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Important Bio-fuel Crops: Advantages and Disadvantages

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Abstract Biofuels production, driven by the potential to contribute to energy security, climate change mitigation and rural development, has experienced rapid growth in recent years. Now days increased interest in promoting bioenergy, including biofuels, as a renewable energy source growing concerns about the economic, environmental and social sustainabil-ity of biofuels, as well as about their ability to actually meet the energy security expecta-tions. At present biofuels become an extremely important form of bioenergy.

Present study focusing on advantages and disadvantages of some multipurpose, short dura-tion annual crops such as Jatropha, sweet sorghum, castor, soybean, flax etc. Jatropha is considered as major biofuel crop but it is not a food crop since the oil is non-edible and is, in fact, poisonous. Most of the Jatropha currently grown is toxic which renders the seed-cake unsuitable for use as livestock feed and may present a human safety hazard. Fruiting is fairly continuous which increases the cost of harvesting. Knowledge of the agronomy of Jatropha and how agronomic practices contribute to yield is generally lacking. While other crops such as castor, Jatropha, soybean, sunflower, sweet sorghum can either simultane-ously yield fuel along with food and/or fodder or can be cultivated in rotation with food crops. Even small private farmers can get market for biofuels and will be an opportunity for socio economic development. Some of these crops are already commercially well known and can be scaled up to produce bioenergy are also discussed.

Index Terms— s

1 INTRODUCTION

Biofuels are considered in part, a solution to such issues as sustainable develop-ment, energy security and a reduction of greenhouse gas emissions. Biodiesel, an environ-mental friendly diesel fuel similar to petro-diesel in combustion properties, has received considerable attention in the recent past worldwide. Biodiesel is a methyl or ethyl ester of fatty acid made from renewable biological resources such as vegetable oils (both edible and no edible), recycled waste vegetable oil and animal fats (Demirbas, 2000; Kinney and Clemente, 2005; Wilson et al., 2005). The use of vegetable oils as alternative fuels has been found since 1900, when the inventor of the diesel engine Rudolph Diesel first tested peanut oil in his compression ignition engine (Shay, 1993). However, due to cheap petro-leum products such non-conventional fuels never took off until recently. Biodiesel derived from various biofuel crop is already being used in USA and Europe to reduce air pollution, and dependence on depleting fossil fuel localised in specific regions of the world. (Ma and Hanna, 1999; Sarin et al., 2007; Ranganathan et al., 2008; Agarwal, 2007; Berchmans and Hirata, 2008; Foidl et al., 1996; Openshaw, 2000; Meher et al., 2006).

The Jatropha curcas Linnaeus plant originated from Mexico and was spread to Asia and Africa by Portuguese traders as a hedge plant. Several research has indicated that J. curcas L. oil-producing seeds are toxic to humans, animals and birds, hence it is com-monly referred to as "Black vomit nut", "Purge nut" , "Physic nut", "Pinoncillo", "Ameri-can purging nut", "Barbados purging nut", "poison n ut tree" the "graveyard tree", etc (Ak-intayo, 2004; Gubitz et al., 1999). J. curcas L. is actually a tree known by more than 200 multi-language names (Katembo and Gray, 2007). Its oil is commonly known as hell oil, oil infernale (Makkar, et al., 1998; Gubitz, Staubamann et al., 1999). Indeed the seed and oil were found to be toxic to mice (Adams, 1974), rats (Liberalino et al., 1988), calves, sheep and goats (Ahmed and Adam, 1979, b), humans (Mampane et al., 1987; Abdu-Aguye et al., 1986; Koltin et al., 2006), chickens (Samia et al., 1992). Recently J. curcas

L. poisoning in pediatric patients was reported in Mauritius where a total of eleven cases of pignon d'Inde poisoning due to consumption of Jatropha seeds was reported in one day (Rai and Lakhanpal, 2008)

Since biofuels can be produced from a diverse set of crops, each country is adopt-ing a strategy that exploits the comparative advantages which holds with respect to such crops. For example, the sugarcane and maize are the main feedstock for ethanol in Brazil and US respectively, while the production of biodiesel in Malaysia is from oil palm. The Government of India (GOI) has launched a National Mission on Biofuels with the aim of achieving a target of 20% blending of biodiesel by 2012 (GOI, 2003).

Present study reveals an alternative approach focusing on multipurpose, short dura-tion annual crops such as sweet sorghum, castor, soybean, flax etc. that can either simulta-neously yield fuel along with food and/or fodder or can be cultivated in rotation with food crops.

DISADVANTAGES OF MAIN BIOFULE CROP

Cultivation of Jatropha as biodiesel plant has certain drawbacks as follows

1. SCARCITY OF AGRICULTURAL LAND AND THREAT TO FOOD PRODUCTION:

Due to scarcity of agricultural land and the need for vast amount of land for cultiva-

tion of biofuel feedstock, biofuels crops are considered a threat to both food production and forests. India has vast resources of marginal land also called wasteland, which are con-sidered to provide little economic or ecological benefits; the national biofuel mission em-phasizes cultivation of biofuel crops on such lands. However several researchers have con-tested the categorization of such lands as wastelands on the grounds that such lands are an integral part of the livelihood of rural poor.

The leaves of Jatropha are not suitable for livestock i.e., not suitable as fodder. The situation with regard to the severe shortage of fodder for livestock has in fact been deemed the other food crisis. In this context plantation of Jatropha on common lands, which are often grazing lands, is likely to worsen the fodder crisis. Jatropha yields insignificant amount of wood per tree. Thus policies, which promote crops that provide diverse benefits, would have much less adverse im-pact on the rural poor.

2. VARIATION IN THE PRODUCTION OF JATROPHA:

Although Jatropha Curcas may have the potential to grow in diverse agro climatic conditions, withstand drought and pest attacks, there is bound be accompanying variation in im-portant parameters like seed yield, oil content and nutrient requirements etc. which are critical to economic viability of plantations. The survey carried out by the National Oil Seeds and Vegetable Oil Development Board is said to have reported variation in oil content ranging from 21% to 48%. There is also no scientific evidence on the absence of pests and diseases in Jatropha plantations. In fact cultivation practices reported by Tamil Nadu Agricultural University, Coimbatore (TNAU) mention of pests like defoliators, bark eaters, stem borers etc., which call for pest management techniques (Balooni, 2003). Further high plantation densities like 2500 plants per hectare are possible only under good soil and wa-ter conditions while on rain fed plantations on marginal soils optimum density is said to be about 1600 plants per hectare. The resulting effect is that production per hectare is likely to be lower on such lands. Such wide variation in key economic parameters and the lack of standardized seed material, cultivation practices call for intensive research and develop-ment prior to a large-scale planting based on incomplete information

3. The need for timely irrigation during initial years:

One of the major reasons for selection of Jatropha is its low water requirement and therefore its suitability to dry and arid lands. It may be true that perennial crops are better adapted to withstand long spells of dry weather compared to short dura-tion crops, however even trees require well spaced irrigation especially during the initial few years of devel-opment barring which their growth and productivity is permanently affected.

Numerous scientific studies on horticultural crops have shown that irrigation re-gime has a significant positive impact on both yield and quality of fruits. A study by Prayas reports wide variation in seed yield ranging from 0.4 tons/hectare to 12 tons/hectare the best yields having been reported only un-der irrigated conditions and intensive cultiva-tion (Prayas). As if in recognition of this fact, agronomic experiments and field trials on Jatropha at institutions like the Tamil Nadu Agricul-tural University are being conducted under irrigated condi-tions. It is quite likely that fruit and hence seed production of Jatro-pha in dry rain fed conditions would be below par and hence economically unviable.

4. Long maturation phase:

Long gestation periods also do not motivate farmers to take up tree plantation ad ventures. Jatropha (3 to 4 yr) have a long maturation phase and that various uncertainties exist especial-ly in cultivation and marketing such crops present significant barriers to adoption especially for small farmers. A study on the planting of Jatropha as part of the Horticulture program of the Employment Guarantee Scheme in Maharashtra shows that subsidies are mainly benefiting the large farmers who are the adopters (Prayas). This study also found that the total sub-sidy that was provided exceeded the cost of cultivation. Small and marginal farmers might at best benefit indirectly if they gain from new employment opportunities in the plantations of adopting farmers or if there is an increase in the price of crops displaced by Jatropha. Small farmers are also likely to be more skeptical of buyback contracts being offered by biodiesel com-panies with little track record with farmers in a given region. Shorter duration crops like Sweet Sorghum and Castor are likely to offer better prospects for poor farmers especially dur-ing the initial stages of development of the biofuel industry.

ADVANTAGES OF SOME OTHER BIOFULE PLANTS

Some plants which can be cultivated for biodiesel production and will be an alternative to *Jatropha* are as follows

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1. SWEET SORGHUM (SORGHUM BICOLOR (L) MOENCH):

Sorghum is considered the most important crop in arid and semiarid regions of the world. Globally, it occupies about 45 million hectares with Africa and India accounting for about 80% of the global acreage. Although sorghum is best known as a grain crop, sweet sorghum is a close variant used mainly as livestock fodder since its high rate of photosyn-thesis produces leafy stalks that make excellent silage. The stalks are rich in juice, which can be processed into sugar, jaggery or distilled to produce ethanol. Therefore the juice, grain and bagasse (the fibrous residue that remains after juice extraction) can be used to coproduce a combination of food, fodder, ethanol and elec-tricity (Gnansounou, 2005). The resistance to drought, saline, alkaline soils, to water logging has been proven by its wide prevalence in various regions of the world today (FAO, Reddy et al, 2005). The familiar-ity with cultivation of sorghum, the ability and willingness to adopt sweet sorghum is much high-er compared to that for Jatropha. The yield of biofuel per hec-tare per year is higher for sweet sorghum. The comparative advantage of sweet sorghum with Sugarcane is that its grow-ing period of 4 months and water requirement of 8000 cubic metre (over two crops) are about 4 times lower than that for sugarcane (1216 month growing season and 36000 cubic me-tres of water). The cost of cultivation is also about three times lower than sugarcane (Reddy et al,2005).

5 2. CASTOR (RICINUS COMMUNIS L.):

Castor is cultivated around the world because of the commer-cial importance of its oil which is used in the manufacture of a number of industrial chemicals, cosmetics, phar-maceuticals

etc. The Indian variety of castor seed has an oil content of 48% out of which 42% can be extracted. The residual oil cake, which contains about 5.5 % Nitrogen, 1.8 % Phosphorus and 1.1 % Potassium and is used as organic manure. Castor grows well under hot and humid tropical conditions with growing period of 4 to 5 months. Castor is grown either as a pure crop in rotation with wheat, linseed etc., or is grown mixed with cotton, groundnut, arhar, green gram, jowar, bajra and cow-pea. The average yield of seed and oil is 1250 kg/hectare and 550 lit/hectare respectively. India is the world's largest producer and exporter of castor oil. It is currently cultivated on about 700,000 hectares mostly in Gujarat and Andhra Pradesh under rain fed conditions. The comparative advantage of Castor is that its growing period is much shorter than that of Jatropha and there is considera-bly greater experience and awareness among farmers about its cultivation. Being an annual crop it gives farmers the ability to rotate or shift away easily depending on market condi-tions.

3. SOYBEAN – GLYCINE MAX (L.) MAR.

Soybean is an annual crop grown in temperate, subtropical and tropical climates although it is a subtropical plant by origin. Soybean is grown around the world, and its primary producers are the United States, Brazil, Argentina, China, and India. The world-wide average area under the cultivation of soybean is almost 79 million hectares (Conner et al. 2004). The beans are produced in seed-pods, which are harvested by combine method. In favorable conditions, a high yield of soybeans around the world is approxi-mately 1,700 kg/ ha. Soybean oil is the major edible oil in the world. Soybean is used as an edible vegetable, source for cooking oil, crop for pasture, fodder, or silage, and source for oils used in the manufacture of paints, linoleum, oil cloth, printing inks, soap, insecti-cides, and disinfectants (Roecklein et al. 1982). Soybean oil is the primary source for bio-diesel production in the US, and over 283 million liters of biodiesel were produced in 2005 (NBB, 2005). The average oil content for soybeans is 18-20%, with protein content of 40%. It does not tolerate excessive heat or cold, and grows best on fertile, well drained soils with pH ranges of 6.0-6.5. Soybean is a leguminous crop that, when grown on the same fields in rotation with other crops, will have increased yields because its symbiotic relationship with nitrogen-fixing bacteria supplies the soybeans and other subsequent crops with a natural source of nitrogen. Due to this self-sufficiency in N-production, the inputs required to grow soybean crops are potentially lower than many other oil crops which must be planted each season after harvest.

4. FLAX (LINSEED OIL) – LINUM USITATISSIMUM L.

Flax has long tradition in mainland agriculture and used for fiber (linen) and seed oil (Thomas Jefferson Agricultural Institute, 2006). The growing season for flax is ap-proximately 120 days. The demand for flax and linseed oil has decreased since the mid-20th century because of heavier reliance on petroleum products. Flax is a broadleaf plant that prefers cool growing seasons with growth requirement similar to those of oats and wheat. Seed oil is used for fast drying, making the oil suitable for paints and varnishes and it also has various nutritional benefits. Flax also works well as an inter-crop to utilize fal-low land. Straw from seed flax varieties has been used in the manufacture of upholstery cushioning, rugs, and paper (Duke 1983). Leftover seedcake remaining after oil extraction provides a high-value livestock feed, as well as dietary supplement for humans. Flax is a species with a low nitrogen requirement, and no specialized farm machinery is required to plant or harvest its seeds. Flax plants are tolerant to drought, grazing, herbicides, high pH, viruses and weeds.

Under ideal growing conditions the yield of flax was up to 2 t/ ha (Casa et al. 1999). High-yielding flax varieties have shown the capacity to yield between 1,200-1,400 lbs /ac of seed. The flax seed has oil content approximately 40%.

5. SUNFLOWER – HELIANTHUS ANNUUS L.

Sunflower is an annual broadleaf plant with a growing cycle of approximately four months from planting to maturity. Production of sunflower takes place all over the world for edible oil. The worldwide annual average production of sunflower seed was 27.6 mil-lion MT during the 2005/2006 (FAO, 2005). Sunflowers require approximately 120 days until maturity, being in full flower for 70-80 of those days (MAFRI, 2004). It is important to grow sunflower in rotation with other crops, as they are highly susceptible to diseases. Sunflower should not be grown in a single location more than once every four growing seasons (Duke, 1983). Nitrogen requirements are high for such a short growing period, in the range of 90 lbs/ ac following a non-leguminous crop or fallow conditions. Sunflower does supply a large volume of biomass along with its seed production, up to 10-12 t / ha being possible under favorable conditions. Sunflower can grow in a wide variety of conditions. (Pimentel and Patzek, 2005). The oil content of sunflower seeds ranges from 25-45%, depending on the variety grown.

6. PEANUT OR GROUNDNUT – ARACHIS HYPOGEAE L.

The peanut is a leguminous, herbaceous annual plant that is primarily used as an edible crop in all parts of the world. It is suited to temperate, subtropical, and tropical cli-mates, where the plant can grow up to 2 feet tall or higher. Peanuts are used primarily for human consumption, whether it is through roasting of seeds, or the production of peanut butter or peanut oil. The peanut shells have multiple uses as by-products, such as high-fiber roughage in livestock feed, a fuel source for heating, mulch, and the manufacture of fertilizers (Putnam et al. 1992). Peanut oil was the original oil used in Rudolph Diesel's engine that he designed in the 1890's, although it was later replaced by petroleum-derived fuels.

Maturity can be expected to be reached between 100-150 days after planting, al-though some varieties may mature within 80-90 days under the right conditions. Oil con-tent of peanuts ranges from 40-55%. Maximum oil content of the peanut is reached 6-7 weeks after pollination and pod formation (Miranowski, 2005).

REFERENCES

The current scenario of biofuel crop relies mostly on Jatropha but it is not best suited for meeting the nation's biofuel goals

and providing relief to the rural poor. Jatro-pha has substantial risks and challenges that need to be considered before huge amount of time and money invested in scaling it up. The above study raises best alternative crops which have excellent advantages over Jatropha and can be used by policy makers before large scale investments towards biofuel production.

For reduction of the nation's dependence on petroleum imports with the aid of bio-fuels, different type of biofuel crops should be targeted to achieve good results. These are better alternatives to marginal lands that would not adversely affect food production. Re-generation of common lands or rural development is our main goal. it is suggested that instead of cultivation of single purpose crops like Jatropha, other multipurpose crops like Sweet sorghum, Castor, Soybean, Flax, Sunflower, groundnut should be cultivated would supply biofuels along with food and fodder and fuel wood for cooking.

Sweet sorghum have adventitious properties like resistance to drought, saline, alka-line soils, to water logging conditions and all plant parts can be used to produce a combi-nation of food, fodder, ethanol and electricity. The comparative advantage of Castor is that its growing period is much shorter than that of Jatropha. Soybean is a leguminous crop with nitrogen-fixing bacteria which result in increased yield of other rotational crops. Flax is a species with a low nitrogen requirement and has tolerance to drought, grazing, herbi-cides, high pH, viruses and weeds. Sunflower does supply a large volume of biomass along with its seed production. Peanut oil was used in Rudolph Diesel's engine but later on re-placed by petroleum-derived fuels but it has potential to produce biodiesel along with edi-ble seed oil.

The familiarity with cultivation of these alternative crops, the ability and willing-ness to adopt is much higher compared to that for Jatropha. The reliance on just one or two crops also presents a higher risk of scarcity in biofuel supply due drought or pest at-tacks that might result in crop failure. This is especially important in cases where cultiva-tion is to be undertaken on marginal lands with little or no variable inputs. Scientific re-search should therefore be directed towards development of a wide variety of crops that are suited to the diverse socioeconomic and environmental conditions in rural India. At the same time the efforts of scientists and extension agencies should be complimented by minimum support prices for biofuel crops.

It can be concluded that due to certain drawbacks of Jatropha it is essential to give alternatives. It is need to focus on multipurpose, short duration annual crops with high ac-ceptability to Indian farmers. It will not only helpful in socio economic development but also useful in enhancing rural development.

REFERENCES

[1] Abdu-Aguye I, Sannusi A, Alafiya-Tayo RA, Bhusnurmath SR (1986). Acute toxicity studies with Jatropha curcas L. Hum. xicol., 5: -274.

[2] Adams SEI (1974). Toxic effects of Jatropha curcas in mice. Toxicol. 4: 67-76.

[3] Agarwal AK (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Prog. Energ. Combust. Sci., 33: 233-271.

[4] Ahmed OMM, Adam SEI (1979a). Effects of Jatropha curcas on calves. Vet. Pathol., 16: 476-482

[5] Akintayo ET (2004). Characteristics and composition of Parkia biglobbossa and Jatropha curcas oils and cakes. Bioresour. Technol., 92: 307-310.

[6] Balooni K., (2003) Economics of Wastelands Agroforestry in India: A Review, New For-ests,26: 101-136, 2003

[7] Berchmans HJ, Hirata S (2008). Biodiesel production from crude Jatropha curcas L. seed oil with a high content of free fatty acids. Bioresour. Technol., 99: 1716-1721.

[8] Casa, R., Russell, G., Lo Cascio, B., Rossini, F. (1999). Environmental effects on linseed (Linum usitatissimum L.) yield and growth of flax at different stand densities. European Journal of Agronomy 11, 267-278.

[9] Chen. M, (1991), Coping with Seasonality and Drought, Sage, New Delhi 1991

[10] Conner, T., Paschal, E.H., Barbero, A., Johnson, E. (2004). The challenges and potential for future agronomic traits in soybeans. AgBioForum 7 (1/2), 47-50.

[11] Demirbas A (2000). Conversion of biomass using glycerine to liquid fuel for blending gasoline as alternative engine fuel. Energy Convers. Manage. 41: 1741-1748.

[12] FAO-Sweet sorghum in China. In: World food summit, five years later. Agriculture De-partment, Food and Agriculture Organization of the United Nations (FAO). Karanj For Biodiesel.

[13] FAO-UN(Food and Agriculture Organization of the United Nations). 2005. December 2

Foidl N, Foidl G, Sanchez M, Mittelbach M, Hackel S (1996), Jatropha curcas L. as a resource for the production of biofuel in Nicaragua. Bioresour. Technol., 58, 77-82.

[14] Gnansounou E., Dauriat A., Wyman C.E., (2005), Refining sweet sorghum to ethanol and sugar: economic tradeoffs in the context of North China, Bioresource Technology, Vol 96, 985 -1002.

[15] GOI, (2003), Report of the Committee on Development of Biofuels, Planning Commis-sion,Government of India.

Gubitz GM, Mittelbach M, Trabi M (1999). Exploitation of the tropical oil seed plant Jat-ropha curcas L. Bioresour. Technol., 67: 73-82. http://planningcommission.nic.in/reports/genrep/cmtt_bio.pdfJ.M .P. Martinez, R.B. Llavori, M.J.A. Cabo, and T.B. Pedersen, "Integrating Data Warehouses with Web Data: A Survey," *IEEE Trans. Knowledge and Data Eng.*, preprint, 21 Dec. 2007, doi:10.1109/TKDE.2007.190746.(PrePrint)

[16] Katembo BI, Gray PS (2007). Africa, Seeds Biofuel. J. Multidisciplinary Res. 1: 1-6. Kinney AJ, Clemente TE (2005). Modifying soybean oil for enhanced performance in bio-diesel blends. Fuel Process Technol. 86: 1137- 1147.

[17] Koltin D, Uziel Y, Schneidermann D, Kotzki S, Wolach B, Fainmesser P (2006). A case of Jatropha multifida poisoning resembling organophosphate intoxication. Clin. Toxicol. (Phila). 44: 337-338.

[18] Liberalino AAA, Bambira EA, Moraes-Santos T, Viera EC (1988). Jatropha curcas L. seeds: Chemical analysis and toxicity. Arquivos de biologia e technologia 31: 539-550.

[19] Ma F, Hanna MA (1999). Biodiesel Production: a review. Bioresour. Technol., 70: 1-15.

[20] MAFRI (Manitoba Agriculture, Food and Rural Initiative). February (2004) Sunflower Production and Management [Accessed 2006] Available at http://www.gov.mb.ca/agriculture/crops/oilseeds.

[21] Makkar HPS, Aderibigbe AO, Becker K (1998). Comparative evaluation of non-toxic and toxic varieties of *Jatropha curcas* for chemical composition, digestibility, protein degrad-ability and toxic factors. Food Chem. 62: 207-215.

[22] Mampane JK, Jobert PH, Hay IT (1987). *Jatropha curcas*: use as traditional Tswana medi-cine and its role as a cause of acute poisoning. Phytother. Res., 1: 50-51.

[23] Meher LC, Sagar DV, Naik SN (2006). Technical aspects of biodiesel

production by trans-esterification- A review. Renew. Sust. Energy Rev. 10: 248-268.
[24] Miranowski, John A. (2005) Chapter 3: Energy Consumption in US Agriculture, in *Agri-culture as a Producer and Consumer of Energy* (eds. J.L. Outlaw, K.J. Collins, and J.A. Duffield). CAB International Cambridge, MA oilcrops market assessment. [Accessed 2006] Available at http://www.fao.org/es/esc/en/20953/21017/index.html.
[25] Openshaw K (2000). A review of *Jatropha* curcas: an oil plant of unfulfilled promise. Biomass Energy. 19: 1-15.
[26] Pimentel, D., Patzek, T.W. 2005. Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. Natural Resources Research 14 (1), 65-76.
[27] Putnam, D.H., Oplinger, E.S., Teynor, T.M., Oelke, E.A., Kelling, K.A., Doll, J.D. (1992) *Peanut* from: Alternative Field Crops Manual. [Accessed 2006] University of Wisconsin-Extension, Cooperative Extension, University of Minnesota Center for Alternative Plant and Animal Products, and the Minnesota Extension Service. Available at http://www.hort.purdue.edu/newcrop/afcm/peanut.html.
[28] Rai DK, Lakhanpal P (2008). *Jatropha curcas* poisoning in pediatric patients, Mauritius. Internet J. Pediatrics Neonatol. 8: 1-6.
[29] Ranganathan SV, Narasimhan SL, Muthukumar K (2008). An overview of enzymatic pro-duction of biodiesel. Bioresour. Technol., 99: 3975- 3981.
[30] Reddy B.V.S, Ramesh S, Reddy P. S., Ramaiah B, Salimath PM, Kachapur R.,2005, Sweet Sorghum – A Potential Alternate Raw Material for Bi oethanol and Bioenergy, in *Interna-tional Sorghum and Millets Newsletter 2005*
[31] Roecklein, J.C., Ching, C.T.K., Hilton, H.W., Nishimoto, R., Osgood, R.V. (1982) A Method for Evaluation of Alternative Crops for Hawaiian Agriculture. UH-College of Tropical Agriculture and Human Resources and the Hawaiian Sugar Planters' Association. Joint project for the Governor's Agriculture Coordinating Committee
[32] Samia MA, Badwi EL, Mausa HM, Adam SEI (1992). Response of brown hisex chicks to low levels of *Jatropha curcas, Ricinus communis* or their mixture. Vet. Hum. Toxicol., 34: 304-306.
[33] Sarin R, Sharma M, Sinharay S, Malhotra RK (2007). *Jatropha*-Palm biodiesel blends: An optimum mix for Asia. Fuel 86: 1365-1371.
[34] Shay EG (1993). Diesel fuel from vegetable oil: Status and opportunities. Biomass Bio-energ. 4: 227-242.
[35] Staubamann R, Ncube I, Gubitz GM, Steiner W, Read JS (1999). Esterase and lipase activ-ity in *Jatropha curcas* L. seeds. J. Biotechnol. 75: 117-126
[36] Thomas Jefferson Agricultural Institute, (2005) Growing Flax: Production tips, economics, and more. [Accessed 2006] Available at http://www.jeffersoninstitute.org/pubs/flax/shtml.
[37] Wilson SC, Mathews M, Austin G, von Blottnitz H (2005). Review of the status of bio-diesel related activities in South Africa. Report for the City of Cape Town, South Africa p. 76.
[38] Wright, G.C., Smith, C.J., Woodroofe, M.R. (1988) The effect of irrigation and nitrogen fertilizer on rapeseed (*Brassica napes*) production in South-Eastern Australia I. Growth and seed yield. Irrigation Science 9(1), 1-13.