10. Agricultural Mechanization and Energy Management

The machines developed for seeding and planting, interculture, plant protection, harvesting and threshing and transport are discussed here.

Animal-drawn tool carrier: Animal-drawn wheeled tool-carrier has been developed with attachment of tools for tillage, seeding and interculture. The unit consists of main-frame, tool-bar and wheels (pneumatic/iron wheels) with provisions for attachment of tools and lifting of tools on turns. This tool-carrier showed advantage in terms of higher command area (2.0–2.5 times) over conventional implements. The unit with attachments may cost Rs 20,000. Its performance as work rate (ha/hr) for sowing, weeding and seed bed preparation is 0.10, 0.15, 0.10 compared to 0.03, 0.07, 0.10 by MB plough, seed drill, cultivar blade hoe respectively. The tool-carrier permitted higher command area per season (4–5 ha).

Animal-drawn tool carrier with attachment for tillage, seeding and weeding operations

Tractor-operated, 7-row seed-cum-fertilizer attachment for rotavator: The attachment has seven sets of plastics rotors for metering different seeds. It has a provision for varying seed and fertilizer rates also. The machine was used for planting six rows of soybean and chickpea and seven rows of wheat. Average capacity of the unit varied between 0.4 and 0.45 ha/hr.

Tractor-operated zero-till drill with rotary slit-opener: This is useful for zero till-drilling of wheat after combine-harvesting of rice. In this, seven rotary disk-type openers with trapezoidal-shaped blades are mounted on a shaft powered by a tractor, 45 hp or above, from PTO through gear from and side-chain drive for cutting surface straw and opening narrow slits in soil. Secondary furrow openers with small shoe and delivery boots for seed and fertilizer are positioned right behind the rotary slit-openers. Average field capacity and field efficiency of the drill are 0.41 ha/hr and 85% on controlled path operations. An additional toolbar on the main-frame is provided for mounting furrow openers in staggered manner for improving functional performance and smooth flow of straw.

Animal-drawn inter-row crop seeder: Animal-drawn inter-row crop seeder for rice and sesbania has been developed for row seeding of rice intercropped with sesbania. For biasi operation, seeding unit was removed and same equipment with two-row biasi tool was operated in row spaces where sesbania got chopped and mixed into the soil. The inter-row crop seeder serves tripple

Animal-drawn inter-row crop seeder for rice and sesbania

purpose of seeding of rice and sesbania, placement of fertilizer and biasi operation with chopping of sesbania. The cost of the inter-row crop seeder is Rs 3,500.

Barrow-type seed-cum-fertilizer spreader: Implement has spreaders with trapezoidal and bucket hopper for urea and diammonium phosphate (DAP) spreading with adjustable orifice for rate up to 100 kg/ha. Effective swath for urea is 6 m, having uniformity coefficient of 75.25%. Effective swath for DAP is 5 m with uniformity coefficient of 81.43%.

Tractor-mounted inclined-plate planter with raised-bed forming attachment for intercrop: For sowing bold seeds of groundnut, cotton, maize, a six-row machine has been developed. On the rear tool bar of the frame, shoe-type furrow openers with modular units of seed-boxes are clamped. Each seed box (15 kg capacity) is provided with inclined-plate (120-mm diameter)-type seed-metering mechanism. The provision has been made for different crops by selecting seed plates and by changing transmission ratio. Row spacing (225–450 mm) between furrow openers can be changed by sliding furrow openers on the rear tool bar of the main-frame. Depth of planter is controlled by tractor hydraulic system. Field capacity of the machine varies from 0.45 to 0.60 ha/hr with 65–75% field efficiency at about 3 km/hr.

Tractor-mounted inclined-plate planter with raised-bed forming attachment for intercrop

Single/two-row inclined-plate planters for sowing cotton and other crops: These planters are suitable for small and medium-size pair of bullocks. They can be used for sowing soybean, pigeonpea, cotton, chickpea, peas, groundnut at row spacing varying from 250 to 900 mm. The field capacity of 2-row animal-drawn planter is 0.11 ha/hr for row-to-row spacing of 450 mm.

Four-row vegetable transplanter: A tractor-mounted vegetable transplanter has been developed. With this, minimum percentage of seedlings in lying-down position was 3.86% for 450 mm row spacing for rolling type design with open press wheel on the straight shaft. For 330 mm row spacing for cauliflower, the minimum percentage of seedlings in lying-down position was 5.26 for rolling-type design 2 on the straight shaft.

Tractor-operated vegetable transplanter: Two-row vegetable transplanter is provided with opening type finger with flappers. Power from the wheel is supplied to planting mechanism through shaft, chain and sprockets. Plant spacing in the machine is kept at 300 mm and can be varied by changing sprockets or number of fingers. Two persons (one for each row) are required to place seedlings in the flappers when there are open. To increase planting speed, number of persons for seedling feeding are increased to two per tow. After seedling is dropped, the soil is compacted with two moving inclined wheels. The machine is operated at forward speed of 1 km/hr. The capacity of machine is 0.07 – 0.08 ha/hr for two-row model. Cost of operation is Rs 2,200/ha.

Tractor-operated vegetable transplanter

Tractor-operated multipurpose implement for sugarcane: This facilitates interculture and earthing up operations in addition to planting of sugarcane-setts. In three-row machine, operator lifts cane from seed-tray and puts it on the slanting chute. Cane slides down and cutter cuts canes into setts automatically, and in interculture mode implement

Tractor-operated multipurpose implement for sugarcane

has 6 standard tynes with reversible shovels, which provide soil cover in three rows of cane placed in opened furrows.

Animal-drawn single-row and 2-row inclined-plate planter: The planter consists of modular seed boxes, main-frame, ground drive wheel, power transmission system, furrow opener, beam and handle. The seed box-furrow opener assembly may be adjusted on the tool bar of the main-frame for row spacing varying from 25 to 90 cm. The ground drive wheel has spring loaded for slip-free rotation. The fertilizer unit is optional. The 2-row planter has a field capacity of 0.1 ha/hr at draught value of 50 kg for planting of cotton at 90 cm row spacing.

Power-tiller-mounted earthing-cum-fertilizer applicator: The earthing-up unit for sugarcane consists of single ridger body (20 kg weight), which also performs shaping of ridges. Field capacity of the machine is 0.15 ha/hr and the cost of operation is Rs 750/ha.

Power tiller-mounted earthing-cum-fertilizer applicator

Tractor-operated aero blast sprayer: This consists of a tank of 400 litres capacity, pump, fan, control value, filling unit, spout adjustable handle and spraying nozzles, its air blast is produced by centrifugal blower. The air blast distributes chemical in the form of very fine particles throughout its swath width, which is on one side of the tractor. Machine can cover about 1.7 ha/hr at a speed of 1.5 km/hr. Application rate can be varied from 100 to 400 litres/ha. Effective width of sprayer is 13 m distance. The cost of machine is Rs 80,000 and of operation is Rs 500/ha compared to Rs 700/ha by conventional method.

Bullock-drawn sprayer for field crops: The commercially available bullock-drawn sprayer (length × width × height 3.90 m × 1.80 m × 1.85 m) having 6 nozzles and boom (length 5.4 m) was modified in respect of orientation of beam and hitch system, operator seat and clutching system for the pump. The unit having 90 cm ground clearance was operated at the speed ratio (wheel: pump) of 1: 4. The hollow cone nozzles at 45-cm spacing gave swath of 3 m. The field test results have indicated average discharge of 440 ml/min/nozzle at average pressure of 324 kPa, giving draught value of 95 kg. The height of the boom is made variable from 30 to 100 cm. A manufacturer of cotton sprayer has adopted modifications. Cost of the sprayer is Rs 25,000.

Tractor-mounted turmeric harvester: This was evaluated to harvest turmeric rhizomes on raised bed, and indicated reduction in soil load by 30–35%. The harvester was tested in farmers' fields also at Thondamuthur in Coimbatore district. Its harvesting efficiency was 98% at forward speed of 2.5 km/hr, and damaged and undug rhizome were 4% and 2–3% respectively.

Self-propelled fodder harvester: It consists of 1,450-mm cutter bar. Power to wheel is provided through extension with chains and sprockets with the chassis suitably strengthened. The field capacity of machine is 0.1 ha/hr, and cost of operation is Rs 900/ha.

Self-propelled fodder harvester

Curry-leaf stripper: Two operators can strip approximately 40–50 kg leaflets per hour, and the cost of stripper is approximately Rs 15,000. It saves to a tune of 80% in labour and 60% in cost over conventional method.

Power-operated maize dehusker-cum-sheller: Maize dehuskers-cum-threshers, spike-tooth type (modified version of wheat thresher) and axial-flow type (modified version of sunflower thresher) have been developed. Recovery of grain with these is 97%. The cost of the machine is Rs 45,000 and of operation is Rs 5,000/tonnes.

Tractor-mounted banana shredder: The shredding unit consists of 4 blades placed perpendicular to each other at 225 cm distance. Additionally, 12 spikes with flat-cutting edge are fitted with a gap of 120 mm between rows. The blades are driven by PTO of tractor with a bevel gear-box and the hopper is trapezoidal with a height of 800 mm. It takes 1.2 min to shred stem having average height of 2,400 mm. The cost of operation is Rs 300/hr.

Tractor-mounted banana shredder

Tree climber: A tree climber has been developed for harvesting coconut and arecanut. Climber has two components. The upper component is provided with a seating arrangement and lower component is having provision for holding foot, the upper component can be moved up or down over the tree. The operator can safely climb a tree of 10 m height in 1.5 min. Its cost is Rs 2,000.

Tree climber helps operator to climb 10 m in 1.5 minutes

Tractor-mounted banana-clump remover: A nine-tyne cultivator frame has been adopted for development of the equipment. Two numbers of 100 mm × 15 mm × 1,000 mm sub-soiler shanks with shares of 190 mm × 40 mm × 5 mm were fitted in the frame at 225 mm spacing. These two sub soilers perform as a fork while removing banana clump. A deflector has been provided to push soil sideways. Cost of the components is Rs 6,000. The field capacity and cost of operation are 0.5 ha/hr and Rs 500/ha, respectively.

Two-wheel donkey cart: Two-wheel steel cart was developed for large white Kathiawad breed donkeys (body weight, 150–170 kg) matching their draught capacity (25% of body weight). With the help of the steel cart a pair of donkeys could transport 500 kg load compared to 40–50 kg carrying on back load. The unit cost of the cart is Rs 6,000.

Two-wheel steel cart for donkeys

Two-wheel bullock cart: A standard chassis of 2-tonne payload capacity with options for interchangeability of pneumatic wheels by iron wheels and hitch arrangement for single and a pair of bullocks has been developed. The chassis has the provision for mounting of different sizes of platforms for operations such as platform for transportation of crop, straw, grain bags, platform for transport of materials/passengers and tankers for transport of oil/water. The pneumatic wheel cart is recommended for transport of 2 tonnes payload on the tar road, 1.5 tonne payload on earthen road and 1 tonne payload under field conditions. The developed cart is superior to conventional wooden wheel cart in load carrying capacity, draught and power requirements. The unit cost of the cart is Rs 15,000.

ERGONOMICS AND SAFETY

Survey of agricultural accidents: Development of safer equipment and minimization of accidents are important links in enhancing farm mechanization strategies. An agricultural accidents survey was carried out with large sample size of villages for a period of one year. The results indicated that of the total accidents, 63.4% were due to farm machines and hand tools, whereas 36.6% accidents were due to snake bites, animal bites, fall in well, lightening, heat stroke etc. Of the total accidents, 5.5% were fatal and 94.5% were non-fatal. The overall annual accident incidence rate was 334 accidents per lakh workers, whereas the annual fatality rate was 18.3 per lakh workers.

Anthropometric and strength data of agricultural workers: Data on 79 body dimensions from 12 states and strength data on 16 parameters from 6 states were collected. The mean stature and weight of Indian agricultural workers on the basis of data worked out to be 163.0 cm and 53.8 kg for male-workers and 151.2 cm and 45.9 kg for female-workers. The mean values for strength

Agricultural accidents data

State	No. of villages surveyed	Data collection period	No. of accidents reported			Accident incidence rate/lakh workers/year	Fatality rate/lakh workers/ year
			Farm machinery and hand tools	Others	Total		
Tamil Nadu	240 from 6 districts	July 04–June 05	265 (46.2%)	308 (53.7%)	573 (100%)	245	10.0
Orissa	240 from 6 districts	July 04–June 05	412 (83.3%)	104 (16.7%)	516 (100%)	1520	17.7
Madhya Pradesh	360 from 9 districts	July 04–June 05	120 (63.5%)	69 (36.5%)	189 (100%)	294	18.7
Punjab	200 from 5 districts	Jan 05–Dec 05	32 (78.0%)	9 (22.0%)	41 (100%)	66	12.8
Rajasthan	280 from 7 districts	July 05–June 06	218 (48.1%)	235 (51.8%)	453 (100%)	373	42.8
Arunachal Pradesh	160 from 4 districts	July 05–June 06	61 (71.8%)	24 (28.2%)	85 (100%)	558	6.5
West Bengal	120 from 3 districts	Sep 06–Aug 07	352 (79.1%)	93 (20.9%)	445 (100%)	294	15.2
Total			1,460 (63.4%)	842 (36.6%)	2,302 (100%)		
Weighted mean						334	18.3

Severity-wise data of victims of agricultural accidents

States	Agricultural accidents		
	Fatal	Non-fatal	Total
Tamil Nadu	24 (4.2)*	549 (95.8)	573 (100)
Orissa	6 (1.2)	510 (98.8)	516 (100)
Madhya Pradesh	12 (6.3)	177 (93.6)	189 (100)
Punjab	8 (19.5)	33 (80.5)	41 (100)
Rajasthan	52 (11.5)	401 (88.5)	453 (100)
Arunachal Pradesh	1 (1.2)	84 (98.8)	85 (100)
West Bengal	23 (5.2)	422 (94.8)	445 (100)
Total	126	2176	2302
% of total accidents	5.5	94.5	100

*Figures in parentheses indicate per cent of total accidents

data in pushing and pulling by both hands in standing posture are 226 N and 223 N for male-workers 151 N and 169 N and for female-workers respectively.

Safety gadgets for power-operated chaff cutter: An automatic belt conveyor system for powered chaff cutter has been developed to ensure that operator's hands shall not reach cutting machine to cause an accident. The top of the conveyor trough near feed roller is covered to distance of 40 cm to prevent insertion of hand. A guard for the idler pulley of conveyor at outer end is provided to prevent accidental contact of persons or parts of clothing being caught in the transmission system. Guard for cutter head, guard

Safety gadgets ensure that operator's hands do not reach cutting machines

for belt transmission system, cover for electric motor, guard for idle roller conveyor, guard for feed rollers are provided to prevent accidental contact of persons or parts of clothing being caught in transmission system. The unit also includes feed reversing mechanism for the safety of operator, as feeding can be instantly stopped or reversed as required without stopping machine.

Ergonomical evaluation of power tiller: A 6.7 kW power tiller was evaluated with 10 male subjects. The salient findings are:

- Rota-puddling in wet soil is more energy-intensive operation than rota-tilling in dry soil. However, muscular load on forearm is higher during rota-tilling than rota-puddling operation. Transportation is more comfortable operation as compared to rota-tilling and rota-puddling operation.

- The frequency-weighted vibration acceleration (rms) is highest during transportation followed by rota-tilling and rota-puddling. The most detrimental frequency of vibration in hand-tractor operation is 31.5 Hz, which exceeds 1 hr exposure limit.
- Isolator with high stiffness (16.3 kN/mm) and high damping coefficient (0.51 N s/mm) is better for reduction of vibration during field operation of power tiller. Engine mounting and handle isolator reduced frequency un-weighted and frequency-weighted vibration acceleration (rms). The average reduction of frequency weighted vibration acceleration (rms) by handle grip was 11.31%.
- Designed glove from elastomeric material is most preferred by hand-tractor operators. It reduces about 14% frequency-weighted vibration acceleration (rms) below 50 Hz and above 160 Hz frequencies.
- Mounting of isolators reduces heart rate of the operator to 23.9, 18.4 and 15.4% during transportation, rota-tilling and rota-puddling operations. The corresponding reduction in energy expenditure rate is 1.41, 0.35 and 1.52 kJ/min. In these operations, about 54.5, 53.0 and 43.65% work related body parts discomfort in hands, arms, shoulders and neck was reduced.

Ergonomically designed sugarcane harvesting knife: A sugarcane harvesting knife has been ergonomically designed. The weight of the knife is 486 g. Performance of this knife was compared with existing Dharmapuri sugarcane harvesting tool weighing 585 g. The harvesting capacity of

Equipment for women workers

The following improved equipment were evaluated and their brief performance is given here.

Equipment for women workers and performance

Equipment	Centre	Brief results
4-row rice seeder	CIAE	• Twelve female subjects participated in the study • Mean HR during work - 144 beats/min • Mean ΔHR – 61 beats/min • Output – 917 m^2/hr
4-row rice transplanter	CIAE	• Twelve female subjects participated in the study • Mean HR during work - 148 beats/min • Mean ΔHR - 62 beats/min • Force required - 251 N • Output – 245 m^2/hr
Single-row-finger-type rotary weeder	TNAU	• Twelve female subjects participated in the study • Mean HR during work - 125 beats/min • Mean ΔHR - 43 beats/min • Energy expenditure – 25.1 kJ/min • ODR – 5.4 on 10 point scale • Force required - 91 N • Output – 0.016 ha/hr
Sugarcane detrasher	TNAU	• Twelve female subjects participated in the study • Mean HR during work - 113 beats/min • Mean ΔHR - 44 beats/min • Energy expenditure - 16.5 kJ/min • ODR - 5.0 on 10 point scale • Output - 119.8 kg/hr
Vaibhav sickle	NERIST	• Eleven female subjects participated in the study • Mean HR during work - 129 beats/min • Mean ΔHR - 42 beats/min • Energy expenditure - 16.7 kJ/min • Output – 61.9 m^2/hr
Naveen sickle	NERIST	• Mean HR during work - 126 beats/min • Mean ΔHR - 38 beats/min • Energy expenditure - 15.9 kJ/min • Output – 61.9 m^2/hr

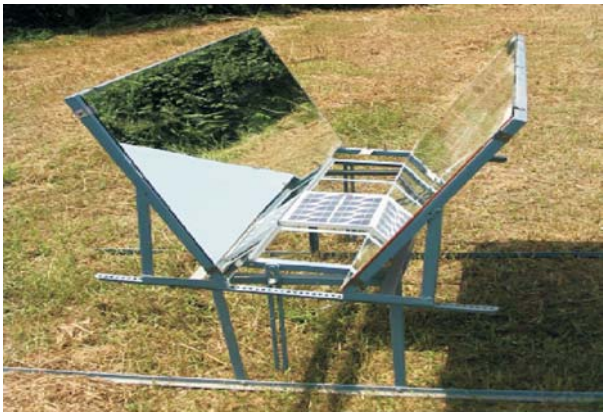
Ergo refined sugarcane harvesting knife in operation

the improved knife was 9.8 m^2/hr against 9.4 m^2/hr of traditional tool. However the mean heart rate (HR) during work with the improved knife was lower, i.e. 115 beats/min, as against 132 beats/min for the traditional tool. The corresponding HR (increase in HR over rest) were 41 and 54 beats/min. Thus, operation with newly developed knife involves less drudgery.

ENERGY

Concentrator for solar photovoltaic panel (SPV): The most important constraint in the widespread adoption of SPV panels is its very high initial cost. The cost of panel per unit output has been reduced by developing solar concentrators which increase solar energy incident on SPV panels. Stationary solar concentrator and tracking solar concentrator designs are being studied. A stationary concentrator has been fabricated. Its Fill factor has been found to be 0.7. The output of the SPV panel with stationary concentrator has been 56% higher compared to output of SPV panel without concentrator, with 16% estimated increase in cost of SPV panel.

Triple-purpose integrated solar device: An improved 3-in-1 compact integrated device has been designed and developed, which can be used as solar water heater during winter, solar cooker during clear days and solar dryer on availability of fruit or



Concentrator for solar photovoltaic panel

vegetables. The device has 25% enhanced capacity of water and 13.4% less area of window but having 35% more effective utilization of energy compared to earlier developed model. As a water heater, 50 litres hot water of 50–60°C could be obtained in winter afternoon while as a cooker food for a family could be boiled within 2–3 hr in summer (loading time 10 AM). As a dryer, fruit and vegetables like *ber*, grated carrot, spinach, watermelon flakes, tomato slices etc. could be dehydrated efficiently with regulation of temperature during day-time and continuation of the drying process even in the night through the heated water. The device can save about 230 kWh during winter as a water heater and 70 kWh as a solar cooker when used in the forenoon of 210 days in a year. In addition, 50 kg fruit and vegetables can be dehydrated from the same device saving additional 30 kWh and providing the dried material for its subsequent use. Year-round utility makes it a useful domestic appliance.

Year-round utility makes triple-purpose integrated solar device a useful domestic appliance

Fixed-dome type biogas plants: Two non-functional 60 m^3 capacity KVIC type biogas plants were converted into fixed-dome type biogas plants at a Gurudwara near Ludhiana. All brick construction for the dome of the biogas plant has been done. Both the plants were commissioned using cattle dung, water and fresh digested slurry available from a running biogas plant. The gas available is being used for routine cooking of meals (*Langar*) in the Gurudwara.

Biogas plant slurry dewatering machine: A rotating-cylinder type machine for partial removal of water from digested slurry discharged from

large-capacity cattle dung-based biogas plants has been developed. The machine handles fresh digested slurry at around 4,800 litres/hr. The total solids content of the input slurry varied between 6.0 and 6.5%, of dewatered slurry between 10.5 and 11.0%, and that of filtered water between 2.4 and 2.5%. The filtered water can be recycled in the plant for dilution of input cattle dung. The machine can handle digested slurry available from a battery of 4 or 5 plants each of 85 m^3 capacity. At Palampur (Himachal Pradesh), the input slurry was fed into machine under gravity. However, in plains, a slurry pump may be used for feeding the input slurry into the machine. The estimated cost of the machine is Rs 40,000, excluding prime mover.

Biogas plant slurry dewatering machine

Durable improved biomass cook stoves: Durable improved biomass cook stoves for agro-industrial and community applications have been developed. Single pot stove for agro-industrial applications has a power rating of 9.9 kW at fuel-wood (*Acacia nilotica*) burning rate of 8 kg/hr. This stove has thermal efficiency of about 35%. Cost of single pot cook stove is around Rs 1,200, and double pot cook stove Rs 1,800.

Biomass briquetting: A briquetting facility consisting of a piston press-type briquetting machine, a rotary die-type pelleting machine, flash dryer with cyclone separator, a 62.5 kVA genset, a hammer mill for size reduction of the biomass and water softening plant-cum-boiler for heating of the biomass has been installed. The rated capacity of the piston-press type machine is 500 kg/hr of briquettes of 50 mm diameter. The machine was used for briquetting of saw-dust, sugarcane-bagasse, cotton-stalk, pearl millet stalk, rice-straw, wheat-straw, groundnut-shell and *Jatropha*-shell, in powder and granular forms. Good-quality briquettes were obtained in all cases. The estimated cost of the briquettes was Rs 2,100/tonne for saw-dust and around Rs 3,000/tonne for sugarcane bagasse, cotton stalk, pearl millet stalk and wheat straw. The cost of briquetting was lower with saw-dust, primarily because of lower requirements of pre-treatment of feedstock and higher output.

Good-quality pellets of 22 mm and 10 mm size could be made in rotary die-type machine when feedstock was mixed with 50% de-oiled cake on volume basis. The briquettes prepared from the feedstock having low ash content could be used in gasifiers without any difficulty. Briquettes and pellets of all the feedstock studied could be used in improved portable metallic stoves and inverted downdraft gasifiers for thermal applications.

Agro-industrial application of biomass gasifier: A throatless downdraft gasifier of SPRERI design was installed in a commercial bakery at Udaipur. The industry has two ovens, each consuming approximately 6.5 kg of lpg/hr. One of the ovens, which normally operated up to 16 hr/day, has been provided with producer gas supply. One batch of the product takes around 20 min at a temperature of 230–250°C. The gasifier consumes 40 kg/hr of biomass and operates for 15–16 hr everyday.

Efficient process for biodiesel extraction from *Pongamia* and *Jatropha*: Higher oil recovery from seeds of pongamia and jatropha was obtained with CRIDA modified oil expeller. Pretreatment of the seed enhanced the oil recovery from 24 to 28% in pongamia and from 26 to 30% in jatropha over conventional steaming process. Oil quality also improved with seed pretreatment. With seed pretreatment, viscosity of oil decreased by 2.7 to 3.7 centistrokes, which is close to BIS specifications, thus contributing to higher oil recovery. More than 94% of the biodiesel was recovered in the case of jatropha oil when CRIDA process was used, which reduced the catalyst requirement when compared to the two-stage process for high free fatty acid oils with biodiesel recovery of 88%. The recovery of biodiesel was around 91% in case of pongamia using CRIDA process as against 86% with normal process.The flash point of the CRIDA biodiesel was around 127°C while that of normal biodiesel was 135°C.

Jatropha biodiesel with CRIDA process

Pongamia biodiesel with CRIDA process

This is useful in burning the fuel at lower operating temperature.Performance of a 5 HP water cooled engine coupled with eddy current dynamometer was tested using the B20, B40, B80, B100 biodiesel.

Testing of tractor with fuel blends of *jatropha* ethyl ester and diesel: A 35 HP tractor was tested in laboratory at varying loads using blends of jatropha ethyl ester (JEE) and diesel. The jatropha ethyl ester was produced in batches by single stage trans-esterification method using KOH and ethanol; and on an average ester recovery of 90% was observed using optimized parameters. The engine efficiency of the tractor increased with increase in load on the tractor and increase in JEE blending percentage in diesel. The thermal efficiency ranged from 25 to 27% at maximum power of tractor. Similarly, NO_2 levels increased with increase in JEE blending in diesel from B-30 to B-50. The smoke emission from tractor increased considerably with increase in brake power.

Mechanical fish harvesting devices for fish ponds

Bycatch reduction devices (BRD) for selective shrimp trawling: Field experiments with horizontally oriented fish eye BRD (10 cm × 30 cm)

Operation of radial escapement device

installed in the upper half of the cod end of shrimp trawl, showed 100% efficiency in excluding seven species of fin fishes, viz. *Parastromateus niger, Leiognathus equulus, Pampus argenteus, Thryssa mystax, Alepes djedaba, Encrassicholina devisi* and *Stolephorous waitei.* Above 50% escapement was observed in 25 other species. Semi-circular fish eye BRD (20 cm × 30 cm) showed 100% efficiency excluding *Caranx semifasciatus* and *Secutor ruconius,* and 8 species showed escapement of more than 50%. Loss of target catch shrimp and squid [*Uroteuthis* (*Photololigo*) *duvauceli*] was minimal in these two designs. Field experiments with vertically orientated oval fish eye BRD (20 cm × 30 cm) showed 100% efficiency in excluding 12 species of finfishes and 1 lobster species; and 37 species showed escapement above 50%, while catch loss of cephalopods and shrimp was higher in this design.

Radial escapement device with 150 mm mesh netting (covered codend method) showed 100% efficiency in excluding fin fishes. *Uroconger lepturus, Nibea maculata, Scatophagus argus, Selar crumenophthalmus, Trypauchen vagina, Leiognathus brevirostris, Penaeus semisulcatus;* and 8 species showed escapement above 50%. Among 68 species, 19 species showed 0% escapement that consisted of 8 species of finfishes, 3 species of shrimps, 1 species of cephalopod, 2 species of crabs, and 5 species of other molluscan shells. Shrimp loss was about 8.32%.

Development of traps: Collapsible traps for crab, lobster and fish were designed and fabricated. Fishing trials were conducted with collapsible crab traps in Kochi backwaters using different baits. Of the different baits used, chicken waste showed higher catches of *Scylla serreta* than other baits. A design of collapsible fish trap for inland fishing was developed and the same was tried in the inland waters of Kerala mainly for *Eutroplus* spp. The catch rates of fish were better with these traps than with traditional fish traps; and that is also being patented.

Operation of fish traps

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