Jatropha Curcas Oil as a Substitute for Diesel Engine Oil*

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INTRODUCTION

Since the oil crisis in 1974, most oil-importing countries have been highly motivated to develop alternative sources of energy to meet their national energy needs.

In 1980, Thailand spent about 3,000 million dollars for imported oil (30.5% of the import budget) to be used in industry, transportation, electric power generation and agriculture. To overcome the energy problems, a great deal of research on solar energy, wind energy, hydropower, biomass energy and biogas has been carried out by government organizations and educational institutes.

At the Thai Farm Machinery Training Center of the Agricultural Engineering Division, Department of Agriculture, under the Ministry of Agricultural and Cooperatives, emphasis has been placed on studies of alternative fuels that can be used as a substitute for diesel engine oil, since diesel engines are widely used by Thai farmers. The government spent about 415 million dollars for imported diesel oil in 1980. Experiments concerned with the operation of diesel engines with diesel fuel combined with biogas, soybean oil and various kinds of vegetable oil have been made at the Center.

Tests were made with diesel engines using Jatropha curcas oil as part of a research project carried out with the co-operation of the Yanmar (Thailand) Co., Ltd., and very satisfactory results were obtained. The engine performance and fuel consumption compared favourably with running the engines on normal diesel engine oil.

Appropriate technologies for the production and utilization of Jatropha curcas oil as a substitute for diesel engine oil were considered. The study also included plans to implement the use of Jatropha curcas oil and to assess its potential for becoming a self-sufficient fuel for agricultural farm machinery in Thailand.

JATROPHA CURCAS

Jatropha curcas is a plant in the Family Euphorbiaceae which has origins in tropical America and West Africa. The common names for this plant are physic nut and purging nut. It is known by different names in various Asian countries (in Thailand it is variously referred to as sabu dum, see lord or mai yao; in Burma it is known as thinbankyeksu; in Indonesia as jarak budeg; in the Philip-

*Extracted and translated from the Thai version by On-Anong Suraniranat, Information Scientist, Renewable Energy Resources Information Center, AIT.

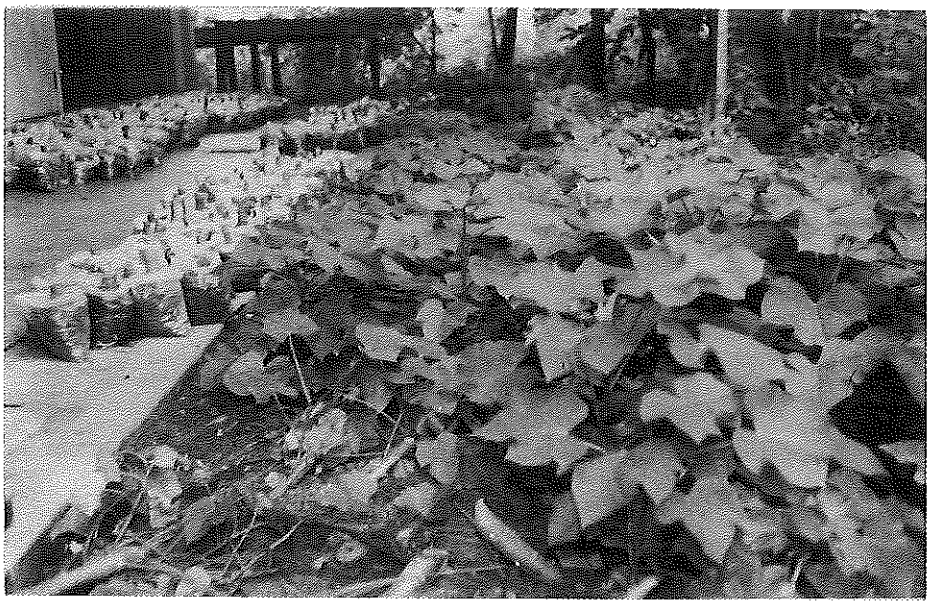

Fig. 1 Jatropha curcas plants.

Fig. 2 Jatropha curcas fruits.

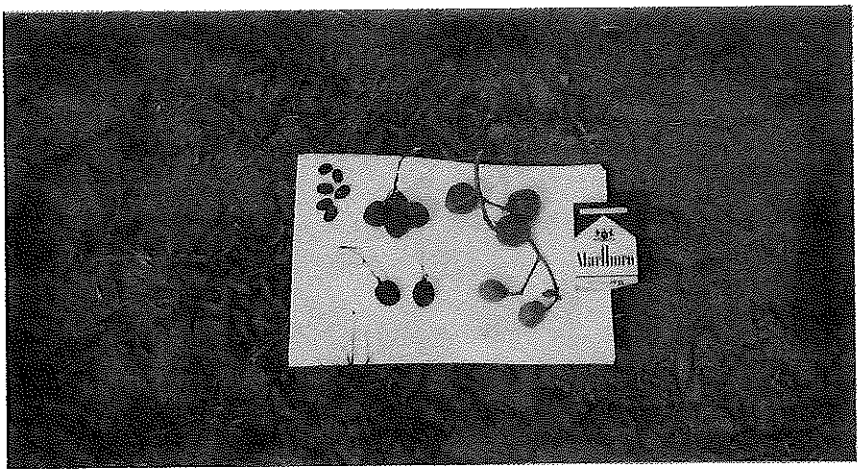

Fig. 3 Jatropha curcas seeds.

pines as tuba; in India as bagherenda or nepalam; and in Sri Lanka as rope endaru).

It is a shrub or small tree which can grow up to 7 m high and has thick branchlets; but on arid escarpments it does not exceed 2 m in height. It grows wild in many tropical regions, and is very adaptable as regards soil. It can be grown on arid, stony land. For planting, one can use a seedling; but the more usual practice is to use a stem cutting. Stem cuttings (45-100 cm) are buried in the soil and soon develop roots. Propagation by cuttings is more rapid than by seeds, and is most effective during the rainy season.

Bushes begin to yield oil when they are 4-5 months old, and can live up to 50 years. The seeds, even when dry, remain on the bush for a long time. They are usually allowed to fall to the ground and are then collected. In Thailand, the fruits are ripe at the end of September. A fruit contains 2 or 3 seeds which are separated from one another by the septums of an ellipsoid, sparsely lobed capsule about 2-5 cm long. The seed has an ellipsoil shape, 17-19 mm long, 11 mm wide and 8-9 mm thick. The mean yield of air dry seed for a five year old tree is 4-6 kg. The seeds have an oil content of 40-50%, and the kernels have an oil content of 20-25%.

The seed is the source of a semi-drying oil. The oil cake cannot be used as animal feed because of its toxicity, but it can be used as a fertilizer.

OIL EXTRACTION

Several methods of oil extraction have been tested to achieve the maximum amount of oil and the most appropriate methods for rural applications, in consideration of the farmers' ability to cope with the extraction process by themselves.

Solvent Extraction

Whole seeds are ground and then extracted by an organic solvent. The amount of oil obtained from whole seed is 34.96%, and from the kernel alone the oil content is 54.68%.

The Hydraulic Press

By using a hydraulic press, 20-25% oil can be obtained, and 10-15% remains in the oil cake.

The Screw Press

By using a screw press, 25-30% oil can be obtained, and 5-10% remains in the oil cake.

To increase the oil yield, many methods of pre-treatment have been tested, notably sun-drying, roasting, steaming, spraying with water and sun-drying, soaking in water and sun-drying, and oven drying.

The best method found, as described in Fig. 4, yields 25% oil from whole seed.

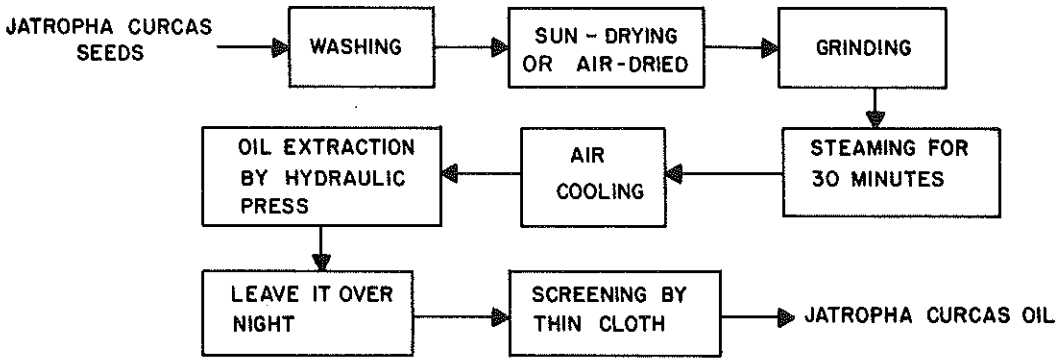

Fig. 4 Jatropha curcas oil production process.

Figs. 5, 6, 7, and 8 show details of the hydraulic press used for oil extraction. This machine costs about US$150 and can also be used for extracting oil from soyabeans, copra and sesame. To obtain high quality oil, the pressing machine should always be cleaned after use. More efficient pressing machines are currently being developed.

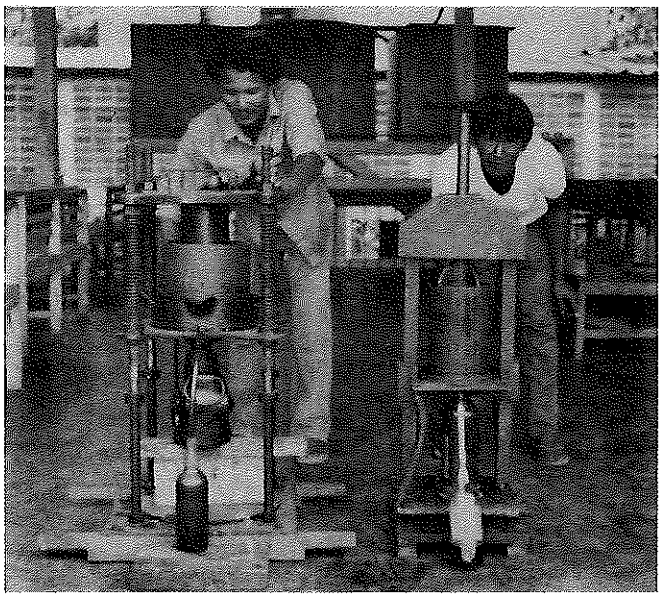

Fig. 5 Jatropha curcas oil pressing machines.

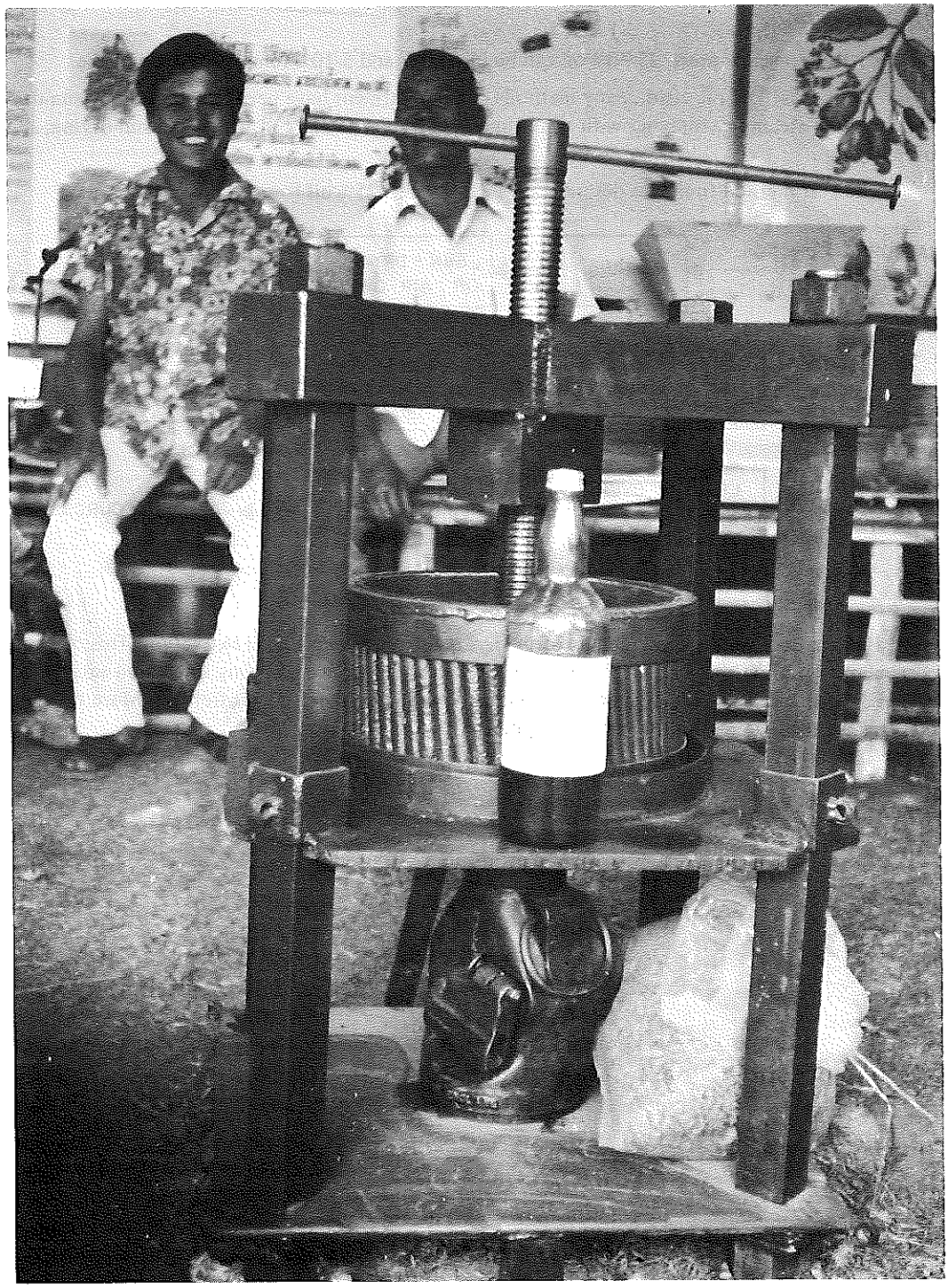

Fig. 6 Another type of Jatropha curcas oil pressing machine.

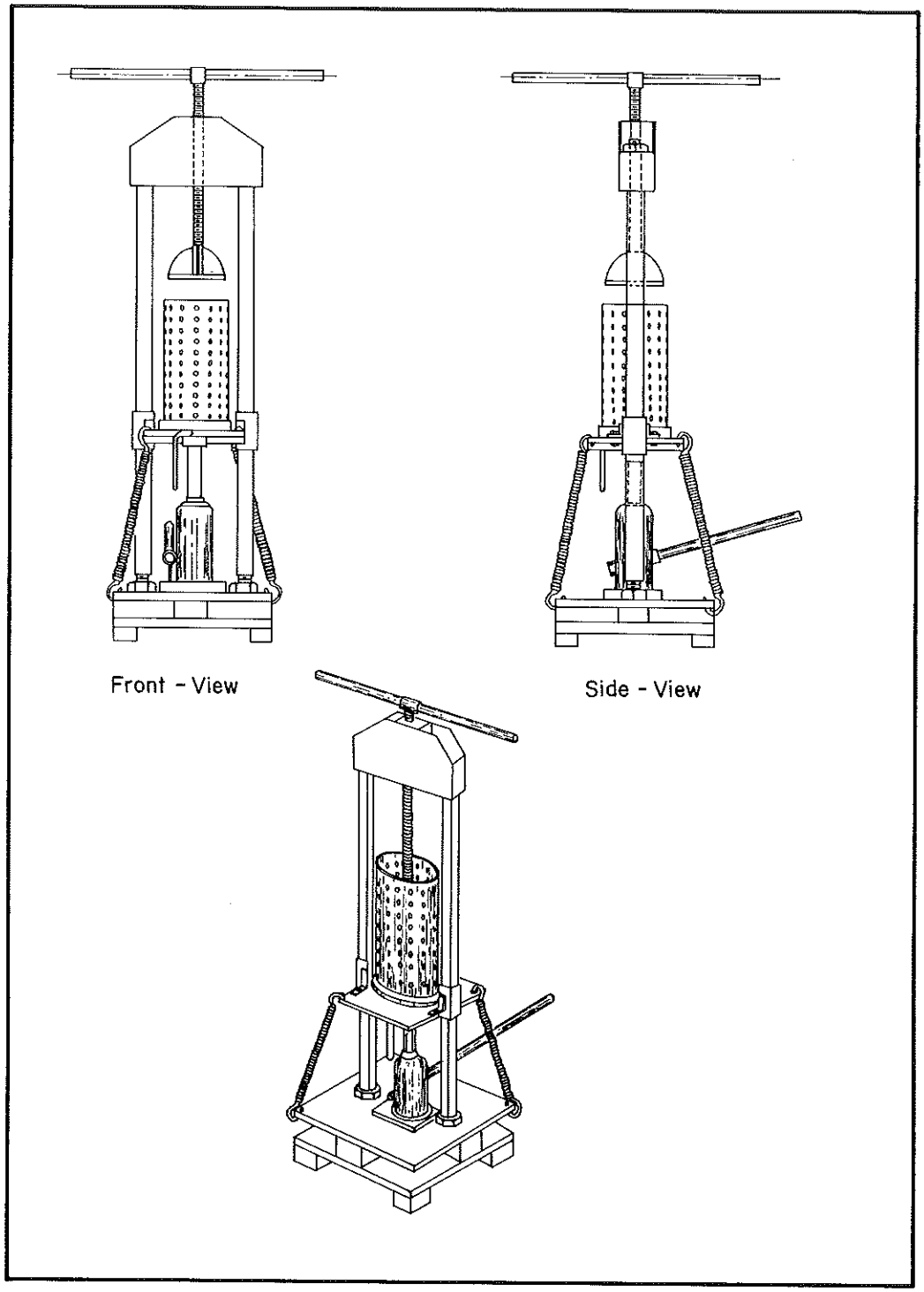

Fig. 7 Jatropha curcas oil pressing machine.

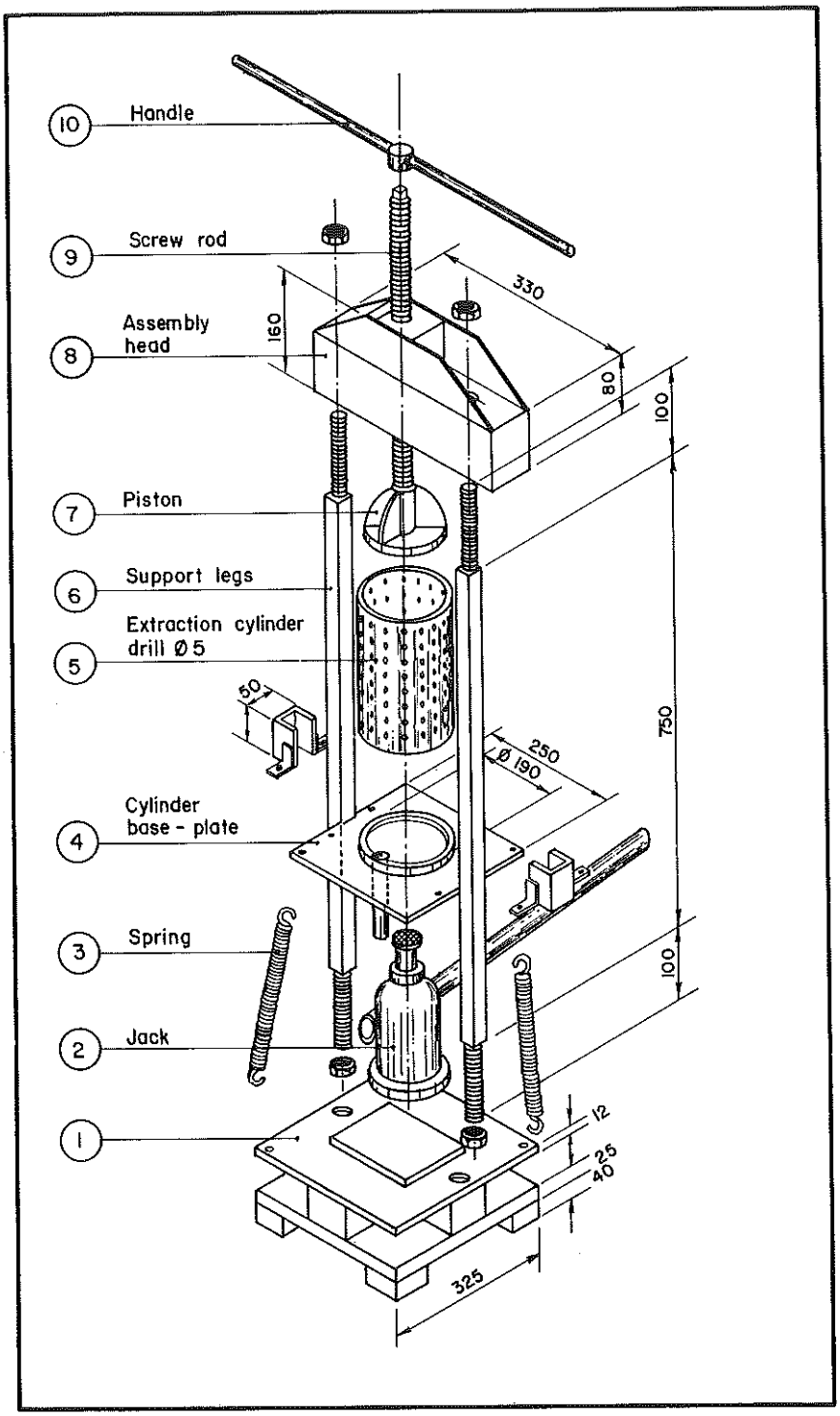

Fig. 8 Details and dimensions of Jatropha curcas oil pressing machine.

CHEMICAL COMPOSITION

The seeds of Jatropha curcas have an oil content of 40-50% and 7% moisture content. The oil contains 21% saturated fatty acid and 79% unsaturated fatty acid. Table 1 shows the results of a chemical analysis of Jatropha curcas oil carried out by the Industate of Osaka Municipal Industry, Japan (2).

Table 1
Chemical analysis of Jatropha curcas oil.

Item	Value
Acid value	38.2
Saponification value	195.0
Iodine value	101.7
Viscosity (31°C) (Fatty acid)	40.4 cp
Palmitic acid	14.2
Stearic acid	6.9
Oleic acid	43.1
Linoleic acid	34.3
Other acid	1.4

To be used as a substitute for diesel oil, the qualities of Jatropha curcas oil were analyzed by the Fiji Koosan Oil Refinary, Tokyo, and the Petroleum Authority of Thailand, and compared with the standard specifications for diesel oil in Japan and Thailand (Table 2).

Table 2
Qualities of Jatropha curcas oil compared to the standard specifications for Diesel oil in Japan and Thailand

	Fuji Koosan Oil Refinery, Tokyo, Japan			Petroleum Authority of Thailand		
	Jatropha curcas oil	Standard specification of diesel oil – Japan	Analysis methods	Jatropha curcas oil	Standard specification of diesel oil – Thailand	Analysis methods
Specific gravity	0.9186	0.82-0.84	JIS-K-2249	0.9188	0.82-0.90	ASTM-D-1298
Flash point	°C 240	50°C up	JIS-K-2265	110°C	52°C up	ASTM-D- 93
Carbon residue	% 0.64	0.15 less	JIS-K-2270	–	0.05% less	ASTM-D- 189
Cetane value	51.0	50 up	JIS-K-2271	–	50 up	ASTM-D- 613
Distillation	°C 295	350 less	JIS-K-2254	–	370°C less	ASTM-D- 86
Kinematic viscosity	cs 50.73	2.7 up	JIS-K-2283	–	1.85-5.0 cs	ASTM-D- 445
Sulphur	%0.13	1.2 less	JIS-K-2273	0.16	1% less	ASTM-D- 129
Caloryfic value	Kcl/kg 9.470	10.170	JIS-K-2271	–	–	ASTM D- –
Pour Point °C	–	–	–	8°C	10°C less	ASTM-D- 97
Colour	–	–	–	L4.0	4 less	ASTM-D-1500

Table 3
Nitrogen, phosphorous and potassium content of Jatropha curcas oil cake compared to other fertilizers

Types of Fertilizer	Moisture Content (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Jatropha curcas oil cake	4.58	4.44	2.09	1.68
Cow-manure	9.70	0.97	0.69	1.66
Chicken-manure	10.19	3.04	6.27	2.08
Duck-manure	17.57	2.37	2.10	1.09
Compost of rice straw	–	0.81	0.18	0.68
Compost of water hyacinth	–	1.43	0.46	0.48
Compost of municipal wastes	–	1.25	0.25	0.65

Jatropha curcas oil cake contains high organic substances, and in particular has a high nitrogen content as compared to other organic fertilizers (see Table 3). Though the phosphorous and potassium content is lower as compared to chicken manure, the oil cake can be a very good source of fertilizer.

DIESEL ENGINE TEST

A Kubota four-stroke cycle diesel engine (7 hp/2,200 r.p.m., with a single horizontal piston, a cylinder volume of 400 cc, and a water cooling system) was run by extracted Jatropha

Table 4
Fuel consumption of the Kubota diesel engine run by Jatropha curcas oil as opposed to being run by Jatropha curcas oil combined with LPG

Engine Revolution (r.p.m.)	Jatropha curcas oil consumption (cc/hr)	Jatropha curcas oil combined with LPG	
		Jatropha curcas oil (cc/hr)	LPG (l/hr)
1500	498	55	27.12
1600	494	62	29.04
1700	528	64	29.04
1800	576	184	24.72
1900	614	182	27.12
2000	665	151	31.68
2100	720	166	32.16
2200	770	204	32.52
2300	852	240	34.48

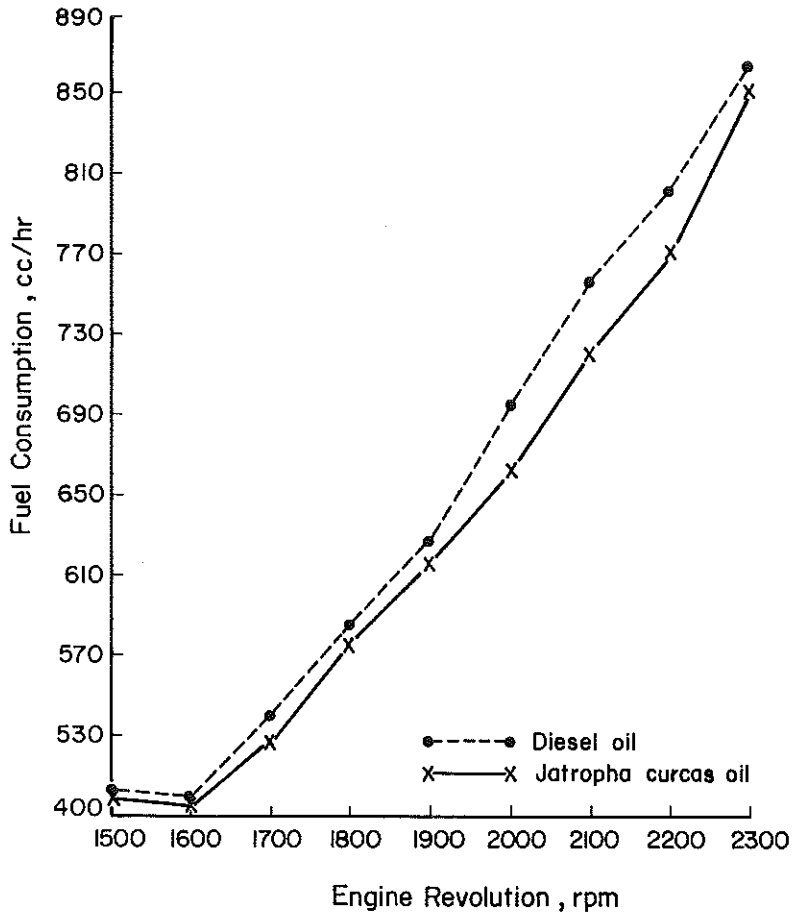

Fig. 9 Comparison of the fuel consumption and engine performance of the Kubota diesel engine run by Jatropha curcas oil as opposed to being run by diesel oil.

curcas oil. The engine performance and fuel consumption results approximate to those obtained using high speed diesel oil. Moreover, the engine ran smoothly and there was no knock phenomenon – even when the engine was accelerated. It was observed that the fuel pump was overloaded, but this difficulty could probably be solved by using a larger fuel filter. Fig. 9 compares the relation of the fuel consumption and the engine revolutions of the tested engine run by Jatropha curcas oil and the same engine run by high speed diesel oil.

The Kubota diesel engine was also run by Jatropha curcas oil combined with LPG, which is available in the local market. The air-filter was replaced by a bigger steel cylinder containing steel wool as filtering material and fitted with an LPG inlet tube. The engine performance and fuel consumption are shown in Table 4 and Fig. 10.

From Table 4, it can be seen that the average fuel consumption of the diesel engine run solely by Jatropha curcas oil was 635.2 cc/hr for engine revolutions of 1,500-2,300 r.p.m. The Jatropha curcas oil consumption was reduced to 145.3 cc/hr when the engine was run by Jatropha curcas oil combined with LPG, and the LPG consumption was 29.8 l/hr. The combined fuel system reduced the consumption of Jatropha curcas oil by 77%.

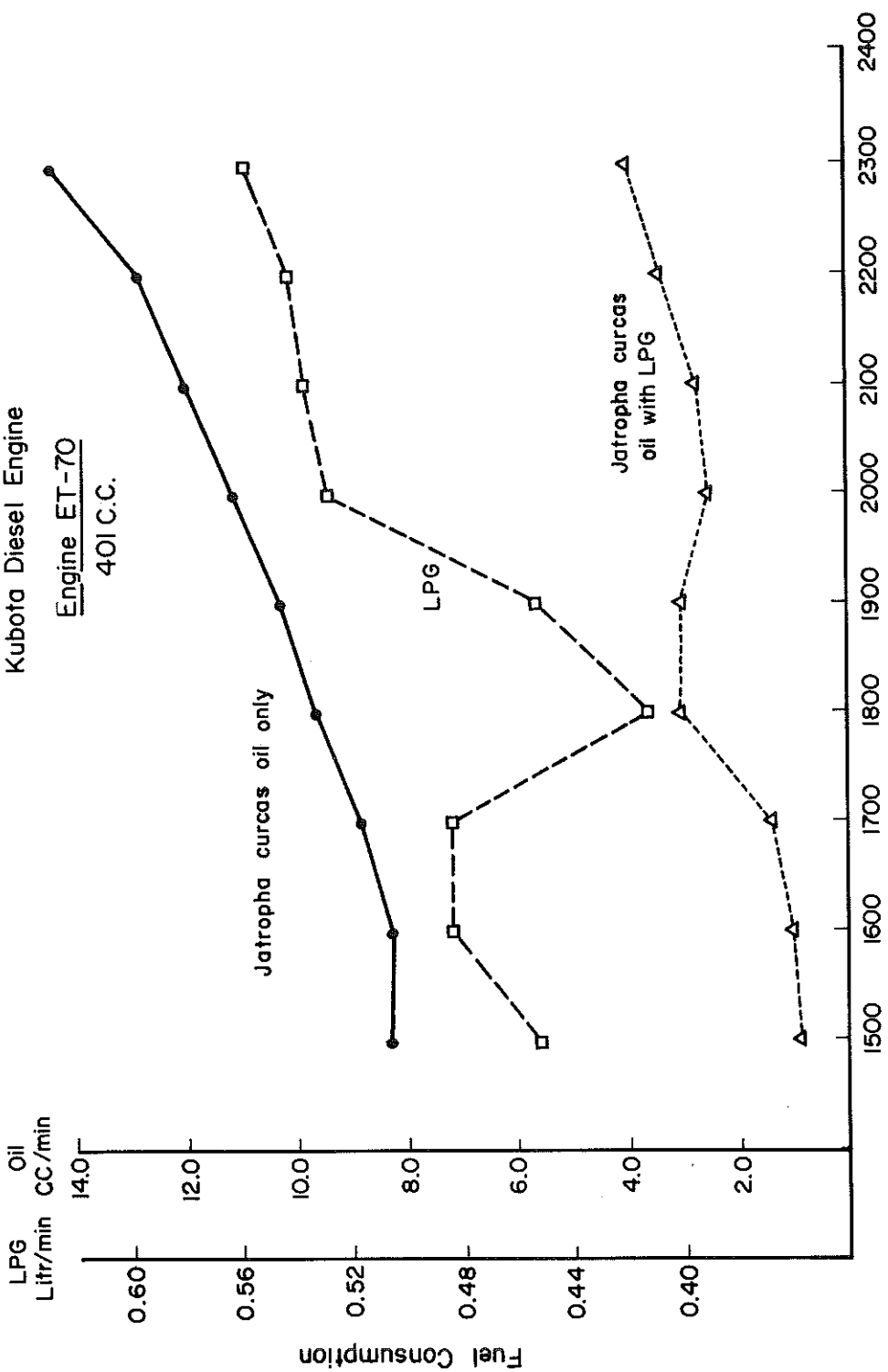

Fig. 10 Fuel consumption of the Kubota diesel engine run by Jatropha curcas oil as opposed to Jatropha curcas oil combined with LPG.

As part of the research carried out in cooperation with the Yanmar (Thailand) Co., Ltd., a diesel engine run by Jatropha curcas oil was tested. The specifications and test conditions of the Yanmar diesel engine and a comparison of the engine performance of the engine are shown in Tables 5 and Table 6 respectively. When Jatropha curcas oil was used, the engine performance and fuel consumption compared very favourably to running the engine with normal diesel engine oil.

Table 5
Specifications and test conditions of a Yanmar diesel engine

Specifications of the YANMAR Diesel engine

Item	
Model	SA 70-L
Type	Horizontal 4 cycle
No. of Cylinders	1
Bore X stroke	80 x 80
Displacement	0.402
Maximum HP/r.p.m.	7.0/2,400
Compression ratio	23:1
Combustion system	Pre-Combustion Type

Test conditions

Item	*Value*
Atmosphere	763/768 mmHg
Abinet Temp. Dry	34/39
Abinet Temp. Wet	31/35
Location of Works	Bangkok, Thailand
Date of test	Sept. 29, 1981
Fuel oil (d = 20°C)	Diesel light ASG 0.83
Lubricating oil (d = 20°C)	ESS-30 ASG 0.89
Dynamometer	Water Brake
Length of arm	0.176 m

Table 6
Comparison of the engine performance of a Yanmar diesel engine run by Jatropha curcas oil as opposed to the use of diesel oil

Continuous rating out-put		**Diesel oil**	**Jatropha curcas oil**
Out-put/speed	PS/r.p.m.	6.5/2,200	6.5/2,200
Fuel consumption	kg/h	1.294	1.506
Fuel specific	g/PSh	199	232
Exhaust gas temperature	°C	473	508
Exhaust gas colour	Sd	2.4	2.8

Table 6 (Cont.)

Maximum rating out-put		Diesel oil	Jatropha curcas oil
Out-put/speed	PS/r.p.m.	7.5/2,400	7.5/2,400
Fuel consumption	Kg/h	1.513	2.652
Fuel specific	g/PSh	201	274
Exhaust gas temperature	°C	513	599
Exhaust gas colour	Sd	3.0	5.6

EXHAUST GAS TEST

In cooperation with the Environment Quality Standards Division under the Office of the National Environment Board, a test was carried out on the exhaust gas of a 7HP Kubota diesel engine and a Yanmar diesel engine of 18HP, each being used with Jatropha curcas oil on the one hand and diesel oil on the other. The results are shown in Table 7. It can be seen from the Table that there is no difference in the average value of smoke and carbon monoxide content contained in the exhaust gas run by Jatropha curcas oil as opposed to diesel oil; and it should be mentioned that the values are lower than the standard specifications set by the Office of the National Environment Board (Smoke – not more than 40%, CO – not more than 60,000 ppm).

The sulphur dioxide content in the exhaust gas was tested by Department of Science Service, Ministry of Science, Energy and Technology. No sulphur dioxide was found in the exhaust gas of the diesel engine run by Jatropha curcas oil, but 125 ppm SO_2 was found in the exhaust gas of the diesel engine run by diesel oil.

Table 7
Smoke and CO contents in the exhaust gas of diesel engines run by Jatropha curcas oil as opposed to diesel oil

	Engine revolution (r.p.m.)	Jatropha curcas oil		High speed diesel oil	
		Smoke (%)	Carbon monoxide (ppm)	Smoke (%)	Carbon monoxide (ppm)
1. Kubota diesel engine (7 hp)	840	12.0	550	10.5	650
	2,160	13.0	450	14.5	750
	2,600	12.0	725	12.5	500
2. Yanmar diesel engine (18 hp)	1,000	11.5	500	10.0	500
	1,600	14.5	650	15.5	500
	2,000	18.5	650	19.0	600
Average	1,733	13.42	587	13.67	583

The diesel engine was then run by Jatropha curcas oil for 1,000 hours, and parts of the engine (the cylinder, piston, rings, valves, injector, etc.) were inspected. It was found that all the parts were still in good condition as shown in Table 8.

Table 8
Results of inspection of engine parts (Kubota Diesel Engine No. ET 70-026159)

	Engine parts		Standard values (mm)	
1.	Cylinder Head (I.D. of Valve Guide)		7	+ 0.022 0.010
2.	Valve (O.D. of Valve Stem)		7	− 0.025 − 0.040
3.	Rocker Arm Shaft (O.D. of Shaft)		14	− 0.016 − 0.027
4.	Rocker Arm (I.D. of Rocker Arm Bushings)		14	+ 0.050 + 0.002
5.	Tappet (O.D. of Tappet Stem)		12	− 0.016 − 0.034
6.	Cylinder Liner (I.D. of Cylinder Liner)		78	+ 0.019 0
7.	Piston (O.D. of Piston)		78	0
8.	Piston Pin (O.D. of Piston Pin)		25	+ 0.011 + 0.002
9.	Connecting Rod (I.D. of Small End Bushing)		25	+ 0.040 + 0.025
10.	Piston Ring (Ring Gap)	1st 2nd 3rd	0.2	+ 0.2 0
		4th (Oil Ring)	0.2	+ 0.2 0
11.	Crank Shaft (O.D. of Crank Pin)		44	− 0.025 − 0.041
	(O.D. of Crankshaft Journals)		40	+ 0.013 + 0.002
12.	Oil Filler Ring (I.D. of Oil Filler Ring)		40	+ 0.025 0

CONCLUSIONS

Our tests confirm that Jatropha curcas oil is a good substitute for diesel engine oil. The tests show that a diesel engine utilizing Jatropha curcas oil approximates in terms of engine perfor-

mance and fuel consumption with one using normal diesel oil. Farmers in rural areas could be self-sufficient in fuel for agricultural farm machines, since Jatropha curcas can be easily planted and the oil can be produced by a simple pressing process.

Development of improved species in conjunction with appropriate cultivation should be envisaged so as to increase seed production. In addition, technological research should be continued in all phases of oil seed processing, extracting and refining, with special regard to developing a small-scale operation which could be applied in rural areas.

REFERENCES

1. RAPEPUNTHU BHASABUTRA & SUKSAN SUTIPONPEIBUN (1982), *The Study of Jatropha Curcas Oil as a Substitute for a Diesel Engine Oil,* Thai Version, Department of Agricultural, Ministry of Agricultural and Cooperatives, Bangkok, 42p.
2. TAKEDA, YOSHIFUMI & MINORU OKADA (1981), *Interim Report on The Study of Jatropha Curcas Oil as a Substitute for Diesel Engine Oil,* Industrial Finance Corporation of Thailand, Bangkok, October 1981, 14p.