



INVESTIGATION OF THE EFFECT OF NANOPARTICLES ON ENGINE PERFORMANCE AND EMISSION CHARACTERISTICS IN DIESEL ENGINES

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ABSTRACT

To overcome the global power crisis, alternatives to fossil fuels, whose reserves are dwindling at an alarming rate, must be discovered. We can make use of a wide variety of plants, including trees, shrubs, and herbs, to produce biodiesel. The oxidation stability and cold filter plugging point of dual biodiesel are the cold flow properties that are discussed in this paper. The best sample is taken and put through its tempo in the diesel engine having variable compression ratio to determine biodiesel blends' performance and emission characteristics. The experimental examination of the engine's performance and emission characteristics. The parameters of the engine evaluated and (i) Carbon Monoxide (CO), (ii) Hydrocarbon (HC), (iii) Nitrogen Oxide (NO_x) were analyzed, also Brake Thermal Efficiency (BTE), Specific fuel consumption (SFC) and emission were compared.



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I. INTRODUCTION

The world is presently accosted with two major challenges: The Fuel energy crises and pollution of ecosystem. The huge variations in crude prices are determined internationally according to the market demands, and current consumption rates limit petroleum reserves to nearly 40 years. For the last 50 years, numerous countries throughout the world have been evolving new crops to boost the biomass substitute base for bio-energy production. Presently India is importing nearly 65% petroleum from other countries and the fluctuating price of crude scattered the Indian economy. Next to the U.S.A and China, India is anticipated to become the next highest consumer of fuel in 2025, with consumption increasing at a 7.5% annual rate. 85% of oil imported is used for transportation and energy production, and the country's economy is heavily dependent on fossil fuel imports. Due to the above, the position of bio fuel as a transportation fuel will be significant. The use of bio oils as a replacement for diesel fuel was established in 1900 by Rudolph Diesel who invented Diesel engine when vegetable oil was considered as an alternative. The use of Oil as diesel fuel was limited as it has high viscosity which is about 10 times the fossil fuels.

The properties of vegetable oils have to be transformed in order to become accustomed of the fuel to existing engines. Numerous vegetable oil derived products has projected as an additional fuel for diesel engines ASTM has established specific standards for biodiesel under ASTM D6751, which specifies the requirements for biodiesel made from vegetable oils, animal fats, and other renewable feedstocks. This standard ensures that biodiesel meets the necessary performance and safety criteria for use in diesel engines. During the 1980s and 1990s, significant research and development (R&D) efforts were dedicated to biodiesel and its potential as a renewable energy source and substitute for conventional diesel fuel. This period was critical for establishing the technical foundation for biodiesel production, performance, and commercialization. Non-edible oils acquired from plant group such as Jatropha, Pongamia pinnata and others are the major commodity sources of biodiesel in India. Bio-diesel can be intermingled with petroleum diesel at any ratio to produce a bio-diesel blend or used in its pure form also.

Biodiesel shares many similarities with petroleum diesel and can operate in compression ignition (CI) engines with modest or no modifications. This is one of the key advantages of biodiesel as an alternative fuel for diesel engines. The similarities in properties make biodiesel a viable substitute for petroleum diesel in various applications, such as transportation, agriculture, and industry. Biodiesel has the advantage of being compatible with the existing fuel storage infrastructure used for petroleum diesel, which means that it does not require separate storage facilities or significant changes to infrastructure. This ease of integration into current systems makes biodiesel a convenient and cost-effective alternative fuel for diesel engines. Nitrogen oxide (NO_x) emissions tend to be higher when using biodiesel, particularly in higher concentrations (like B100 or 100% biodiesel). NO_x is a pollutant that contributes to the formation of ground-level ozone, acid rain, and smog. The reason for the increase in NO_x is that biodiesel generally has a higher cetane number (which improves ignition quality), leading to higher combustion temperatures.

These higher temperatures can promote the formation of NO_x. Solution (EGR System): One potential way to mitigate this issue is through the integration of an Exhaust Gas Recirculation (EGR) system. EGR reduces NO_x emissions by recirculating a portion of the exhaust gases back into the engine's combustion chamber, which helps lower the peak combustion temperature and, in turn, reduces NO_x formation. Biodiesel has virtually no sulfur content, unlike petroleum diesel, which can contribute to the formation of sulfur dioxide (SO₂) and acid rain. This makes biodiesel cleaner in terms of sulfur emissions. Biodiesel contains no aromatics, which are compounds typically found in petroleum diesel that can contribute to the formation of soot and particulate matter during combustion. This characteristic reduces the particulate matter emissions in biodiesel use. Biodiesel contains about 10% oxygen by weight, which allows it to burn more completely and efficiently compared to petroleum diesel. This in-built oxygen helps reduce the formation of carbon monoxide (CO) and unburned hydrocarbons (HC), which are common pollutants produced by incomplete combustion.

Several practices for manufacturing bio-diesel have been established. Stirring by Mechanical means, Cavitation method by Ultrasonic and hydrodynamic and super-critical methanol are a some samples. Some of the benefits of bio-diesel over fossil fuels like diesel and petrol are: Bio-diesel is a virtuous lubricant which is 65% better than petrol & diesel, produces a smaller amount smoke and particulate matter as Bio-diesel is sulphur free and aromatics. It has high cetane number, produces a smaller amount carbon monoxide and hydrocarbon releases, they are renewable, bio-degradable, and non-toxic. The key purposes of this work are the study of comparative of Gongura Seed bio-diesels and its mixture with Diesel in comparison to clean fuel (Diesel). The engine parameters to be evaluated and compared are (i) Brake Thermal Efficiency (BTE), (ii) Smoke Opacity, (iii) Brake Specific Fuel Consumption (BSFC) (iv) Carbon Monoxide (CO) emission (v) Hydrocarbon (HC) emission (vi) Nitrogen Oxide (NO_x) release & (vii) Cylinder pressure. [1] conducted in three operating modes: diesel mode; methanol/diesel mode (methanol mode for short) and methanol-based SiO₂ nanofluid (MSN)/diesel mode (MSN mode for short) where the MSN was injected in the intake manifold.

Experimental studies by [2] used Al₂O₃-based NF and Pg procedure, which resulted in higher levels of nitric oxide (NO_x) by 32.6%, lower smoke emissions by 23.2%, lower hydrocarbon (HC) and carbon monoxide (CO) emission levels by 18.2-21.4%, and greater brake thermal efficiency by 11.5%. [3] said that the trans-esterification process was affected by a number of parameters, including the ratio of (Molar) oil and alcohol (1 vs 4), the quantity of reagent (catalyst – 0.1g), response time for accomplishment (1 Hour), and the process temperature (80 °C). Under the best conditions, the maximum rate of bio-diesel production was more than 92% at 80 °C for 1 hour reaction time. Presence of LaTiO₃ NPs were recorded. [4] demonstrated the preparation of Citrus medica biodiesel by using green and eco-friendly nano-particles (NPs) of synthesized copper oxide. With using aqueous Portulaca oleracea extract. [5] conducted experiments with Six Set of Dual Biodiesel blends with four different Biodiesel. He concluded that at 4.4 HP Brake Power, the mix of D90 + NB5+ JB5 reduces the carbon monoxide by around 47% and BTE increased by about 37% for the blended fuel D90 + JB5+KB5. [6] Author conducted experiments with dual biodiesel with various concentration of Water v/v %.

Finally concluded that 5% of water is the best emulsified fuel. [7] He Conducted experiments with dual biodiesel blends (Rapeseed and Mahua) and concluded that for the blended fuel BL20 emission properties are reduced in comparison to Pure diesel. Slight increase in Nox level was witnessed. [8] the author found the performance and discharge character of several dual bio-diesel mixes were discovered in this article (mixture of jatropha bio-diesel and neem bio-diesel). The outcomes displays that sensible emission features for the blend (BB10 & BB20). [9] Findings the Properties of palm and castor biodiesel and conducted experiments of dual biodiesel blends ranging from 0 to 40%. [10] while his analysis increase in BTE and reduction in SFC was observed with lower value of biodiesel, he also found that emission levels were found lower than clear diesel. [11] have carried out various experiments with Dual Injection diesel engine with blends of palm methyl esters of different ratio. Tremendous change in performance were inked. [12] conducted number of experiments using Jatropha bio diesel with methanol as additives. His results concluded a good BTE for jatropha bio diesel, diesel and dual fuel with an ration of 29%, 30.2% and 28.7% respectively. [13] have done experiments with blends of two fuels pongamia, jatropha added with neat diesel. His results were blends of 20% & 10% of biodiesel with diesel produced near clear diesel performance and emission and suggested as substitute fuel for fossil fuel like diesel and petrol.

[14] investigatied on single cylinder diesel engine fuelled with cotton seed biodiesel blends with nano additives [15] found that a 20% blend of vegetable oil (such as Pongamia or Mustard oil) and 80% clean diesel could be used as an alternative fuel for diesel engines without requiring any modifications to the engine. This is significant because it demonstrates the engine compatibility of biodiesel-like mixtures. This blend showed lower emissions of carbon monoxide (CO) and hydrocarbons (HC) compared to conventional diesel, which is consistent with other biodiesel studies showing cleaner combustion and reduced particulate matter. The results indicate that such a blend can effectively reduce harmful pollutants while maintaining the operational capabilities of the engine. The research revealed that using the blend of vegetable oils and diesel did not result in significant power loss when compared to conventional diesel. This is crucial because the performance of the engine is one of the most important factors for adopting alternative fuels, and maintaining comparable or even improved performance with biodiesel blends makes it a viable option for many diesel engine applications. [16] has piloted tests on a single cylinder, oil cooled, four strokes, direct injection VCR diesel engine with different ratios of palm and jatropha bio-diesel with orthodox diesel fuels. Lower viscosity and better calorific values of bio-diesel fuel leads to greater power brake and vice versa was shown on his study. He has determined that the lower mixes of dual biodiesel blends on bio-diesel can be used as alternate fuel in diesel engine without any adjustment of engine. A.M.

[17] has studied the performance features & properties of dual bio-diesel mined from pongamia pinnate & neem oil. Author has concluded that the neem oil and pongamia oil is mono ester and is formed by means of trans-esterification process and it can be utilized in engine without any changes. [18-21] says that to change diesel fuel by bio-diesel, he has selected oils from palm kernel and eucalyptus. He added with methyl ester of palm kernel in the ratio of 15%, 10% and 5% by volume. He piloted a test in VCR diesel engine with mixed diesel fuel[22]. the incorporation of graphene oxide nano fuels into Tomato Oil methyl ester blends demonstrates potential for improving engine performance and reducing emissions[23]. he ratio of B20, B40, and B60 with Tio2 as a Nanoparticles as 100ppm. Performances and emission characteristics of engine is calculated with blended fuel and neat diesel[24-25].

II. METHODOLOGY

II.1 RESEARCH METHODOLOGY

Currently human all over the world is fronting with two chief tasks which include the fuel devastations and ecosphere dilapidation. With current utilizing rate the reserve of gasoline products is limited to next 40 years only and the cost of crude oil depends on international volatile markets. Numerous countries spread over the world have been evolving novel crops from 1975 in order to advance the bio-mass reserve for production of various forms of bio energy. India's dependence on imported petroleum is a significant issue for its economic stability. Currently, the country imports about 70% of its petroleum needs, making it highly vulnerable to fluctuations in the global oil market. These fluctuations can be driven by geopolitical tensions, supply disruptions, and other factors that lead to volatile oil prices. This reliance on imported oil puts a strain on India's foreign exchange reserves and affects its balance of payments, which is a key concern for the country's economic health. Properties of Gongura Seed Biodiesel and Diesel as given in Table 1& Table2. Research Methodology of the project as shown in figure 1.

Table 1: Properties of Gongura Seed Biodiesel.

Appearance	Light Yellow Liquid
Density	0.88 at 200C
Kinematic Viscosity	1.9-6.0 mm ³ /s at 400C
FFA Content	6.9 wt%
Iodine No	1.38 g ₁₂ /100g-oil
Water Content	0.02 wt%

Source: Authors, (2026).

Table 2: Properties of Diesel.

Calorific Value	43200 kJ/kg
Density	830 at 150C
Kinematic Viscosity	3.1 at 400C
Flash Point	680C
Cetane Number	46.4

Source: Authors, (2026).

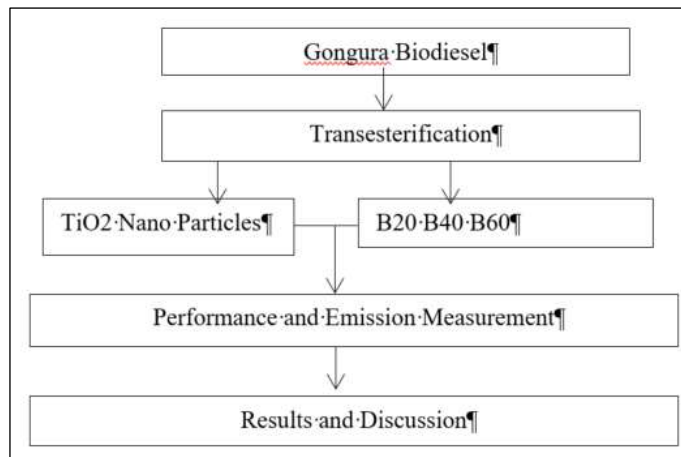


Figure 1: Research Methodology of the Project.

Source: Authors, (2026).

II.2 EXPERIMENTAL DETAILS

From the various ratio of mixed Gongura Seed biodiesel experiments is evaluated for B20, B40 & B-60 to find performances and emissions characteristics of the engine without any modification made on it and keeping the compression ratio as 17.5 running at constant speed 1500rpm. Engine Specifications as given in Table 3. Experimental Setup as shown in figure 2.



Figure 2: Experimental Setup.
Source: Authors, (2026).

Table 3: Engine Specifications.

Manufacturer	Kirloskar,AV-1,water Cooled 4 Stroke
Type	Direct Diesel Engine
Fuel	Diesel
Bore ,Stroke	87.5 x 110 mm
Compression Ratio	17.5
Speed Rpm	1500
Nozzle Opening Pressure	200
Rated Power	5.2 kw@ 1500 rpm

Source: Authors, (2026).

III. RESULTS AND DISCUSSION

III.1 CARBON MONOXIDE (CO)

The Emission of Carbon monoxide with different proportional of load for Gongura Seed biodiesel mix of 0%,20%, 40% & 60% with diesel and plain diesel were depicted in Figure 3. It was experiential during the test, lesser emission of CO was observed with increase in engine load during part load and increase in level during full load. It might be due the maximum fuel consumption due to rich air-fuel mixture. From the below figure we can come to a conclusion that throughout the engine load, substantial drop in CO emission of the Gongura Seed bio diesel blends in comparison to neat Diesel. It is primarily because of higher oxygen level in biodiesel than neat diesel.

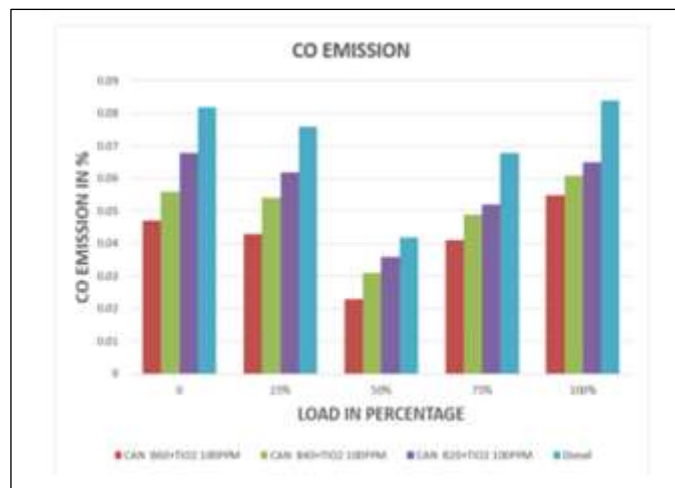


Figure 3: Load Vs CO Emission.
Source: Authors, (2026).

III.2 NITROUS OXIDE

Nox emission of neat diesel fuel and blends of Gongura Seed bio diesel is available from Figure 4. It was discovered that release of Nox was higher than pure diesel fuel for all Gongura Seed bio-diesel. The increase in combustion temperature and the increase in flame temperature could be key reasons for the higher NOx (Nitrogen Oxides) emissions observed when using biodiesel or vegetable oil blends in diesel engines. Nox formation was mostly due to surge in cylinder combustion temperature and percentage of oxygen level. From test results it was found that Nox release is more compared to pure diesel oil than mixes of Gongura Seed oil.

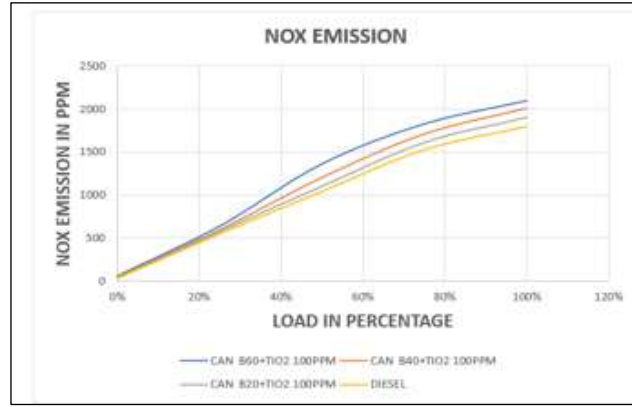


Figure 4: Load Vs NOX Emission.
Source: Authors, (2026).

III.3 HYDROCARBON

Differences of HC emission with engine load while using various mixes of Gonggura Seed bio-diesel and pure diesel is shown in the Figure 5. During testing, for all the loads tested HC emissions were lesser at engine load although it has increased during higher engine load. This is mainly because of larger fuel particle size, timing of injection and chocking of nozzle also changed the combustion timing. It is mainly because of lesser oxygen presented during more fuel injection at higher loads. The key cause of un-burn Hydro carbon is owing to minimum ignition delay linked with fuels having considerable cetane number which reduces the over varied fuel. The above result settled with the references.

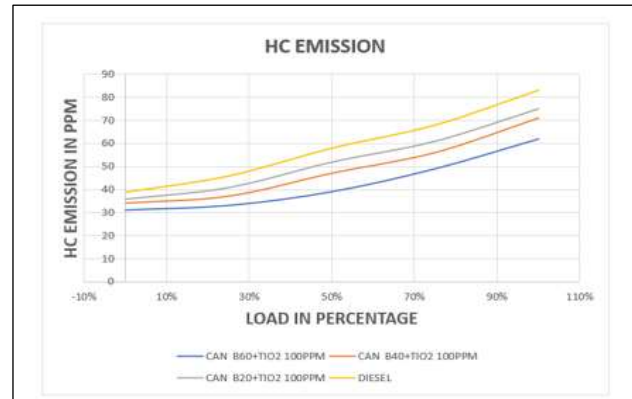


Figure 5: Load Vs HC Emission.
Source: Authors, (2026).

III.4 CO2 EMISSION

As Figure 6 represents the CO₂ emission of Gonggura Seed biodiesel at 20%, 40% & 60% with pure diesel at different engine loads. During the increase in engine load, increase in CO₂ release was observed which might be due to greater fuel consumption linked with load raises. Lesser CO₂ release were observed for various mix of bio-diesel Gonggura Seed and compared with clean diesel fuel. The drop in CO₂ release were clarified on relations of greater oxygen content in bio-diesel mixes of Gonggura Seed as compared to pure diesel fuel.

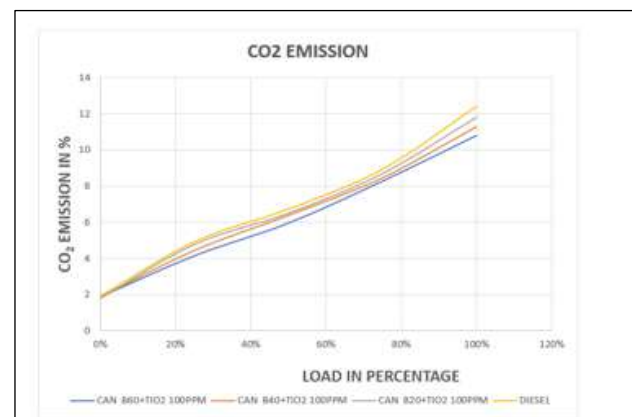


Figure 6: Load Vs CO2 Emission.
Source: Authors, (2026).

III.5 SMOKE OPACITY

The smoke opacity of all candle nut bio-diesel mixture with various engine load and pure diesel is shown in Figure 7. For comparison purpose clean diesel smoke opacity is also added in the graph. Similar to other experiments the result illustrates rise in smoke release with upsurge in engine capacity. It is primarily owing to change in fuel usage in the higher side which causes rich air-fuel mixture. As the percentage of oxygen molecules is more and carbon content is small in the Gonggura Seed bio-diesel in comparison to pure diesel which has caused great burning and reduction in smoke emission was observed.

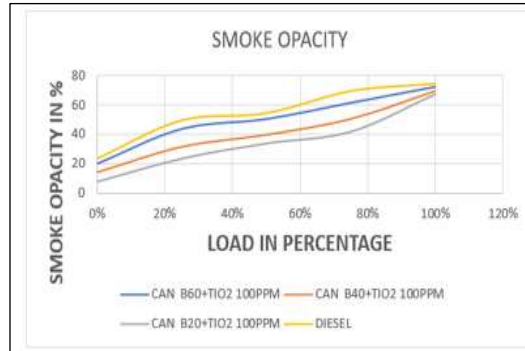


Figure 7: Load vs Smoke Opacity.
Source: Authors, (2026).

III.6 SPECIFIC FUEL CONSUMPTION (SFC)

The smoke Specific fuel consumption of Gonggura Seed bio-diesel with various loads in the engine for different mixes were illustrated in Figure 8. Specific fuel consumption was found to be less with increase in percentage of load for all ratio of blended bio-diesel. It is mainly because of the kinematic viscosity and the good calorific values of the bio-diesel. Illustrations from all graphs shows clearly consumption of fuel is maximum because of the lower content of ester in the fuel.

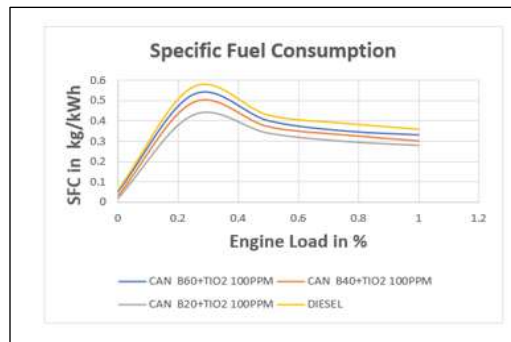


Figure 8: Load vs Specific Fuel Consumption.
Source: Authors, (2026).

III.7 BRAKE THERMAL EFFICIENCY (BTE)

From figure 9, we can understand that the brake thermal efficiency rises during increase in break power for diesel and candle nut biodiesel mixes. The brake thermal efficiency of diesel is higher equated to Gonggura Seed bio-diesel blends. Also from the information, it is well-known that the BTE of lower ration blend is closer to that of pure diesel when compared to Gonggura Seed bio-diesel blends. This disparity in BTE for various bio-diesel mixes is owing to higher viscidness and reduced instability, which principals to deprived blend formation. This results in reduction of brake thermal efficiency for Gonggura Seed bio-diesel mixes.

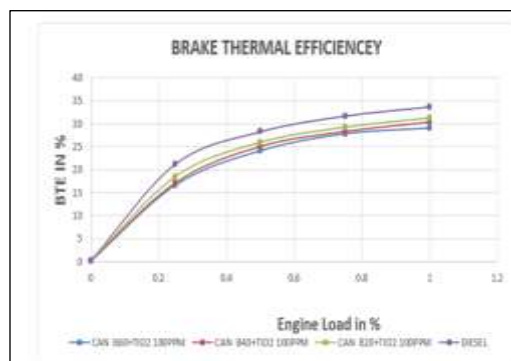


Figure 9: Load vs Brake Thermal Efficiency.
Source: Authors, (2026).

III.8 MAX CYLINDER PRESSURE (BAR)

The distinction of engine's cylinder pressure in response to various eccentric angle at various proportions of Gongura Seed Bio-diesel of various proportions and clean diesel at maximum load. It was witnessed from the experiment that maximum pressure of cylinder of Gongura Seed Bio Diesel mixes is lesser than that of pure diesel. It is chiefly due to higher viscosity and smaller volatility of Gongura Seed bio-diesel. From Figure 10, we can observe that the maximum engine cylinder pressure of diesel is 66 kg/cm² and B20 is 59 kg/cm². From the graph it is easily understood that the maximum engine cylinder is extra for diesel compare to Gongura Seed Bio-diesel mixes and reduces when bio-diesel of larger proportions of diesel was used. It is chiefly because of the delay in ignition time and lesser air/diesel or bio-diesel mixture which is accessible during the combustion & ignition. It has therefore added burning in the diffusion-burning stage than that of the pre-mixed burning point. Because of the above reasons the maximum engine cylinder pressure is smaller for Gongura Seed bio-diesel-diesel mixes.

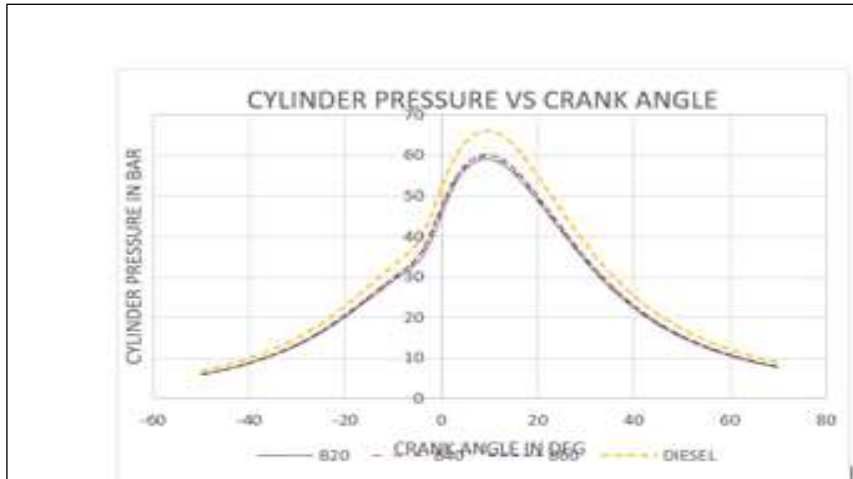


Figure 10: Load vs Cylinder Pressure.

Source: Authors, (2026).

IV. CONCLUSIONS

During the study a direct injection diesel cylinder with single cylinder was used to run with different blends of Gongura Seed biodiesel in the ratio of 20%, 40% & 60% with clean diesel. Performance study of engine and exhaust discharge characters were calculated during several engine load of 0%, 25%, 50%, 75% & 100% with engine speed of 1500 rpm. Emissions like CO, HC, smoke opacity, Co₂ & No₂ were scrutinized. Brake thermal efficiency, Cylinder Pressure and specific fuel consumption were also studied and related with pure diesel. Conclusions that have been found are briefed here as:

- ❖ Exhaust emission of carbon monoxide, smoke and hydro carbons are lesser for the experienced Gongura Seed bio-diesel blends B20, B40 & B60 when compared to clean diesel fuel.
- ❖ Carbon dioxide release through exhaust when using Gongura Seed bio-diesel of 20%, 40% & 60% blends were lesser compared to pure diesel as fuel.
- ❖ Release of NO_x while using Gongura Seed bio-diesel of 20%, 40% & 60% blends improved when equated with pure diesel as fuel for the examined bio-diesel mixes.
- ❖ SFC for Gongura Seed biodiesel blends B20, B40 & B60 are lower in relation to diesel fuel and BTE of Gongura Seed bio-diesel mixes have approached the near value of clean Diesel.
- ❖ Gongura Seed Blends of B20 & B40 are having lower emissions and near BTE to diesel and can be used as substitute fuel.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Sathiyaraj.S, Kumaran.P, Imthiyas.A

Methodology: Sathiyaraj.S, Silamburajan.M, Rengaraju.G

Investigation: Sathiyaraj.S, Imthiyas.A

Discussion of results: Sathiyaraj.S, Imthiyas.A

Writing – Original Draft: Sathiyaraj.S, Kumaran.P, Imthiyas.A

Writing – Review and Editing: Kumaran.P, Imthiyas.A

Resources: Sathiyaraj.S, Silamburajan.M, Rengaraju.G

Supervision: Kumaran.P

Approval of the final text: Kumaran.P, Imthiyas.A

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