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Engine Performance Tests Using Polanga Biodiesel Blends

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Abstract: In the present world it is essential to find an alternate fuel source due to the increased industrialization and depletion in natural resources. The method of obtaining biodiesel from various sources and blending them with diesel is adopted in many economically developed and developing countries around the world. This research includes the utilization of Polanga blends with diesel in CI engine. The physical properties like density, kinematic viscosity and calorific value were measured for different blend. The performance and combustion characteristics of B0, B10, B20 and B30 blends of Polanga bio diesel have been studied and it is found out that the blends of biodiesel could substitute in the place of pure diesel and be used as an alternate source of fuel in the near future, thus saving the natural resources for the future generation. Performance parameters like brake thermal efficiency, fuel consumption, brake specific fuel consumption, brake power and exhaust gas temperature are evaluated in laboratory. The emission characteristics like CO and CO_2 per cent was also studied. Field performance test of power tiller with attached cultivator operated by both diesel and bio diesel was done to know the working speed, actual field capacity, average time of operation, theoretical field capacity, field efficiency, fuel consumption and energy requirement. The energy consumption for cultivating 1 hectare land was found to be 18.15 MJ/ha for diesel where as it decreased from 17.4 MJ/ha to 16.61 MJ/ha from B10 to B30. From the study, the bio diesel blend gives satisfactory result in both laboratories as well as in field test.

I. INTRODUCTION

The Planning Commission of India had set an ambitious target covering 11.2 to 13.4 million hectares of land under Jatropha cultivation. The central government and several state governments are providing fiscal incentives for supporting plantations of Jatropha and other non-edible oilseeds. Several public institutions, state biofuel boards, state agricultural universities and cooperative sectors are also supporting the biofuel mission in different capacities. (Salman Zafar, 2015). It is wise to consider the oil yield potential of different edible and non-edible crops (Table 1.1), before selecting the crop as suitable source of biodiesel production. Considering the food grain scarcity in developing countries like India, edible major crops may be spared as a potential source for bio-diesel production. Typical feed stocks for biodiesel production are soybean, canola/rapeseed, sunflower, cottonseed, palm seed and palm kernel, corn and mustard seed oil. Pork, beef and poultry fat and grease also can be converted to biodiesel. Palm oil and animal fat may have a high free fatty acid content, which causes soap formation that has adverse effects on downstream processing and leads to yield reduction.

Table 1.1 Oil yield potential of different crops

Sl. No.	Crop type	Oil yield potential ('000 l/ha)	Sl. No.	Crop type	Oil yield potential ('000 l/ha)
1	Micro algae	47.5-142.5	5	Rapeseed	1.2
2	Oil Palm	6.0	6	Sunflower	1.0
3	Jatropha	2.0	7	Soybean	0.5
4	Canola	1.25	8	Corn	0.2

Biofuels offer an attractive alternative to fossil fuels, but a consistent scientific framework is needed to ensure policies that maximize the positive and minimize the negative aspects of biofuels. Numerous countries are moving towards the partial and gradual replacement of fossil fuels with biofuels, mainly ethanol and biodiesel.

Polanga biodiesel is a renewable source of energy that can help reduce greenhouse gas emissions and minimize the “carbon footprint” of agriculture. Polanga biodiesel is a safe, non toxic and biodegradable that can be easily used in unmodified diesel engine. Biodiesel is being recommended for existing engines up to 20% of blends in stationary and automotive application. Emissions are satisfactory when we use biodiesel in diesel engines. However, there is a very limited application of biodiesel in agricultural machinery such as power tiller and tractor engine. Therefore, it is proposed to study the performance and emission characteristics of a power tiller in laboratory and field condition.

This chapter deals with the details procedure for biodiesel production from polanga oil, physico-chemical properties analysis of biodiesel, development of experimental setup for performance studies such as brake power, brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), exhaust gas temperature (EGT) and exhaust gas emissions like CO, $CO_{2,}$ etc.

II. TEST FUEL PREPARATION

Biodiesel from polanga was produced in a laboratory scale set up which consists of heating mantle, reaction flask and mechanical stirrer. The working capacity of reaction flask is 2 litre. It consists of three necks for stirrer, condenser and inlet of reactant as well as for placing the thermocouple to observe the reaction temperature. The flask has a stopcock at the bottom for collection of the final product it was observed that the appropriate quality of biodiesel could be produced from polanga oil in following three stages so that the physico-chemical properties were close to those of petro-diesel.

1) *Degumming Process:* It is the first stage of refining process and it removes the organic matters and other impurities present in the unrefined filtered polanga oil using reagent..
2) *Acid Catalyzed Transesterification:* The product of the first stage was mixed with various proportion of anhydrous sulphuric acid (98.4%) starting from 0.1% (v/v) along with methanol in volume basis and stirred at a temperature of 55 °C with reaction time of 2.5 to 3 h.
3) *Alkaline Catalyzed Transesterification:* The product of the intermediate stage (pure triglycerides) is transesterified to mono-esters of fatty acids (biodiesel) using alkali catalyst.

III. PROCEDURE TO MAKE POLANGA METHYL ESTER (BIODIESEL)

The raw polanga oil was extracted by mechanical expeller in which small traces of organic matter, water and other impurities were present. These materials were creating problems in yield and in the phase separation between the glycerol and esters. This necessitates the pre-treatment of polanga oil in the first stage. One litre of polanga oil was mixed 5 ml of phosphoric acid as a reagent. Phosphoric acid helps in dissolving the organic matter and separating it from other impurities. Reaction time 2.5 h was used to investigate for the optimization and their influence on the acid value of crude polanga oil. The mixture was stirred in the air closed reaction flask for 2.5 h at 55°-60° C. The speed of the stirrer was kept same for all test runs. The reactions were carried out with continuous stirring with mechanical stirrer.

The product from the first stage was allowed to settle for 12 h. The upper layer which consisted of methanol–water fraction, organic matter toluene and other impurities was separated from the lower layer. Anhydrous sulphuric acid (98.4%) was used as catalyst in the acid catalyzed transesterification.

Experimentally it was optimized that 0.65% by volume of the H_2SO_4 acid and a molar ratio of 6:1 gave the maximum conversion efficiency of free fatty acids to triglycerides and thereby reducing the acid value of the product of second stage below 4 mg KOH/g. The duration of the reaction was 3 h.

After the reaction was completed the products were allowed to separate in two layers. The lower layers contained impurities and glycerol. The top ester layer is separated and purified by using warm water. After washing, the final product was heated up to 70° C for 15-20 min under vacuum condition and stored for further use.

Biodiesel characterization the formation of methyl ester by three stage transesterification tochiometrically requires six moles of alcohol for every mole of triglyceride. However, transesterification is an equilibrium reaction in which an excess of the alcohol is required to drive the reaction close to completion.

The optimum ratio was found to be 6:1 molar ratio of methanol to oil (triglyceride) which is sufficient to give 85% yield of ester.The reaction was completed up to 85% in 90 min and the reaction was carried out for 2.5 h to achieve complete reaction. The physico-chemical properties of the polanga oil, neat petro-diesel, neat biodiesel (B100) and its blend of 10%, 20%, and 30% at each step were evaluated as per the ASTM standard methods and the results are in accordance with ASTM. It is observed that the chemical characteristics of the polanga oil methyl ester were found to be in the close range of engine requirement.

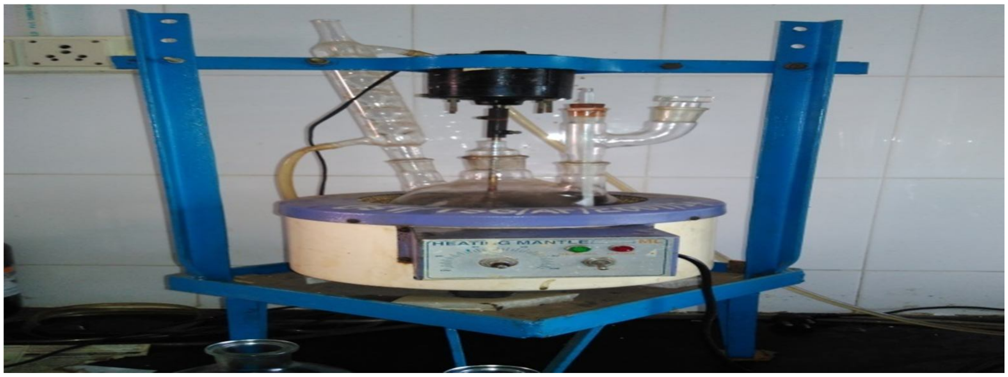

Fig.3.1 Biodiesel heating mantle

A. *Preparation Of Blends*

Three different blends of diesel and biodiesel were prepared for determination of fuel properties and engine performance. The blends prepared are mentioned below:

1) B10=10%bio-diesel+90%diesel
2) B20=20%bio-diesel+80%diesel
3) B30 = 30% bio-diesel + 70% diesel

B. *Determination Of Fuel Properties*

Methods for the determination of properties such as kinematic viscosity, density and heating value of polanga oil, prepared biodiesel and different blends are discussed below:

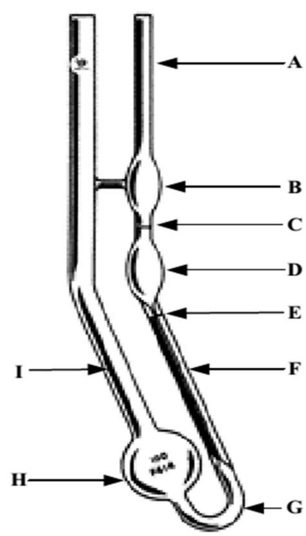

Fig.3.2 (a) Cannon-fenske routine viscometer bath   Fig.3.2 (b) Viscometer

C. *Density*

For the determination of the density of the fuel, a pycnometer of 25 ml capacity was dried completely and weighed. Then, it was filled with the fuel and weighed. Density of the fuel was determined using following relationship:

$$D= \frac{M2-M1}{25}$$

Where, D= density of fuels ample, g/ml

M_2=Weight of pycnometer plus fuel sample, g

M_1=Weight of empty pycnometer, g

Fig. Pycnometer

D. Calorific Value

Bomb calorimeter was used to measure the gross heating value of the fuels (Fig.3.4). Weight and heating value of the capsule was determined. Fuel sample was taken in the capsule and weight of capsule containing fuel was determined. The capsule was stretched over the electrodes with the help of fine magnesium wire. The bomb lid was tightly screwed and bomb was filled with oxygen at 25^0 C atmospheric temperatures. The initial temperature was recorded. The fuel in the capsule burnt and heat liberated by burning of the fuel increased the temperature of water. The maximum temperature attained was recorded. The difference in the 20 initial and maximum temperatures gave the rise in temperature. The gross heating value of fuel sample was calculated by using the following equation:

$CV=\frac{T2-T1}{mf} \times W$

Where, T2=Rise in temperature, ° C

T1=Initial temperature, ° C

Mf=Weight of fuel sample, g

W= Molecular weight of water,

Fig. Bomb Calorimeter

E. Gas Analyzer

Gas analyzer (model NDG15) was used to determine carbon monoxide and carbon dioxide in the exhaust gas (Fig. 3.7). The exhaust gas sample was directly drawn from exhaust gas manifold using a 3 mm pipe and fed to the analyzer for the measurement of carbon monoxide and carbon dioxide content in exhaust gas. The measurements were made under all the selected load conditions. The digital meters were present on the instrument to directly display the reading, the range of carbon monoxide measurement was 0 to 15 per cent (least count 0.023 per cent) and range of carbon dioxide measurement was 0 to 20 per cent (least count 2.2 per cent).

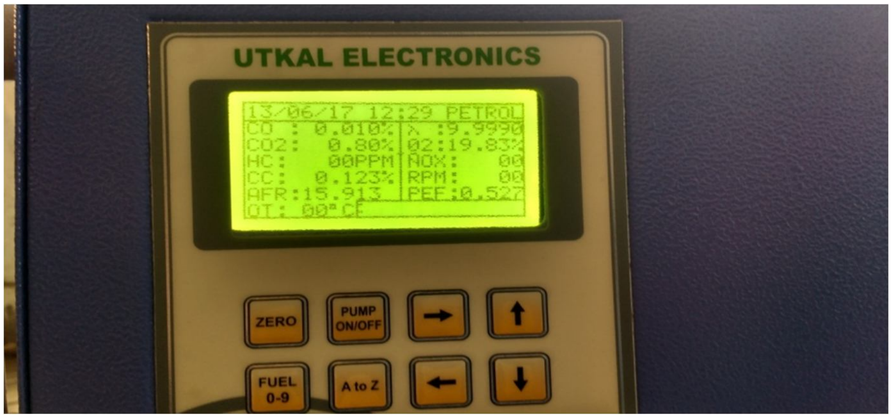

Fig. 3.6 Gas analyser

1) Independent Parameters

Parameters	Level	` Remarks
Blends of bio-diesel and diesel	3	(B10, B20, B30)
Load (% of load)	5	(0%, 25%, 50%, 75% and 100%)

2) Dependent Parameters

a) Brake thermal efficiency, %
b) Fuel consumption, kg/h
c) Brake specific fuel consumption, kg/kWh
d) Exhaust gas temperature, °C
e) CO and CO2 content in exhaust gas

Engine performance study

The engine was run for 30 minutes to make it stable before test. Engine was run using a blend as fuel at no load, 1kW, 2kW, 3kW, and 4kW load. The time taken for testing the engine at different loads using one blend was about 45 minutes. Observations of performance parameters, like brake power, brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperature were taken for each no load and load condition. Experiments were replicated three times and average values of observations were recorded.

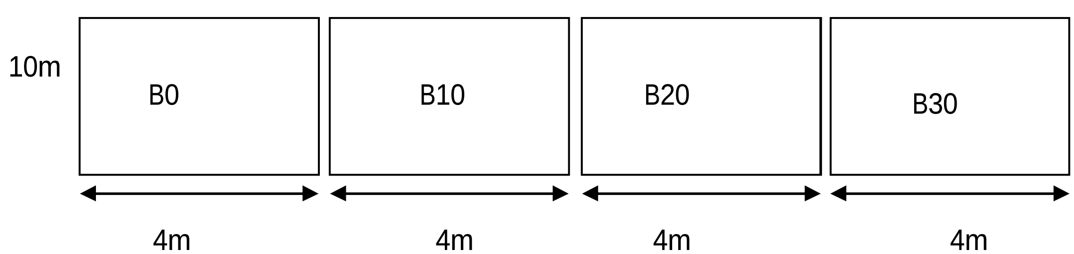

Fig. Layout of field

Performance test was done with 5 tyne cultivator operated by power tiller. The detailed specifications of power tiller and cultivator were given in the appendices.

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IV. RESULT AND DISCUSSION

Data on Power, Fuel consumption, BSFC, EGT and Brake power of diesel and biodiesel blends for different Loads

Fuel Type	Load (%)	Brake Power (kW)	Fuel consumption (kg/h)	Brake Specific Fuel consumption (kg/kWh)	Exhaust Gas Temperature (°C)	Brake thermal efficiency (%)
Diesel	0	0.00	0.43	0.00	114.02	0.00
	25	0.60	0.66	1.11	163.61	7.28
	50	1.37	0.78	0.57	183.34	14.20
	75	2.66	1.08	0.41	219.25	19.85
	100	3.33	1.32	0.40	271.66	20.43
B10	0	0.00	0.45	0.00	123.77	0.00
	25	0.55	0.69	1.25	168.52	6.67
	50	1.34	0.84	0.63	197.18	13.30
	75	2.51	1.14	0.45	232.88	18.37
	100	3.05	1.35	0.44	284.96	18.81
B20	0	0.00	0.47	0.00	129.68	0.00
	25	0.55	0.72	1.31	179.71	7.11
	50	1.30	0.89	0.68	205.44	13.25
	75	2.46	1.20	0.49	245.78	20.05
	100	2.90	1.40	0.48	291.33	18.79
B30	0	0.00	0.48	0.00	135.91	0.00
	25	0.53	0.75	1.42	189.97	6.20
	50	1.24	0.96	0.77	222.08	11.36
	75	2.30	1.29	0.56	265.16	17.70
	100	2.79	1.47	0.53	308.7	17.77

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Fig. Performance evolution at field

V. MEASUREMENT OF SOIL MOISTURE

Soil moisture was measured by soil moisture kit. Before taking soil moisture observations, the ML3 theta-probe was calibrated with reference to the values obtained by gravimetric method. The soil moisture measurement depth by ML3 theta-probe is about 5cm. For measurement of soil moisture content at higher soil depths, the soil was dug out to the required depth and soil moisture content was measured by the probe.

Fig.3.9 Soil moisture kit

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A. Variables Taken For Experiment

1) Independent variable
a) Load (0%, 25%, 50%, 75%, and 100%)
b) Bio-diesel blend (B0, B10, B20, B30)
c) 2. Dependent variable
d) Depth of operation
e) Width of operation
f) Actual field capacity
g) Fuel consumption
h) Field efficiency

2) *Speed Of Operation*

The time required to cover 10 m distance was measured with the help of stopwatch. Total five replications were taken for each set of observation.

$$S = \frac{D}{t} X\,3.6$$

Where, S= speed of implement, km/hr
D= Distance of 10 m
t= time required to cover distance D, sec

3) *Theoretical field capacity*

It is the function of speed of transplanter and the width of operation expressed in ha/hr and it can be calculated by the following equation:

$$TFC = \frac{W\,X\,S}{C}$$

Where, TFC= theoretical field capacity, ha/hr
W= Operating width of the implement, m
S= Implement speed, km/hr
C= Constant, 10

4) *Actual Field capacity*

The actual operating time along with time lost for every event such as turning, filling seed, seedling and fertilizer in boxes and also uploading of nursery and adjustments were recorded in the field test area.

$$EFC = \frac{A}{TP + TN}$$

Where, EFC= Effective field capacity, ha/h
T_P= Total productive time, h
T_N= Total non-productive time, h

5) *Field efficiency*

It is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity and it can be calculated by the following equation.

$$Eff = \frac{EFC}{TFC} X100$$

Where,
Eff= Field efficiency, %
EFC= Actual field capacity, ha/h
TFC= Theoretical field capacity, ha/h

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6) Fuel consumption

The fuel consumption for cultivating operation under each field of diesel and biodiesel blend were measured by the standard method, the graduated fuel tank was filled up to top level by keeping the power tiller on level land and after completing the operation, the fuel tank was filled up again. The difference of two observations gave the fuel consumed in the concerned operation.

7) Draft

Draft was measured using a digital drawbar dynamometer attached to the front of the power tiller on which the implement was mounted. Another auxiliary power tiller was used to pull the implement mounted power tiller through the drawbar dynamometer. The auxiliary power tiller pulls the implement-mounted power tiller with the latter in neutral gear but with the implement in the operating position. Draft was recorded in the measured distance of 20 m. On the same field, the implement was lifted off the ground and the draft recorded. The difference between the two readings, gives the draft of the implement.

8) Energy requirement

Energy consumption can be calculated by the formula below

Drawbar power (hp) = $\frac{\text{Draft(kgf)} \times \text{Speed(m/sec)}}{75} \times 100$

Drawbar power (Watt or J/sec) = Drawbar power (hp) X 745.7

Energy requirement (MJ/ha) = $\frac{Power\left(\frac{J}{sec}\right) \times Actual\ field\ capacity\left(\frac{h}{ha}\right) \times 3600}{1000000}$

VI. RESULT AND DISCUSSION

Data on Power, Fuel consumption, BSFC, EGT and Brake power of diesel and biodiesel blends for different Loads

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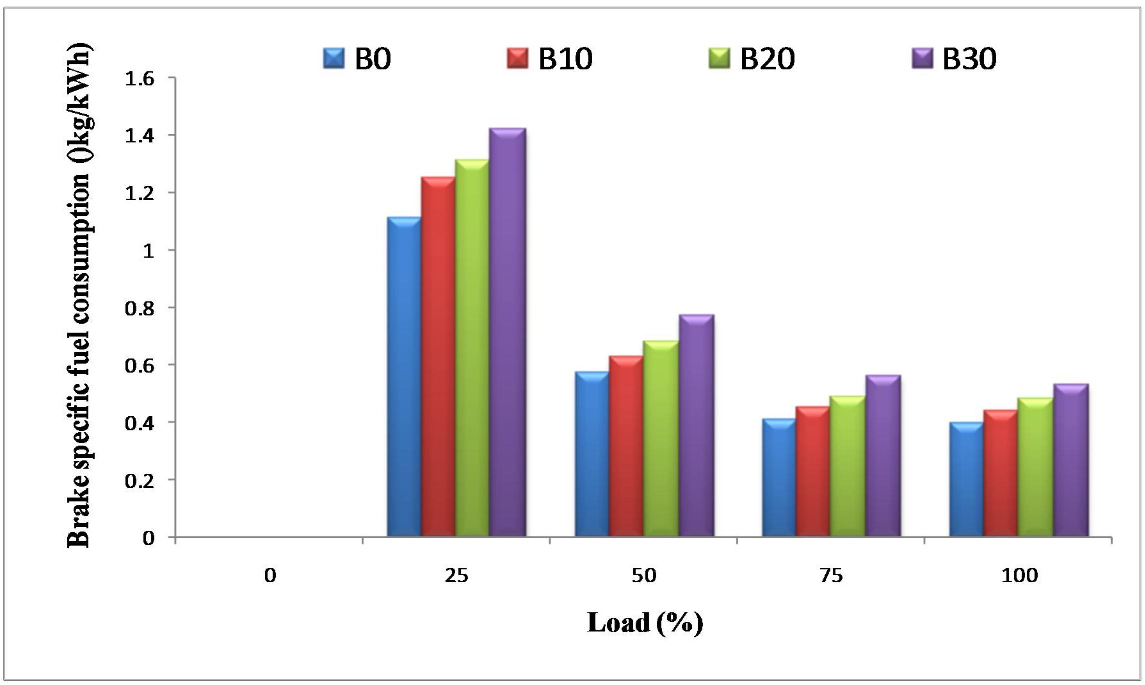

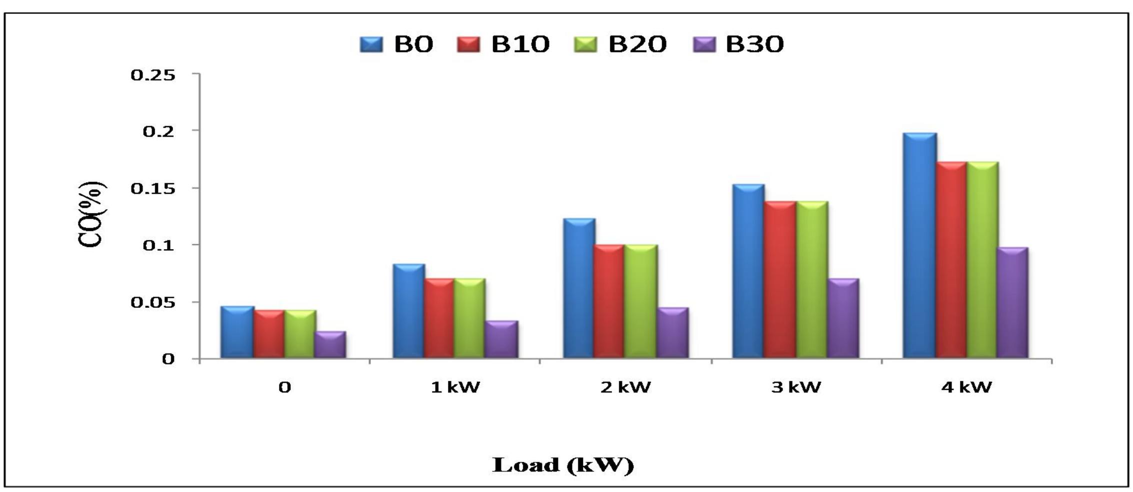

Based on the experiments the following conclusions could be obtained:

The specific fuel consumption when using biodiesel fuel is expected to increase as compared to the consumption of diesel fuel. BSFC decreased sharply with increase in load for all fuel samples and increases with increase in blend percentage. The CO reduction by biodiesel varied from 0.045 to 0.023 per cent from diesel to B30 for no load. But for the same blend, CO emission percent increases with increase in load.

From the study, the bio diesel blend gives satisfactory result in both laboratory as well as in field test.

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