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AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

DATE: 9/11/87

MEMORANDUM

TO: AID/PPC/CDIE/DI, room 209 SA-18

FROM: AID/SCI, Victoria Ose

SUBJECT: Transmittal of AID/SCI Progress Report(s)

Attached for permanent retention/proper disposition is the following

AID/SCI Progress Report No. 4. 555
Rec'd 7/28/87 - Interim.
2d half of 1986 - rec'd 3/9/87
1st half of 1986 - rec'd 10/20/86
2d half of 1985 - rec'd 3/14/86
1st half of 1985 - rec'd 8/13/85
2d half of 1984 - rec'd 3/25/85

~~Attachment~~

att:
3 cys each

DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF PERADENIYA
PERADENIYA

10th February 1986

3.A.48
4,555

Our Ref. No.....

Your Ref No.....

Director General,
NARESA,
47/5, Maitland Place,
Colombo 7.

PROJECT RG/AID/05

Please find enclosed the progress report for the period July - December 1985 and the study tour report of Mr. H.D. Fernando and Mr. J.B. Rajeswaran. The delay is regretted.

Yours faithfully,

S.K. Senéviratne
Grantee

PROGRESS REPORT

1) Report for the 2nd half of 1985

2) Grantees : Dr. S.G. Ilangantilleke
Mr. S.K Seneviratne
Mr. J.B. Rajeswaran

3) Grant No : RG/AID/05

4) TITLE : Promoting Jatropha Carcas (Rata Endaru) oil as a fuel substitute for diesel engine fuel in Sri Lanka.

5) Date of Award : 2nd October, 1984

6) Progress to date : 1) A Study tour to Thailand was undertaken by Mr. J.B. Rajeswaran and Mr. Harendra D Fernando. Mr. Fernando also carried out a study tour in the United States of America.

2) Jatropha seed collected previously has been de-hulled, prior to using them for extraction.

3) A hydraulic press type extraction machine has been designed and fabricated.

4) More quantities of seed have been collected.

6.1 Study Tours to Thailand and the U.S.A.

A comprehensive trip report on the observations, results and opinions of the two researchers is annexed. However, it should be listed that, from the point of view of objectively directing this project in Sri Lanka, the main conclusions gathered are as follows :

1) For the extraction of oil, Hydraulic presses similar to those used in Thailand should be used, rather than standard worm-type expellers. This is because they are more practical at village-level and low-cost in manufacture.

2) The extracted oil needs to undergo some form of processing i.e. refining, blending, transesterification, converting to a Micro-emulion, or a combination of above processes.

3) In the cultivation of Jatropha, the experience of researchers in Thailand should be noted, as elucidated in the study tour report.

6.2 De-hulling of Jatropha seed.

The quantum of seed collected earlier has been manually de-hulled. Manual labour was initially employed at the standard rate of Rs. 33/91 per day, for de-hulling. However, since this process was found to be very slow, the seeds were de-hulled at home by these labourers, and payment was made at the rate of Rs. 5/- per pounds for de-hulled seeds.

During de-hulling, the weights of the seeds were recorded before and after de-hulling, and the weight of shells were recorded separately. It was found that from a total weight of 604 kilos of seed, a quantum of 331.5 kilos were obtained as de-hulled seeds. Approximately 54% was lost as shells in de-hulling Jatropha

6.3 Extraction of Oil.

Although it was the intention of the researchers earlier to initially arrange with coconut oil producers to extract oil and subsequently to purchase a worm-type horizontal baby expeller. both approaches

have now been discarded. This is because firstly, coconut oil producers were unwilling to take on quantities of Jatropha for oil extraction and secondly because it is now intended to use a hydraulic type press similar to that used in Thailand.

To this extent, an extraction machine has now been designed and fabricated (see drawing annexed). It is intended to use this press in conjunction with a grinder and steamer, to extract oil.

6.4 Supply of Seed Material.

It was the intention of the researchers earlier to initiate an intensive cultivation of Jatropha, both for the purpose of securing a steady source of supply as well as for conducting a study in Agronomy.

However, the experience of the researchers in Thailand, where it has been reported that Jatropha yields in fence stands is far greater than in intensive cultivation, has prompted the researchers to push back the growing of Jatropha to a later date (see Study Tour Report - Thailand). The fact that Jatropha required for experimentation is readily available is evident by the fact that another 1630 kilos has been collected in December, 1985.

It is intended to pursue with the cultivation of Jatropha in 1986.

7.0 Plan of work for the first half of 1986.

1) Extract Jatropha Oil.
2) Chemically analyse sampes of oil.
3) Make arrangements to purchase diesel engines and suitable Test Cells.

5

7.1 Extraction.

A hydraulic-press type machine has been designed and fabricated (see annexed drawing). The extraction of de-hulled Jatropha will consist of the following steps.

1) De-hulled seed would be ground, using a standard Grinder.
2) Ground seeds would then be bagged, in batches of one or two kilos.
3) Seeds bags would then be heated for 15 minutes, at 100°c, using a steamer.
4) These bags would then be placed in the cylinalrical container, and oil would be pressed out.
5) Oil extracted would be filtered, and collected in containers.

7.2 Chemical Analyses.

Arrangements have been made with Dr. Chakra Wijesundera, Section of Fats and Oils, C.I.S.I.R, and with the Chemistry Department of the University of Peradeniya to analyse Jatropha Oil. The oil will be tested for properties such as Fatty Acid Content, Kinematic Viscosity, Flash point, Calorific value, etc.

7.3 Purchase of Engines and Test Cells.

Quotations will be called for the supply of a diesel engine and a Test bed to test and analyze engine performance. Test beds will be required to measure engine torque, air flow rates, combustion temperatures, mechanical and thermal efficiencies, fuel consumption etc.

9.0 Signature of Grantee: .....

10.0 Signature of Head/Department: .....

HEAD DEPT. OF MECHANICAL ENGINEERING
UNIVERSITY OF PERADENIYA
SRI LANKA

REPORT ON THE STUDY TOUR TO THAILAND AND THE UNITED STATES OF AMERICA

[USAID sponsored project on the feasibility of promoting Jatropha Curcas as a fuel substitute for diesel engine fuel in Sri Lanka]

STUDY TOUR UNDERTAKEN BY:-

1) Mr. Harendra Fernando - Thailand - 25th Aug. 1985 to 31st Aug. 1985
Dept. of Agric Engineering - U.S.A - 3rd Sept. 1985 to 26th Sept. 1985
University of Peradeniya

2) Mr. J. B. Rajeswaran - Thailand - 25th Aug. 1985 to 31st Aug. 1985
Dept of Agronomy,
Batticaloa University College

PART I

REPORT ON THE STUDY TOUR TO THAILAND

Summary

This survey report describes the Agronomic studies, oil extraction and Engine testing methods relating to JATROPHA CURCAS in Thailand. The study tour to Bangkok extended for 7 days from the 25th August to 31st August and included visits to ADRC laboratories, the Khon-Kaen University, Field Crop Research Centre/Tharphra, Mahasarakam field crop experimental station and to farmers fields in Khon-Kaen, organized by the ADRC project staff and a private visit to the Thai farm Machinery training Centre.

A wide range of agronomic studies on varietal evaluating, spacing, methods of propagation, fertilizer application, pruning and pest control methods are being carried out all over the country on Jatropha Curcas, commonly known as "Sabu-Dam" in Thailand.

A survey was also conducted on the extraction methods employed, and the use of extracted Jatropha oil in diesel engines. The performance of a hydraulic press in extraction was found to be good, being efficient, practical and low cost. Not much reaearch had been done on testing oil in engines.

The details of the trials, observations, Researcher's views and opinions are given in this report and a summary conclusions is arrived at the end.

ADRC - Field Experimental plots :-

Though no systematic classification of varieties have been done on Jatropha, the different provincial ecotypes have been collected, grown and evaluated for their performances. The studies have in general shown no significant difference between the varieties.

Studies on selecting the optional plant density for Jatropha has also been carried out at this station with plants spaced at 50 x 50cm, 50 x 75cm, 100x 100cm, 50 x 100cm. The closest spacing of 50 x 50 cm seems to be promising.

Studies on the methods of propagation on a commercial scale show that seed propagation seems to be superior to vegetative propagation in that they produce plants which seem to be more healthy having a faster growth rate. However research is being carried out on methods of vegetative propagation using irradiated cuttings.

The general researcher opinion at this station strongly suggest that seed yield obtainable in farms in such organized commercial cultivation of Jatropha is much lower than that obtained from the natural fence stands and are more prone to pest and disease incidence than the latter.

Tharphra field crop experimental stations

The main lines of research interests in this station has been to ascertain the optimal spacing and fertilizer requirements for Jatropha. The spacing studies conducted here also confirm 50 x 50 cm as optimum. According to the research workers, the fertilizer studies have been discouraging showing no marked increases in yields.

There is also some work being carried out on the evaluation of different methods of pruning. An experiment evaluating 3 types of pruning of the main stem at 1', 1 1/2' and 2' suggested that heading back at 1' is ideal.

The only pest problem that has caused some concern at this station are Aphids. Insecticide spraying is practised here as a general method of control.

Kohn-Kaen University Field Crop trials :-

Spacing trials conducted at this station shows that closer spacing appears to be more favourable, whereas fertilizer trials indicate that an application of NPK mixture (15:15:15) 4 months after planting is ideal. Viral diseases have also been reported at this station.

Field Crop Research Station at Mahasarakam and Roi-Et :-

Fertilizer application at 12 levels with Jatropha at different spacing have been tested at this station. The results indicate no significant difference between varying levels of fertilizer. An experiment with 4 methods of pruning with 1', 2', 3' and a control, show that the control plants performed better than the pruned plants.

A study is carried out to determine the ideal size of cutting for propagation, planted at 25, 50, 75 and 100cm cuttings.

The problem reported at these stations arte water logging and severe aphid and catterpillar attacks. Jatropha is considered to be very susceptible to water logged conditions.

Planting :-

Studies with spacing at 50 x 50cm, 100 x 100cm show that field planting at 50 x 50cm proves to be the best. Jatropha seems to be very susceptible to waterlogging and hence this is an important consideration in site selection.

Pruning & Training :-

Under commercially cultivated conditions, Jatropha is maintained at a convenient height of 2m to enable easy harvesting. This is accomplished by pruning and training combined with horizontal cut on the main stem at a specified height. Experiments involving different heights firmly suggest that pruning at a height of 1 foot above the ground is more favourable in terms of production.

Fertilizer response :-

Studies have been conducted at various research stations to determine the fertilizer response of this crop. There is a wide concensus of opinion in that this crop responds poorly to application of fertilizers. This may be due to two reasons in our opinion.

i) The poor canopy architecture which increases mutual shading of branches with increased fertilizer application makes the leaves less productive.

ii) The inherently high levels of soil fertility.

Pest and disease incidences :-

Aphid attack seems to be the most severe pest problem under commercial cultivation. However viral diagnosis too have been reported from a few research stations. Insecticide spraying has been reported in cases of such incidences of Aphids.

Harvesting and Yield :-

Bushes begin to yield when they are 4 - 5 months old and continue upto 50 years. It is reported that though Jatropha is seasonal bearing in other countries, it bears continously in Thailand with its peak bearing season at the end of September.

The fruits contains 2 - 3 seeds and is collected generally after it falls from the tree. The mean yield of a year old tree is 4 - 6kg. The seeds have an oil content of 20 - 25%. The yields of fence stands of Jatropha have been reported to be higher than the yield under commercial cultivation.

SUMMARY OF THE AGRONOMIC STUDIES ON JATROPHA CURCAS IN THAILAND

The crop and its environment :-

Jatropha curcas known as "Sabu-dum" in Thailand is a plant belonging to the family Euphobeaceae and is a widespread wild plant in Thailand, inhabiting arid escarpments and capable of growing over a wide variety of soils and stone lands.

Habit :-

This generally grows up as a shrub or a small tree and can grow upto 7 meter in height. These bushes have thick branchlets and begin to yield oil when they are 4 - 5 months old and can live upto 50 years.

Varieties :-

No definite investigation has ben carried out to distinguish varieties. However ecotypes from different provinces have been collected and evaluated for their performances. Studies at ADRC/Khon -Kaen have however not detected any such differences.

Propagation :-

Propagation is done both through seeds and stem cuttings. Studies at ADRC/Khon-Kaen suggested that seed propagated plants are healthier than plants propagated by vegetative means. But Propagation by cuttings seems to be the usual practice in Thailand since it enables more rapid propagation than by seeds. Stem cuttings of 45 - 100cm length appear to be ideal for propagation than one buried in the soil for rooting. Cuttings irriadiated with X-rays are also being tried out.

CONCLUSIONS ASSIMILATED FOR GROWING JATROPHA IN SRI LANKA

Based on the Agronomical experiences in Thailand it is our conclusion that to grow Jatropha succesfully in Sri Lanka, the following should be practiced.

i) Site for growing should be chosen in an arid zone.

ii) Propagation of plants should be tried out both through seed and stem cuttings, and growth and yield should then be compared.

iii) When using stem cuttings, a range from 30 - 125cms should be used with more emphasis on the 45 - 100cm range.

iv) Plant spacing should be ideally 50 x 50cms. However, experiments with different spacing would still prove to be useful.

v) Pruning and training should be carried out on a major part of the cultivatiuon with experiments on a smaller scale allowing the plants to grow freely.

vi) Some experimentation with fertilizer inputs would be useful.

Extraction of oil from Jatropha seeds and engine testing :-

The methods of extracting oil from Jatropha seeds were inspected at the ADRC workshop and at the University of Khon-kaen.

ADRC workshop :-

The oil extraction process includes the following steps:-

dehulling, grinding, extraction and homogenizing.

i) Dehulling :-

The peanut huller is used to dehull the seeds. This machine is not very efficient and results in a high percentage of unhulled seeds. A modification to this peanut huller designed specially for Jatropha seed size is necessary.

ii) Grinding :-

Grinding is done to facilitate the oil extraction and generally results in a higher percentage of oil recovery. A normal mechanical grinding machine is used by the ADRC workshop and the performance seems to be satisfactory.

iii) Steaming :-

Steaming is done using a conventional steamer at 105 C for 30 min. This process of steaming softens the hard ground material further facilitating the oil extraction process. The material is air cooled before it is sent for oil extraction.

iv) Oil extraction :-

Oil extraction is achieved basically by 2 means, viz. horizontal expeller (screw press model) and hydraulic press. The screw press type of oil extraction removes about 25 - 30% of the oil from the seeds leaving about 5 to 10% in the oil cake. The inherent problem with this type of extractor is that the oil cake tends to stick on to the interior of the press resulting in frequent janning. This necessitates frequent discharging.

The hydraulic press is a more efficient model for oil extraction compared to the former and operates on hydraulic pressure. About 20 - 25% of oil could be obtained and 10 - 15% remains in the oil cake. However the hydraulic press found at the ADRC is sophisticated and expensive and cannot be extended to the farmers without modification.

Khon-Kaen University :-

A cheaper and more practicable version of the hydraulic press was demonstrated at this University. This model consists of a hydraulic jack which works though a cylindrical strainer, containing the Jatropha seeds and pressurises it against a fixed screw ram. The screw ram has to be unscrewed each time to unload the oil extracted seed cake.

A further modification to this model was demonstrated at the farm machinery training centre, Tamboi Khong-Nong. This model consists of a spring loaded base plate at the base of the strainer which could conveniently be lowered by relieving hydraulic pressure and contents discharged.

This model seems to be the most practicable, economical and convenient model that could be introduced for oil extraction at the farmers level in Sri Lanka.

Engine Testing :-

No studies have been done on methods of engine testing both at ADRC and at the Khon-Kaen University.

CONCLUSIONS ASSIMILATED FOR THE EXTRACTION OF JATROPHA OIL IN SRI LANKA

i) Dehulling :-

It would be necessary to design and fabricate a huller that could be successfully used on this type of seed, rather than the Peanut huller used in Thailand. A huller using adjustable spacing with light pressure and heavy pressure type rollers is envisaged.

ii) Grinding :-

Purely from an experimental point of view, any mechancal ginder would suffice.

iii) Steaming :-

This process is efficient and economical, and is a concept which can be projected to farmer level.

iv) Oil extraction :-

An economical extraction press can now be designed and fabricated to suit farmer needs and skills. The concept of using a conventional screw-press has been rejected because of the high costs involved.

REPORT ON THE U.S. STUDY TOUR BY MR. H. D. FERNANDO

PART II

Summary

The study tour to the United States of America commenced on the 3rd September, 1985 with a visit to the University of Illinois and finished on the 20th September, 1985 with a visit to the South West Research Institute, San Antonio, Texas. Visits were also made in between to the U.S. Dept. of Agriculture, Peoria, Illinois and Texas A&M University, College Station, Texas.

On the whole, the most useful information was obtained at the University of Illinois where the methods and pros and cons of processing vegetable oils were discussed, prior to their use as fuel substitutes. Studies with officials at the U.S. Dept. of Agriculture further elucidated the processing of vegetable oils. Some literature and previous work conducted on engines using vegetable oils as substitutes was available at Texas A&M University. Finally at San Antonio, Texas the researcher was exposed to sophisticated technology using high-speed photography to study the spray characteristics of vegetable oils used during combustion.

This report describes in detail the nature and the extent to which vegetable oils are used as fuel substitutes in the above Institute and discusses the usefulness of such information to the project in Sri Lanka where the feasibility of promoting Jatropha Curcas oil as substitute for diesel fuel is being studied.

Observations

i) The mixture needs to be agitated.

ii) It is essential that no moisture is absorbed by KOH, since the reaction then tends to produce a soapy solution

iii) Reaction takes place at room temperature

iv) Since reversible, CH_3COOH has to be added after the ester is formed, so that the backward reaction is stopped

v) It is necessary to use at least two or three times the stoichiometric amounts of CH_3OH

vi) Ethanol and NaOH may be used as well, if ethyl esters were to be formed

vii) Ester is seperated from Glycerol by gravity

Conclusions

i) May, not be feasable or economic at farm level, due to the procedures associated in seperating the catalyst and the Acetic acid components.

ii) Viscosity does come down, but not as far as the value of diesel

iii) Cetane ratings are increased from 38 to about 50

Microemulsions

Microemulsions are made by the reaction of an oil with Alcohol, using a surfectant to help form the bond between molecules.

The viscosity of the microemulsion may be approximately calculated using the formula

This formula could yield a rough guide to the proportions of Alcohol and Surfectant necessary, to produce an Emulsion of acceptable viscosity.

Eg: as demonstrated :-	60ml	Soya oil
	20ml	Ethanol
	11ml	Butanol
TOTAL	91ml	

The procedure for making micro-emulsions were noted. It was observed that if no Butanol is used, the alcohol will seperate from the oil, and two clear immiscible solutions will be formed.

General conclusions

a) Economic at farm level

b) The major problem here is that while the alcohol brings down the viscosity of oil, it also brings down the Cetane rating. A suitable compromise is difficult to achieve.

B) ENGINE TESTING PROCEDURES

There were many engine tests being carried out here, incorporating computers for data analysis. A significant aspect here was that the researcher in charge, Prof. C. Goering had devised a preliminary shorter version of the 200 hour screening test for alternative fuels. The 200 hour test is that proposed by the Engine Manufacturer's Association (EVA).

However, the cost of such a program is well beyond the funds allocated for the project in Sri lanka. The shorter version adapted by Prof. Goering is therefore very attractive because if Jatropha oil characteristics were favourable for this less costly method, then a 200 hour screening test could be considered.

Some of the engine tests being carried out here were on 400 cc. diesel engines similar to the type of engines that may be used in Sri Lanka. However the degree of sophistication was such that it was not possible to study all the methods and procedures in such a short time. There is clearly a need for an expert to assist the researchers in setting up a test-procedure for engine testing, in due course.

STUDY TOUR AT THE UNIVERSITY OF ILLINOIS

Two aspects on the use of vegetable oils were studied. They are:-

i) Processing of vegetable oils, prior to their use as fuel substitutes
ii) Engine testing procedures

Processing : Two methods of processsing oil were studied. They are :- Transesterfication
Microemulsions

The properties of oils are changed by the above two processes, so that they may be used to good effect in running diesel engines. Since viscosity is the prime concern in the use of oils as substitutes, both processes are designed to lower the viscosity to acceptable levels.

Transesterification :

This is a process where the oil is made to react with an alcohol, to produce an Ester and a Glycerol. A catalyst is required.

The procedure for making esters were noted and the following observations were made.

(b) STUDY TOUR AT THE U.S. DEPT. OF AGRICULTURE, PEORIA, ILLINOIS

The information gathered at the University of Illinois were further evaluated here, with Mr. Bernie Friedman. In addition to much more detailed procedures in the preperation of Esters and Micro emulsions, useful information and advice was also received on the refining of vegetable oils. ie. reroval of tar content, reduction of acid content, etc. It is envisaged that in Sri lanka, tests will be conducted with refined-blended oils initially, with a view to arriving at the most economic and practical form of oil that could conceivably be used as a substitute for diesel fuel.

(c) STUDY TOUR AT TEXAS A&M UNIVERSITY

Here more information and insight into the use of Esters was supplied by Dr. Wayne M. Lepori. Dr. Lepori is convinced, unlike the researchers at Illinois, that trans-esters are the best form of vegetable oil as fuel substitutes. Since some of his workshops had been ravaged by fire not so long ago, it was not possible to see work done on engine testing. However, literature supplied by Dr. Lepori, and an insight into some bio-mass work being conduted at present, proved to be useful.

A visit was also arranged by Dr. Lepori, to view extraction mechines being used to expel oil. However, it was felt that this type of machinery was not suitable for the project in Sri Lanka particularly when compared to the efficient and economical Hydraulic Presses used in Thailand.

(d) STUDY TOUR AT THE SOUTH-WEST RESEARCH INSTITUTE, SAN-ANTONIAO, TEXAS

In this Institute, Dr. Thomas Ryan conducted a tour of their large number of engine test cells. The outstanding feature here was the equipment used to measure engine and injector performance. Sophisticated high resolution fast photography is used to study spray characteristics of vegetable oils and diesel fuels. Obviously this type of experimentation is far beyond the scope of the research work in Sri Lanka. However, one useful aspect that evolved from this visit is that there exists a possibility whereby samples of oil would be sent by Sri Lanka to this institute, for analysis on atomisation to be conducted by them. This aspect will be pursued.

GENERAL CONCLUSIONS ON U.S. STUDY TOUR

It can be concluded that as a result of the experience gathered from U.S. researchers, the project in Sri Lanka can now be more objectively directed. It is now clear that in order to produce an economic mode of alternate fuel to farmers in Sri Lanka, the vegetable oil being tested needs to undergo some form of processing. It is intended to experiment with Jatropha oil in its various stages and forms of processed products -ie, purified and blended with diesel, purified and in the form of a trans-ester and as a micro-emulsion etc.

It is also clear now that a computer needs to be linked up for the instrumentation associated with engine-testing in data analysis. Expert advice at that stage of the project would be essential then.