Awang Noor & M.Nazre
Faculty of Forestry, University Putra Malaysia
43400 Serdang, Selangor, Malaysia
Tel: 60-3-8946-7169 E-mail: kamziah@putra.upm.edu.my

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Abstract

Plant species diversity of a logged-over coastal forest within the Pasir Tengkorak Forest Reserve, Langkawi Island, Malaysia was assessed by establishing a 1-ha plot. All plants above 1.0 cm dbh (diameter of a tree at breast height), or 4.5 feet above ground level, the accepted point of diameter measurement for most trees were enumerated. Species diversity was defined as a combination of species richness and evenness. The jackknife estimate and species-area curve were applied to estimate the species richness. It was estimated using Simpson's index of diversity, Shannon-Weiner function and Brillouin index. Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness were also used to estimate species evenness. A total of 3414 individual trees representing 120 species, 81 genera and 31 families were recorded. Species with highest relative abundance were *Swintonia sp1* (0.12), *Garcinia eugnifolia* (0.09) and *Syzygium sp1* (0.05). The jackknife estimate of species richness was 132.9 and the regress ion equation to estimate species richness was $Ln\,\hat{S} = 2.53 + 0.24\ ln\ (A)$ with r^2 = 96.0 %. Species diversity was high with Simpson's index of diversity with a value of 0.96, while Shannon-Weiner index was 5.42 and Brillouin's Index was 5.14. However, Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness were 0.264, 0.378, and 0.419, respectively. Results indicated that species richness and species diversity were high, but evenness was low in this logged-over coastal forest.

Keywords: Coastal forest, Species richness, Diversity, Evenness

1. Introduction

Langkawi is located in the northern west coast of Peninsular Malaysia, bordering the south of Thailand -off the coast of Kedah and is made up of 99 islands when the tide is high and 104 islands when the tide is low. The largest of the islands is Pulau Langkawi with an area of about 478.5 sq km. The present study was conducted at Compartment 2, Machinchang Forest Reserve also known as Pasir Tengkorak Forest Reserve, Langkawi Island, Malaysia**.** Pasir Tengkorak Forest Reserve is a coastal forest with elevation not more than 300m a.s.l and located 40 km from Pekan Kuah, Langkawi and has been promoted as recreational forest and ecotourism destination.

Generally, tropical forests are known to have high species diversity. In Malaysia, biological diversity research has been carried out to assess species richness, diversity, similarity of various forest ecosystems (e.g. Faridah Hanum *et al.*, 2001a and 2001b, and Rusea *et al.*, 2001). This study was, therefore designed to explain variation in composition and diversity components of tree species in a 1-ha plot at Pasir Tengkorak Forest Reserve, Langkawi Island, Malaysia**.** Several statistical approaches were adopted as suggested by Krebbs (1999) to study species richness, species diversity, species similarity and species accumulation.

2. Materials and methods

2.1 Study area

The present study was conducted at Compartment 2, Machinchang Forest Reserve, Langkawi Island, Malaysia. Initial observation reveals that the forests show a predominance of species associated with the Indo-Burmese mainland and it is considerably due to altitude, soil and rock type. A 1-ha plot (i.e. 100m x 100m) was established at the elevation 130m a.s.l. within the Pasir Tengkorak Forest Reserve. The 1-ha plot was divided into 100 quadrats of 10m x 10m each.

2.2 Methods

In each quadrate, data were gathered from trees and shrubs with diameter at breast height (dbh) of 1.0 cm and above. Other parameters recorded were species name and height. Data collected were classified and analyzed to calculate species richness, species diversity, similarity and rank abundance. The species richness estimators were computed based on the Jackknife method, species diversity index were calculated using Simpson's Index, Shannon-Wiener Index and Brillouin's Index. The evenness indexes were measured by Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness. Density, frequency, basal area and their relative values and importance value index (IVI) of the tree species were also calculated following Mueller-Dombois and Ellenberg (1974).

2.2.1 Species richness

Species richness is one of the most important elements in biodiversity, because the number of species existing at a site is a quantitative measure of biodiversity and allows comparison with other sites. The Jackknife method and Species Area Curve Estimates were applied to estimate the species richness in the 1-ha plot.

The Jackknife method

A non-parametric approach to estimate species richness is given by the formula:

$$\hat{S} = s + \left(\frac{n-1}{n}k\right) \quad [1]$$

where $\hat{S}$ = jackknife estimate of species richness.
s = observed total number of species present in n quadrats.
n = total number of quadrats samples
k = total number of unique species.

Unique species is defined as the species that occur in only one quadrat.

Species area curve estimate

Species Area Curve plots the area examined with cumulative sampling area (x-axis) versus the total number of species found in the quadrate samplings (y-axis). The curve determines whether species richness is increasing or has leveled off in the sample. The point at which the species are curve estimate levels off is the point where additional sampling is yielding no additional information about the number of species.

Another method of estimating species richness discussed by Krebbs (1999) is to extrapolate the species-area curve for the community. A regression line is fitted and used to predict the number of species on a plot or any particular size. This method is useful only for communities that have enough data to compute a species-area curve, and so it could not be used on sparsely sampled sites.

Preston (1962) suggested that the species-area curve is a log-log relationship of the form:

$$log(S) = a + log(A) \quad [2]$$

where S = Number of species (= species richness)

A = Area sampled

a = y-intercept of the regression

2.2.2 Species diversity

Species diversity is the number of different species in a particular area (species richness) weighted by some measure of abundance such as number of individuals or biomass. The non-parametric measures of diversity proposed by this study are the Simpson's Index, the Shannon-Wiener Function and Brillouin's Index of Diversity. This index of diversity indicates the probability of picking two trees at random are different species. Higher values of the indices represent greater diversity.

Both Simpson's Index and the Shannon-Wiener Function indices are calculated using information about the proportion (p_i) of individuals in the total sample (N) that are represented by a given species (i) such that:

$$p_i = \frac{n_i}{N}$$

Simpson's index of diversity

The Simpson's Index is given by

$$D = \sum p_i^2 \quad [3]$$

where D = Simpson's index

p_i = Proportion of species i in the community

This probability is converted into a measure of diversity by using the complement of Simpson's original measure:

$$Simpson's\ index\ of\ diversity = \begin{pmatrix} \text{Prob of picking two organisms at} \\ \text{random that are diff species} \end{pmatrix}$$

$$= 1 - \begin{pmatrix} \text{Prob of picking two organisms} \\ \text{that are the same species} \end{pmatrix}$$

Thus,

$$1 - D = 1 - \sum (p_i)^2 \quad [4]$$

where $(1 - D)$ = Simpson's index of diversity

p_i = Proportion of individuals of species i in the community

Simpson's index ($1 - D$) ranges from 0 (low density) to almost 1($1 - 1/s$).

Shannon-Wiener index of diversity

Measures of species diversity can also be estimated based on information theory. This uncertainty can be measured by the Shahnon-Weiner function:

$$H' = \sum_{i=1}^{s} (p_i)(\log_2 p_i) \quad [5]$$

where H' = Information content of sample (bits/individual)

= Index of species diversity

s = Number of species

p_i = Proportion of total sample belonging to i^{th} species

Information content is a measure of the amount of uncertainty, so that the larger the value of H', the greater the uncertainty. The Shannon-Weiner measures H' increases with the number of species in the community and in theory can reach very large values. In practice, for biological communities H' does not seem to exceed 5.0 (Washington 1984). The theoretical maximum value is log (S), and the minimum value (when $N > S$) is log [$N/(N - S)$] (Fager 1972).

Brillouin's index of diversity

In any case in which data are assume from a finite collection and sampling is done without replacement, the appropriate information-theoretic measure of diversity is Brillouin's formula:

$$\hat{H} = \frac{1}{N} \log \left(\frac{N!}{n_1! n_2! n_3! \ldots} \right) \quad [6]$$

where $\hat{H}$ = Brillouin's index

N = Total number of individuals in entire collection

n_1 = Number of individuals belonging to species 1

n_2 = Number of individuals belonging to species 2

Any base of logarithm may be used. If base 2 logs are used, the units of H are bits per individual. The Brillouin's index is like the Shannon function in being most sensitive to the abundance of rare species.

For further reading on heterogeneity measures see Krebbs (1999).

2.2.3 Species evenness

Another measure of species diversity is the species richness, which is the relative abundance with which each species is represented in an area. The Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness are discussed in this paper. Those indices are discussed in details in Krebbs (1999).

Simpson's measure of evenness

For Simpson's measure of heterogeneity, maximum diversity is obtained when all abundances are equal ($p = 1/S$), so in a very large population:

$$\hat{D}_{MAX} = \frac{1}{s}$$

where $\hat{D}_{MAX}$ = Maximum possible value for Simpson's index (eq. [3])

s = Number of species in the sample

It is concluded from this formula that the maximum possible value of the reciprocal of Simpson's index (*1/D*) is always equal to the number of species observed in the sample. This leads to the definition of Simpson's index of evenness as:

$$E_{1/D} = \frac{1/\hat{D}}{s} \qquad [7]$$

where $E_{1/\hat{D}}$ = Simpson's measure of evenness

$\hat{D}$ = Simpson's index (eq. [3])

s = Number of species in the sample

The index ranges from 0 to 1 and is relatively unaffected by the rare species in the sample.

Camargo's index of evenness

Camargo (1993) proposed an index of evenness that is unaffected by species richness:

$$E' = 1.0 - \left(\sum_{i=1}^{s} \sum_{j=i+1}^{s} \left[\frac{|p_i - p_j|}{s}\right]\right) \qquad [8]$$

where E' = Camargo's index of evenness

p_i = Proportion of species *i* in total sample

p_j = Proportion of species *j* in total sample

s = Number of species in total sample

This index, like Simpson's, is relatively unaffected by the rare species in the sample.

Smith and Wilson's index of evenness

Smith and Wilson (1996) proposed an index of evenness based on the variance in abundance of the species. The index is defined as:

$$E_{var} = 1 - \left[\frac{2}{\pi \arctan\left\{\sum_{i=1}^{s}\left(\log_e(n_i) - \sum_{j=1}^{s} \log_e(n_j)/s\right)^2 / s\right\}}\right] \qquad [9]$$

where E_{var} = Smith and Wilson's index of evenness

n_i = Number of individuals in species *i* in sample (*i = 1, 2, ..., s*)

n_j = Number of individuals in species *j* in sample (*j = 1, 2, ..., s*)

s = Number of species in entire sample

According to Smith and Wilson, this is the best index of evenness because it is independent of species richness and is sensitive to both rare and common species in the community.

3. Results and discussion

(Note 1)

A total of 3414 individual trees representing 120 species, 81 genera and 31 families were recorded within the 1-ha study site. Species with highest relative abundance were *Swintonia sp1* (0.12), *Garcinia eugnifolia* (0.09) and *Syzygium sp1* (0.05). Fig. 1 shows the relative abundance of plant species in the 1-ha plot.

3.1 Species richness

The non-parametric Jackknife method was applied to estimate the species richness. Analysis was conducted using software (*ECOMETH; http://www.ExeterSoftware.com*).

(Note 2)

Result shows that the Jackknife estimator of species richness tends to overestimate the number of species observed in the 1-ha plot with an estimated number of 132.9 species. This study also discovered that there exist 13 unique species occurring, in only one quadrate (Table 1).

(Note 3)

Fig. 2 shows that the slope of the species area curve for the 1-ha study site declined as sample area increased but did not approach an asymptote. Using equation [2], the resulting regression equation is *Ln* $\hat{S}$ = *2.53 + 0.24 ln(A)* with r^2 = 96.01%. The estimated linear regression line is also plotted in Fig. 2.

3.2 Species diversity

(Note 4)

Analysis using equation [4] indicated that Simpson's index of diversity was 0.96, which suggests that diversity is high in the 1-ha plot. The Shannon-Weiner index of species diversity (equation [5]) was=5.61. This value exceeds the maximum value assumed for *H'* (i.e. *log S*), but this is not surprising since the forest area is highly diverse (referring to the result from Simpson's index of diversity). The estimate of the Brillouin's Index (equation [6]) was 5.50. These results are similar to those obtained by using Shannon-Weiner function (equation [5]). No decision has been made on which function is a better measure. In practice, this argument is irrelevant to field ecologist because both indices are almost identical for most ecological samples when *N* is large (Krebbs 1999).

3.3 Species evenness

(Note 5)

Results showed that the Simpson's measure of evenness (equation [7]) was 0.219; while Smith and Wilson's index of evenness (equation [8]) based on the variance of abundance of the species was 0.325. Similarly, Smith and Wilson's index of evenness (equation [9]) was estimated as 0.303. All the results suggest that evenness was low in the 1-ha plot at the Pasir Tengkorak Forest Reserve.

3.4 Analysis of vegetation

(Note 6)

Total density and basal area for the 10 most dominant species, were respectively 1812 trees ha^{-1} and 21.32 m^2 ha^{-1} in the 1-ha plot. *Swintonia sp1* was found to be the most dominant with the highest IVI index (46.8) followed by *Syzygium sp1* (36.3) and *Garcinia eugnifolia* (25.2) (Table 4).

(Note 7)

The distribution of dbh classes conformed to reverse 'j' shape curve, with 86.5% of trees having dbh between 1-10cm, 305 trees (8.9%) having dbh between >10-20cm, followed by 4.6% trees in the dbh class >20-100cm. There were about 25 trees with a diameter greater than 50 cm (Table 5).

4. Conclusion

The non-parametric Jackknife method was applied to estimate the species richness. The diversity estimated using Simpson's index of diversity, Shannon-Weiner function and Brillouin index for the 1-ha plot was high and the evenness index was low ranging from 0.2 – 0.3. The evenness is considered high when it varies near value of 1. Although the two evenness measures result in different index of evenness, the Smith and Wilson's index of evenness is more preferred because it is independent of species richness and is sensitive to both and rare common species in the community (Krebs 1999).

The highest score for abundance rank was *Swintonia sp1* (0.12), *Garcinia eugnifolia* (0.09) and *Syzygium sp1* (0.05). These three species were the most common ones found in each subplot. The relative abundance functions as an estimate of diversity at one point in time and location or knowing what species are present at a given location. This is common way for diversity measure by measuring the number and relative abundance of species in an ecosystem (Gaines *et al.*, 1999).

Anacardiaceae and Myrtaceae families were the most common species and widespread all over the country. However, Myrtaceae family was commonly found in the coastal beach, while Anacardiaceae was commonly found at the lowland forest. Myrtaceae has centers of diversity in Australia, Southeast Asia, and tropical to southern temperate America, but has little representation in Africa (Peter *et al.*, 2001**)**, so it is very common species in the coastal beach area and has relative highest abundance.

Both above-mentioned families showed the highest basal area, with 7.34 m^2 ha^{-1} 6.7534 m^2 ha^{-1}, respectively, consisting most of the unmatured trees. Unmatured trees react as a regeneration part and may be viewed as an early indicator of forest recovery. It was shown that regeneration of the 1-ha plot was considerably high, with lack of supervision from local enforcement. The generation sapling will be degraded by human activities because Pasir Tengkorak Forest Reserve is well known as recreational forest.

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Table 1. Jackknife estimate of species richness

Total number of species	120
Jackknife estimates of species richness	132.9
Standard deviation	3.89
95% confidence limit	125.1 to 140.6
Number of unique species	13

Table 2. Diversity indices at the 1-ha plot at Pasir Tengkorak Forest Reserve.

Measures of heterogeneity	**Index**
Simpson's index of diversity	0.962
Shannon-Wiener index of diversity	5.607
Brillouin's index of diversity	5.501

Table 3. Evenness indices at the 1-ha plot at Pasir Tengkorak Forest Reserve.

Measures of evenness	**Index**
Simpson's measure of evenness	0.219
Camargo's index of evenness	0.325
Smith and Wilson's Index of Evenness	0.303

Table 4. Analysis of vegetation within the 1-ha plot at Pasir Tengkorak Forest Reserve.

Species name	D(tree ha^{-1})	F	BA	RD	RF	RBA (%)	Mean HT (m)	IVI
Swintonia sp1	411	83	7.34	12.04	10.63	24.13	7.32	46.80
Garcinia eugnifolia	299	88	1.56	8.76	11.27	5.14	5.34	25.17
Syzygium sp.1	180	69	6.75	5.27	8.83	22.22	7.84	36.33
Barringtonia sp.	149	62	0.36	4.36	7.94	1.19	5.41	13.49
Callophyllum sp1	124	40	0.76	3.63	5.12	2.49	6.35	11.24
Knema sp.1	124	57	0.45	3.63	7.30	1.47	4.80	12.40
Pentace sp.1	111	52	1.92	3.25	6.66	6.30	7.35	16.21
Antidesma sp.1	90	35	0.15	2.64	4.48	0.49	4.18	7.61
Ardisia sp.1	87	45	0.12	2.55	5.76	0.39	4.27	8.70
Messua sp.1	85	61	1.08	2.49	7.81	3.56	6.89	13.86
Diosspyross sp.	81	46	0.38	2.37	5.89	1.26	5.69	9.52
Memecylon sp.1	71	43	0.46	2.08	5.51	1.51	6.88	9.10
Others	1602	100	9.07	46.92	12.80	29.84	-	89.57
Total	3414	781	30.39	100	100	100		300.0

D = Density, F = Frequency, BA = Basal Area, RD = Relative Density, RF = Relative Frequency,
RBA = Relative Basal Area, IVI = Importance Value Index

Table 5. Distribution of different classes of trees and percentages of distribution.

Dbh class (cm)	**No. of trees**	**%**
1 - 10	2954	86.53
>10 - 20	305	8.93
>20 - 30	99	2.90
>30 - 40	22	0.64
>40 - 50	9	0.26
>50 - 60	17	0.50
>60 - 70	2	0.06
>70 - 80	1	0.03
>80 - 90	3	0.09
>90 - 100	2	0.06
Total	3414	100

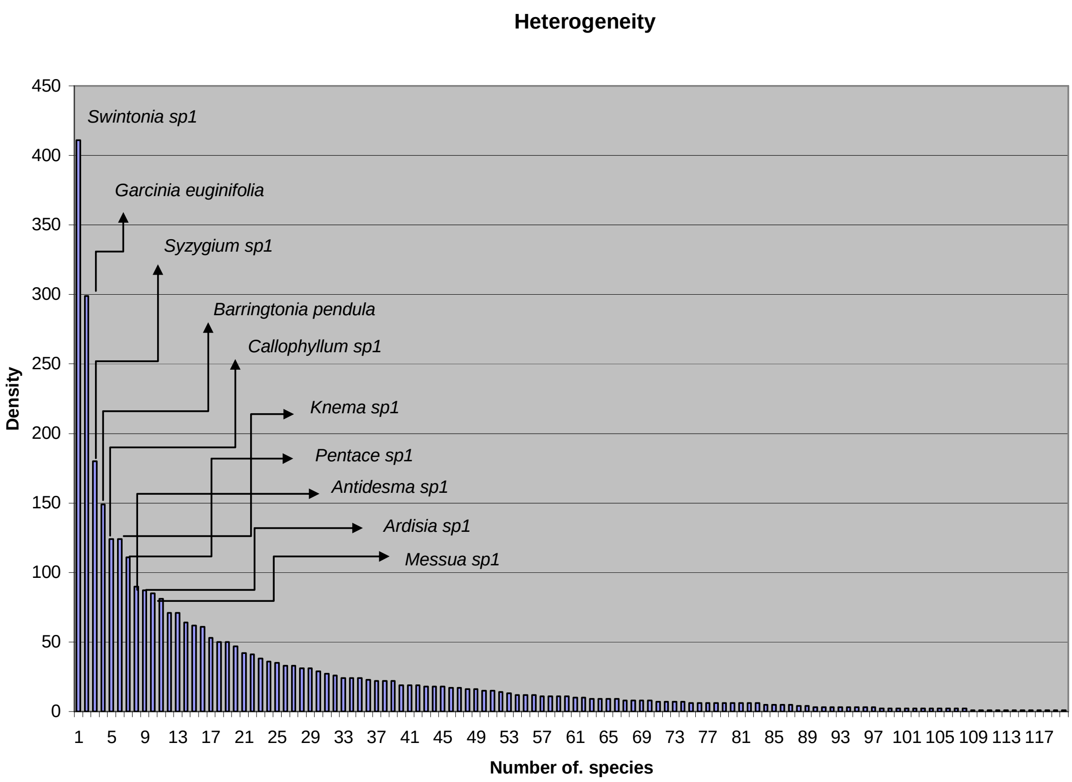

Figure 1. Heterogeneity in 1-ha plot at Pasir Tengkorak Forest Reserve

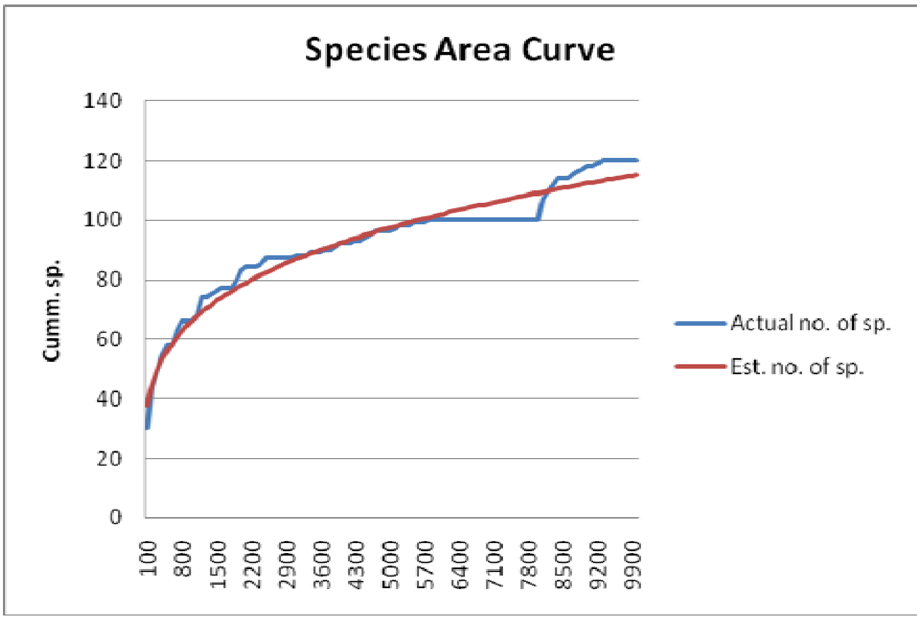

Figure 2. Species area curve estimate

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Rice Husk Biochar for Rice Based Cropping System in Acid Soil 1. The Characteristics of Rice Husk Biochar and Its Influence on the Properties of Acid Sulfate Soils and Rice Growth in West Kalimantan, Indonesia

Agusalim Masulili
Pancabhakti University
Jl. Kom Yos Sudarso, Pontianak, West Kalimanatan, Indonesia

Wani Hadi Utomo (Corresponding author)
Center for Soils and Land Resources Management, Brawijaya University
Jl. Veteran, Malang 65144, East Java, Indonesia
Tel: 62-341-553-623 E-mail: hadi_utomo@hotmail.com

Syechfani MS
Center for Soils and Land Resources Management, Brawijaya University
Jl. Veteran, Malang 65144, East Java, Indonesia

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Abstract

The experiments were carried out to study the characteristics of biochar made from rice husk and its potential as a soil amendment in acid soils. Biochar was produced by pyrolysis; after which it was applied as a soil amendment. The soil was incubated for 30 days, and then it was planted with rice. For comparison, soil was applied with: rice straw, rice husk, rice husk ash, *Chromolaena odorata* biomass, and no soil amendment. The characteristics of biochar were: water content 4.96%, pH 8.70, C 18.72%, P 0.12%, CEC 17.57cmol kg^{-1}, K 0.20%, Ca 0.41%, Mg 0.62%, and Na 1.40%. Application of biochar decreased soil bulk density, soil strength, exchangeable Al, and soluble Fe and increased porosity, available soil water content, C-organic, soil pH, available P, CEC, exchangeable K, and Ca. Out of these improvements, only soil carbon, phosphorus, exchangeable Al, soluble Fe, and soil strength significantly influenced rice biomass.

Keywords: Biochar, Soil amendment, Rice straw, Soil strength, CEC

1. Introduction

Increasing food production both to meet in-country requirements and to help the world overcome food crises is one of the major issues facing Indonesia today. However, good productive land is limited and has mostly been utilized either for food crop production or other uses. The only available land for agricultural expansion is that of acid sulfate soil, having a total area of about 6.7 millions ha and is spread out in Sumatera, Kalimantan, and Papua (Widjaja-Adi *et al.*, 1992). These soils have a high iron sulfate mineral content of predominantly Pyrite, and when the soil is drained it will release sulfuric acid, which in turn will release Fe, Al, and other heavy metals that are dangerous for plants and other living organisms. When these soils are used for rice, Moore (1990) found that the most important constraints were: (i) acidity (which includes the combined effects of pH, Al toxicity, and P deficiency), and (ii) Fe stress (which is due to the combined effects of Fe toxicity and deficiencies of other divalent cations such as Ca).

The acid sulfate soil in Sungai Kakap, West Kalimantan has been utilized for intensive rice growing since 1980. Thus, in addition to the above problems, growing rice in these lands faces the problem of soil compaction due to intensive tillage with puddling and removal of biomass continuously. Measurement prior to the conduction of the experiment showed that soil organic matter in these soils was less than 0.9%. In this soil, organic matter is very important because in addition to being a source of plant nutrition, organic matter is the major source of negative charge, which is important for helping the soil to adsorb cations in the soil solution (Ponamperuma, 1982)

A common treatment to reduce the solubility of Al, Fe and other heavy metals in soil is to increase the soil pH, which is mostly done by liming (Ahmad and Tan, 1982; Hakim *et al*., 1989; Haby, 2002). The ability of liming to increase soil pH, decrease Al and Fe solubility, and increase crop yield is widely known (Shamshuddin and Auxtero, 1991; Haby, 2002; Kadery, Brown *et al*., 2008). In Indonesia, the source of lime materials exists mostly in Java, which is far from the location where the liming needs to be done. Furthermore, liming only treats the symptoms of acid sulfate soils rather than the cause (Thomas *et al.*, 2003); therefore, the beneficial effects of liming are short lived, and it has to be done repeatedly (Shamsuddin *et al.*, 1998). This makes liming very expensive and it is often un-economic for small farmers to obtain lime materials.

The other treatment suggested for improving the properties of acid sulfate soil is the application of organic matter (Kaderi, 2004; Shamsuddin *et al*., 2004). With negative charge provided by carboxyl compounds, organic matter is able to minimize toxicity by decreasing the solubility of heavy metals in the soil solutions. Positive effects of organic matter application on the properties of acidic soils, such as increasing soil pH and CEC, and decreasing heavy metal toxicity, have been reported elsewhere (see Hesse, 1982; El Sharkawi *et al*., 2006). Organic matter is easy to find locally and is relatively cheap, especially if the organic matter used is the un-harvested biomass of the crop itself.

For rice-based cropping systems, the use of rice straw and rice husk has been practiced for a long time (Ponamperuma, 1982; Eagle *et al*., 2000; Singh *et al*., 2008; Kaewpradit *et al*., 2009). The advantages and drawbacks of burning vs incorporation of rice straw in rice growing have been discussed by Williams *et al*. (1972). Sitio *et al*. (2007) used rice husk ash (RHA) for the improvement of rice growth and yield in the peat soil of Sumatra. Karmakar *et al*. (2009) studied the effect of application of fly ash, rice husk ash, and paper factory sludge on the growth and yield of rice in the acid lateritic soil of India. They showed that the application of these industrial wastes improved soil properties by decreasing soil bulk density and increasing soil pH, organic carbon, available nutrients, and rice yield. The ability of rice husk and rice husk ash to remove heavy metals from the system has also been shown by Mahvi *et al*. (2005). Again, the main limitation in using such organic matter is the easiness of these materials to be decomposed, and therefore its application must be done repeatedly from year to year. On the other hand, there is now competition in biomass utilizations with the emergence of demand in the sectors of energy resources and animal feeding. In addition, decomposition and mineralization of organic matter has been attributed as one of the major sources of global warming due to emissions of methane and nitrous-oxide (Rondon *et al*., 2007)

Lately, looking the recalcitrant of C-organic in a black carbon material which is also known as biochar, many scientists interested in using this black carbon material as a soil amendment (Glasser *et al.*, 2002; Topolianz *et al.*, 2007; Woolf, 2008). Although there are still some objections (Ernsting and Smolker, 2009; Senjen,2009), a lot of experimental results have indicated that biochar applications can improve soil properties (Lehman *et al.,* 2003; Liang *et al.*, 2006; Chan *et al.*, 2007) and increase crop yield (Yamato *et al.*, 2006; Chan *et al.*, 2008). Chan *et al.* (2007) showed that biochar application had improved some physical soil properties, such as increased soil aggregation, water holding capacity, and decreased soil strength. An increase in saturated hydraulic conductivity of upland rice soil with biochar application has been reported by Asai *et al.* (2009). Furthermore, Chan *et al.* (2007) also showed that the application of biochar could increase soil organic carbon, soil pH, and CEC. The increase of CEC with the application of biochar has also been shown by Liang *et al.* (2006).Yamato *et al*. (2006) showed that the application of biochar made from *Acacia magnum* could increase soil pH, Ca, base saturation, and CEC and decrease Al^{+} saturation. Novak *et al.* (2009) showed that the application of biochar in the acidic coastal soil of the Southern US could increase soil pH, soil organic matter, Mn, and Ca and decrease S and Zn. On this sandy soil, the application of biochar did not significantly influence the CEC of the soil. The increase in soil biological activity has been reported by Rondon *et al*. (2007) for nitrogen fixation in *Phaseolus vulgaris* L. and by Chan *et al*. (2008) for earthworm and microbial biomass.

The increase in crop yield with biochar application has been reported elsewhere for crops such as cowpea (Yamato *et al.,* 2006), soybean (Tagoe *et al.*, 2008), maize (Yamato *et al.*, 2006; Rodríguez *et al.*, 2009), and upland rice (Asai *et al*., 2009). Haefele (2007) and Haefele *et al*. (2008) discussed the possibility of biochar applications for rice-based cropping systems. Reichenauer *et al*. (2009) applied biochar in tsunami-affected paddy fields in Sri Lanka, and the experimental results showed that the application of 2 t rice-husk-charcoal ha^{-1} increased the grain yield from less than 4 t ha^{-1} for the control treatment to more than 5 t ha^{-1} for the biochar treatment.

The objective of the works reported here was to study the characteristics of biochar produced from rice husk grown in acidic soil and its potential to improve the properties and productivity of acid sulfate soils and the growth of lowland rice in West Kalimantan, Indonesia.

2. Materials and methods

2.1 Production and characterization of biochar

To ensure that the rice husk had come from the acid sulfate soil of West Kalimantan, Indonesia, we harvested it directly the rice from the field and then brought it for rice milling to get the rice husk. The rice husk was then put in a piece of pyrolysis apparatus which consisted of a stainless reactor of 500 mm length with a 15 cm inside diameter. The rice husk was then heated externally by an electric furnace (5000 W) to a temperature of 600 ^oC. The reactor for the biochar production is presented in Figure 1.

The Biochar was ground to pass through a 0.50 mm sieve. The Biochar moisture content was measured by oven drying a sub sample of 2 g at a temperature of 80 ^oC for 24 hours. Biochar characterization was done according to the method described by Ahmedna *et al.* (1997). The bulk density was determined by filling a 10 ml tube with dry ground biochar. The tubes were capped, tamped to a constant volume, and weighed. Bulk density was calculated by dividing the weight of the dry sample with the volume of the packed materials.

To measure the pH, 1% suspensions of biochar were prepared by diluting the biochar with de-ionized water. Then they were heated to about 90 ^oC and stirred for 20 minutes to allow the dissolution of the soluble biochar components. The suspensions were then cooled to room temperature, after which the pH was measured with a pH-meter (Jenway 3305). Total C determination was done using the method described in ASTM D 3176 (ASTM, 2006). Total P was read with a spectrometer (Vitatron) and Ca, Mg, Na, and Si were measured using AAS (Shimatzu)

2.2 Experimental setup

A glass house experiment was set up to study the effect of rice husk biochar on rice growth. The soil used was collected from the experimental station of BPTP West Kalimantan in Sungai Kakap. Soil samples were collected from depths of up to 20 cm, and then dried, ground, and passed through a 2.0 mm sieve. 5 kg of ground soil was then put in a plastic pot with an inside diameter of 30 cm. The organic soil amendments used were:

(1) No soil amendment, as the control (Co)

(2) Rice Straw (RS), 15 t ha^{-1}

(3) Rice husk (RH), 15 t ha^{-1}

(4) Rice husk ash (RHA), 10 t ha^{-1}

(5) Rice husk biochar (RHB), 10 t ha^{-1}

(6) *Chromolaena odorata* (Chr), 15 t ha^{-1}

These six treatments were arranged in Fully Randomized Design with 4 replications. The amount of soil amendment applied was calculated based on the surface area of the plastic pot, and the amendments were mixed to a 20 cm depth, after which they were incubated at water content close to the field capacity for 30 days.

Rice straw, rice husk, and *Chromolaena odorata* were chopped and ground, and rice husk ash and rice husk biochar were ground and passed through a sieve with a 2.0 mm diameter. *Chromolaena odorata* is a bush plant which grows extensively in West Kalimantan. At the end of incubation, soil strength was measured with a hand penetrometer (Daikie) to a depth of 15 cm, then 2 undisturbed samples of about 50g were taken for bulk density and soil water determination; and a disturbed sample of about 100 g was taken for chemical properties analysis.

Twenty day old rice seedlings were transplanted to this incubated soil. The rice plants were grown as lowland rice, and they were fertilized with 135 kg N ha^{-1}, 72 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}. The plants were harvested at 45 days after planting, and measurements were done for plant height, number of tillers, productive tillers, and total dry mass.

2.3 Soil Analysis

Particle size analysis was performed by the pipette method (Soil Survey Laboratory Staff, 1992), and soil bulk density was determined by the clod method as described by Blake and Harke (1986)

Total porosity was calculated from the soil water content (v/v) at a matrix potential of 0 kPa, and available soil water was calculated by subtracting the soil water content at a matrix potential of -33 kPa (field capacity) with that at a matrix potential of –15 MPa (wilting point). The soil water content at these matrix potentials was determined using pressure plate apparatus.

Soil pH was measured in 1:2.5 ratio soil solutions (with de-ionized water) with a pH meter (Jenway 3305). The Walkley and Black wet oxidation method was used to determine organic C content (Soil Survey Laboratory Staff, 1992). Total N content was measured by the Kjeldhal method (Bremner and Mulyaeny, 1982). Exchange Al^{3+} and Fe^{2+} were extracted with 1M KCl (Barnhisel and Bertsch, 1982). The CEC was extracted with 1M NH_4Oac (buffered at pH 7.0), and exchangeable base concentrations were measured using AAS (Shimatzu).

3. Results and discussion

3.1 Characteristics of the biochar

The analytical results presented in Table 1 show that biochar made from rice husk grown in acidic soil had slightly alkaline properties with a pH of 8.7, relatively higher than that of rice husk ash. Compared to rice straw and rice husk, rice husk ash and rice husk biochar had a higher elemental Ca, Mg, and Na, but a lower content of C-organic. Thus burning rice husk, either by pyrolysis which produces biochar, or directly fire burned rice husk which produces rice husk ash, decreases organic carbon in the materials. Rice husk biochar had a CEC of 17.57 cmol kg^{-1}, and this was much higher than that of rice husk ash.

A comparison of rice straw and rice husk shows that, except in C-organic content, both materials have relatively similar properties. The C-organic content of rice husk was relatively higher than that of rice straw. Except in C-organic content, which is lower than in that of rice straw, the properties of soil amendment made from *Chromolaena* is about the same as those of amendments made from rice straw and rice husk.

3.2 Soil properties

Applications of organic soil amendments improve some of the physical properties of acid sulfate soil of West Kalimantan (Table 2). Bulk Density (BD) decreased from 1.24 Mg m^{-3} in the control experiment to 1.14 Mg m^{-3} in the rice straw treated soil. The BD of the soil treated with rice husk biochar was 1.17 Mg m^{-3}, which is not significantly different to that of soil treated with the rice straw soil amendment. The decrease of soil bulk density with the organic soil amendment application in this treatment could be explained as being a result of the incorporation of the soil which has a relatively high BD (1.24 Mg m^{-3}) and a lower density of organic soil amendment (less than 1.00 Mg m^{-3}). However, looking at the total soil porosity and available soil water (Table 2), it is un-doubtable that the decrease in soil bulk density of the soil treated with organic soil amendment was, at least partly, due to the formation of soil aggregate.

The increase in soil porosity with soil aggregation, which in turn will decrease soil bulk density, has been discussed elsewhere (see for example, Harris *et al.*, 1966). This process will increase total porosity, and at the same time will increase soil water retention (Sharma and Uehara, 1968). Since water retention in micro pores (equal to a matrix potential of –15 MPa) is relatively constant, this process will increase the available soil water. The result in Table 2 shows that application of organic soil amendment increases total soil porosity from about 40% (control) to more than 50% in all treated soil. The increase in total soil porosity was followed by the increase in available soil water from 11.34% for untreated control soil to 15.47% for rice husk biochar treated soil.

As a consequence of the formation of soil pores by aggregation and a decrease in soil bulk density, soil strength, which was measured as the resistance of the soil to penetration, will decrease (Goodman and Ennos, 1999). In untreated control soil with a soil bulk density of 1.24 Mg m^{-3}, the penetration resistance was 500 Nm^{-2} decreasing to 390 Nm^{-2} in rice husk ash treated soil. The penetration resistance of rice husk biochar treated soil was 393.34 Nm^{-2}. This is not significantly different from that of rice husk ash treated soil. The decrease of soil strength with application of biochar has also been observed by Chan *et al*. (2007) for hard settling soil in Australia.

The effect of rice husk biochar and other soil amendments on the chemical properties of acid sulfate soil in West Kalimantan is presented in Table 3. In general, application of organic soil amendments significantly improved the chemical properties of acid sulfate soil. There was an increase in soil organic matter content, soil pH, and CEC and a decrease in exchangeable Al and soluble Fe. The results in Table 3 also show that application of organic soil amendments increased the content of P, K and Ca, but did not significantly influence the amount of Mg and Na. The highest CEC, P and K were observed in soil treated with rice husk biochar, but did not significantly different from that of treated with rice husk ash.

Rice husk ash and rice husk biochar had a high pH (Table 1); therefore, it is reasonable that the soil treated with rice husk biochar and rice husk ash also had a high pH. This result indicated that rice husk biochar could be used as a substitution for lime materials to increase the pH of acidic soils. The increase in CEC of the soil with organic soil amendments would probably be due to the negative charge arising from the carboxyl groups of the organic matter. The increase in CEC and soil pH with the addition of organic matter has been shown elsewhere (see Bot and Benites, 2005). Biochar has a high CEC (see Table 1), and with its high recalcitrance (Glaser *et al.*, 2002), it is reasonable that soil applied with biochar had the highest CEC. An increase in soil CEC with the application of biochar has also been shown by Chan *et al*. (2007)

The decrease in exchangeable Al and soluble Fe in rice husk biochar and other organic soil amendments is undoubtedly due to the increase of CEC in the soil. The results in Table 3 show that exchangeable Al and soluble Fe decreases as CEC increases. The improvement of the soil's physical properties, especially soil aggregation, might also contribute to the lowering of Fe in lowland rice. This soil structure improvement will make the soil condition more oxidative so the solubility of the Fe decreases.

The increase in elemental plant nutrients P, K, and Ca is as a result of addition of plant nutrients in the organic soil amendments as has been suggested by Ponamperuma (1982). For the P nutrient, however, this increase could have also been as a result of increasing the soil pH due to rice husk ash or rice husk biochar application. It is interesting to note that, although the C-organic content in rice husk biochar is lower than that of rice straw or rice husk, the highest level of soil organic matter was observed in rice husk biochar tretaed soil. This phenomenon indicated the recalcitrance of

C-organic in rice husk biochar as has been suggested by many researchers (e.g. Glasser *et al*. 2002; Lehman *et al.,* 2003; Rondon *et al*., 2007)

3.3 Rice growth

The improvement of the soil's physical and chemical properties due to rice husk biochar and other organic soil amendment applications was followed by the improvement of the growth of rice planted in this acid sulfate soil (Table 4). Plant height, number of tillers, number of productive tillers, and total dry biomass of rice grown in organic amendment treated soils were significantly (p=0.05) higher compared to that of un-treated soil.

The highest number of tillers was obtained by rice husk biochar treatment. However, from a total dry biomass point of view, soil treated with Chromalaena amendments produced the highest yield with 76.5 g per plant, although it does not significantly differ to that produced by the rice husk biochar amendment.

There were many factors contributing to the improvement of this rice growth, and these factors can work either individually or simultaneously. Indeed, the decrease in exchangeable Al and soluble Fe would have been important factors for this growth improvement. The contribution of elemental plant nutrients from the organic soil amendments, especially P, would have also had an important effect. As shown by the results given in Table 3, application of organic soil amendments increased the available P, K, and Ca in the soil; however, the influence of the soil's physical improvement, especially the increase in soil macro pores and the decrease in soil strength can not be neglected.

From looking at an individual correlation analysis, there was a significant correlation between the rice biomass yield with soil organic matter content (r = 0.836), total P (r = 0.834), exchangeable Al (r = -0.864), soluble Fe (r = - 0.913) and soil strength, Qp (r = - 0.814). Thus rice biomass increased with increasing soil organic matter content and total P, and decreased with decreasing exchangeable Al, soluble Fe, and soil strength. Multiple regression analysis of these factors with rice biomass yielded a regression equation of:

$$\textbf{Rice biomass} = -1660.5 - 454.31\textbf{C} + 13001.71\textbf{P} - 45.20\ \textbf{Al} + 218.00\ \textbf{Fe} - 2.81\textbf{Qp}$$

4. Conclusion

The experimental results of biochar made from rice husk grown in acid sulfate soil and other organic soil amendment applications significantly improve some properties of the acid sulfate soil of West Kalimantan, Indonesia, namely: decreasing soil bulk density, soil strength, exchangeable Al, and soluble Fe, and increasing soil pH, soil organic matter, total P, CEC, exchangeable K, and exchangeable Ca.

The improvement of soil properties with organic soil amendment applications resulted in an improvement of rice growth as shown by an increase in plant height, number of tillers, and dry biomass. A significant negative correlation occurred between dry biomass and exchangeable Al, soluble Fe, and soil strength; and a significant positive correlation occurred between dry biomass, soil organic matter, and total P.

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Table 1. The characteristics of rice husk biochar and 4 other soil amendments

Properties	Rice straw	Rice husk	RHA	RHB	Chromolaena
Water content (%)	12.2	11.26	6.74	4.96	13.3
BD (Mg m^{-3})	-	-	0.96	0.84	-
pH	-	-	8.4	8.7	-
C (%)	33.4	43.77	5.09	18.72	28.55
N (%)	0.35	0.32	0	0	0.46
P (%)	0.1	0.07	0.06	0.12	0.13
CEC (cmol kg^{-1})	-	-	6.7	17.57	-
K (%)	0.1	0.12	0.16	0.2	0.1
Ca (%)	0.12	0.27	0.33	0.41	0.18
Mg (%)	0.18	0.16	0.21	0.42	0.15
Na (%)	0.42	0.6	1.26	1.4	0.67

Table 2. Effect of rice husk biochar and other soil amendments on the physical properties of acid sulfate soils of West Kalimantan, Indonesia

Soil amendments	BD (Mg m^{-3})	Total pore (% v/v)	Available water (% v/v)	Penetration resistance (N m^{-2})
Control	1.24 b	44.43 a	11.34 a	500.00 c
Rice straw	1.14 a	52.07 b	15.35 c	403.35 b
Rice Husk	1.16 a	52.10 b	13.76 abc	410.24 b
Rice Husk Ash	1.15 a	54.21 b	14.64 bc	390.00 a
Rice Husk Biochar	1.17 a	53.16 b	15.47 c	393.34 a
Cromolaena	1.19 ab	47.30 ab	12.46 ab	403.30 b

Means followed by the same letters at each column are not significantly different (P = 0.05)

Table 3. Effect of rice husk biochar and other soil amendments on the chemical properties of acid sulfate soils of West Kalimantan, Indonesia

Soil amendments	pH	C (%)	total P (%)	CEC	K	Ca	Mg	Na	Al (%)	Fe (%)
				(cmol kg-1)						
Before exp [1)]	3.75	0.78	0.25	6.84	0.19	0.34	3.31	0,31	3.31	3.04
Control	3.36 a	0.54 a	0,21 a	6.64 a	0.20 a	0.24 a	3.55	0.2	3.84c	3.61 c
Rice straw	3.68 ab	3.58 cd	0.30 ab	7.32 bc	0.22 ab	0.23 a	3.45	0.24	3.42abc	3.34 b
Rice husk	3.96 b	3.73 cd	0.31 b	7.20 ab	0.34 bc	0.45 b	3.43	0.22	3.47abc	3.22 ab
Rice husk ash	3.98 b	2.78 b	0.27 ab	7.79 bc	0.43 cd	0.44 b	3.56	0.25	3.57 bc	3.34 b
Rice husk biochar	4.40 c	4.09 d	0.32 b	8.03 c	0.51 d	0.44 b	3.57	0.32	2.96 a	3.10 a
Chromolaena	4.06 bc	3.22 bc	0.29 ab	7.15 ab	0.25 ab	0.22 a	3.45 NS	0.27 NS	3.31ab	3.28

Means followed by the same letters at each column are not significantly different (P=0.05)

1) Soil properties before experiment

Table 4. Effect of rice husk biochar and other soil amendments on the growth of rice growing on acid sulfate soils of West Kalimantan, Indonesia

Soil amendment	plant height (cm)	Number of tillers	Number of productive tillers	Total dry biomass (g)
Control	75.17 a	9.00 a	5.00 a	29.53 a
Rice straw	85.67 b	12.00 b	7.33 b	50.93 b
Rice husk	84.00 b	14.33 bc	8.00 b	64.97 bc
Rice husk ash	78.33 a	14.00 bc	8.00 b	57.87 b
Rice husk biochar	86.17 b	17.33 d	9.67 c	75.93 c
Chromalaena	85.00 b	15.00 cd	10.00 c	76.50 c

Means followed by the same letters at each column are not significantly different (P=0.05)

Figure 1. The reactor pyrolysis for producing rice husk biochar

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The Influence of Drying Temperature on the Hygroscopicity of Rubberwood *(Hevea Brasiliensis)*

Hueishing Sik (Corresponding author) & Khengten Choo
Forest Products Division, Forest Research Institute Malaysia
Kepong, 52109 Selangor Darul Ehsan, Malaysia
Tel: 60-3-6279-7402 E-mail: sik@frim.gov.my

Sarani Zakaria, Sahrim Ahmad, Maisarah Yusoff & Chinhua Chia
Faculty of Science and Technology, Universiti Kebangsaan Malaysia
43600 Bangi, Selangor Darul Ehsan, Malaysia
Tel: 6-03-8921-3261 E-mail: sarani@ukm.my

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Abstract

The influence of drying temperature on the hysteresis effect of rubberwood is determined in this study. Results showed reductions in sorption capacity of rubberwood dried at high temperatures as compared to the control conventional temperature dried material at respective corresponding set conditions. The reduction of the hygroscopicity of rubberwood is a combined effect of both physical, morphological structure and chemical composition as affected by the drying temperature. This improvement is found to be primarily attributed to the (i) hysteresis effect enhanced by increased drying temperature, (ii) loss of hygroscopic hemicelluloses, and (iii) rearrangement/ degradation of amorphous cellulose content in the cell wall.

Keywords: High temperature drying, Relative humidity, Sorption, Dimensional stability, Hysteresis, X-ray diffraction analysis

1. Introduction

Hevea brasiliensis or rubber trees of Euphorbiaceae family were introduced into Malaysia more than a century ago. Currently, it is of economic importance to the wood-based furniture manufacturing sector. Malaysia timber industry has been for more than two decades, a major export earner, of which more than 70% of the furniture exported is derived from this important and yet sustainable resource material.

Wood is often subjected to treatments at elevated temperatures in many kinds of processing activities such as drying, pulping, production of wood composites and etc. The extent of the effect of temperature on the physical, structural and chemical properties of wood depends on time of treatment, atmosphere, pressure, water content and state of distribution (Fengel and Wegener 1989). Drying is an important process in the manufacturing of wooden products such as joinery and furniture components where minimum warping, low drying stress and uniform moisture distribution are required. An effective drying practice will render suitable kiln-dried material for further processing into quality end-products, which in turns give minimum or negligible problem that may arise during service. According to Choo and Hashim (1994), rubberwood is a relatively fast drying lumber. It is reported that boards of 25mm thickness take approximately 6-8 days to dry to 8-10% from an initial green moisture content of about 60%. Final dry bulb temperature (DBT) setting for rubberwood drying is approximately 65.5°C for rubberwood of less than 50mm thickness (Choo and Hashim 1994).

Generally, wood is a hygroscopic material which will readily takes up moisture and swells when exposed to a wetter condition, or expels moisture and shrinks into a smaller dimension when subjected to a condition of lower humidity until equilibrium is reached. The dimensional stability properties of a particular wood are important to reduce incidences of undesirable or excessive 'movement' which, could results in severe warping in finished product during service. The dimensional stability of wood can be enhanced through wood modification, involving either the chemical reaction through heat treatment or chemical treatment (Rowell 2004). Chemical modifications in wood structure occurring at high temperature has improved several physical structures resulting in reduced shrinkage and swelling, low equilibrium moisture content, enhanced weather resistance, better decay resistance and etc (Yildiz and Gumuskaya 2007).

The application of drying method also influences the dimensional stability of wood (Bekhta and Niemz 2003). Drying at high temperature tends to lower the equilibrium moisture content of wood. Drying at high temperature is accomplished at dry-bulb temperatures of 100°C or higher, usually from 110°C to 121°C (Boone 1983). This drying regime has been mentioned as a time and cost saving processing practice in view of the escalating cost of production in the wood-based manufacturing sector. High Temperature (HT) drying of softwoods such as plantation grown radiata pine and other southern pines has long been practised in countries like Australia, New Zealand and in the United States. However, HT drying of tropical hardwoods is still unknown in Malaysia and other tropical hardwoods producing regions. Dehumidification system and steam-heated, forced-air drying system (conventional kiln) are used in Peninsular Malaysia to dry rubberwood, with the latter being the more preferred system (Anonymous 1982) and still accounts for more than 90% of the kiln drying practice in the country. The high temperature regime had been mentioned as a tool in reducing drying time, resulting in lower inventory costs and smaller plant sites (Milota 2000). The application of high temperatures in artificial drying greatly reduces the sorption capacity of wood (Kollmann and Schneider 1963) and hence, wood that has been exposed to high temperatures is less hygroscopic (Kininmonth 1976).

Sorption consists of both adsorption and desorption processes. When wood attained its equilibrium moisture content (EMC) at any given relative humidity (RH) from a higher or lower RH, the adsorption and desorption isotherms form a “loop” and the difference in moisture content is call hysteresis (Kollmann and Cote 1984). Adsorption involves the attraction of water molecules to hydrogen bonding sites present in cellulose, hemicellulose and lignin. According to Hirai *et al.* (1972), the crystallinity of wood cellulose, when heated increases initially and decreases as the heating time extended. The increased of the width of cellulose crystallite and crystallinity during the initial stage of heating in the range of 120-160°C was observed and then remained constant (Hill 2006), while decrease of crystallinity after 160°C was reported (Roffael and Schaller 1971). Increase in crystallisation could be due to the loss of hemicellulose, the most hygroscopic component of the wood (Hill 2006).

In this study, the sorption hysteresis of rubberwood dried at high temperatures is compared to the control samples dried at conventional temperature. Besides, its relation to the cellulose crystallinity and hemicellulose content will be investigated.

2. Materials and Methods

2.1 Drying Procedure

Rubberwood logs from 25-30 year-old rubber trees of RRIM 600 clone were obtained for this study. Sawn furniture dimensional stock of 30mm (T) x 100mm (W) x 600 mm (L) were prepared for the HT drying runs at dry bulb temperatures (DBTs) of 100°C, 120°C, 130°C, 140°C and 150°C. While the DBT for control conventional drying run was set at 60°C. The drying runs were conducted in a laboratory experimental kiln and the respective DBT settings were maintained throughout each experiment. All test pieces were dried from the green condition (with initial moisture content at an average of 68%) until the average moisture content for each drying run was reduced down to approximately 6% based on estimated oven-dried weight.

2.2 Sorption hysteresis study

After drying, the rubberwood specimens were fine dressed to a thickness of 3mm and cut to a standard length of 50mm and width of 100mm (Figure 1). The specimens were then exposed to a series of seven sets of EMC conditions (Table 1) in a Tabai Espec Corp. Temperature and Humidity Chamber (model SH 641), with constant humidity-temperature settings as tabulated. The exposure tests were conducted in two stages, i.e. the first stage investigated the adsorption behaviour of dried samples at a series of set EMC conditions from 8% to 20% EMC. Whereas, the second stage assessed the desorption behaviour of the dried samples from 20% EMC down to 8% EMC condition. During each respective EMC step, the individual samples will be weighed periodically until constant weight is achieved, before proceeding to the next set condition. At the end of testing, the test specimens were oven-dried at 103 ± 2ºC for calculation of the EMC [equation 1] of the rubberwood attained at respective EMC conditions. Moisture exclusion efficiency (MEE) [equation 2] of rubberwood treated at high temperatures is calculated based on the EMC obtained by the control samples.

$$\text{EMC (\%) attained} = [(M_b - M_a)/\ M_a \times 100\% \qquad (1)$$

Where,

EMC = Equilibrium moisture content attained by rubberwood

M_a = Oven dry weight

M_b = Weight attained at equilibrium

$$MEE\ (\%) = \frac{MC\ (control) - MC\ (High\ temperature\ dried)}{MC\ (control)} \times 100\% \quad (2)$$

Where,

MEE = Moisture exclusion efficiency

MC = Moisture content of wood

2.3 X-ray diffraction analysis

Specimens for X-ray diffraction (XRD) analysis were obtained from the same matched sample (Figure 1) board used for hygroscopic study. XRD specimens of 20mm x 20mm wide measured at 2mm thickness at two different layers acquired from each dried test samples. The first layer (L1) was measured from the wood surface to 2mm deep into the specimen and the second layer (L2) was obtained at another 2mm deep adjacent to the first layer (Figure 1). The crystallite size of cellulose was estimated from the full width at half maximum (FWHM) according to the Scherrer equation [equation 3].

$$D = 0.9\lambda/(\beta_{1/2}\cos\ \theta) \quad (3)$$

where D is the crystallite size; λ is the X-ray wavelength; $\beta_{1/2}$ is the angular width at half maximum intensity of the diffraction peak; θ is the angular position of the diffraction peak.

2.4 Analysis of holocellulose and alpha-cellulose content

Determination of holocellulose content of rubberwood after drying at respective temperatures was based on analytical method for pulp chemistry by Wise *et al.* (1946). The alpha-cellulose content was determined based on TAPPI standard methods (TAPPI T 203 os-74 1994).

3. Results and discussions

3.1 Sorption hysteresis of rubberwood

The mean EMC values of rubberwood dried respectively at control conventional and high temperatures after achieving equilibration with respective set EMC conditions in both adsorption and desorption processes, are presented in respective error bar charts at 95% confidence level (Figure 2.1-7 and Figure 3.1-7). The EMC values were calculated using equation (1).

Generally, the reductions in sorption capacity of rubberwood dried at high temperatures as compared to the control conventional temperature dried material were observed during adsorption process (Figure 2.1-7) and desorption process (Figure 3.1-7) in the sorption study. Several researchers reported that HT dried wood is less hygroscopic (Espenas 1971; Price and Koch 1980), with lower EMC value compared to wood which has been dried using conventional method (Calvert 1958). Hygroscopicity of wood decreases as degree of thermal degradation increases was reported (Seborg *et al.* 1953)

ANOVA has been performed to test the significance of the overall experimental effect, i.e. temperature effect in this case study, though it is unable to show which treatment groups differed. Hence, in addition to ANOVA, Post Hoc Test (PHT) which is based on *pairwise comparisons* that are designed to compare all different combinations of the treatment groups (Field 2000) is carried out.

Analysis of variance (ANOVA) showed that the overall experimental effect was highly significant ($P< 0.001$) for mean values of all temperature groups against the various set EMC conditions during both sorption processes, except for mean values attained at 8% EMC condition during desorption process (Figure 3.1) with significant level, $P> 0.05$ at 95% confidence level. PHT showed that EMC values of control samples (60°C) attained at 8%, 10%, 12%, 14% and 16% EMC condition during adsorption are significant ($P<0.01$) compared to respective HT groups. While at 18% and 20% EMC condition during adsorption, the control samples showed significant differences ($P< 0.05$) compared to all HT groups except for 100°C-dried samples. On the other hand, ANOVA showed that the temperature effect on EMC values attained during desorption at 8% EMC condition are not significant at 95% confidence level for all temperature groups. Nonetheless, PHT showed that at higher humidity range from 49% to 90%, the EMC values of control samples are significant compared to all HT treatment groups except for 100°C-dried samples during desorption at 10% EMC condition.

PHT showed that temperature treatment affected the adsorption and desorption behaviour of rubberwood differently especially among the HT treatment groups. The reduction in hygroscopicity of rubberwood was enhanced as the drying temperature increases. In addition, rubberwood dried at 130°C have generally equilibrated with the lowest EMC over the relative humidity range (37% to 90% @ 30°C) tested during adsorption, while it attained the lowest EMC except at 8% and 16% EMC conditions during desorption compared to the rest of the drying runs. PHT showed that these reductions as observed in 130°C rubberwood are significant compared to control, 100°, 120°C and 140°C over the relative humidity range of 37% to 68% during adsorption process. Whereas, reductions in adsorption recorded in 130°C-dried rubberwood over the higher relative humidity range of 77% to 90% are significant ($P< 0.05$) compared to the control, 100°C and 120°C-dried samples. This distinct finding will be further discussed under the of X-ray diffraction and holocellulose content analysis. Generally, the reductions of desorption capacity are not significantly different between the HT treatment groups at least up to 150°C (100°C-150°C). PHT showed The EMC values did not differ significantly ($P> 0.05$) between 120°C, 130°C, 140°C and 150°C- dried samples during desorption at 12%, 14%, 16% and 20% EMC conditions. Whereas, the EMC values as indicated by PHT, did not differ significantly ($P> 0.05$) between 120°C, 130°C and 140°C- dried samples during desorption at 10% and 18% EMC conditions. Overall, the differences in hygroscopicity due to HT treatment were more distinct during adsorption as compared to the desorption process of rubberwood, similar to an earlier observation during heat treatment of hardwood species as reported by Chang and Keith (1978).

The EMC values attained during adsorption are comparatively lower than the desorption process at corresponding set EMC conditions. This trend agrees with the general observation of hysteresis effect recorded during the adsorption and desorption of various materials including wood. This effect may have been accentuated by the increased temperatures employed in the study as reflected by the relatively lower EMCs attained by rubberwood samples dried at high temperatures compared to the conventional temperature dried material(Figure 2.1-7 and Figure 3.1-7).

The reduction in EMC as a result of wood modification has been reported in terms of a parameter referred to as the moisture exclusion efficiency (MEE) (Hill 2006). The dimensional stabilisation through temperature treatment can be gauged using the MEE based on equation (2). The MEE (%) of HT dried samples were presented in Table 2. In this study, the positive MEE values attained has indicated that the HT drying is effective in reducing the sorption capacity of rubberwood. For a specific humidity, MEE values generally increase for rubberwood which were subjected to higher temperature during adsorption process. This indicates that the HT drying is much more effective at reducing the moisture uptakes of rubberwood at all humidity levels.

3.2 X-ray diffraction and holocellulose content analysis

The X-ray diffractograms for the rubberwood dried at control conventional and high temperatures are shown in Figure 4.

A typical type I cellulose pattern with 002 peaks at 2θ of the diffractograms showed that the respective 002 peaks recorded in dried rubberwoods obtained from L1 layer of various drying temperatures remained in the same vertical alignment at the angular position of the peak. In addition, an increase of the sharpness of 002 peak can be observed as the drying temperature increased from control conventional temperature of 60ºC to 130ºC, and followed by a decrease after 130ºC. These findings are also reflected by the mean crystallite size determined for rubberwood obtained at L1 and L2 layers that were dried at various temperatures as shown in Figure 5. In general, the cellulose crystallite size of L1 layers from various drying treatment temperatures was slightly higher than those of L2 layers due to a more intense temperature effect caused by direct heat contact. Moreover, the relatively small value deviations between the crystallite size determined at L1 and L2 layers indicated that the effect of temperature on the crystallinity of rubberwood are not just superficial, as the enhancement of the morphology properties of rubberwood can be observed at least up to 4mm deep into the L2 layer of the wood (Figure 5).

The increase in peak heights as shown in Figure 4 indicates increase in crystallisation. Increase in crystallisation could be attributed to loss of hemicelluloses and degradation/ rearrangement of amorphous cellulose content (Hill 2006). Therefore, the highest reduction in sorption capacity as observed in 130ºC–dried rubberwood (Figure 2.1-7 and 3.1-7) could be explained by its improved crystallinity, resulting in fewer hydrogen bonding sites as compared to other levels of temperature treatments employed in the study. According to Tjeerdsma *et al.* (1998), significant reduction in water adsorption of heat-treated wood could be attributed to the increase in the relative proportion of the crystalline cellulose, in which the hydroxyl groups are not easily accessible to water molecules.

Figure 6 showed the holocellulose (alpha-cellulose and hemicellulose) content of rubberwood dried at control conventional and high temperatures. The holocellulose content of all samples were not affected by the high temperatures which showed that rubberwood were quite thermally stable at least up to 150ºC. However, a slight decrease of hemicelluloses content of rubberwood was observed as treatment temperature increased from 120ºC to 150ºC. In high temperature dried material, Hinterstoisser *et al.* (1992) found an increase of hot water extractible carbohydrates that contained monosaccharides which served as units for the hemicelluloses, and was subsequently inferred by her as a decomposition of hemicelluloses. Due to their generally amorphous nature, hemicelluloses are non-crystalline, highly branched heteropolysaccharides (Sjöeström 1981; Fengel and Wegener 1984) and they contain the greatest proportion of accessible OH content of the cell wall and are less thermally stable than cellulose or lignin (Hill 2006).

Decomposition of the hemicelluloses, which is the most hygroscopic component in wood (Hill 2006) and/or coupled with the enhanced hysteresis effect after drying at high temperatures, could be the main reason for the decrease in moisture uptake of rubberwood dried at 140ºC and 150ºC despite a slight decrease of crystallinity/ mean crystallite size (Figure 4 and 5) compared to 130ºC. Lower higroscopicity of heat-treated wood is attributed to the irreversible structural changes of wood constutuents, such as the loss and chemical changes of hygroscopic hemicelluloses (Mitchell *et al.* 1953). On the other hand, conventional temperature and 100ºC dried rubberwood showed lower holocellulose content compared to those obtained at higher temperatures, which could be attributed to the longer exposure treatment time required to dry the timber down to the targeted MC. Treatment time has been reported as one of the important factors that influences the magnitude of the temperature effect on the physical, structural and chemical properties of wood (Fengel and Wegener 1989).

According to Obataya *et al.* (2002), the modification of lignin and of the lignin carbohydrate complex during the heat treatment of wood is responsible for the irreversible reduction of wood hygroscopic. Repellin and Guyonnet (2005) also suggested that structural modifications and chemical changes of lignin also play an important role in reduction of wood hygroscopicity besides the disappearance of hemicellulose adsorption sites that accompanies hemicellulose destruction. Hence, the findings of this paper will be enhanced with further study in relation to the chemical components changes aforementioned due to the influence of drying temperature.

4. Conclusions

The application of high temperature drying is found to be able to reduce the hygroscopicity of rubberwood compared to the conventional temperature dried material. Results showed reductions in sorption capacity of rubberwood dried at high temperatures as compared to the control conventional temperature dried material at respective corresponding set conditions. During both sorption processes, rubberwood dried at 130°C have equilibrated with the lowest EMC over the relative humidity range (37% to 90% @ 30°C) tested. These findings are explained by X-ray diffraction analysis, where an increase of the sharpness of 002 peak of type I cellulose pattern can be observed, as the drying temperature increased from control conventional temperature of 60ºC to 130ºC, and followed by a decrease after 130ºC. The reduction of the hygroscopicity of rubberwood is a combined effect of both physical, morphological structure and chemical composition as affected by the drying temperature. This improvement is found to be primarily attributed to the (i) hysteresis effect enhanced by increased drying temperature, changes in (ii) chemical composition i.e. loss of hygroscopic hemicelluloses, and (iii) morphological structure of the wood caused by rearrangement/ degradation of amorphous cellulose content in the cell wall, which led to the reduction in sorption capacity, hence better wood dimensional stability is expected.

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Table 1. Equilibrium moisture content (EMC) settings

*Relative Humidity @ 30 ºC	Set EMC Condition (%)
37	8
49	10
60	12
68	14
77	16
83	18
90	20

Note: *The EMC settings were based on the EMC curves for wood established by Building Research Establishment, Princes Risborough Laboratory and published by Timber Research and Development Association (TRADA).

Table 2. Moisture exclusion efficiency, MEE (%) of high temperature dried rubberwood

	Relative Humidity (%)						
Adsorption Process *	*37*	*49*	*60*	*68*	*77*	*83*	*90*
Drying Temperature (°C)	Moisture Exclusion Efficiency (%)						
100 ºC	11.8	10.1	9.6	7.1	4.7	4.1	2.4
120 ºC	16.8	16.4	15.5	12.5	6.1	6.1	3.6
130 ºC	26.2	24.1	22.0	19.0	16.4	16.7	12.6
140 ºC	21.5	15.0	13.9	12.3	12.0	10.2	9.5
150 ºC	24.8	21.1	17.8	14.7	12.9	10.8	9.9
	Relative Humidity (%)						
Desorption Process *	*90*	*83*	*77*	*68*	*60*	*49*	*37*
Drying Temperature (°C)	Moisture Exclusion Efficiency (%)						
100 ºC	8.0	4.7	5.5	6.8	7.9	8.2	6.9
120 ºC	10.4	6.3	7.5	9.0	9.2	9.7	8.6
130 ºC	9.8	7.4	8.6	11.0	9.5	11.5	10.9
140 ºC	9.6	6.6	8.2	9.8	10.3	11.2	10.6
150 ºC	8.3	5.5	7.3	9.4	9.7	9.3	9.6

Note: *All test carried out at constant set temperature of 30ºC.

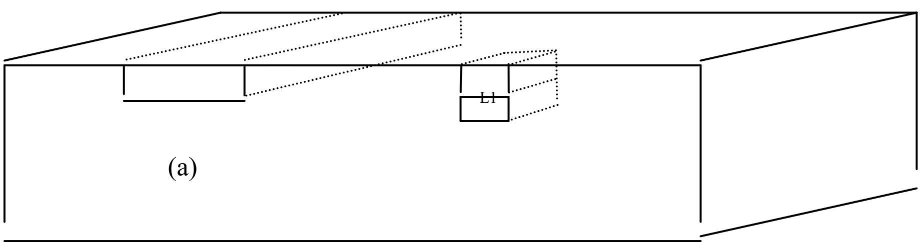

Figure 1. Sampling for analysis: Test specimens for (a) sorption study and (b) XRD analysis obtained from matched samples after drying at respective temperatures.

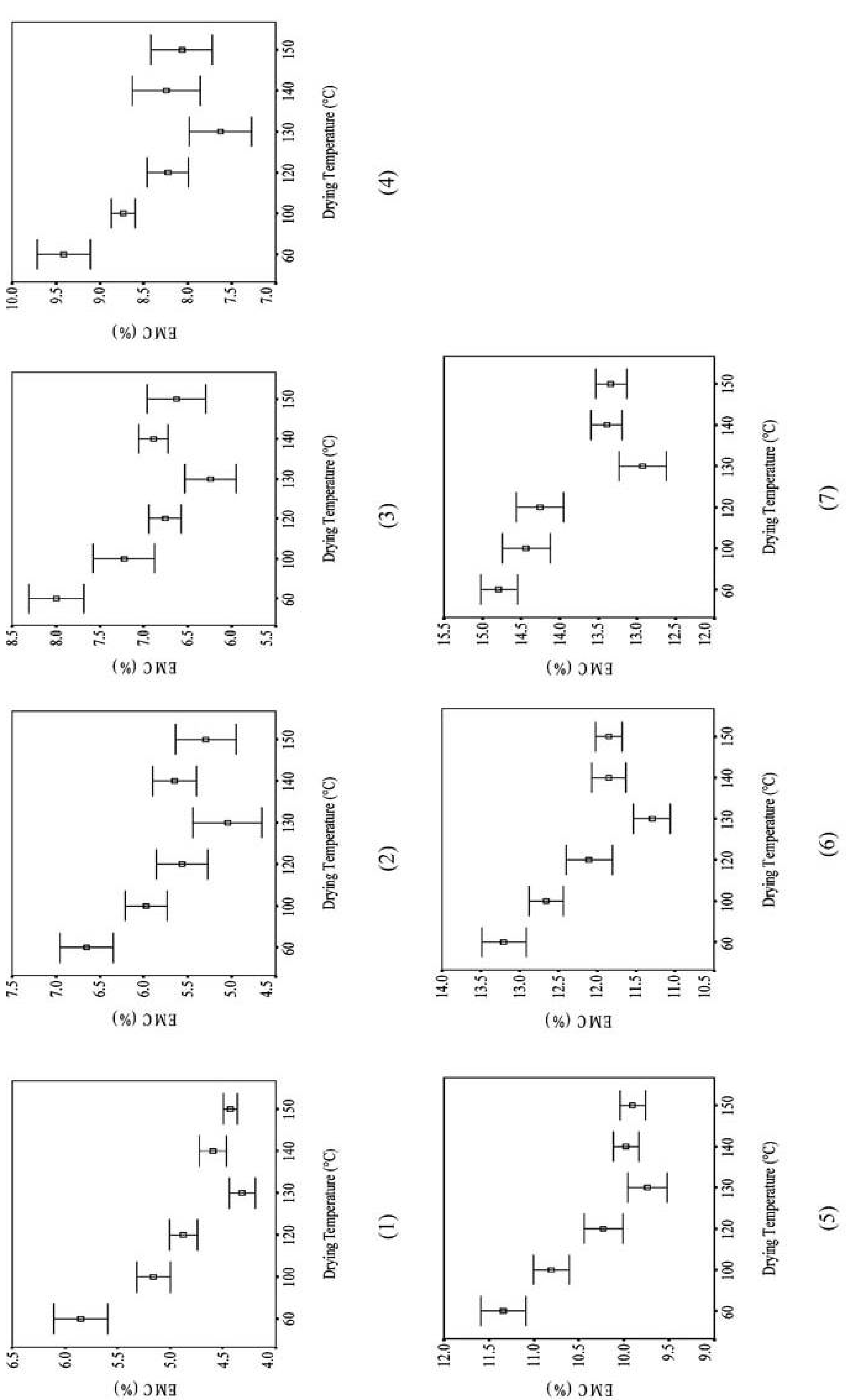

Figure 2. 1-7 Mean EMC value of conventional and high temperature-dried rubberwood with error bar at 95% confidence level, attained after conditioning at (1) 8%; (2) 10%; (3) 12%; (4) 14%; (5) 16%; (6) 18% and (7) 20% EMC conditions during adsorption process.

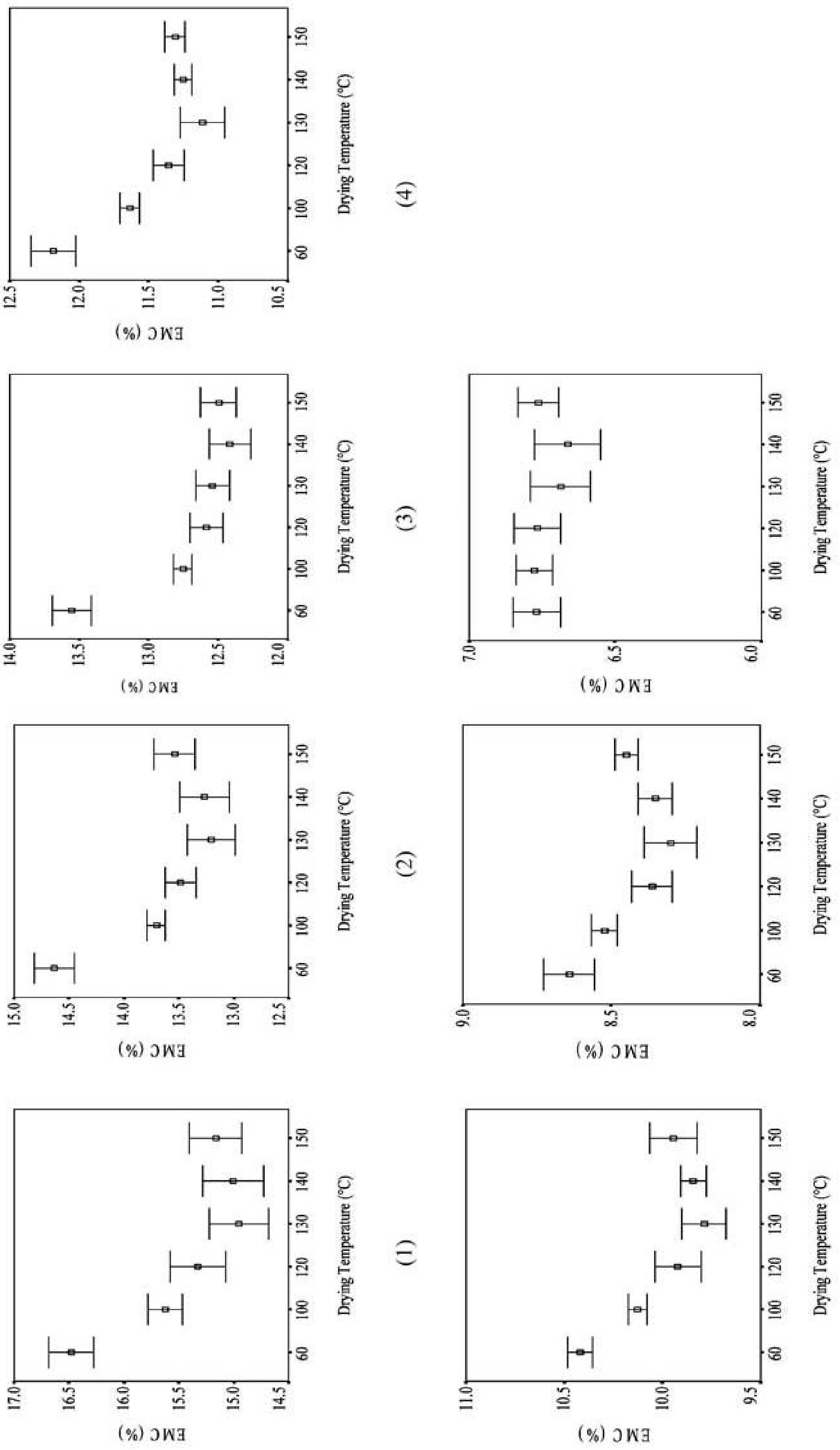

Figure 3. 1-7 Mean EMC value of conventional and high temperature-dried rubberwood with error bar at 95% confidence level, attained after conditioning at (1) 20%; (2) 18%; (3) 16%; (4) 14%; (5) 12%; (6) 10% and (7) 8% EMC conditions during desorption process.

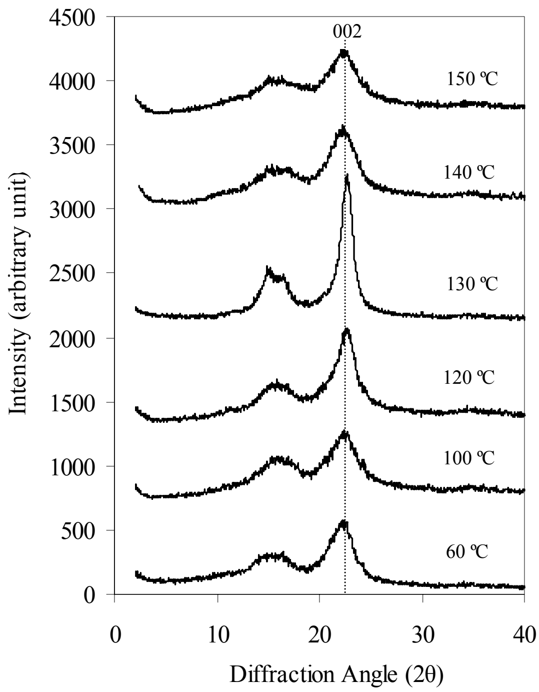

Figure 4. The X-ray diffractograms for the rubberwood samples dried at control conventional and high temperatures.

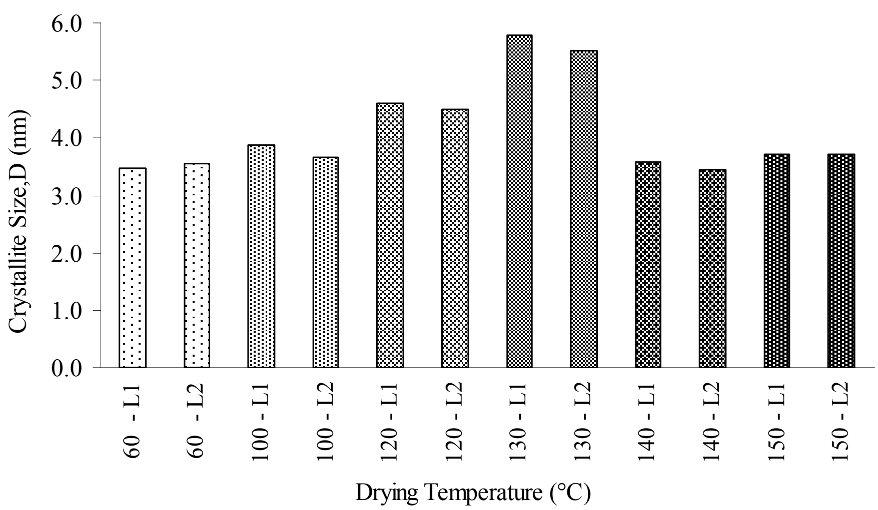

Figure 5. Mean crystallite size determined from the peaks of the 002 crystalline reflection of cellulose in rubberwood dried at control conventional and high temperatures. L1 and L2 are respectively the first and second layer from the wood surface.

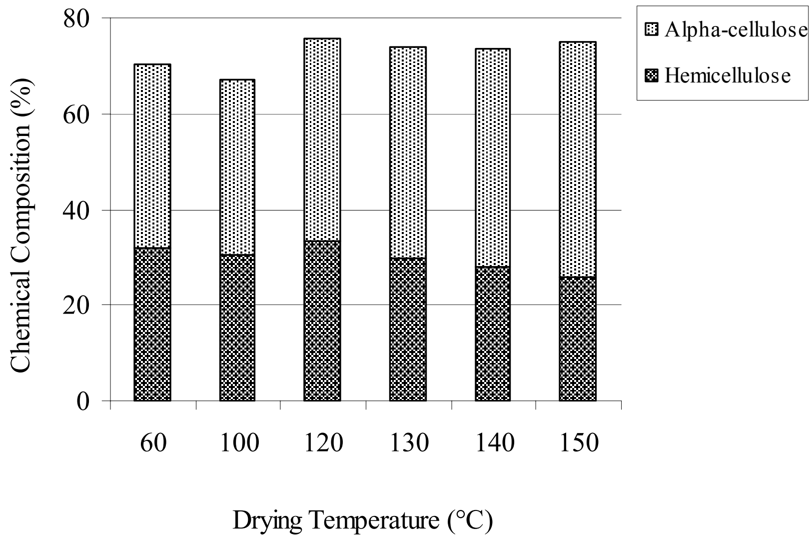

Figure 6. The holocellulose content of rubberwood dried at control conventional and high temperatures.

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Analysis of Profitability and Risk in New Agriculture Using Dynamic Non-Linear Programming Model

Rakesh Kumar Sharma (Corresponding author)
Department of Economics, Government College for Girls (RKMV)
Shimla 171001, Himachal Pradesh, India
Tel: 91-941-809-5808 E-mail: rakeshinshimla@yahoo.co.in

Prem Lall Sankhayan
Department of Ecology and Natural Resource Management (INA)
Norwegian University of Life Sciences (UMB), Box 5003, NO-1432 Aas, Norway

Ranveer Singh
Agro Economic Research Centre, Himachal Pradesh University
Summerhill, Shimla, Himachal Pradesh, India

Abstract

Cropping pattern in the Himalayan region of India has undergone a significant change in the recent past. Introduction of horticultural crops such as vegetables, fruits and flowers has led to more intensive agriculture. Such a change, resulting in higher incomes and improvements of the overall living conditions has, however, been accompanied with increased income risk. This emphasizes the need for proper analysis of the cropping pattern, at an appropriate scale, such as a micro watershed. This was achieved by constructing a dynamic non-linear programming model incorporating appropriate objective function, constraints and crop and livestock activity budgets along with risk component present in the gross returns. The model was then solved under alternate policy scenarios by using General Algebraic Modeling Systems (GAMS) for the next 20 years. The optimum cropping plans were then compared with each other and with the existing plan. Tomato and carnation are the preferred crops, if the sole objective is profit maximization. Optimum plan with risk consideration was also assessed by fixing the variance in gross returns at the current level. It reduced the area under tomato in rainy season by growing capsicum and beans. Similarly, peas replaced tomato in winter season and chrysanthemum replaced carnation. By comparing it with the existing plan, it can be inferred that the people are more concerned to risk than the profits. The profits and risks from floriculture are relatively very high as compared to other crops. By removing constraints in credit availability, irrigation facilities, transportation and market yards, large scale production of vegetables and flowers can help in raising the income level.

Keywords: Cropping pattern, Gross margins, Himachal Pradesh, Covariance

1. Introduction

Himalayan agricultural system is characterized by small landholdings and mixed crop-livestock farming practices (Tulachan & Neupane, 1999). Rain-fed terraced fields, often with high slope, result in low productivity of crops. Increasing human population is putting more pressure on arable land in the rural areas (Gohp, 2002). This calls for urgent attention on the part of planners and policy makers for devising strategy to raise income levels and to improve the human environment (Pokhriyal & Bist, 1998). Experience has shown that the state of substantial gains in crop and livestock production can be achieved through intensive farming, crop genetic improvement and better land management practices that help in the improvement of soil conservation and crop yields (Powell *et al.*, 2004). Though the mountain areas find it difficult to increase resource use efficiency due to fragility and relative isolation, the subsidies and support system has helped in sustenance and development options in Himachal Pradesh (Jodha, 2005). In the past one decade or so, the response of cultivators in the region has been through the inclusion of vegetable and flower crops and improved breeds of cattle in the agricultural system. This has led to substantial increase in their incomes and living conditions, accompanied with changed levels of risk.

The effect of such a change in the agriculture over the last few years, therefore, needs to be closely monitored with respect to its profitability and risk. Because of the numerous complexities and the constraints involved in this phenomenon, the real world conditions can best be approximated through economic or bio-economic modeling approach. This requires systems approach to analyze the problem in totality rather than analyzing it in parts. Studies at micro watershed level are more effective for policy formulation and can be linked to greater issues at regional/national/international levels (Sankhayan *et al.*, 2003). This study, therefore, represent one such effort where dynamic non-linear programming model is used for analyzing the profitability and risk in the newly emerged horticultural crops under alternate policy regimes at a micro watershed level in the state of Himachal Pradesh. It also aims at making some policy recommendations for eliminating certain constraints in horticultural development.

2. Methods

2.1 The study area

Himachal Pradesh has been divided into four agro-climatic zones on the basis of altitude, temperature, topography, rainfall and humidity (Chand, 1997). These are: (i) subtropical, sub montane and low hills (ii) sub temperate, sub humid mid hills (iii) wet temperate high hills (iv) dry temperate high hills and cold desert. The watershed under study i.e., Chabri, is situated in the third zone. It is located in the Shimla hills of western Himalayas in Solan district of Himachal Pradesh (Fig. 1). It measures 8.96 km^2 and is catchments of Chabri rivulet that drains into Ashwani River. Located between 77^0 10' and 77^0 12' in the East and 30^0 57' and 30^0 58' in the North, the micro watershed is a small mountainous oval shaped valley with steep slopes, typical of the landscape pattern in the mid hill zone of the state of Himachal Pradesh.

Altitudes range from 1650m to 1950m above mean sea level. Average annual rainfall during the period 1993-2003 was 596mm and snowfall was 65cm (Gohp, 2005). Average daily temperatures vary from -4^{o}C to 28^{o}C during the year. The micro watershed is bounded by Ashwani River to the north-west and south-west, by the boundary of Solan and Shimla districts to the north and by Giri River to the south-east. It has nine villages and 102 households having a human population of 703 people. The population density is rather low, i.e. 78 persons per km^2.

Out of the total watershed land area, about 68.1 ha are under crop cultivation. According to the official records, about 58% of the watershed area is under forest owned by the state. The mixed farming system with crop cultivation, livestock rearing and forest product extraction is similar to other regions of the Himachal Pradesh (Sharma *et al.*, 2008).

Out of 102 households, about 46% of the farmers own less than one ha land. Average family size in the watershed is 6.9 with an operational landholding of about 0.73 ha. Literacy rate is about 85.5%, comparatively better among males. About 68% of the total population is active work force. Some of the workforce is also engaged in non-farm activities and supplementing the farm income of households. There are a very few people who are earning through wage labor. The major dependence for the livelihood of most households in the watershed is on mixed farming system.

2.2 Data sources

All the nine villages in the selected watershed were surveyed for the study. A list of all households in the villages was prepared and all the 102 households were interviewed for the required information. The household data on demographic profile, land holding, cropping pattern and input-output of crops and livestock was collected through a household survey. Information so obtained, pertains to the agricultural year 2005-06. For better assessment of the watershed utility, only the paid out costs have been included in the budgets.

Time series data on land use and cropping pattern as available for each village with the local revenue official was also taken into account while gathering first hand information. Data on price and yield of crops for the last five years were obtained from the Directorate of Land Records, Directorate of Agriculture, and the related study conducted in Agro-Economic Research Center, Shimla (Singh *et al.*, 2006). Some data gaps were bridged through cooperative marketing societies, discussions with the farmers, extension workers, government officials, NGOs and local leaders in the study area.

2.3 The model

The dynamic mathematical programming bio-economic model developed by Sankhayan and Hofstad (Sankhayan & Hofstad, 2001) at village level and later modified and used at watershed level in Nepal (Sankhayan *et al.*, 2003) has been suitably modified to account for the conditions characteristic of the selected watershed in Himachal Pradesh. It is solved with the general algebraic modeling system (GAMS)/MINOS (Brooke *et al.*, 1998). The model is solved for income optimization from crop and livestock activities and with due considerations to the risk in gross returns from crop activities over a time period of 20 years. Results for the existing scenario were then compared with the optimum plans with and without risk component and with the alternate model scenarios.

The following sections discuss in more details the dynamic programming model in respect of its various components, such as the objective function, inputs and outputs, and constraints.

2.3.1 Maximizing the net cash income from crops and animal activities

The model considers a watershed aggregate utility maximization objective function that is realized by maximizing the net cash income from crop and animal activities under several constraints. This function can be expressed as follows:

$$\text{Maximize} \quad \sum_{t=1}^{T} 1/(1+\partial)^t U_t$$

where, U_t is the total discounted gross margins from crop and animal activities in the t[th] year for the entire model horizon and the same is defined as:

$$U_t = p_t^c x_t^c + p_t^l x_t^l$$

where, x_t^c and x_t^l are the column vector representing units of crop and livestock units for each time period. Whereas the land units are in hectare, the animals are taken as such. p_t^c and p_t^l are row vectors of annual gross margins per unit of crop and livestock in rupees. ∂ is the annual percent discount rate, taken as 5% per annum in this study, to convert the stream of gross margins over the model horizon into present value equivalent. t is the time period measured in years over model horizon; t=1,2,…., T, where T = 20.

The variations in yields and prices of crops over the last five years have been incorporated in the model with variance-covariance matrix as done by the Hazel (1971). This makes the risk equation quadratic and the dynamic model non-linear. The variance has also been discounted in the model so as to account for the level of risk over the years. Whereas discounting of income helps in analyzing the present value of the future income, the discounted variance in income over time (VIT) brings us closer to reality by ensuring that the risks in gross returns become less important with more distant future. The objective function for maximizing income is subjected to the following set of activities and constraints in the model:

2.3.2 Activities used in the model

Only crops and livestock product activities have been included in this model. Crops that are grown on at least half ha are included in the model. Budgets of these crops were prepared by incorporating gross margins. Similarly, the gross margins from livestock were also included. Income from off-farm activities, mainly the earnings from salaried jobs outside watershed and the forest activities, were not included in the model due to higher expenditure levels in urban centers and banned commercial activity in forest. The model provides for labor hiring for all activities. Though this is provided for each of the 12 months, the hiring is expected to take place only during the peak months. The growth rate of population was treated exogenous to the model and the same is given by the following equation:

$$P_t = P_0(1+\rho)^t$$

where, ρ = average annual percent growth rate.

Like the human population, the livestock population in the watershed is assumed to grow at a constant rate over the model time period. Growth rate for each livestock unit was estimated from the figures obtained from livestock census conducted in the past. Given the ratio of workers to total population (RWP) and average working days per month (WDM), both as exogenous variables, labor availability during m[th] month in the t[th] year can be found out as follows:

$$LABOR_{mt} = RWP.WDM_m.P_t$$

2.3.3 Constraints in the model

Households are assumed to make decisions under a number of constraints. Constraints for land were incorporated according to crop growing seasons, i.e., rainy (*kharif)* and winter (*rabi)* by different land use types, such as irrigated and unirrigated land. Because of incorporation of crop activities by annual crop seasons in the model, only annual land availability constraints were used within relatively homogenous land units. Labor availability constraints (man equivalent days) are considered according to months. The labor availability increases with growth of population over the run of the model. This can be supplemented through labor hiring. Only 15% of the annual gross margins have been kept available for working capital. This has been done with due considerations to high initial investment requirements for cash crops like flowers, their associated costs, and consumption requirements. This constraint has also been used for sensitivity in the model scenario.

2.3.4 Model scenarios and calibrations

In addition to the base scenario**,** which represents business as usual, four other scenarios have been introduced to analyze the dynamics of cropping patterns in the study watershed. A brief explanation of these scenarios is presented in Table 1. To represent the ground reality, model was calibrated for the base year in respect of cropping pattern as obtained from the survey data. The model was then run under different scenarios over a period of 20 years, i.e., from 2007 to 2026.

3. Results and discussion

3.1 Existing cropping pattern in the watershed

The cultivated land area in the watershed is mainly rain fed with two distinct cropping seasons in a year, namely, *kharif* (rains) and *rabi* (winters). Out of the total cultivable land area of 68.14 ha, only 31.44 ha of the land has year-round irrigation facilities, whereas, the 36.70 ha of the land is rain fed (Table 2).

The most widely cultivated crops during the *kharif* season are maize, tomato and capsicum, whereas wheat and barley are the dominant crops during the *rabi* season. Cash crops such as beans, potato, ginger and cabbage are also grown on some area. Farmers grow many other crops for self consumption, but due to the very small proportion of the land area, it is difficult to estimate it at household level, though the total area under such crops may be quite significant for the whole watershed. However, vegetable crops on unirrigated land are grown in *kharif* season only but on irrigated land it is grown in both seasons.

Over the last few years, the area under less remunerative crops has been rapidly declining, whereas, the area under horticultural crops (vegetables and flowers) has increased by 35% over the period from 1990-91 to 2004-05 in this watershed area (Sharma *et al.*, 2007). It also matches with the overall trends in Himachal Pradesh (Bhatti *et al.*, 2002; Singh *et al.*, 2006).

In the *rabi* season, due to the less availability of water and maintenance of soil fertility level for cash crops, a major part of the cultivable land is held as fallow. Crops such as maize, wheat and barley are still grown despite their low gross margins (Chand, 1997). Several factors like risk minimization, self sufficiency, and less labor and capital requirements are sustaining this practice.

Closer integration of farmers in the market economy is the driving force behind the shift in the cropping area from food grain crops to production of cash crops (Sharma, 2005; Sharma *et al.*, 2007). Vegetables grown in this region are off-seasonal in nature and therefore, it fetches good prices in the market, whereas, the food grains are mainly grown for self consumption, but in case of vegetables, more than 90% of total produce goes to market as marketed-surplus (Singh *et al.*, 2000).

The agricultural operations in the flower cultivation extend throughout the year in *kharif* and *rabi* seasons. Not only this activity is more profitable, but it also provides better utilization of household labor as the operations are spread more evenly over the year. Flower crops such as carnation, gladiolus, chrysanthemum and lily occupy about 8.19 ha of land. While carnation, lily and chrysanthemum require controlled conditions of poly house, the gladiolus is grown in the open fields. Gladiolus is grown mainly in those areas where the construction of poly houses is not feasible. Although the chrysanthemum can also be grown in open field, the farmers in this watershed prefer to cultivate it within uncovered structure of poly house, required for black out conditions in the later stages for speedier growth of flower to reap the better prices in market. Though per hectare profitability of gladiolus is very low in comparison to other flower crops, they are still grown at equal importance due to low investment and labor requirements. Lily is a newly introduced flower and occupies very little area in the watershed.

Flower cultivation which started in the mid nineties has become very popular now in this watershed, mainly due to favorable agro-climatic conditions, technical know-how and easy access to the markets. Availability of sufficient sunshine and mild weather even during the winter months, enable growers to produce cut flowers under relatively simple protected structures (Mysore & Uva, 2000).

3.2 Data inputs to the model

3.2.1 Crop and livestock budgets

Traditional crops and cash crops are simultaneously grown in the watershed. Though the gross margins from flowers cultivation are very high in comparison to other crops (Table 3), but due to the constraints such as irrigation, leveled land, and high capital and labor requirements, it is produced only on about 12% of the cultivated land. Those who are not able to cultivate flowers due to these constraints, grow vegetable crops like capsicum, tomato, potato, beans, peas etc. In the watershed, only flower cultivation requires market borrowings, whereas, the cultivation of other crops is financed from past savings. Due to initial heavy investment requirements for poly house structures, per hectare cost of borrowings is very high for all flower crops except gladiolus, which is grown in open fields. By taking into account the durability of capital goods**,** the cost is split on yearly basis and interest payments are made at current rate of 12.5%.

Traditional crops such as maize, wheat, barley and pulses are still grown on significant area, despite low gross margins. Among vegetables, capsicum requires more variable cost than others, whereas, the tomato is the crop with highest gross margins. But capsicum commands equal importance mainly due to less risk in price variation. Except the crops of flowers, cost of production of all crops is meted out from the past savings of the households.

Livestock rearing is also an important component of farming system in the watershed. Among all livestock heads, cross-bred cow realize highest gross margins to people followed by buffalo and local cows (Table 4). Though the rearing of other classes of livestock cannot be seen in isolation to the milk producing animal, their role in providing dung for farm-yard manure has a special significance in the context of cash crops' cultivation. Due to the insignificant contribution of this activity to gross income, and low variation in yield and output price, the risk from this activity is not considered in the model.

3.2.2 Variations in gross returns over last five years

Variations in the gross returns over the last five years have been included in the model (Table 5). A complete set of variance-covariance matrix was constructed with the last five year data of yield and output price. As the diagonal elements represent the variance, other elements denote the covariance among the crops. It has helped in introducing the risk element in economic model and finding the optimum cropping pattern. Among vegetables, the variance in gross returns during the last five years is highest in case of tomato followed by garlic and peas. Traditional crops like maize, wheat and barley have the lowest variance level. In floriculture, all the flowers have a high variance level but the carnation tops in the list followed by lily and gladiolus.

3.3 Economic model and the dynamics of cropping pattern

In the scenario 1, total discounted gross margins (TDGM) are calculated by fixing activities at present level over the entire model horizon. TDGM, which is the present value of income from crop and livestock activities over the model horizon, turns out 321,278 thousand rupees. In this business as usual scenario, the variance in gross returns (VIT) is estimated at 3,327,000 thousand rupees. This variance level, which emerges from the existing cropping pattern, represents the actual risk level taken by the people of this watershed. Preference for crop diversification over optimum plans is due to various reasons, such as risk aversion, bottleneck in capital, labor and irrigation, small land holdings, preferences for leisure, and less enterprise. Annual capital requirements for crop and livestock activities in the watershed are presently about 3,892 thousand rupees.

Scenario 2 is a true optimum plan with no considerations of risk. TDGM is maximized at a level of 785837 thousand rupees which is more than double the TDGM of base. Though true optimization plans can lead to the highest increase in income but such plans are risk inefficient (Olarinde *et al.*, 2008). Only tomato is grown in both the seasons, in addition to the carnation flower (Fig. 2). Tomato is grown on significant land area in the existing plan, as it is a widely cultivated crop in the whole district due to favorable agro-climatic conditions, high productivity, and good quality of produce. The area under this crop, however, diminishes marginally over time horizon as a result of increase in land area under carnation.

Carnation is being cultivated in various suitable regions of the state due to better returns. In the *rabi* season, wheat is grown on un-irrigated land only after the middle of time horizon. It means that under the given constraints, it is better to keep the unirrigated land as fallow and divert the scarce resources to other crops in order to optimize income. Though the cultivation of traditional crops for sustainable landscape development in these mountains have been strongly recommended (Nautiyal & Kaechele, 2007), but factors, such as profits, risk and input availability plays more significant role in determining the crop plan.

By relaxing the capital availability constraint by two percent in Scenario 3, the irrigated land is speedily occupied by carnation. Consequently, it reduces the land area under tomato in both seasons in direct proportions (Fig. 3). It helps in raising the TDGM to 1,091,551 thousand rupees, the highest level in any of the model scenario. This clearly depicts the importance of capital for such ventures, which helps in maximization of income of the farmers.

In the scenario 4, unirrigated land in *rabi* season is reduced annually by 3.11 percent followed by an increase in irrigation facilities by 2 percent. These rates have been taken so as to maintain the total land area at current level at the end of model horizon. With the increase in irrigation facilities on more land, it is only tomato which occupies the newly irrigated land (Fig. 4). Though the level of TDGM is slightly higher than in the scenario 2, but the risk level as reflected by VIT is also very high. It means that with the higher cultivation of tomato, farmers have to bear more risk.

The scenario 5 is based on maximization of TDGM by fixing the VIT at the level as calculated in scenario 1. This is done for knowing the optimum cropping pattern with the risk level of existing plan. The TDGM is maximized at 602,388 thousand rupees, which is near double than the existing plan. It means that this cropping plan has a potential to double the income with the current level of risk. Capsicum and beans, which were non existent in the earlier optimum plans, are now grown on more land than the tomato (Fig. 5). Similarly, in the *rabi* season, peas completely replaces tomato on irrigated land, whereas, wheat occupies all of the unirrigated land.

In this scenario, all crops with high risk in gross returns have been replaced by the crops with less risk level. By comparing it to the existing plan, it is observed that the farmers are more considerate to risk than the profits. Therefore, they diversify agriculture by cultivating several crops with low risk level than only a few crops that maximize the income. This is supported by many evidences which suggest that individuals have reasonably accurate perceptions of risks, which have a fundamental impact on their welfare (Amaresh & Omar, 2008). However, crops such as, maize and barley, which are dominant crops in the watershed are missing in the optimum plans either due to less margins or due to the constraints of model.

As far as the labor requirements for agricultural activities are concerned, farmers in the watershed seem self sufficient except in two or three peak season months in optimizing plan 2, 3 and 4. Forest activities that are not included in this model will further strengthen the pressure on human labor in the peak season. The labor requirements are bound to increase manifold with the emerging cropping patterns, requiring higher human labor (Chand, 1997). During peak season, labor requirements grow continuously over model horizon in all the scenarios.

4. Conclusions

Growing cash requirements of the farmers have favorably affected the farm enterprise, resulting in rapid shift in traditional cropping patterns towards cash crops of vegetables and flowers. Though the farmers suitably diversify their cropping pattern due to risk considerations yet the knowledge of optimized cropping plans may further suggest some better options for raising income levels. The efforts at calculating costs, returns and risks for the new emerging profitable as well as riskier crops, can help farmers in selecting appropriate crop combinations. Such knowledge dissemination at micro level should be supplemented with the suitable policy interventions for timely supply of necessary farm inputs and credit facilities.

In addition to flowers, the production of continental vegetables in the controlled conditions can be equally profitable and also provide necessary crop rotations. Permanent irrigation facility is the main factor that facilitates the cultivation of cash crops. It not only helps in attaining higher income levels, but also saves scarce farm resources from traditional crops, which are mostly economically unviable in the hilly regions. Therefore, more irrigation facilities are needed for these profitable enterprises in the entire watershed. Water for irrigation in the region comes from the Chabri rivulet that drains from this cedar and oak forested watershed. Therefore, the tree species like oak should be properly conserved and propagated for better water conservation. Construction of check dams and water reservoirs, rain water harvesting and lift irrigation systems with equitable and judicious water distribution are also required for the growing agricultural intensification across the villages.

Policy interventions from government towards more irrigation facilities, better transportation network and development of new market yards can prove useful in achieving large scale production of vegetables and flowers. Such intensification of agriculture has the potential not only to increase the living standard of farmers but also provide self employment in the state.

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Table 1. Brief description of model scenarios

S.N	Abbreviation for model scenario	Objective	TDGM (in rupees)	VIT (in rupees)	Brief explanation of model scenario
1	EP	Calculation of TDGM and VIT	321278	3327000	Area under crops as exists in year 2006 is fixed for the model horizon
2	MTDGM	Maximization of TDGM	785837	243237200	Neither the activity nor the VIT is fixed.
3	MTDGM-HRI	Maximization of TDGM	1091551	152722600	Capital constraint is relaxed by two percent
4	MTDGM-HI	Maximization of TDGM	814264	275470300	Irrigated area in *rabi* season is increased by 2% p.a. and the unirrigated area is reduced by 3.11%
5	MTDGM-FV	Maximization of TDGM	602388	3327000	VIT found in scenario 1 is fixed

Table 2. Existing cropping pattern in the watershed (Area in hectares)

	Crop	Crop growing months	Total Area	Irrigated	Unirrigated	Fertilized	Non Fertilized
Kharif crops (Rainy)							
Vegetables:	Capsicum	July-October	6.48	6.48	0	6.48	0
	Tomato	July-October	6.02	6.02	0	6.02	0
	Beans	July-October	5.48	3.4	2.08	3.9	1.58
	Potato	July-October	1.64	1.64	0	1.64	0
	Cabbage	July-October	0.16	0.16	0	0.16	0
Other crops:	Maize	July-October	28.18	13.2	14.98	13.76	14.42
	Pulses	July-October	2.44	1.8	0.64	1.9	0.54
	Ginger	July-October	0.28	0.28	0	0	0.28
	Miscl./Kharif Fallow	July-October	9.27	3	6.27	2.5	6.77
	Total Kharif		59.95	35.98	23.97	36.36	23.59
Rabi Crops (Winter)							
Vegetables:	Tomato	March-June	5.22	5.22	0	5.22	0
	Capsicum	March-June	5.20	5.20	0	5.20	0
	Peas	Nov-June	2.36	2.36	0	2.36	0
	Potato	March-June	0.68	0.68	0	0.68	0
	Cabbage	March-June	0.04	0.04	0	0.04	0
Other crops:	Barley	Nov-June	10.76	4.24	6.52	0	10.76
	Wheat	Nov-June	9.85	3.56	6.29	0	9.85
	Garlic	Nov-June	0.92	0.92	0	0.92	0
	Ginger	March-June	0.37	0.37	0	0	0.37
	Mustard	Nov-June	0.16	0.04	0.12	0	0.16
	Miscl. / Rabi fallow	Nov-June	24.39	0.62	23.77	6	18.39
	Total Rabi		59.95	23.25	36.7	20.42	39.53
Annual Crops							
Flowers:	Gladiolus	July-June	3.04	3.04	0	3.04	0
	Carnation	July-June	3.08	3.08	0	3.08	0
	Chrysanthemum	July-June	1.72	1.72	0	1.72	0
	Lily	July-June	0.35	0.35	0	0.35	0
	Total Flowers		8.19	8.19	0	8.19	0
Fruit Crops	Fruit crops	July-June	7.08	0	7.08	0	7.08

Note- Crops grown on less than .5 ha are not considered in the model

Table 3. Paid-out cost and gross margins from crops in the watershed (rupees ha^{-1})

	1	2	3	4	5	6	7	8	9	10
	Crops	Cost of seed	Cost of fertilizers	Cost of plant protection chemicals	Interest on capital	Miscl. cost	Total Variable cost (1 to 6)	Value of main and by-product	Gross Margins (8-7)	Variance in Gross returns
Kharif Season										
Vegetables:	Capsicum	12675	1174	1282	0	125	15256	185475	170219	379
	Tomato	3947	1455	1580	0	128	7110	215460	208350	3413
	Beans	7500	340	148	0	88	8075	109986	101911	377
	Potato	1575	1571	331	0	22	3500	68964	65464	298
Other crops:	Maize	2530	868	0	0	19	3416	13738	10322	2
	Pulses	960		0	0	20	980	17063	16083	2
Rabi Season										
Vegetables:	Capsicum(I)	12675	1174	1282	0	125	15256	145953	130697	379
	Tomato(I)	3947	1455	933	0	128	6463	189000	182537	3413
	Potato(I)	1575	1571	331	0	22	3500	55964	52464	298
	Peas(I)	3750	1498	853	0	123	6223	159693	153470	470
Other crops:	Wheat(I)	900		0	0	22	922	14435	13513	3
	Barley(I)	900		0	0	20	920	10422	9502	4
	Garlic(I)	6371	1377	213	0	19	7980	130968	122988	2933
	Wheat(UI)	900		0	0	22	922	12596	11674	3
	Barley(UI)	900		0	0	20	920	9549	8629	4
Annual crops										
Flowers:	Gladiolus	64583	60000	22000	0	389	146972	540874	393902	1912
	Carnation	266000	60000	40000	168250	7856	542106	3542400	3000294	3204
	Chrysanthemum	160000	50000	50000	178250	9350	447600	2964000	2516400	672
	Lily	203000	40000	20000	205750	8050	476800	2032320	1555520	3074
Fruit crops	Fruit crops	333	1250	1000	0	135	2718	45503	42785	

Table 4. Annual paid-out cost and gross margins per livestock head in the watershed (Rupees)

1 Livestock	2 Number	3 Value of inputs bought	4 Value of Main Product	5 Value of By-Product	6 Total Value (4+5)	7 Gross Margins (6-3)
Cross bred cow (in milk)	77	2000	20748	274	21022	19022
Cross bred cow (dry)	8	1000	0	228	228	-772
Cross bred Heifer	7	100	0	91	91	-9
Cross bred young stock male	31	100	0	46	46	-54
Cross bred young stock female	39	100	0	46	46	-54
Cross bred bullock	12	800	0	183	183	-618
Local cow (in milk)	69	900	8148	160	8308	7408
Local cow (dry)	30	300	0	137	137	-163
Local heifer	5	120	0	68	68	-52
Local young stock male	29	100	0	37	37	-64
Local young stock female	31	100	0	37	37	-64
Local bullock	102	800	0	137	137	-663
Buffalo (in milk)	19	1400	16488	274	16762	15362
Buffalo (dry)	10	750	0	228	228	-522
Buffalo young stock male	1	100	0	137	137	37
Buffalo young stock female	1	100	0	137	137	37

Table 5. Variance-covariance matrix of per hectare gross returns from crops over the last five years (in million rupees)

	Maize	Capsicum	Tomato	Beans	Pulses	Potato	Wheat(I)	Barley(I)	Peas(I)	Garlic(I)
Maize	2	3	-26	7	-1	10	0	-1	-17	68
Capsicum	3	379	-518	-70	-11	-280	4	20	115	1866
Tomato	-26	-518	1209	-265	41	227	31	2	276	-2891
Beans	7	-70	-265	377	-23	98	-46	-33	-370	-519
Pulses	-1	-11	41	-23	2	3	3	2	25	-51
Potato	10	-280	227	98	3	298	-2	-19	-195	-1013
Wheat(I)	0	4	31	-46	3	-2	8	5	48	59
Barley(I)	-1	20	2	-33	2	-19	5	4	41	100
Peas(I)	-17	115	276	-370	25	-195	48	41	470	351
Garlic(I)	68	1866	-2891	-519	-51	-1013	59	100	351	11210
Wheat(UI)	0	4	31	-46	3	-2	8	5	48	59
Barley(UI)	-1	20	2	-33	2	-19	5	4	41	100
Capsicum(I)	3	379	-518	-70	-11	-280	4	20	115	1866
Tomato(I)	-26	-518	1209	-265	41	227	31	2	276	-2891
Potato(I)	10	-280	227	98	3	298	-2	-19	-195	-1013
Gladiolus	162	954	146	-3618	149	336	449	234	1811	14229
Carnation	539	-3857	9992	-11169	687	6657	1426	377	3535	15475
Chrysanthemum	-76	-686	1112	426	56	228	75	56	631	-6473
Lily	146	584	-2889	994	-134	450	-158	-128	-1970	6631

Table 5 (Continued)

	Wheat(UI)	Barley(UI)	Capsicum(I)	Tomato(I)	Potato(I)	Gladiolus	Carnation	Chrysanth.	Lily
Maize	0	-1	3	-26	10	162	539	-76	146
Capsicum	4	20	379	-518	-280	954	-3857	-686	584
Tomato	31	2	-518	1209	227	146	9992	1112	-2889
Beans	-46	-33	-70	-265	98	-3618	-11169	426	994
Pulses	3	2	-11	41	3	149	687	56	-134
Potato	-2	-19	-280	227	298	336	6657	228	450
Wheat(I)	8	5	4	31	-2	449	1426	75	-158
Barley(I)	5	4	20	2	-19	234	377	56	-128
Peas(I)	48	41	115	276	-195	1811	3535	631	-1970
Garlic(I)	59	100	1866	-2891	-1013	14229	15475	-6473	6631
Wheat(UI)	8	5	4	31	-2	449	1426	75	-158
Barley(UI)	5	4	20	2	-19	234	377	56	-128
Capsicum(I)	4	20	379	-518	-280	954	-3857	-686	584
Tomato(I)	31	2	-518	1209	227	146	9992	1112	-2889
Potato(I)	-2	-19	-280	227	298	336	6657	228	450
Gladiolus	449	234	954	146	336	69022	228734	-21487	10652
Carnation	1426	377	-3857	9992	6657	228734	895113	-68761	31518
Chrysanth.	75	56	-686	1112	228	-21487	-68761	18406	-12161
Lily	-158	-128	584	-2889	450	10652	31518	-12161	16145

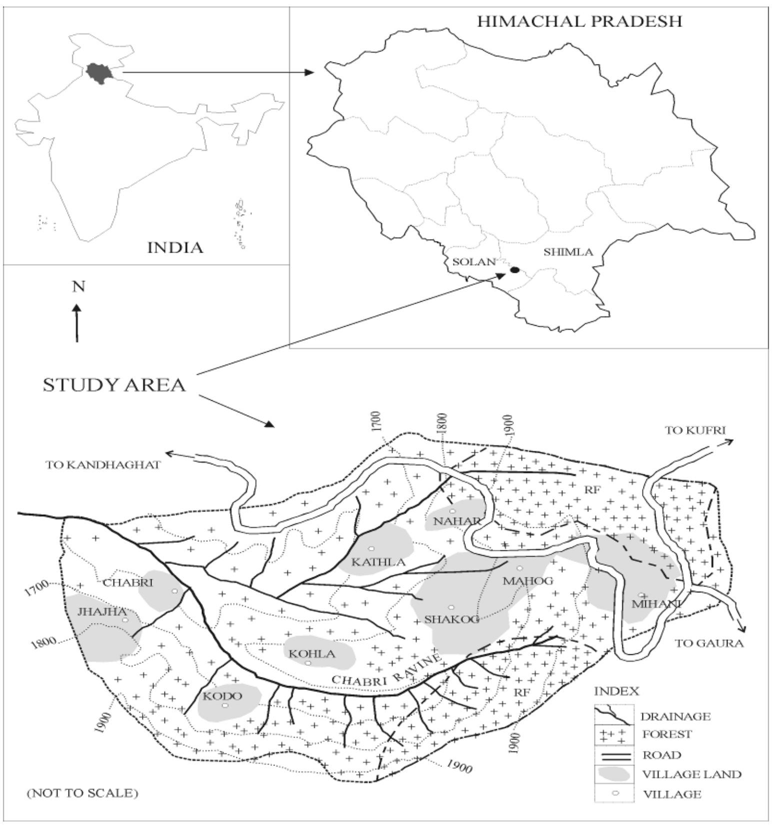

Figure 1. Map of the study area

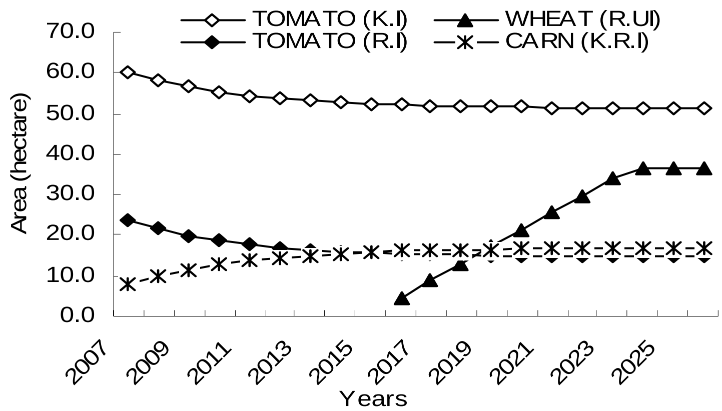

Figure 2. Cropping pattern in scenario 2 over model horizon

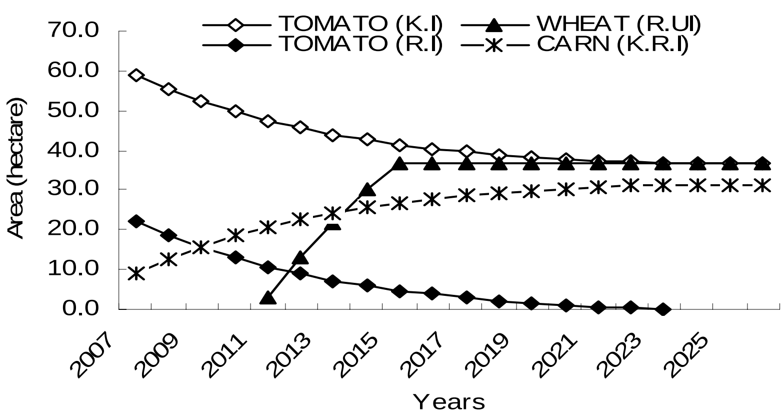

Figure 3. Cropping pattern in scenario 3 over model horizon

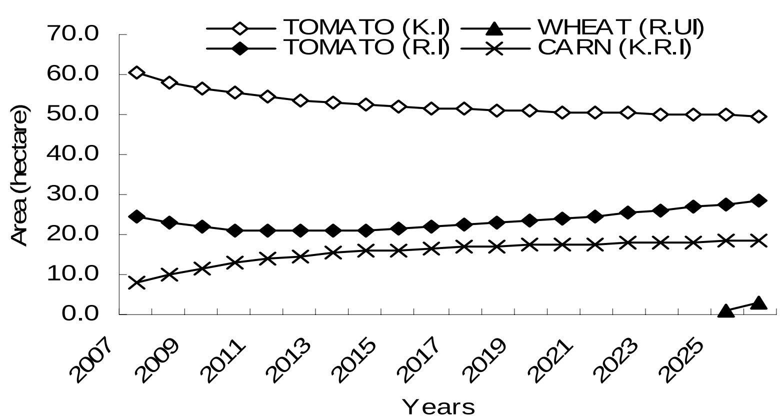

Figure 4. Cropping pattern in scenario 4 over model horizon

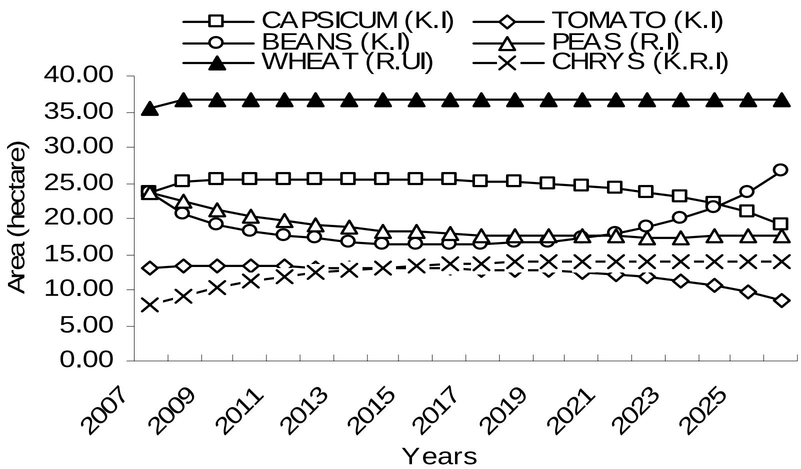

Figure 5. Cropping pattern in scenario 5 over model horizon

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Influence of Cowpea Mottle Virus and Cucumber Mosaic Virus on the Growth and Yield of Six Lines of Soybean (*Glycine Max* L.)

Olawale Arogundade (Corresponding author)
Fruit Research Programme, National Horticultural Research Institute
Idi Isin, PMB 5432, Ibadan, Nigeria
Tel: 234-8055-360425 E-mail: arogundade_olawale@yahoo.co.uk

Olusegun Samuel Balogun
Department of Crop Protection, Faculty of Agriculture, University of Ilorin
PMB 1515, Ilorin, Kwara State, Nigeria
Tel: 234-803-581-4131 E-mail: Samcleo1@yahoo.com

Olumide Shokalu
Soybean Research Programme, National Cereal Research Institute
Badeggi, PMB 8, Niger State, Nigeria
Tel: 234-806-062-6265 E-mail: olushokalu@yahoo.co.uk

Taiye Hussein Aliyu
Department of Crop Protection, Faculty of Agriculture
University of Ilorin, PMB 1515, Ilorin, Kwara State, Nigeria
Tel: 234-803-047-2667 E-mail: aliyutaiyehussein@yahoo.com

Abstract

Cowpea mottle virus is of localised importance on cowpea in Nigeria infecting several leguminous species and Cucumber mosaic virus is of worldwide distribution infecting several horticultural crops.

A study was carried out in the screen house of the crop production pavilion, Faculty of Agriculture, University of Ilorin, Ilorin, Kwara State, Nigeria to determine the pathogenic response of six lines of soybean (TGx 1844-18E, TGx 1448-2E, TGx- 1910-8F, TGx 1019-2EN, TGx 1844-4E and TGx 1876-4E) to single and mixed infection with cowpea mottle virus (CMeV) and cucumber mosaic virus (CMV).The Lines obtained from National Cereal Research Institute, Badeggi were used for the experiment.

Two viable Seeds were sown per 4litre plastic pots filled with sterilized soil; inoculation of viral isolates was carried out mechanically on the soybean at two weeks after planting.

The results revealed that all Soybean lines tested were susceptible to single and mixed infection of the two viruses. However the tolerance level of the legumes, as shown by the percentage loss in selected growth and yield attributes indicated that line TGx 1910-8F is the most tolerant while TGx 1844-18E is the most susceptible to single and mixed infection.

Hence, TGx 1910-8F is most suitable in areas where there is an outbreak of disease caused by CMeV and CMV.

Keywords: *Glycine max,* Horticultural crops, Leguminous species, Outbreak, Susceptible, Tolerance

1. Introduction

Soybean is an annual grain legume that varies in growth habit and height. It may grow prostrate, not growing higher than 20cm, or even up to 2meters in height (IITA Report, 2007). It plays an important role in the nutrition of people in developing countries of the tropics and subtropics, especially in sub-Saharan Africa, Asia Central and South America. Due to its high quality and inexpensive protein content, this is about 40% of the seed (Weingarther, 1987). The oil and protein contents in soybean together account for about 60% of dry soybean seed by weight, protein at 40% and oil at 20%. The remainder consists of 35% carbohydrate and about 5% ash. The oil is high in essential fatty acids, devoid of cholesterol and constitutes more than 50% of the world's edible vegetable oil in trade (Ogundipe and Weingatner, 1992).

Increasing demand for edible oil proteins in developing countries has led to the recent expansion of soybeans production in Nigeria. Many varieties have since been produced by introduction, breeding and selection and with the outstanding ones released for large scale production in different ecological zones (Dashiell and Root, 1985). According to Baten *et al.* (1992), soybean was the world's most important grain legume crop in terms of total production, consumption and international trade. The IITA report (2007) puts the total land area under soybean in the world at 95.2million ha and total production at 212.6million tonnes.

The three major soybean producing countries as at 2005 were USA (29million ha), Brazil (23million ha), and Argentina (14million ha). In terms of total production, USA produced 83million tones, followed by Brazil (52million tones, and Argentina (38million tons). While in Africa, soybean was grown on an average of 1.16million ha with an average production of 1.26million tones in 2005. African countries with the largest area of production were Nigeria (601,000ha), South Africa (150.000ha) Uganda (144000 ha), Malawi (68,000 ha) (FAO report, 2005).

Soybean cultivation has become well-established in several areas of the Southern Guinea Savanna Zone (SGSZ) like Benue, Niger, Kaduna, which are currently the major commercial soybean producing areas in Nigeria.

In Nigeria, a number of diseases have been reported on the soybean crop. These includes: *Cercospora* leafspot, bacteria blight, red leaf blotch, crown rot and soybean mosaic virus (Akem, 1996). The latest disease on soybean in the country is rust (Shokalu *et al*., 2000). Soybean mosaic virus (SMV) is the most frequently isolated virus of soybean, it probably occurs wherever soybean is grown, the symptoms vary according to the particular viral strain, host genotype, weather and time of infection (Sinclair and Shurtleff, 1975). Cowpea mild mottle virus (CMMV) has been reported on soybean from Nigeria (IITA, 1980; Anno Nyako, 1984). Cowpea mottle virus is of localized importance on cowpea in Nigeria (Kareem and Taiwo, 2007). The objectives of this study were to evaluate the response of some soybean cultivars in Nigeria to infection singly with cowpea mottle virus and to determine their tolerance rating

2. Materials and Methods

Isolates of Cowpea mottle virus were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Six Soybean lines; TGx 1844-18E, TGx 1448-2E, TGx- 1910-8F, TGx 1019-2EN, TGx 1844-4E and TGx 1876-4E obtained from IITA, Ibadan were used for the study.

In the screen house, perforated plastic pots where filled with sandy loam soil obtained behind the crop production pavilion, Faculty of Agriculture, University of Ilorin. The soil was steam sterilized to eliminate any soil inhibiting micro organisms and enriched with 15:15:15 NPK fertilizer. Two seeds each of the Soybean lines were sown in separate pots in December 2007. The pots were arranged in a randomised complete block design with three replications and a total of 72 pots were utilized for the study. The seedlings were constantly watered and weeds removed manually as they emerge.

The CMeV and CMV extracts were extracted from infected leaves obtained from the stock of the plant Virology Laboratory at the International Institute for Tropical Agriculture (IITA). Infected leaf samples were macerated in phosphate buffer (pH 7.2) at the rate of 1g/5ml of buffer in pre-cooled mortar and pestle. The inoculation was done by mechanical transmission of virus through sap. The sap was applied on the surfaces of the oldest leaves previously dusted which carborundum. The sap was applied by rubbing the leaves gently with a cotton wool dipped in the sap. Inoculated plants were rinsed thereafter with water. Plants that were mocked-inoculated with buffer only served as control. Inoculation was done two weeks after planting with single and mixed infection consisting of CMeV, CMV and CMeV + CMV.

Data were collected at the time of infection as well as on weekly basis. Plant height and number of leaves were taken weekly over a period of 9 weeks after inoculation. Yield parameter such as number of pods, dry weight of pods and dry weight of grain were also taken. The pods were harvested, sun dried to about 12% moisture content and weighed with the aid of an electronic balance. The pods were threshed manually and weighed. All data were subjected to analysis of variance having regards for the factorial nature of the treatment design and the significant differences between them were determined at $P < 0.05$, using the new Duncan's Multiple Range Test.

The lines were rated for tolerance based on the mean losses incurred in selected growth and yield attributes of infected plants compared to the non -infected plants of the same variety. Following Balogun and Bakare rating (2007), the scales used include 0-15% loss----Very tolerant; 16-30% loss----Moderately tolerant; 31-50% loss ----Mildly tolerant; 51-100% loss ----very susceptible.

3. Results

The six lines used for the experiment showed symptomatic response to infection by Cowpea mottle virus (CMeV) and Cucumber mosaic virus (CMV) under single and mixed infection situations but to seemingly different extent.

In susceptible lines, infection with CMeV manifested as leaf mottling, which progressed to leaf wrinkling. Such leaves appeared relatively smaller in size than normal leaves. Generally, plants that were susceptible to infection with CMV alone manifested only mild mosaic symptoms while those plants that were susceptible to mixed infection with CMV and CMeV showed a combination of mosaic, necrosis and stunting as was also observed in severe CMeV infections (Plate 1). It was observed that CMeV induced striking symptoms even on the fruit setting and the fruits of severely infected plants. Plate 2 shows Soybean line TGx 1019-2EN manifesting serious distortions on the fruit set. All mocked inoculated control plants were free from the infections and had a normal fruit set as shown in plate 3.

The main effect of variety and inoculation on growth parameters as at 7 weeks after inoculation as shown (table 1), ranging from week 2 through week 7 after inoculation, viral inoculated plants were generally significantly shorter than the healthy control. However, there were no significant differences between inoculated plants until the 6^{th} and 7^{th} week. Even then, those inoculated singly with cowpea mottle virus and those inoculated with a mixture of cowpea mottle virus and cucumber mosaic virus were not significantly different. Consideration of the different treatment combinations showed that the soybean plants responded in various ways to the different inoculation regimes (Treatments). It is apparent however that those plants inoculated with CMeV were the most severely affected.

In the number of leaves, analysis of the main effect of inoculation (i.e. regardless of the variety involved) shows that there were generally significant differences at $p<0.05$ between the viral inoculated soybean plants from week 2 through week 5 after inoculation. However, there were no significant differences between the control and CMV inoculated plants at 4^{th}, 6^{th} and 7^{th} week after inoculation. There was no significant difference between all treatments including the control at week 8 as shown in Table 2.

3.1 Effects on yield parameters

Table 3 shows the main effect of variety and inoculation on number of pods, weight of grains and weight of grains. As with the growth parameters, analysis of variance shows that the yield parameters in mock inoculated plants significantly differed from those in viral inoculated ones with mock inoculated plants having higher values compared to the viral inoculated ones.

3.2 Tolerance and susceptibility rating

Considering the level of tolerance and susceptibility to the diseases by the soybeans lines as shown in table 4, TGx 1910-8F, TGx 1844-4E & TGx 1876-4E showed levels of tolerance to both single and mix infection while TGx 1019-2EN and TGx 1844-18E showed levels of susceptibility to both single and mix infection of CMeV and CMV.

4. Discussion

Recently, there has not been a record on the response of soybean cultivars to CMV in this part of the world. However, it has been reported that soybean in this part of the world is susceptible to cowpea mild mottle virus (IITA, 1980; Anno-Nyako, 1984) but nothing had been said about mixed infection of the two viral diseases on soybean.

The experiment showed that all the lines of soybean used are susceptible to CMV, CMeV as well as a mixed infection with CMeV and CMV. The study showed that soybean lines; TGX 1844-18E and TGX 1019-2EN are highly susceptible to cowpea mottle virus as they expressed some symptoms showing deviation from the normal state of the plant physiology. Symptoms include stunting, mosaic pattern, mottling of the leaves and malformed leaves structures. Plants inoculated with CMV did not cause development of visible symptoms on some of the tested soybean cultivars. Smith (1992) had also observed that CMV does not normally cause visible symptoms on Soybean. The soybean plants under mixed infection with CMV and CMeV showed symptoms similar to those manifested by plants under CMeV alone. This could be as a result of the effect of the CMeV in the combination. It was also an indication that the combination of the two viruses was not synergistic in the soybean cultivars.

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Table 1. Effect of variety and viral inoculation on the height of soybean at different times after inoculation

	Weeks after inoculation							
Variety	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
TGx 1910 – 8F	6.2 h	9.0 hi	13. 6 f	21.6efg	31.2cde	40.5bcd	52.8a	55.6a
TGx 1448 – 2E	10.0de	12.3de	16.3cde	22.6def	27.3ef	29.3g	34.3cde	36.9de
TGx1844– 18E	14.8a	17.2a	20.6b	28.6bc	33.2bcd	42.2d	50.7a	54.4a
TGx 1844 – 4E	9.1ef	11.5def	17.5c	24.1de	31.2cde	41.8bc	48.8a	50.7ab
TGx 1019–2EN	8.2fg	11.2efg	15.5cdef	22.6def	25.3f	29.3g	32.8def	36.3de
TGx 1876 – 4E	5.6h	8.2i	13.4f	20.3fg	29.4cdef	46.9a	56.4a	64.2a
S. E	0.37	0.40	0.67	1.08	1.75	1.43	1.57	1.50
Viral Treatment								
CMeV	10.6a	12.9a	17.5b	24.1b	30.8b	36.5b	39.7c	40.8c
CMV	9.7b	12.1b	16.8b	24.5b	31.2b	38.1b	43.1b	43.7b
CMeV + CMV	9.3b	11.9b	16.8b	23.9b	30.4b	36.3b	39.8c	41.7c
Control	9.8b	12.4b	19.0a	28.0a	36.2a	41.2a	46.4a	54.4a
S. E	0.18	0.20	0.32	0.52	0.85	0.70	0.76	0.73

Means followed by the same letter(s) are not significantly different at P<0.05 using the new Duncan's multiple range test

Table 2. Effect of variety and viral inoculation on number of leaves of soybean at different times after inoculation

Weeks after inoculation

Variety	0	1	2	3	4	5	6	7	8	9
TGx 1910 – 8F	2.1f	3.2cd	4.5a	6.7a	8.0a	8.4b	9.2bc	8.8b	9.0b	8.6b
TGx 1448 – 2E	2.3ef	3.0de	3.9cdef	5.4cdef	6.2efg	7.3c	7.8de	7.7cd	7.8cd	6.9cd
TGx1844– 18E	2.0f	3.0de	3.9cdef	5.8bcde	6.3def	7.3c	8.2cd	7.8cd	7.5cde	6.7cd
TGx 1844 – 4E	2.6cd	3.0de	3.9cdef	5.2def	6.7cde	8.1b	9.8b	8.2bc	8.6bc	7.4bcd
TGx1019–2EN	2.3ef	3.2cd	3.9cdef	5.2def	5.4g	5.7e	7.6def	7.3cd	7.5cde	7.1cd
TGx1876 – 4E	2.0f	3.0de	4.0cdef	5.5bcdef	7.0bcd	9.8a	11.0a	12.0a	13.0a	10.9a
S.E	0.08	0.06	0.12	0.20	0.25	0.22	0.33	0.33	0.37	0.40
Viral Treatment										
CMeV	2.5a	3.0b	3.7c	5.4b	6.5b	7.2b	7.5b	7.5b	7.6a	6.8a
CMV	2.5a	3.1b	4.0b	5.6b	6.8ab	7.4b	8.3a	7.6ab	7.1a	6.0b
CMeV + CMV	2.4b	3.1b	3.9b	5.4b	6.5b	7.3b	7.5b	7.4b	7.4a	5.9b
Control	2.5ab	3.5a	4.5a	6.1a	7.1a	7.8a	8.1a	8.0a	7.6a	6.1b
S.E	0.04	0.03	0.06	0.10	0.12	0.10	0.16	0.16	0.18	0.19

Means followed by the same letter(s) are not significantly different at P<0.05 using the new Duncan's multiple range test

Table 3. Effect of variety and viral inoculation on yield parameters

Variety	No. of pods	Dry weight of pods (g)	Dry weight of grains (g)
TGx 1910 – 8F	19.8a	5.2a	3.9a
TGx 1448 – 2E	14.7c	4.4abc	2.9abc
TGx1844– 18E	8.3d	2.8de	1.7f
TGx 1844 – 4E	19.3ab	5.0a	3.8a
TGx1019–2EN	16.8abc	5.0a	3.5a
TGx1876 – 4E	15.4c	5.2a	3.4a
S.E	1.09	0.35	0.22
Viral Treatment			
CMeV	10.9c	3.1b	1.9b
CMV	13.0b	3.6b	2.1b
CMeV + CMV	12.3b	3.2b	1.9b
Control	18.1a	6.7a	5.3a
S.E	0.53	0.17	0.10

Means followed by the same letter(s) are not significantly different at P<0.05 using the new Duncan's multiple range test

Table 4. Comparative percentage losses in soybean varieties under single and mixed infection

Variety	Infection type	Percentage losses*					Tolerance/susceptibility rating
		Grain Wt	Pod Wt	Leaf area	Final Ht	Mean Cum. Loss	
TGx1910-8F	Single	60.5	43.1	19.8	23.5	36.7	Mildly Tolerant
	Mix	45.6	25.0	16.2	21.2	27.0	Moderately Tolerant
TGx1448-2E	Single	79.5	70.0	37.6	28.7	53.9	Very susceptible
	Mix	65.2	41.3	38.5	19.5	41.1	Mildly Tolerant
TGx1844-4E	Single	50.0	35.7	22.9	13.5	30.5	Moderately tolerant
	Mix	50.9	42.9	19.1	9.5	30.6	Moderately tolerant
TGx1019-2EN	Single	75.9	66.8	37.3	28.7	52.2	Very susceptible
	Mix	69.6	61.2	37.1	28	51.3	Very susceptible
TGx1876-4E	Single	68.4	62.1	8.1	5.3	36.0	Mildly Tolerant
	Mix	63.2	48.4	27.4	21.1	40.0	Mildly Tolerant
TGx1844-18E	Single	79.8	74.2	63.5	49.5	66.8	Very susceptible
	Mix	78.7	70.9	73.9	47.1	67.7	Very susceptible

Effect on plant growth

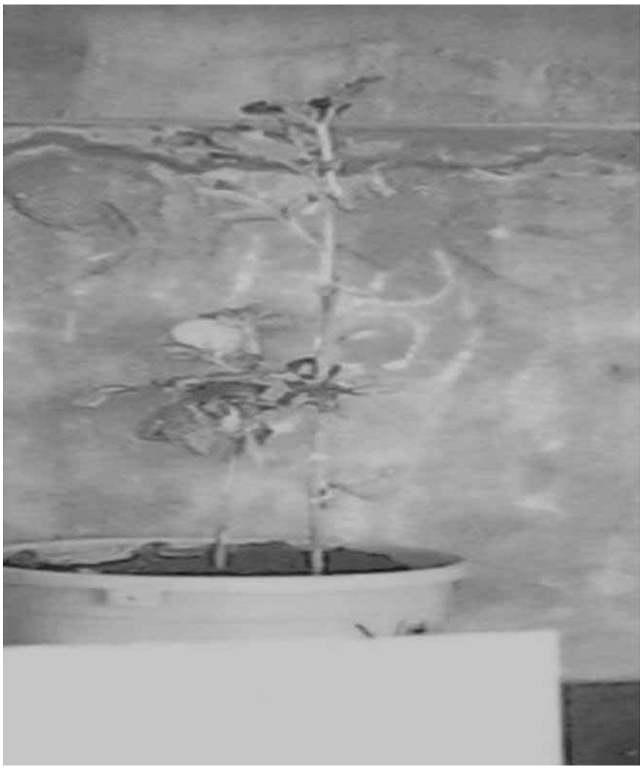

Plate 1. Soybean Soybean line TGx 1019-2 EN under CMeV infection

Effect on yield attributes

Plate 2

plate3

Comparative fruiting pattern between diseased (Left) and an apparently healthy soybean plant (Right).

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Analysis of Competition Power of Iranian Almond Export

Azizi Jafar (Corresponding author)
Department of Agricultural Economics, Islamic Azad University Branch of Rasht
PO box 41335-3516, Rasht, Iran
Tel: 98-912-338-5994 E-mail: Jafar574@yahoo.com

Yazdani Saeed
Department of Agricultural Economics, University of Tehran, Iran
Tel: 98-912-167-4771 E-mail: Syazdani@ut.ac.ir

Abstract

This study has been done in 2007 year to examine the competition power of Iranian almond in export markets and its relative advantages among the countries that are involved almond production and trade. A time series data for years 1970-2002 were analyzed to reach the study objectives. The RCA and RSCA indices were estimated to measure the competition power of almond in World market. The results indicated that based on introduced criteria, the value of RCA has been dropped from 222.71 in 1970 to 4.10 in 2002. So, this means that the position of Iran in almond export market is decreasing. Negative correlation between RCA of Iran and the USA shows that United State has been able to outshine Iran export market using new technologies. According to the estimated export function, it seems that the variables such as domestic GDP, wholesale price Index and foreign exchange rate have a significant impact on export of almond.

Keywords: Almond, Export, Competition, Relative advantage

1. Introduction

Almond is a tree from *rosaceae* family and from *prunus* gender that originated from wild species in low slopes of central Asia and eastern south mountains. The cultivation of almond from Greece was spread to Mediterranean shores in specific areas about 450 years ago. Most of botanists believe that the origin of almond is Iran. They also believe that almond was taken from Asia to Europe and from Europe to the North of Africa. It was also taken to California in the middle of the 19th century. The almond tree grows pretty well in Mediterranean climate conditions which have dry and hot summers and mild winters. In all part of Iran except Bushehr, Khuzestan, Hormozgan, Guilan, Mazandaran provinces and some areas in Gorgon and Gonbad almond in being produced. The main production areas are; Chaharmahal Bakhtiyari, Tehran, Qazvin, Semnan, East Azerbaijan, Fars, and Yazd. Almond mostly can be produced in a dry area. The main variety of almond which is being produced in the world are nun Pril, California, Mishen, Noplastantra, Tampson and Pirless. The time of blossom, productivity, sensitivity to plagues and diseases, access to markets and taste are the main factors affecting on variety selection in different part on the country. The main variety of almond which is produced in Iran are; Peste Badam, Mohebali and Mamaei. Almond is a rich nuts in terms of nutrition and its consumption in the world is high. Unshelled almond is consumed in raw as well as used in bakery and sweets industries. The extracted oil of almond is also being used in medical industry. The wood of almond tree crust is used in providing pulp, Neopan, etc (Garden assistance of agricultural ministry, 1381). In overall almond is one of the most important non-oil export products in Iran. The government of Iran also emphasizes on export of non-oil products in the 4th economic development program. Therefore, it is a need to study the trend of export and its structure in comparison to the other exporting countries. We need to find the ways of increasing the share of Iran in world export market. We have to develop a program which can encourage the firms to act more efficient in the world market. This study tries to show the relative advantages of Iranian almond and make some practical suggestions.

1.1 The purposes of the study

The main objectives of this study are;

1) to determine the relative advantage and competition power of Iranian almond..

2) to analysis the correlation between the export of Iranian almond and other producing countries in international competition market.

3) to estimate the export function of almond and examine the factors affecting on export.

1.2 The hypothesis of the study

1) Iran has relative advantage in almond production comparing to the main producing countries (e.g. the USA, China, and Spain).

2) The competition power of Iranian almond has decreased through the time.

3) Almond wholesale price Index has negative effect, and GNP and Domestic Product (DP) have positive impact on almond export.

1.3 A review on previous studies

Pawl, in 1992, has studied those factors affected on almond export as well as factors which cause instability in exports income. He has used a time series data of agricultural export products for years 1970 – 89. The results of this study showed that the estimated parameters of price and the amount of exported products such as coffee, tea, linen and cotton have negative signs. Also calculated correlation of price and the export of sugar and tobacco were positive. So this shows that there is a fluctuation in demand income gained from almond in export market (Pawl, 1992).

Naryanan and Redi in 1992 have studied the behavior of net presentation development of exports for some agricultural goods, in India. They have used in their study a times series data for yeas 1360-1376, which had been published by Foods and Agricultural Organization. The obtained results showed that domestic production and wholesale price index have positive and negative effects respectively. Export price, domestic product, foreign exchange rate, and gross national product with positive effect have become significant in orange exports function. There is instability in export income obtained from exporting sweet lemon, orange, and the whole citreous fruits.

Salami and Pishbahar in 2000 year have studied the existence and non existence of relative advantage and their trend changes during 1990-2000 for some groups of garden products in Iran. They used RSCA and RCA measures in their studies. The obtained results indicated that although Iran has relative advantage, based on calculated criteria in the production but general policies of commerce and economical behavior of producers and exporters have been in a manner that they couldn't show a proper respond against export structure changes of countries in the area and world(Salami and Pishbahar, 2000).

Helliner in 1990 has used RCA indicator to show the direction of export trade strategy of some goods in short time. He states that when RCA criteria show relative advantage fluctuations and competition power of export goods, the general trade policies of the country have impact on RCA. He believes that RCA criteria can be used as an export strategy for those goods (Helliner in 1990).

2. Method of study

Exporting goods and services have important role in the economics of countries. When trade is flourished, all countries try to make proper policies in order to active the engine of economic growth. So, competition in the field of trade increases, and those countries are successful which have a clear and specific strategy for exporting their products (Pal, 1992).One recognition instrument of exports feedback in different countries, is trade share changes or relative advantage which has become well known during the time, and one criteria which has been presented to measure the export action of countries and different goods, is the criteria of relative advantage which has become well known in RCA that presented for the first time in 1965 by Ballasa.

The RCA emphasizes on the existing structure of exports to study the possibility of joining the developing countries to World Trade Organization (WTO). The RCA Index is defined as follows (Helliner, 1990):

$$RCA = \left[\frac{\frac{X_{ij}}{X_{Tj}}}{\frac{X_{iw}}{X_{Tw}}} \right] \quad (1)$$

Where, X_{ij} is the exports value of *ith* goods for *jth* country.

X_{Tj} is the value of total exports of agricultural products of *jth* country,

X_{iW} is the exports value of *ith* goods in the world and X_{TW} is the total exports value of world agricultural products.

When the calculated value of is less than one, it means that country doesn't have the relative advantage in *ith* product. In contrast, if it is grater than one, it would have relative advantage. The variation of RCA is a main reason for absence of specific export strategy (Goldin, 1990).

Unsymmetrical indicator of relative advantage, is considered to be a weak point of RCA indicator. To overcome the weakness of RCA indicator, a symmetrical ratio of this indicator is presented by Leamer in 1992.

$$RSCA_{ij} = \frac{RCA_{ij} - 1}{RCA_{ij} + 1} \quad (2)$$

The RSCA indicator varies between *-1* to *+1*. Regarding to the results of the previous studies, the most important factors which have impact on export are as follows: the price of goods, the wholesale price index, foreign exchange rate, the amount of domestic production, and gross national product of country. In the present study, two linear functions and two forms of linear logarithm functions were estimated to examine the effective factors on export of almond: (Xiaming and et. al. 1997).

$$X_t^s = A\, PE_{it}^{a1}\, PD_{it}^{a2}\, DP_{it}^{a3}\, GNP_{it}^{a4}\, ER_{it}^{a5} \quad (3)$$

Where, X_t^s is the amount of almond export,

PE_i is almond export price,

PL is wholesale price Index,

DP_i is domestic production of almond,

GNP_i is gross national product and

ER_i is foreign exchange rate, that we will have a >0, a <0, a >0, a <0 and a >0.

The Linear function form also is as follows (DESS, 1991):

$$X_t^s = A + a_1 PE_{it} + a_2 PD_{it} + a_3 DP_{it} + a_4 GNP_{it} + a_5 ER_{it} \quad (4)$$

In a linear functional form It is expected that export price has a positive effect on the amount of exports (Gymah, 1991).

For existence or non existence of instability, first of all, a logarithmic function is estimated for income earned from almond export and time as follows:

$$LnE_t = b_o + b_1 Lnt \quad (5)$$

Where, E_t is income gained from export of almond and *t* is a time trend.

b_o and b_1 are parameters. Then the level of instability and fluctuation in almond export income could be calculated using the following formula (Arnade and Vsavada, 1995)

$$I^* = \sum \frac{(LnE_t^N - LnE_t^o)^2}{n} \quad (6)$$

Where, I show the amount of instability, LnE_t^N is the natural logarithm of export income, LnE_t^o is the amount of export income obtained from export function.

The larger value of I, the higher will be the amount of instability in export income (Gelezakose,1972).

Required information and data for this study were collected in the form of time series data, from Ministry of Commerce, F.A.O statistical lists, Customs Office, International Bank, Agricultural Ministry and other related organizations.

3. Results and Discussions

3.1 Calculating RCA and RSCA criteria for main exporting countries of almond in the world

According to F.A.O information in 2002, the total area almond production in the world were 1,731,890 hectares. The main three almond producing countries are; Spain, the USA, and Tunes respectively. Iran is placed in the fifth position in terms of production. The volume of almond production in main countries is; USA 444 thousands, Spain 315 thousands and Iran 100 thousands ton. The value of exported almond in the world has an annual increase of 8.5 percent during 1970- 2002. The volume of almond exported by Iran is low comparing to the whole world. The share of Iran from shelled almond exports was about 1.7 percent in 2002. On the other hand, a few number of world countries import almond from Iran in recent years. Even though there is an increasing tern in almond export but still its main buyers of Iranian almond are limited to three Asian countries such as United Arab Emirates, Ukraine and Pakistan.

There are some actions taken by Iranian agricultural ministry in order to extend the cultivated area of almond in the fourth 5 year Economics and Social Development Program, but it should be noted that any development program has to be done based on relative advantage principle. In order to increase the almond exports there is a need for provision of a precise export strategy and proper direction for exports of this important product. To examine the strengths of countries in world trade market the RCA and RSCA indices were computed during years 1970-2002 for almond of famous countries such as: Iran, USA, China and Spain. The results are reported in table 1. As the data in table 1 show the RCA criteria for Iran, USA, Spain are equal to 222.71, 1.22 and 6.8, respectively. Also, RSCA criteria for these countries are equal to 0.99, 1, 0.74, respectively. According to these results we can say that there are relative advantages of almond exports in 1970, for all these three countries (i.e. Iran, USA, and Spain), it is clear that Iran's relative advantage indicator is higher than other countries. The trend of RCA of Iran during 1970-2002 show that Iran's position in almond exports market is dropping and there is no strategy to support Iran's position in world market. The RSCA criteria trend also confirms this result. The estimated RSCA index for Iran show that Iran position in world market has been declined from 0.99 percent in 1970 to 0.60in 2002. The USA's RCA was facing with a fluctuation at the beginning of study period but later it shows an increasing trend so that it has increased from 0.73 in 1981 to 5.70 in 2002. This indicate that The USA has got a specific export strategy enabling the USA to increase her market share in world market and also improve its efficiency to gain relative advantages in almond export. The USA's RCA at the beginning of the study period has been facing with a significant fluctuation and its negative value shows there is not a relative advantage but from 1982 it has taken an ascending process that shows its relative advantage. Spain's RCA and RSCA criteria for almond show that this country, like Iran, does not have a clear export strategy in almond market. Spain also like Iran didn't have a relative advantage in almond export market in 1991, 2000, 1996 and 2001. Based on these criteria, the amount of relative advantage for Spain is lower than Iran's relative advantage, so that the value of Iran's relative advantage descending was higher rate comparing to Spain ones. The average value of RCA for Iran was 90.51 for the USA was 2.61 and for Spain was 5.17. So, the first and second theories of this study confirm that relative advantage of Iran almond exports, in comparison with other competitors is higher but this advantage is descending. Based on RSCA and RCA criteria, Chinas almond doesn’t have a relative advantage and it isn’t disputable. The result also indicate that RSCA and RCA criteria for Iran show a relative advantage of almond in export market and this relative advantage has a descending process. For the USA and Spain, in some years, it shows that there aren’t relative advantages, but about USA this relative advantage has an ascending trend.

3.2 Correlation of RCA criteria among almond exporting countries

Iran, USA, China and Spain are the largest exporting countries in the world, so that they have about 73 percent of whole market in the world. The USA share of almond and shelled almond is about 63 and 70 percent of world market respectively, so that it has enough power to determine the world price of almond. Based on obtained results from the following table (Table 2), the correlation coefficient of Iran's RCA with America RCA is significant. In other words, USA almond is considered to be a big competitor for Iran almond in world markets, and this correlation is equal to -0.689. So, considering the position of USA in world market and its negative correlation with Iran's export advantage, a precise export program is required to increase the volume of Iran's export. According to the data reported in table 2 there is a positive relationship between Iran and Spain RCA and it is significant in 5 percent level.

3.3 Estimation of almond export function and determining their stability

In order to recognize effective factors on exports of almond, and to examine each factor, almond exports function was estimated. A time series data have been used to estimate the function of exports. Indoor to examine the stationary of time series variables, the unite root and co-integration of variations were used. When time series data are used, their stationary states have to be considered. It means that, two variables may have linear relationship with each other in a short time, but, in long time, there won't be a significant relationship between them. In this case, they are called divergent. In some studies, with this theory that average and variance of a variable aren't changed during the time, time series variables have been used, while they may be unstable and their average and variance change during the time. If these unstable variations was presented in a model, and considered as stable ones, then the model will face with a problem and their coefficients will be different from the real ones. In order to test the stationary the following hypothesis was used;

The existence of unit root is $H_o: \beta=0$

Nonexistence of unit root is $H_1: \beta\neq0$

If β is significant, the hypothesis of H_0 will be rejected and variable is stationary. As mentioned earlier an ADF test was applied to test the Unit root. The results are presented in the table3. As it is shown in the table, variations have been studied both in the form of logarithm and first difference level. The Unit Root test shows that the variables are stationary and hypothesis was rejected. In table 3, the results show that because some variations are not stable, so, the first difference level for unit root test has been used. Because in differential conditions, ADF values are bigger than critical values, the stability of variations is confirmed. Different tests have been used to test the stable relation between variables. The results confirm the convergence. In the present study a Philips prone method has been also used. In this method a time series was regressed on other assuming with and without progress. Those functions which are convergent can't be far from each other in long time, so, their long term relation will be significant. The obtained results of Philips prone test are presented in the table 4. Regarding to the results reported in table 4 two statistics of *TAU* and *RHO* show almost similar results. These two statistics confirm the convergence of model in 3 levels: zero average, simple average and process. In other words, those data that are used in the present study are in the direction of doing convergent analysis and their results are supposed to be trusted. The functions of almond export in Iran two forms of linear Logarithm model and linear. The obtained results of final calculation, after removing multi co linearity, are presented in table 5. The export functions were estimated using SPSS software. The results show that in linear logarithm model, parameters of variables such as internal production, and indicator of wholesale price index have significant impact on export (Table5). This model shows that 1 percent increase in almond internal production will increase 8.1 percent of its export presentation. Also, 1 percent increase in almond wholesale price will reduce its export to 5.59 percent. So, the third hypothesis of this study is confirmed. The value of R squares is 0.64 that shows the variables in the model describe 64 percent of change in dependent variable (export). In linear model, variables such as; foreign- exchange rate and the indicator of wholesale price were significant. The calculated coefficient for foreign exchange rate indicates that if we have one unit increase in foreign exchange rate, then the amount of almond export presentation will increase about 145.53 units. Also, one unit increase in indicator of almond internal wholesale price will reduce 3.13 units of almond exports. The R square of linear model was 0.66 indicating that 66 percent of changes in dependent variable were explained by independent variable.

Due to the multi-co linearity problem only the export price was entered in the model.

In order to test the co integration the export function was estimated on time variable as follows;

$$LnE = 5.5 + 3.\ 21\ Lnt$$

$$se\ (1/\ 91)\ ^{**}\ (1/\ 75)\ ^{***}$$

$$R^2 = 89.1$$

The value of income variance is equal to 37.2 that show the whole value of almond export has high fluctuations and it is increasing where as export volume is reducing. So, considering these effective factors on export which have been studied in our model. There is a must to improve those effective variables and try to have an efficient program to improve the export of almond.

4. Conclusion

Almond is a garden product which is considered as a non-oil export product in Iran. The export of Almond has a significant fluctuation in recent years. This study has been done in 2007 year to examine the competition power of Iranian almond in export markets and its relative advantages among the countries that are involved almond production and trade. The required information for the present study was time series information of production and exports (during 1970-2002). The required indices for measurement of export competition power have been RCA and RSCA criteria. The results are reported in table 1. As the data in table 11 show the RCA criteria for Iran, USA, Spain are equal to 222.71, 1.22 and 6.8, respectively. Also, RSCA criteria for these countries are equal to 0.99, 1, 0.74, respectively. So, this point shows that the position of Iran in almond export market is fading. Negative correlation between RCA of Iran and the USA one shows that the USA has been able to outshine Iran export market using new technologies. Regarding to the result of estimated export function the value of income variance is equal to 37.2 that show the whole value of almond export has high fluctuations and it is increasing where as export volume is reducing. The results also indicate that there is a grate need for a suitable strategy for Iranian almond export market. Government should makes a number of measures to support the exporters and remove their weakness.

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Table 1. The amounts of RCA and RSCA criteria for main exporting countries of almond in the world

year	RCA					RSCA			
	Iran	*USA*	*Spain*	*China*		*Iran*	*USA*	*Spain*	*China*
1970	222.71	1.22	6.8	0		09911	0.988	0.7435	-1
1971	251.41	0.63	7.11	0		0.9921	-0.2272	0.7534	-1
1972	195.35	1.07	6.49	0		0.9898	0.0329	0.7329	-1
1973	154.9	0.43	5.44	0		0.9872	-0.3982	0.6896	-1
1974	278.4	1.12	5.28	0		0.9928	0.0578	0.6810	-1
1975	164.73	1.29	8.68	0		0.9879	0.1268	0.7934	-1
1976	92.24	0.34	8.57	0		0.9786	-0.4885	0.7910	-1
1977	95.14	0.61	6.28	0		0.9792	-0.2444	0.7251	-1
1978	51.98	0.67	5.62	0		0.9622	-0.1984	0.6979	-1
1979	57.19	0.75	7.8	0		0.9656	-0.1417	0.7726	-1
1980	199.79	0.87	13.21	0		0.99	-0.069	0.8593	-1
1981	130.58	0.73	36.45	0		0.9848	-0.1558	09466	-1
1982	171.75	2.53	7.27	0		0.9848	0.4329	0.7582	-1
1983	208.84	2.34	6.12	0		0.9908	0.4013	0.7193	-1
1984	158.95	0.52	1.78	0		0.9875	-0.3126	0.2812	-1
1985	25.16	2.16	3.83	0		0.9235	0.3666	0.5855	-1
1986	34.48	2	3.54	0		0.9436	0.3364	0.5596	-1
1987	34.84	2.72	3.39	0		0.9442	0.462	0.5442	-1
1988	9.97	4.23	2.15	0		0.8176	0.6175	0.3653	-1
1989	12.57	4	2.56	0.05		0.8526	0.6002	0.4378	-0.9073
1990	25.58	3.65	3.47	0		0.9248	0.5696	0.5527	-1
1991	70.8	3.33	0.95	0		0.9721	0.5383	-0.0261	-1
1992	38.87	3.64	1.24	0		0.9498	0.569	0.1079	-1
1993	40.22	2.45	1.55	0		0.9515	0.4205	0.2153	-1
1994	31.42	4	1.15	0		0.9383	0.6005	0.06886	-1
1995	35.63	4	1.4	0.02		0.9454	0.6029	0.1668	-0.9606
1996	72.1	4.57	0.93	0		0.9726	0.6408	-0.034	-1
1997	3.95	5.7	1.69	0		0.5956	0.7014	0.2566	-1
1998	5.74	5.34	1.73	0		0.7032	0.6843	0.2673	-1
1999	13.62	5.47	1.23	0		0.8632	0.6906	0.1034	-1
2000	3.31	5.32	0.97	0		0.5361	0.6838	-0.016	-1
2001	4.11	5.69	0.82	0.03		0.6083	0.7011	-0.098	-1
2002	4.10	5.67	0.80	0.03		0.608	0.700	-0.097	-1
Average	90.51	2.61	5.17	0		0.91	0.27	0.47	-0.99
Variance	6972.23	3.29	41.86	0		0.02	0.15	0.1	0

Source: investigation findings

Table 2. Correlation of RCA amount of almond exporting countries in the world.

	Iran	USA	China	Spain
Iran	1			
USA	-0.689 (0.0001)	1		
China	-0.276 (0.126)	0.320 (0.074)	1	
Spain	0.389 (0.028)	-0.512 (0.003)	-0.158 (0.387)	1

Numbers inside parenthesis show significant possible surface.

Surface: investigation calculations.

Table 3. The obtained results of unit root test using ADF test

variation	ADF	Critical amount	significant surface
D(InX)	-4.16	-2.10	1%
D(InPD)	-2.1	-2.05	10%
D(InPE)	-3.07	-2.14	5%
InGNP	-5.71	-2.32	1%
D(InER)	-7.31	-4.55	1%
LnDP	-4.33	-3.49	10%

Source: findings of investigation

Table 4. Unit root test based on A.F.P

Conditions of Coefficient	The number of Pause	Rho	Probable surface Of Rho	TAU	Probable surface Of Rho
Zero average	1	-2.74	0.504	-2.33	0.927
Simple average	1	-3.55	1.89	-2.46	0.382
Trend	1	-6.74	1.61	-2.12	0.194

Source: findings of investigation

Table 5. Calculation of presentation functions of IRAN almond exports

Coefficients	Linear model		Linear- logarithmic model	
	T statistics	Amount of coefficients	T statistics	Amount of coefficients
Constant	-7217.648	-2.494	-22194.9	-3.48
export price	0.221	-0.167	0.036	-0.795
Wholesale price indicator	-3.13	-2.161	-5.56	-1.301
Domestic production	0.143	-0.115	8.10189	3.645
Gross National Product	-0.043	0.053	-0.059	-0.198
Foreign exchange rate	145.53	2.026	0.86	0.45
R	0.662		0.64	
R	0.604		0.59	
F	7.762		10.627	
D.W	1.65		1.62	

Source: findings of investigation

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Candidate Genes Polymorphism and Its Association to Prolificacy in Chinese Goats

Yuanqing He (Corresponding author)
Institute of Life Sciences, Jiangsu University
301 Xuefu Road, Zhenjiang 212013, China
Tel: 86-511-8879-1702 E-mail: yqhe@ujs.edu.cn

Xiaoke Ma, Xiaoyong Liu, Cunxia Zhang & Jun Li
Institute of Life Sciences, Jiangsu University
301 Xuefu Road, Zhenjiang 212013, China

Abstract

To find the candidate gene concerned with prolificacy in goats, the most part nucleotide sequence of four genes, including GDF9 gene, BMP15 gene, BMPR1B gene, and INHα gene were identified in three goat breeds for their probable association to the high fecundity. The results showed that none of polymorphism of GDF9 gene, BMP15 gene and BMPR1B gene was tested in goats, and one mutation was detected in INHα gene. The genotype distributions of INHα gene were significantly difference between year-round estrous goat breeds and seasonal estrous goat breeds revealing the association to the prolificacy in goats.

Keywords: Goat, PCR-SSCP, Reproduction

1. Introduction

The process of ovarian folliculogenesis is composed of proliferation and differentiation of the constitutive cells in developing follicles [Silva et al, 2005]. The number of mature oocytes released during one reproductive cycle and oestrum were determined by a complex exchange of endocrine signals between the pituitary gland and the ovary and by paracrine and possibly autocrine signals within ovarian follicles involving the oocyte and its adjacent somatic cells [Galloway *et al.*, 2000; Eppig, 2001; Durlinger *et al.*, 2002; Knight and Glister, 2003]. In goats, little information is available on the local factors that regulate this process. Many mammals including primates, goats, cattle, deer and possums normally have an ovulation rate of 1 or sometimes 2 whereas other mammals such as rats, mice, hamsters, cats, dogs and pigs have ovulation rates that are between 4 and 15. Current knowledge of major genes for prolificacy in domestic animals falls into three categories: (1) genes where the mutation has been identified and DNA testing is available; (2) genes where the mode of inheritance has been described but the mutation has not been identified; (3) putative genes where there is evidence of apparent genetic segregation but there are insufficient records to ascertain the mode of inheritance [Davis, 2004].

Many years have gone since people have great interest in identification of major genes for prolificacy in ovis aries. In recent years, a number of natural genetic mutations have been identified with ovulation rates varying between 0 and 4 in sheep breeds including one point mutation in the GDF9 gene ($FecG^H$), five different mutations in the bone morphogenetic protein 15 gene ($FecX^G$, $FecX^B$, $FecX^I$, $FecX^H$, $FecX^L$), and one in the BMPR1B gene (FecB). It was certificated that these mutations had great association to the ovulation rate of different sheep breeds, especially the FecB mutation (Booroola breed) and $FecX^G$ (Inverdale breed). In the present study, these genes were selected again to detect the probably effects on goat prolificacy.

Inhibin, a glycoprotein, is a gonadal hormone, which can inhibit the synthesis and secretion of pituitary follicle-stimulating hormone (FSH), which has an important role in the recruitment and development of ovarian follicles during the folliculogenesis, and Ala257Thr missense mutation of INHα gene, has an important role of its receptor binding, and has been indicated as candidate gene in premature ovarian failure (POF) pathogenesis. Therefore, the INHα gene was selected as the fourth candidate gene. We investigated the single nucleotide polymorphism (SNP) of the four genes in goat breeds by single strand conformation polymorphism (SSCP) method, and discuss the association to the reproductive traits in goats.

2. Materials and methods

2.1 Animal samples and DNA extraction

All the samples were collected in china. 170 Haimen goats were collected from haimen goat conservation base located in haimen city of Jiangsu province, 80 Boer goats and 40 huanghui goats were collected from Boer reproductive base located in feng city in Jiangsu province. Ovulatory activity of most goat breeds in generally inhibited for several consecutive months of the year, referred to as the anestrous seasonality, which occurs during the spring and summer. However, Haimen goat, which was an excellent local breed in China, displays significant characteristics of year-round estrus and higher average litter size. The other goat breeds in this study display significant characteristics of seasonal estrus [Tu, 1989]. These does were chosen at random. Genomic DNA was extracted from whole blood by phenol-chloroform method, and then dissolved in TE buffer (10mmol/l Tris-HCl (PH 8.0), 1mmol/l EDTA (PH 8.0)) and kept at -20℃

2.2 Single-stranded conformation polymorphism (SSCP) for genes

Primers were designed from nucleotide sequence GenBank accession number AF078545(GDF9), AF236078(BMP15 exon1), AF236079(BMP15 exon2), AF357007 (BMPR1B), BTU16237(INHα). The polymerase chain reaction were carried out as follows: denaturation at 94℃ for 5 min, followed by 33 cycles of denaturation at 94℃ for 40 sec, annealing at different temperature and different time by the primer, extension at 72℃ for 40 sec, with a final extension at 72℃ for 10 min on Mastercycler 5333 (Eppendorf AG, Hamburg, Germany). The PCR products were heated to 95℃ for 5 min to denature the samples, and immediately placed on ice to prevent DNA strands from reannealing. A 3µl aliquot of each sample was electrophoresed overnight at 200-300 V. The SSCP gels consisted of 0.5×Tris-borate-EDTA (TBE) buffer, 8% or 10% or 12%polyacrylamide, 5% glycerol, 10µl (25% w/v) ammonium persulphate and 10µl N, N, N′, N-tetramethylethylenedia-mine (TEMED) for every 10 ml of nondenaturing gel. Electrophoresis was performed at low temperature (4℃), using 0.5×TBE running buffer. The DNA was visualized using silver staining.

2.3 Cloning and sequencing

PCR products were separated on 1.0% agarose gels and re-extracted using Gene clean II kit (Promega, Madison, WI USA). Each DNA fragment was ligated into the pGEM-T Easy vector (Promega, Madison, WI USA) at 16℃ overnight according to the manufacturer's instructions. The ligation reactions were carried out in 10 µl volume containing PCR product 1µl, pGEM-T easy vector (50ng/µl) 1µl, T4 ligase (3U/µl) 1µl, 2×ligation buffer 5µl, ddH2O 2µl. Each DNA fragment was then transformed into Escherichia coli DH5α competence cell. Positive clones of transformed cells were identified by restriction enzyme digestion. Two clones of each genotype were selected and sequenced. Each clone was sequenced for twice. The target DNA fragments in recombinant plasmids were sequenced from both directions using an automatic ABI 377 sequencer (Perkin Elmer Applied Biosystems, Forster City, CA, USA) by Shanghai Sangon Biotechnological Engineering Technololgy&Services Co.Ltd. (Shanghai, China).

2.4 Statistical analysis

Distribution of genotypes between different goat breeds was analyzed using chi-square method.

3. Results

3.1 SSCP analysis of four genes

Primer pairs were used to amplify genomic DNA of different genes, and the PCR products were separated on 1.5% agarose gels. The results showed that amplication products had good specificity, which could be directly analyzed by SSCP. The PCR products were electrophoresed overnight and visualized by silver staining. The results showed the primers of BMP15 gene, GDF9 gene and BMPR1B gene had no polymorphism (figure 1), and the primers of INHα gene showed different genotypes (figure 2).

3.2 Sequencing of different genotypes

In this study, we did not find any mutation in GDF9 gene, BMP15 gene and BMPR1B gene, and find a mutation in INHα gene resulting different bandtype and sequence difference, it was C865T (figure 3). The C865T mutation existed in the exon of INHα gene, and did not induce an amino acid change and was silent. Sequence alignment indicated that the homology of 884bp nucleotides of 5'-flanking sequence and exon of caprine INHα gene between this study and Bos Taurus gene (BTU16237) in GenBank was 98.2%, and the homology of exon and deduced amino acid sequence was 97% and 98% respectively.

3.3 Allele and genotype frequencies of INHα gene in different goat breeds

Allele and genotype frequencies of exon of INHα gene in different goat breeds were shown in Table 1. For this mutation, the distribution of gene frequency in Haimen goats was obviously different from the other goat breeds, and the bb genotype was also higher than the other goat breeds significantly, which means that the frequency of genotype bb was obviously higher in year-round estrous goat breeds than in seasonal estrous goat breeds. These results preliminarily showed an association between genotype bb and year-round estrus in goats.

3.4 Chi-square analysis for INHα genotype distribution in different goat breeds

We also analyzed the genotype distribution by chi-square method, and the test result was summarized in Table 2. For C865T mutation, the differences of genotype distributions were significant (P<0.001) between Haimen goats and the other goat breeds, which also means that the difference of genotype distributions were significant between year-round estrous goat breeds and seasonal estrous goat breeds. Furthermore, the difference of genotype distributions were not significant (P=0.11>0.05) between Boer goats and Huanghuai goats.

4. Discussion

DNA tests are the key to the utilization of these genes in the sheep industry and have also been a useful tool for determining the genetic basis of high prolificacy in distantly related breeds around the world. A variety of inheritance patterns are associated with these genes and there is a wide range in the size of the effect on ovulation rate. Artificial insemination and embryo transfer programmes have been used to successfully introgress the Booroola and Inverdale genes into other breeds in several countries, and these artificial breeding technologies have been particularly useful while only small numbers of progeny tested individuals have been available [Davis, 2004]. The goat breeding is just like the sheep, we also need to find out the key mutations in the candidate genes and know how these mutations affect the reproduction and how to increase the reproductive capability including reproductive seasonality and litter size, which will be a rapid and economic method to improve the goat breeding speed.

GDF9, BMP15, and BMPR1B gene enhanced the primary and preantral follicular growth in vitro and in vivo, and expressed in all the stages of the normal ovarian follicle development [Hayashi et al, 1999; Vitt et al, 2000; Hanrahan et al, 2004]. These genes were detected increasing ovulation in sheep breeds, especially $FecG^H$ mutation of GDF9 gene in Belcare and cambridge breeds, $FecX^G$, $Fecx^B$, $Fecx^I$, $Fecx^H$ and $Fecx^L$ mutation of BMP15 gene in several sheep breeds, and FecB mutation in BMPR1B gene[Davis et al, 2006]. In the present study, the results indicated that none of these mutations can be detected in all goat breeds including the high fecundity and low fecundity goat breeds, these mutations had no obviously effect on the difference of prolificacy in goats. They cannot be regarded as the major gene associated with the fecundity of goats. This conclusion also agrees with another research in Chinese [Hua, et al, 2008].

INHα gene was also detected in all individuals as the candidate gene. Recent years many studies on human research indicated that INHα gene was a strong candidate gene for premature ovarian failure (POF) [Harris *et al.*, 2005; Munz *et al.*, 2004]. They found the Ala257Thr missense mutation in INHα gene with high statistical significance in POF (9 out of 80, 11.2%) (Fisher's exact test, P=0.0005), and the conclusion was the INHα gene is a strong candidate gene for ovarian failure [Dixit *et al.*, 2004]. Other studies showed that INHα gene had the significant additive effect on the sheep prolificacy, INHA, INHBA, and INHBB had obviously gene effect on litter size [Jaeger, et al, 1994; Hiendleder, et al, 1996; Hiendleder, et al, 2002]. Another study showed that INHα gene had TaqI restriction fragment length polymorphism (RFLP), and TaqI A allele associated to the average litter size on sheep breed [Leyhe, et al, 1994; Sise, et al,1991]. In this study, we found a mutation (C865T) for the first time existed in the exon of the gene, which made an obviously difference in the gene frequency and the genotype frequency between the year-round estrous goat breed and the seasonal estrous goat breeds. We had known that inhibin gene is a completely conserved gene, and any mutation maybe lead to the functional decrease or failure. To certificate the difference of three goat breeds, we applied the Chi-square method to analyze the genotype distribution. The results presented that the differences of genotype distributions were significant (P<0.001) between Haimen goats and the other goat breeds, which also showed that the difference of genotype distributions were significant between year-round estrous goat breed and seasonal estrous goat breeds. According to these results, we concluded that INHα gene can be regarded as a candidate gene of goat high prolificacy.

Acknowledgments

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Note

Abbreviations: GDF9 gene, Growth differentiation factor-9 gene; BMP15 gene, bone morphogenetic protein 15 gene; BMPR1B gene, bone morphogenetic protein receptor 1B; INHα gene, inhibin α gene.

Table 1. Gene frequency and genotype frequency of the INHα gene in goat breeds

Breed	No.	Gene frequency		Genotype frequency		
		B	*b*	*BB*	*Bb*	*bb*
Haimen goats	170	0.04	0.96	0 (0)	0.08 (14)	0.92 (156)
Boer goats	80	0.44	0.56	0 (0)	0.84 (67)	0.16 (13)
Huanghuai goats	40	0.39	0.61	0.02 (1)	0.70 (28)	0.28 (11)

Note: the numbers in the brackets are the genotype individuals.

Table 2. Chi-square testing of genotype distributions of INHαgene in goat breeds

breed	Boer goats	Huanghuai goats
Haimen goats	141.64***	82.83***
Boer goats		4.32

* P<0.05, ** P<0.01, *** P<0.001

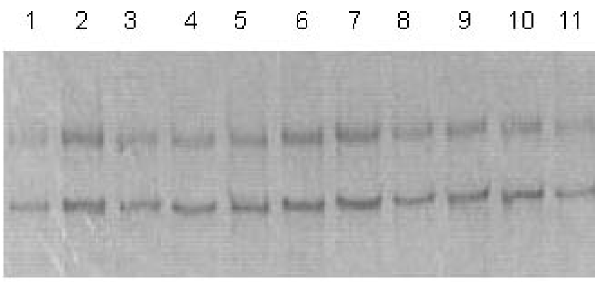

Fig.1 SSCP results of GDF9 gene, BMP15 gene and BMPR1B gene(simplex bandtype)

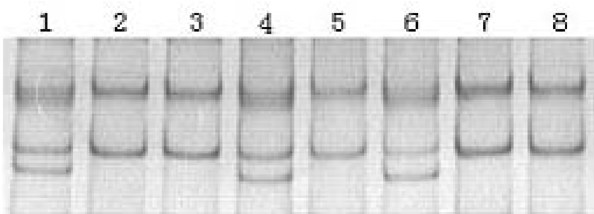

Fig.2 SSCP results of INHα gene(polymorphic bandtype)

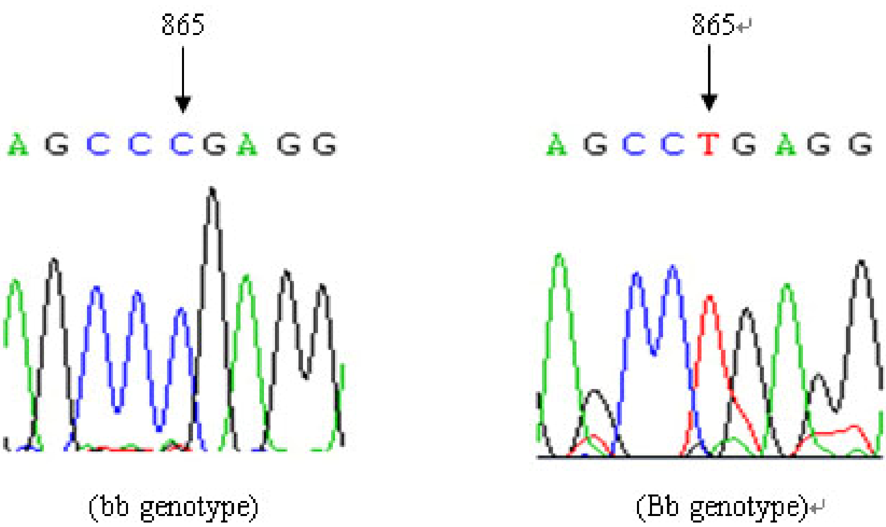

Fig.3 Sequence comparison of bb and Bb genotypes at 865bp of INH α gene in goats

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Building the Capacity of Farmer Based Organisation for Sustainable Rice Farming in Northern Ghana

Quaye Wilhemina (Corresponding author), Yawson Ivy, Manful John Tawiah & Gayin Joseph
CSIR – Food Research Institute P. O. Box M20 Accra, Ghana
Tel: 233-20-813-2401 E-mail: quayewilhemina@yahoo.com

The Food Security and Rice Producers Organisation Project (FSRPOP) was sponsored by French Embassy in Ghana

Abstract

This study assessed the perceptions of stakeholders concerning implementation activities of a Food Security and Rice Producers Organisation Project (FSRPOP) in Northern Ghana. The project aimed at building the capacities of farmer based organisations (FBOs) to assist rice farmers access credit, organise production inputs and improve market access. The study results showed that although access to input supply and production credit improved, enhancing farmers' marketing capacity was not successful. The management capacity of the FBOs was weak in performing more complex administrative issues and market facilitating roles. Timely provision of production inputs, use of custom based processing and credit inventory system for maximum profit were some of the lessons learnt. Facilitation of farmer - medium scale buyer linkages and the development of lessons-based action plan for change with beneficiaries were recommended

Keywords: Stakeholders, Rice, Development, Sustainability, Ghana

1. Introduction

Rice is a commodity of strategic importance to Africa and has become the fastest-growing food source to both rich and poor households (Nwanze *et al* 2006). Rice has become a major staple in Ghana in recent times although the crop has been cultivated for several years. It is an important food for both rural and urban dwellers, and is gradually taking over from traditional, mainly root and cereal crops, staples (Quaye *et al* 2000). Factors affecting increased consumption of rice have been identified to include rising incomes, trade liberalization, extensive promotion and effective marketing strategies of rice importers and ease of cooking among others (Oteng 1997; Day *et al* 1997; Tomlin's *et al* 2007).

Consumption of milled rice in Ghana went up from below 100,000 Mt to over 600,000Mt between 1985 and 2003 (Tomlin's *et al* 2005). Unfortunately, the sharp rise in consumption has not impacted positively on the local rice production levels since a significant proportion of rice consumed is imported (Quaye 2007). Rice is cultivated in four main ecological areas in Ghana. These include rainfed upland (in Northern Ghana), rainfed lowland (Northern Ghana), and Inland swamp-inland valley of central Ghana and irrigated – Northern and Southern Ghana. The major challenge faced by local farmers is the high cost of production since most of the agricultural inputs are imported (Khor, 2006). Other constraints limiting production include lack of access to credit, shortage of water, pests, diseases, unavailability of suitable varieties, low quality of locally processed rice and inefficient markets for inputs and produce (Furuya and Sakurai, 2003; Adolph and Chancellor, 2006).

It is against this background that development efforts to revamp the rice industry in Ghana have become crucial in recent times. One such effort is the lowland Rice Development Project (LRDP) and its extension, Food Security and Rice Producers Organization Project (FSRPOP). The LRDP was implemented in the Northern region of Ghana in 1999 – 2003 and the extension (FSRPOP) in 2003-2007. The first component (LRDP) aimed at demonstrating the viability of rice production in the treated lowland of the Northern Region. The second component (FSRPOP) aimed at sustaining the rice intensive cropping scheme developed under LRDP. This was done by building the capacities of farmer based organisations (FBOs) to fulfill some of the tasks ensured previously by LRDP, such as organise access to inputs and tractor services, monitor cropping activities, manage and sustain their collective structures (storage and water), access and manage credit as well as organise marketing of paddy. An APEX body (named Northern Region Intensive Lowland Rice Farmers' Cooperative Union -NILRIFACU) representing all FBOs at the regional level was formed to act as a mouth-piece and effectively negotiate with stakeholders including input suppliers, tractor owners, banks, rice processors and traders on behalf of the farmers

To alleviate the marketing problems faced by rice farmers in Ghana, FSRPOP project implemented a Parboiled Rice Quality Improvement Programme in the Northern Region where rice production is predominant with the following objectives:

- To produce on a pilot-basis in 4 selected communities located around *Tamale* (The regional capital of the Northern region of Ghana), high quality parboiled and milled rice. This is done using improved equipment and designing appropriate programmes of schedules or list of good practices for small-scale rice producers and processors, with close field supervision and technical support.
- Under the FSRPOP marketing support programme, the high quality parboiled and milled rice produced was then to be bought by the APEX bagged in 3-kg sachets, branded, advertised and displayed nationwide at a price equivalent to the Asian imported rice. Extra incomes generated by the sale of this rice were to be distributed equitably among the different stakeholders (Farmers, Processors and Millers) and therefore constituted incentives to follow the designed programmes of schedules.

Study Objectives/purpose

Specific objectives of this study were as follows:

- to investigate stakeholders' perceptions of project performance
- To document lessons learnt from the implementation strategies
- To make recommendations for improvement in project performance

2. Methodology/Study design

Qualitative research methodology was employed in the field survey to address study objectives. This was complemented with review of literature on FBOs. Using participatory appraisal techniques semi structured interviews, group discussions and informal interactions were conducted among the different stakeholders participating in the Food Security and Rice Producers Organisation Project (FSRPOP) in Northern Ghana.

2.1 Sampling

The sampling frame was the FSRPOP beneficiaries. This included four farmer groups selected from Sakapaligu, Kumbungu, Kuoku and Gbalahi communities in Northern Region; two processor groups and millers from Tamale and Kumbumgu and an APEX body with representatives from all farmer groups mandated to oversee the programme. The target communities were selected based on level of rice production and processing activities as well as involvement in the lowland Rice Development Project (LRDP) implemented in 1999 – 2003 in the same region**.**

The project covered 100 farmers in the four groups, 10 processors and 2 millers; which constituted the sampling frame for this study. From the sample frame, a total of 82 stakeholders comprising of 70 farmers in the four groups, 10 processors and 2 millers were interviewed. In addition, the APEX body consisting of farmer representatives and community leaders was also interviewed

2.2 Data collection

Data collection instruments were semi-structured questionnaire and interview guide for interviews and focus group discussions respectively. The semi-structured questionnaire which comprised several open-ended questions allowed respondents a wide range of options and encouraged them to express their views on the project implementation strategies. Respondents were tasked to evaluate project performance with respect to targets and achievements as well as expected impact on beneficiaries. Focus group discussions were useful for triangulation and consensus building on key issues relating to project output indicators (Borgatti 1999; Denzin and Lincoln 2005).

2.3 Data Processing and Analysis

Statistical Package for Social Scientist (SPSS) version 16.0 was used for data analysis. The data was cleaned and processed. SPSS analysis outputs were then exported into a well designed Excel Template to generate indicator results and relevant inferences made.

A GAP analysis was employed (Timsina *et al* 2004). This sought to identify programme interventions, gauge set targets against achievements, and the variance noted. The assessment team also interacted with project monitoring task team and a meeting was also held with the French Embassy representative coordinating the FSRPOP project.

3. Findings

3.1 Intervention Strategies and GAP Analysis

As indicated in the methodology, the GAP analysis identifies programme interventions, gauges set targets against achievements, and the variance noted. Generally, the project provided support to FBOs to strengthen their capabilities. The purpose was to enable the FBOs relate better with the financial institutions improving on farmer access to credit, organise production inputs and also improve on access to market. In addition to technical support the FBOs were provided with logistics to facilitate the movement and operations of its officials. The analysis was done at various levels including farmer, processor, miller and APEX.

3.1.1 Farmer

Some of the constraints facing rice farmers identified under the lowland Rice Development Project (LRDP) were poor farming practices, lack of capital, high cost of production inputs such as fertilizer and seed, lack of access to market as well as lack of price incentive to produce high quality paddy. At the farmer level, the FSRPOP programme sought to remove these constraints especially lack of access to market in order to improve on the livelihood of farmers. It was expected that about 70 tonnes of paddy rice from farmer fields would be purchased for quality improvement processing activity. The FSRPOP instituted a system to encourage farmers produce high quality rice by way of production contract and input credit as incentives. The primary objective of providing ready market for farmers' produce was achieved. However, some farmers refused to sell to the APEX; only a third of volume of paddy expected was sold. Apparently open market conditions at the time of harvest were better than anticipated based on the previous year's experience. Farmers actually expected the APEX to offer higher selling prices than the open market. Open market price for paddy rice was $16 per 95kg –bag as compared to $14 per 83kg-bag offered by APEX. Generally farmers did not consider the weight of paddy per bag but rather 'bag' as the unit of measurement. Thus although the unit selling price (approximately $0.17/kg) was the same for APEX and the open market farmers did not realized this as a problem of standardization. Table 1 gives a summary of farmers' constraints, proposed interventions, achievements and deviations identified.

3.1.2 Processor

At the processor level, the FSRPOP sought to provide technical assistance on best processing practices that would enhance rice quality. Two groups of processors from Tamale and Kumbugu benefited. Selected processors were indirectly linked up with participating farmers. The processors were given paddy rice organized from participating farmers by the APEX body for processing on service charge basis. Total service charge per 83-kg paddy bag for processing was US$5.4 and US$5.65 for Kumbugu and Tamale processors in the Northern region respectively. The difference in service charges was due to variations in processing costs.

Table 2 shows summary of processors constraints, interventions, achievements and deviations identified. The main challenges facing rice processors in the study area included inadequate access to quality raw material from farmers, inefficiencies in processing techniques, poor condition of drying space and inadequate access to urban market as well as low demand for local rice by the Ghanaian populace. The FSRPOP was therefore designed to improve access to quality raw material/paddy rice, provide technical assistance on best processing practices, and provide improved vessels which reduce fuel, water and labour costs and also make provision of cement for repair and maintenance of drying floors. The improved vessel has a higher capacity of parboiling one 83-kg bag of paddy as compared to a third for the traditional pot. A total of 10 women processors benefited from the FSRPOP arrangement.

3.1.3 Millers

One of the factors affecting the quality of milled rice is the condition of the mill used. Two mills close to the location of processors were identified for rehabilitation under FSRPOP. These millers were supplied with shafts sieves, blades, bearings, belts and housing. The project management in collaboration with stakeholders and the APEX body estimated milling charge of US$1.25 per 83-kg parboiled paddy bag (milling passed twice) instead of existing milling charge of US$1.0 (milling passed once). This was actually paid as expected. Table 3 shows summary of millers' constraints, proposed interventions and achievements.

3.1.4 APEX

Under the lowland Rice Development Project, it was identified that farmer based organizations in the study area were weak and unable to negotiate effectively with main stakeholders in the rice industry at the regional level. The FSRPOP aimed at building the capacity of the APEX body, which is the farmers' representative body at the regional level, to better serve the interest of farmers and also work effectively towards the achievement of the overall project goal of producing high quality parboiled-milled rice for an attractive market price**.** Table 4 shows summary of interventions, achievements and deviations identified at the APEX level.

3.2 Perceptions about project performance

3.2.1 Farmers' perception

Assessing the activities of the APEX body, about 75% of the farmers visited in the project areas were quite satisfied with its capability with regards to helping farmers to access credit facility, inputs and tractor services (See figure 1). Individual farmers could not have had that opportunity. The rest (25%) complained about delays on the part of the APEX body in assisting farmers to access inputs and tractor services.

In relation to the marketing arrangements, half of the farmers did not have confidence in the capacity of the APEX body. Although majority of the farmers understood that whatever profit accruing from the quality improvement program was to be shared equitably among stakeholders, they felt the offer price for paddy at harvest was unattractive. Generally, farmers would want to store produce and sell when there are urgent needs for cash. This notwithstanding, farmers were willing to honour their contractual obligations if the price offer was attractive. Farmers also complained about the lack of communication on efforts being made by APEX to access urban market for parboiled and milled rice at the time of the survey**.**

Sahakpaligu

In the Sahakpaligu area, all the farmers (100%) who participated in the project were happy with the APEX activities with respect to credit and input arrangements. Access to credit facilitated their planting activities more easily. The farmers also indicated that access to land preparation services as well as farming inputs especially fertilizer contributed immensely to the relatively high yields achieved. The average yield/acre (0.4 hectare) obtained by these farmers was 10bags (a bag is 83-kg paddy); minimum and maximum of 6bags and 18 bags respectively.

Perception of this group on the marketing arrangements by the APEX body was fairly good. Although the buying price of paddy at US$14 per 83-kg bag offered by the Apex body was wrongly perceived to be a little lower than the average market price of US$16 per 95kg-bag of paddy, the farmers sold off most of the paddy rice they had harvested to the Apex body. This is because they believed in the sustainability of the project as well as the terms of agreement of the project. Selling off the paddy to the Apex body made credit repayment easier. Extra sales made after deductions were perceived as profit since family labour was used. They also took into consideration the fact that transportation cost of conveying the paddy to the market was eliminated therefore making up for the difference in market price of the paddy compared to the price offered by the Apex body.

Kumbungu

In this area the average yield per acre (0.4 hectare) of paddy rice harvested was approximately 10bags. Farmers in this area also perceived the project as being beneficial to them especially in terms of building the capacity of APEX to help farmers' access credit, inputs and tractor services. All the farmers in this area were contented because hitherto most of them could not afford to purchase basic farm inputs such as fertilizer for increased yield of their produce. They also expressed satisfaction at the training programmes they received under the project. Most of the farmers stated that training on the method of application of fertilizer was most beneficial to them since some of them lacked that requisite knowledge. On the whole this group was the most appreciative of the project and they expressed their willingness in sustaining its activities. They were known to be the group that sold off its entire rice paddy harvested to the Apex body. They had confidence in the marketing arrangement.

Kuoku

Farmers in this area indicated that though the project design was good and laudable in terms of building the capacity of the APEX to assist farmers' access credit, inputs and services for farming, poor climatic conditions coupled with unleveled fields prevented them from obtaining the full benefits of the project. Poor rainfall observed in this area during the planting period of the paddy rice was translated into low yields of approximately 7bags/acre of paddy rice harvested. The lowest yield in this area was 3bags/acre (0.4 hectare) and the highest was 11bags/acre under the project. The farmers indicated that though yields gained under the project were low due to poor climatic conditions it was nonetheless superior to yield per acre for non-participating farmers. They were however not too happy with the marketing arrangements.

Gbalahi

Farmers who participated in the programme in this area complained of some problems that did not make them realize the benefits of the project. They alleged that the credit, input and tractor service arrangements came a bit too late into the farming season. Hence the late cropping of the paddy rice resulted in low yields/acre of approximately 6.5bags/acre. They maintained that normally yields could be as high as 18bags/acre (0.4 hectare). Farmers in this area were also not happy with the marketing arrangements offered by the APEX body. They hinted that the buying price of US$14 per -bag of paddy proposed by the Apex body was too modest compared to the existing market value of US$16 per -bag and therefore refused to sell any of the harvested rice to the APEX body. Farmers did not consider differences in weight of bagged rice sold (open market vis-à-vis offer by APEX body) and cost deduction for land preparation and inputs credit offered by APEX as per contract agreement.

3.2.2 Perception of Processors

All the two-processor groups interacted with gave positive outlook of the programme. Though initially unhappy about the service fee due to the relatively high cost of fuel, they were happy with upward adjustment of service fee from proposed US$4.65 including milling charges to US$5.4 - US$5.65. Proposed margin/Man-day or labour cost of US$2 per 83kg-bag was maintained. Processors were particularly impressed about the provision of improved vessels and cement for floor maintenance as already indicated. They however attributed relatively low quality of parboiled and milled rice to poor quality of paddy.

3.2.3 Perception of Millers

All the 2 millers involved in the project were happy about the performance of the APEX relating to decisions to rehabilitate milling facilities. They were also happy about the opportunity to review milling charges upwards for efficient milling services (milling passed twice to get clean rice). However how to sustain milling efficiency was a problem since milling twice added extra cost to the normal milling charges. Training on regular maintenance of milling facility was most beneficial to them.

3.2.4 Perception of APEX

Evaluating their performance, the farmer representatives were quick to point out that input supply arrangement was very effective and good for the farmers. They were also able to assist farmers to obtain inputs at relatively low prices. Loan transactions with the financial institutions were not smooth because a lot of time was spent on due diligence making sure only credit-worthy farmers participated in the programme. Again there were difficulties with paddy purchases since some farmers refused to sell or just sold enough to defray loan commitments. Only a third of expected volume of paddy was purchased. APEX members admitted that their organization was still young at the time of the survey. Administratively, it would have taken some time and a lot of education for them to become the strong organization expected. At the time of interview, APEX members were still not clear about the fate of parboiled and milled rice in stock while other stakeholders kept pestering them on profit sharing schemes when the milled rice was finally sold.

Generally, the APEX members were satisfied with rate of recovery obtained by processors. They claimed losses were more production related; due to immature and unfilled grains. This was caused by poor rains. Again some tarpaulins used for threshing were in pretty bad conditions. They perceived the project to be laudable however there were delays in credit release and field monitoring was not very effective due to lack of means of transport in certain occasions. At the processing level, quality improvement was below excellent. They claimed some of the rice had stones and black spots which might have been the result of poor quality paddy used.

The APEX body expressed their willingness to continue the programme but possibly with some modifications. From experience, they proposed limiting the programme to the farmer level. This meant that the APEX would assist farmers to access credit for input supplies that is deductible at harvest; farmers just selling off enough to defray loan commitments to processors.

3.3 Gender Issues

Women participation in the programme was rather low. Less than 10% of the farmers were females. This actually reflects representation of women in rice cropping. However all the 10 processors participating were females since rice processing is exclusively female activity

4. Discussions

4.1 What went wrong?

- Although the project participating farmers initially had problems with market access and therefore solicited for help at the beginning of the farming activities, these same farmers realized that they could get better prices in other market outlets. Market conditions changed in favour of the farmers due to low supply of local rice on the market in that particular year. Most stakeholders were not honest; some farmers did not declare their yields correctly and one group in *Gbalahi* failed to sell paddy to APEX body.
- Although farmers were given adequate extension training the quality of rice produced in some areas was low. Farmers failed to demonstrate that it is possible to obtain rice without black spots in the lowland. This could be due to irregular rainfall pattern, unleveled fields and deficient full water control.
- Processors had less recovery rates than expected; 59% instead of 62%. Again because by the project design, processors were given paddy to process for a fee it was difficult monitoring their activities to ensure maximum processing recovery. It also became obvious that getting optimum processing recovery under field conditions could sometimes be difficult due to uncontrollable external factors. Technically, there are several factors affecting parboiling recovery rate and quality of parboiled rice. This includes quality of raw materials, moisture content of paddy, drying conditions and parboiling temperature among others (Marcelo *et al* 2004).
- APEX body was too weak in performing more complex administrative issues. Expectation that stakeholder representative (APEX), who were mostly from the rural communities set up under the project could penetrate the urban rice market was too high. Convincing urban dwellers to patronize local rice requires a lot of marketing skills and capacity. Effective promotion on the key selling points of locally produced and processed rice has to be undertaken. The project however did not have such mechanism and promotional strategy in place.

4.2 Emerging Issues

Development of farmer based organizations is a major concern to both governments and development practitioners in developing countries. In Ghana, the Agricultural Services Sub sector Investment Project (AgSSIP) – 2000-2007 funded by the World Bank had a Farmer-Based Organisation (FBO) Development component. Efforts were made to strengthen the capacity of agencies promoting FBOs. Also under the on-going Millennium Challenge Account (MCA) project, the Private Enterprise Foundation with support from the Centre for International Private Enterprise (CIPE) based in Washington D.C., USA undertook an Advocacy Training Programme for Farmer-Based Organisations in some selected districts in Ghana (http://www.pefghana.org/mainsite/projects).

Empirical evidence shows that strong Farmer-Based Organisations (FBOs) are able to access credit, farm inputs, extension services and markets effectively. However there are challenges with FBOs projects. The current study identified lack of innovation and market responsiveness, relatively low product quality and poor management of production contracts as some of the challenges faced by FBOs.

4.2.1 Innovation and market responsiveness

As explained in the introductory to this paper, market opportunities exist in the Ghanaian rice industry for enhanced production by smallholders farmers. However this increasingly depends on farmers' ability to compete in the rice market; yet there are many constraints (including high cost of production, lack of access to credit and inefficient markets for inputs among others) that make it difficult for them to do this. There is the need for more innovative production planning that is responsive to market requirements. In this study there was a problem with linking farmers to appropriate market outlets probably due to lack of information. Markelova *et al* 2008 suggested that collective action can help address some of the above-mentioned constraints. Farmers need to be well organised in order to take advantage of market opportunities. Work done in small-scale farm households in Honduras by Wollni *et al (*2008) also demonstrated that well coordinated farmer-based organization is crucial in addressing supply and demand challenges such as information deficiencies with respect to production processes, technology adoption and consumer preferences.

4.2.2 Product quality

Linked to the issue of market competitiveness is quality of local rice. The industrialization of the food system, including centralized and concentrated retail power, poses specific challenges for small farmers, especially those living in developing countries. Unless farmers are organized or operating very large farms, they cannot provide the reliable supply and quality required by new markets (Poulton *et al* 2006; Norman *et al* 2003). In Uganda for example, the rapid urbanization offers new market opportunities for smallholder farmers to supply higher value markets such as supermarket chains and fast-food restaurants. Supplying these formal outlets offers higher incomes but accessing and maintaining links to these markets requires significant upgrading in terms of product quality and business management. To meet these conditions farmers need to become more organised which require increased levels of social capital, to strengthen internal and external relations with group members, service providers and market chain actors.

Strong leadership and an iterative market-led learning process enabled a smallholder farmers' association to meet the considerable challenges of achieving the stringent quality parameters of a modern food outlet. As explained by von Braun (2006), the rice value chain is increasingly driven from its consumption and retail ends, rather than the production front. In effect, consumers' demand for higher quality rice and improved standards and regulations in the processing and marketing of rice are becoming more important.

4.2.3 Management of production contract

Contract farming can be defined as agricultural production carried out according to a prior agreement under which the farmer commits to producing a given product in a given manner, and the buyer commits to purchasing it at a given price (Minot and Hill 2007). Often the buyer provides the farmer with technical assistance, seed, fertilizer, and other inputs on credit, while offering a guaranteed price for the output. Proponents of contract farming argue that it links small-scale farmers to lucrative markets and reduces the constraints they face in diversifying into high-value commodities and connecting to markets.

Managing production contractual agreement with small-scale farmers posed a major challenge in the current study. In this case rice prices at the time of harvesting were above the contractual prices. Contract designs should therefore be able to capture price sensitivity analysis. Farmers just refused to respect their contractual obligations. Under the contract farmers had lost full autonomy over prices based on prevailing market conditions and product attributes at the time of sale. Contract enforcement has to be effective given the new role for contract farming in developing countries in the light of the industrialisation of agriculture and the globalisation of world markets (Kirsten and Sartorius 2002; Simmons, 2004). Masakure and Henson (2005) suggested that there are systematic differences between farmers in their decisions to contract which needs to be recognized in contract design and management. Contract farming can be facilitated by establishing an investment friendly policy environment, promoting public–private partnerships in extension, mediating disputes between farmers and buyers, and helping to enforce contracts.

5. Conclusions

Performance of the **APEX body** was assessed satisfactory by 75% of the farmers interviewed. The APEX could enhance its capabilities through informal training on effective production and marketing planning. Regular training of FBOs on existing production and marketing arrangements and how to factor this in future predictions and planning activities is crucial. Production inputs arrangement by APEX must be timely to avoid unnecessary delays. Exploring the possibility of linking farmers to medium scale buyers could be a more effective marketing arrangement rather than targeting relatively smaller markets. Rice Inventory Credit System, where stocks are held in the harvest season for sale in the lean season could increase farmers' incomes.

At the farmer level, there is the need for transparency and all inclusive decision making at meetings so as to foster a common interest of all participating farmer groups. Improving the quality of rice starts right from the production stage, therefore best production practices have to be developed with farmers to facilitate adoption of such practices. Farmers need to play their roles by complying to contract regulations and rules agreed upon as a group. A group cohesion mechanism with adequate contract enforcement is crucial for sustainable rice farming.

Processors and millers also have responsibility towards improving the quality of local rice. Again best parboiling practices need to be developed with processors for effective adoption. It was also realized that custom based processing where processors buy improved paddy rice from farmers themselves for processing and then sell off to APEX after processing could serve as a better quality control mechanism. Millers should follow regular maintenance schedules in order to improve upon the milling efficiency.

Overall, the concept of farmer based organisation as a tool to consolidate farmers' strengthens and capabilities in sustainable rice farming was achieved to an appreciable extent. However it is concluded that farmer based organisations should not be burdened with administrative and marketing issues that are beyond their capabilities. Barham and Chitemi (2008) suggested that more mature groups with strong internal institutions, functioning group activities, and a good asset base of natural capital are more likely to improve their market situation.

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APPENDIX 1

LIST OF ABBREVIATIONS

APEX	**Representatives of Farmer based organisations**
FSRPOP	**Food Security and Rice Producers Organisation Project**
FBOs	**Farmer based organisations**
Mt	**Metric tons**
NILRIFACU	**Northern Region Intensive Lowland Rice Farmers Cooperative Union**
LRDP	**lowland Rice Development Project**
SPSS	**Statistical Package for Social Scientist**

APPENDIX 2

QUESTIONNAIRE GUIDE

1. APEX

How was the APEX formed; selection of members/membership

Roles and responsibilities

Difficulties and challenges

Input supplier and credit management

Contract management

Marketing arrangement

2. Farmers

What are some of the constraints and Challenges you face in rice farming and how do you normally cope with them?

Were you involved in decisions on APEX formation and their responsibilities? if yes were you happy about the representation

Did you receive the following services as proposed with the project mangers?

- Technical assistance on best rice farming practices aimed at improving quality and yields
- Timely land preparation on credit
- Timely supply of production inputs on credit
- Ready market arrangement for paddy after harvesting

Did you go by the contract agreement by selling rice to APEX? If no give reasons

How would you describe you describe the performance of APEX body in carrying out their responsibilities stipulated in the Project Agreement? (Excellent, Satisfactory, or not satisfactory) Give reasons.

3. Processors

What are some of the constraints and Challenges you face in rice parboiling and how do you normally cope with them ?

Did you receive the following services as proposed with the project mangers?

- Access to quality raw material
- Provision of technical Assistance on best processing practices
- Provision of improved vessels which reduce fuel, water and labour costs
- Provision of cement for repair and maintenance of drying floors
- Payment for processing services

4. Millers

What are some of the constraints and Challenges you face in milling rice and how do you normally cope with them ?

Did you receive the following services as proposed by the project mangers?

- rehabilitation old rice milling facility by replacing shafts sieves, blades, bearings and belts
- construction of proper housing unit for rehabilitated rice mills

Table 1. Summary of constraints, interventions, achievements and deviations at the farmer level

CONSTRAINTS	PROPOSED INTERVENTIONS
• Poor farming practices	• Technical assistance on best rice farming practices aimed at improving quality and yields to about 70 farmers; cultivating 0.4hectare of rice farm each
• Late land preparation due to lack of capital	• Timely land preparation on credit
• High cost of production inputs such as seed and fertilizer	• Timely supply of production inputs on credit
• Lack of access to market, transportation difficulties and unattractive selling prices especially at harvest	• Ready market arrangement for paddy
• No quality channel: no real incentive to produce high quality rice	• Expected about 70 tonnes of paddy from farmers for quality improvement processing activity
ACHIEVEMENTS	**DEVIATIONS**
• Technical assistance on best rice farming practices provided	• Late programme start off
• Input supply on credit (Agrochemical & improved seeds and fertilizers) provided	• Low quality and low yields obtained in some areas due to external factors like irregular rainfall pattern, unleveled field and its attendant problems with water management
• Ready market arrangement for all farmers	• Some farmers refused to sell paddy to APEX; only a third of expected volume obtained due to relatively low shadow prices

Table 2. Summary of interventions, achievements and deviations at the processor's level

CONSTRAINTS	PROPOSED INTERVENTIONS
• Inadequate access to quality raw material	• Access to quality raw material
• Inefficiencies in processing techniques	• Provision of technical Assistance on best processing practices
• Poor condition of drying space	• Provision of improved vessels which reduce fuel, water and labour costs • Provision of cement for repair and maintenance of drying floors
• Inadequate access to urban market and low demand for local rice	• Payment for processing services
ACHIEVEMENTS	**DEVIATIONS**
• Technical assistance on best rice processing practices and improved processing vessels were provided	• Processors had access to raw material of relatively low quality
• Cement was provided for maintenance of drying floors	• Level of quality of parboiled rice lower than expected
• There was improvement in processing capacities without credit. The programme provided additional work and revenue to processors	• Recovery rate of parboiled rice lower than expected (59% obtained instead of 62% expected).

Table 3. Summary of miller's constraints, interventions and achievements

CONSTRAINTS	PROPOSED INTERVENTIONS
• Inefficient rice milling facilities	• To rehabilitation 2 old rice milling facilities by replacing shafts sieves, blades, bearings and belts
• Lack of proper housing	• To construct housing units for rehabilitated rice mills
• Processors inability to pay realistic milling fees for efficient milling services	• Estimated milling charge of US$1.25 per 83-kg bag of parboiled rice paddy (milling passed twice) proposed instead of existing milling charge of US$1.0
ACHIEVEMENTS	**DEVIATIONS**
• Two rice milling facilities rehabilitated (Shafts sieves, blades, bearings and belts replaced for each mill)	**NIL**
• Housing unit constructed for each rehabilitated mill	
• Milling charge of US$1.25 per 83-kg bag of parboiled rice paddy paid by APEX body	

Table 4. Summary of interventions, achievements and deviations at the APEX level

CONSTRAINTS	**PROPOSED INTERVENTION**
Weak farmer based organization which was unable to negotiate with main stakeholders at the regional level	Build the capacity of APEX to fulfill the following functions • Share information and build consensus between cooperatives • Organize access to inputs and tractor services • Monitor cropping activities • Manage and sustain their collective structures such as storage and water structures • Access and manage credit • Access quality sensitive market
ACHIEVEMENTS	**DEVIATIONS**
• Input and services arrangement was fairly good. • Able to access and managed credit	• APEX body was not strong enough to perform administrative issues. Literacy level was woefully inadequate. • Difficulty in enforcing contractual agreement with farmers • Weak information sharing on the marketing arrangements for parboiled and milled rice

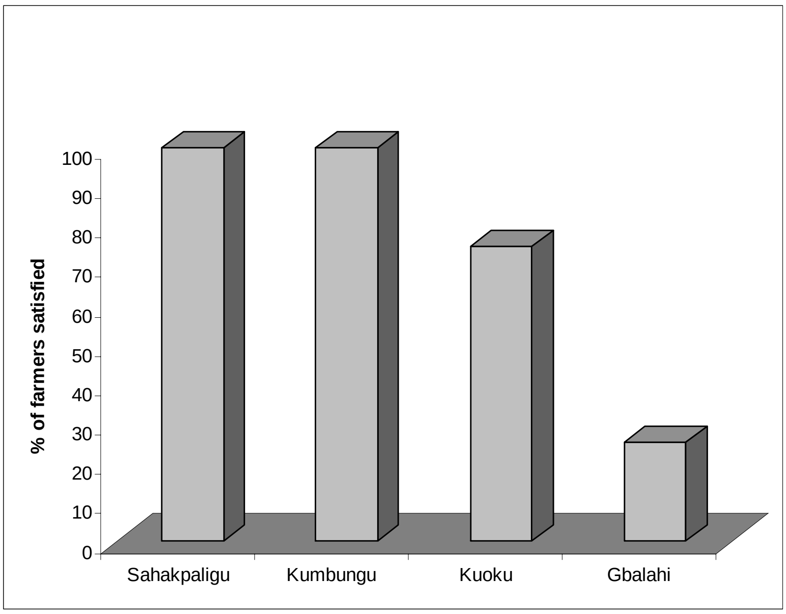

Figure 1. Farmers' satisfaction torwards APEX body performance in project participating communities