

A
Report on
Performance & Emission Test
along with Durability Test of Different TBOs in Agricultural Diesel Generator Set

Sponsored by
Department of Biotechnology
Government of West Bengal

Prepared By
Sri Ranajit Kumar Chakrabarti
Jt. Director
School of Automotive Engineering
Jadavpur University
Kolkata - 700 032

(Project Report upto 31.03.2010)

1.1 Need of Alternate fuel Worldwide

The major sources of the world's energy needs are petroleum, coal and natural gases which are fossil-derived and non renewable. The world, at large, depends on petroleum as the energy source for the transportation sector. Scarcity of traditional petroleum fuels, its over-dependence by nations, increasing emissions of combustion-generated pollutants and their increasing costs have made renewable energy sources more attractive. The world petroleum reserves are finite in nature and declining fast, the production of oil will eventually slow down. Way back in 18th century, the petrol and diesel engines were discovered. Till then, the most conventional fuels used are gasoline and diesel. But there are some disadvantages of fossil fuel that are listed below:

- a. The fossil fuels are of Non renewable type
- b. Fossil fuels produce CO₂ from combustion sources which results in greenhouse effect
- c. Price hike for fossil fuels is rapid
- d. The Govt. is dependent on gulf nations for supply of fossil fuels.

For over a century now, the use of vegetable oils such as soyabean, palm, sunflower, peanut and olive oil as fuel substitutes for fossil-based diesel has been around, with the inventor of the diesel engine Rudolph Diesel being the first to test peanut oil in his compression ignition engine.

Being non-renewable source of energy i.e., the source which cannot be renewed after consumption because the sources of this energy are the creatures existing on land and sea who survived on earth before man has appeared. World is currently in search of such fuels, which are renewable in source, abundant in nature and eco-friendly as well. These are known as alternate fuels. The alternate fuels must meet following criteria, if they are going to be used for automobile application:

- a. Technical acceptability
- b. Economically competitive
- c. Environmentally acceptable

1.2 Alternate fuel scenario of India

In India, there are 15-20 million vehicles and to satisfy the need, India requires 45 million ton of fossil fuels per year. India imports 2/3 rd of its petroleum

requirements last year, which involved a cost of approximately 80,000 crores in foreign exchange. India is mainly dependent on gulf nations for fuel supply. The country will thus have to continue importing oil over 70% of its need until some alternate fuels are used which can make India self sustainable. Previously it has already been stated that almost 95% of the current fuels are either gasoline or diesel. But as these are limited in quantity and the demand for these fuels is increasing day by day, the total quantity may sustain for another 50-75 years only.

So the time has already come to find out the most suitable alternate fuels. The strong competitors are bio-diesel, CNG, LPG etc. These fuels have other advantages also which are superior to petrol and diesel i.e. less polluting, low maintenance cost etc. LPG & CNG are maximum used in automobile. The leading country in making CNG & LPG kit is Italy. Some of the reputed companies are- Lovato, Stargas, Bedini etc. The only disadvantage are that these kits are initially expensive to install (for Maruti 800, it is approximately Rs 20000-25000) and there is a power drop of 10% in comparison to petrol. But the running cost is reduced up to 50-70% in comparison to petrol. Solar cells are used to produce electricity using photovoltaic cell which transforms solar energy into electrical energy. Other alternative fuels are bio-diesel and hydrogen. Bio-diesel is produced from several vegetable oil. This is suitable for operating CI engines. Government of India has already experimented it in some diesel locomotive engines and has been successful so far. Hydrogen engines are being developed in India.

1.3 Use of Vegetable oils as a diesel fuel

Alternative fuels should be easily available, environment friendly and techno-economically competitive. One of such fuels is triglycerides (vegetable oils/animal fats) and their derivatives. Vegetable oils, being renewable, are widely available from a variety of sources and have low sulphur contents close to zero, and hence cause less environmental damage (lower greenhouse effect) than diesel. Besides, vegetable oils and their derivatives are produced widely in the country for food and other purposes. The use of vegetable oils, such as palm, soyabean, sunflower, peanut and olive oil, as alternative fuels for diesel engines dates back almost nine decades, But due to the rapid decline in crude oil reserves, it is again being promoted in many countries. Depending upon the climate and soil conditions, different countries are looking for different types of vegetable oils as substitutes for diesel fuels. For example, soyabean oil in US, rapeseed and sunflower oils in Europe,

palm oil in south-east Asia (mainly Malaysia and Indonesia) and coconut oil in the Philippines are being considered. Besides, some species of plants yielding non-edible oils like Jatropha, Karanja, Mahua, Neem, Castor may play a significant role in providing resources. All these plants may be grown on a massive scale on agricultural/degraded/waste lands, so that the chief resource may be available to produce vegetable oil or biodiesel on 'farm scale'. It has been found that these neat vegetable oils can be used as diesel fuels in conventional diesel engines, but this leads to a number of problems related to the type and grade of oil and local climatic conditions. The injection, atomization and combustion characteristics of vegetable oils in diesel engines are significantly different from those of diesel. The high viscosity of vegetable oils interferes with the injection process and leads to poor fuel atomization. The inefficient mixing of oil with air contributes to incomplete combustion, leading to heavy smoke emission, and the high flash point attributes to lower volatility characteristics. These disadvantages, coupled with the reactivity of unsaturated vegetable oils, do not allow the engine to operate trouble free for longer period of time. These problems can be solved, if the vegetable oil is blended with diesel by volume percentage. These blends have viscosity less than raw vegetable oils and more than diesel viscosity. It has been found that such blends can be burnt in a C.I. Engine producing power. However the durability of the engine while running the blends are to be studied.

1.4 Objective of the Present Work:

In the present investigation on Tree Borne Oil (viz. Neem, Karanja and Jatropha, Mahua, Castor), all the experimental fuels are non-edible vegetable oils which have been considered as potential alternative fuels for C.I. engines. The greatest difference between these five types of oils and diesel oil is arising from the fact that the TBO's have much higher viscosity than diesel oil and also their delay periods are much higher than that of diesel.

The blends of the above vegetables oils with diesel are made in varying proportion of the vegetable oil by volume in order to study the effect of blending on performance and emission characteristics of the engine.

1.5 The major advantages of natural vegetable oil are :

- i) High calorific value : high energy density
- ii) Liquid in form and thus easily t be handled
- iii) When burned it emits less soot
- iv) When burned it has high energy efficiency
- v) It is neither harmful nor toxic to humans, animals, soil or water.
- vi) It is neither flammable nor explosive, and does not release toxic gases
- vii) It is easy to store, transport and handle
- viii) It does not cause damage if accidentally split.
- ix) Its handling does not require special care to be take
- x) It is produced directly by nature : It does not have be transformed.
- xi) It is a recyclable form of energy
- xii) It does not have adverse ecological effects when use
- xiii) It does not contain sulphur : It does not cause acid rain when used.
- xiv) When burned it is neutral in CO₂. no contribution to the greenhouse effect.

1.6 Commercial status of the vegetable oils vis-à-vis diesel.

It has been found that the price of diesel fuel per liter is almost 80% higher than that of biodiesel produced with the TBO's under investigation. The TBO's are now produced not on a large scale basis. In case they are produced commercially in large scale the price of the TBO's shall be much below that of diesel oil.

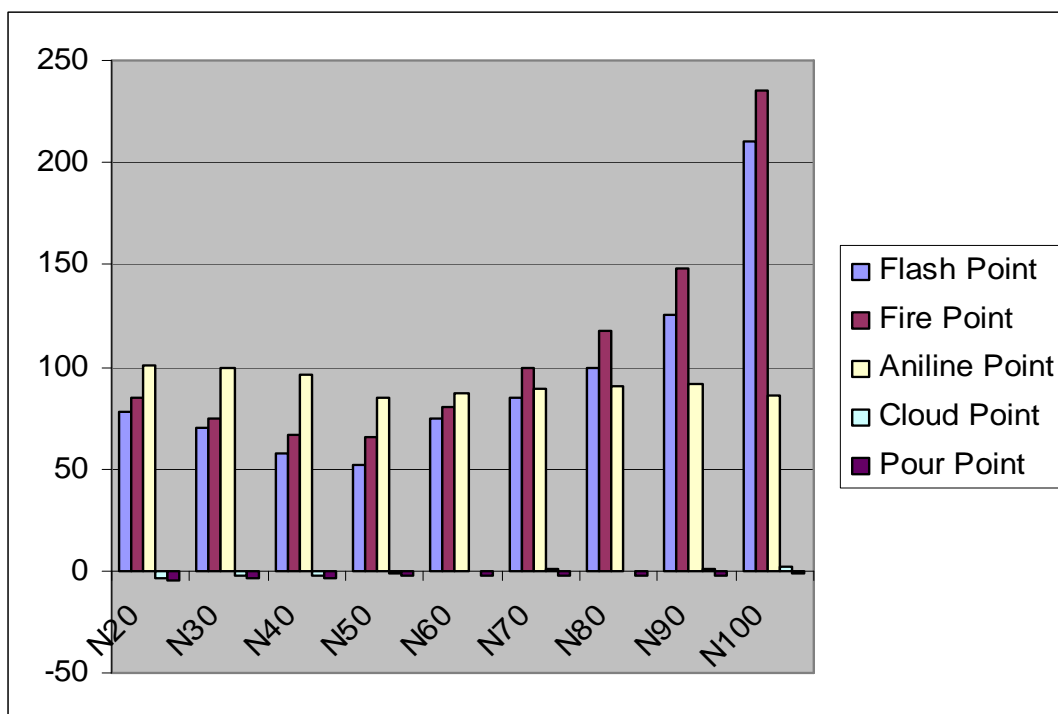
2.0 Properties study of Neem, Karanja, Castor, Mahua and Jatropa Oils.

2.1 Neem and its various blends

In the following table the properties of Neem Oil of various blends (with diesel) have been shown. Blends of Neem Oil starts from N20 and then go high upto N₁₀₀ at an interval 10% increase of blends of Neem Oil.

Various Blends/ Properties	N20	N30	N40	N50	N60	N70	N80	N90	N100
Flash Point	78	70	58	52	75	85	99	125	210
Fire Point	85	75	67	65	80	99	118	148	235
Aniline Point	101	99	96	85	87	89	90	92	86
Cloud Point	-4	-3	-2	-1.2	0	1.1	1.3.	1.5	1.9
Pour Point	-4.4	-4	-3.4	-2.9	-2	-2	-2	-2	-1.5

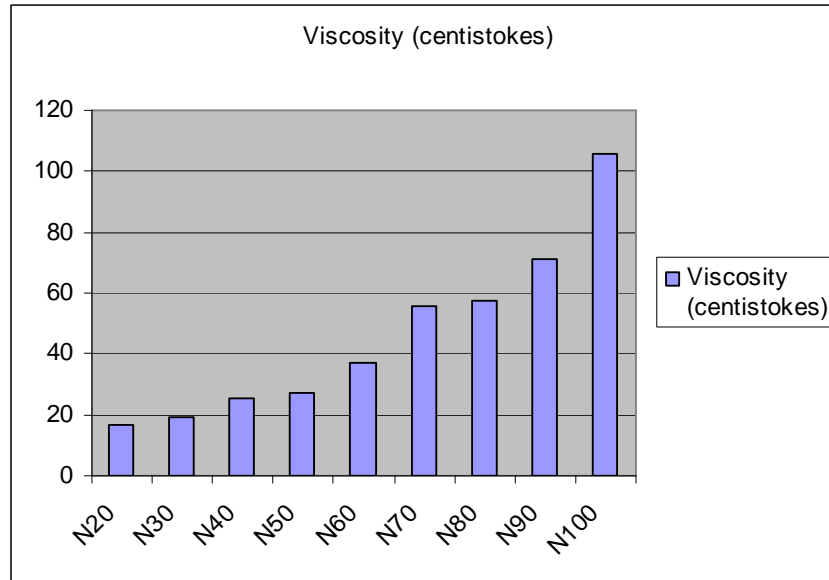
Table 1 : variation of physical Properties of Diesel Blended Neem Oil with Temperature ($^{\circ}\text{C}$)



In the following table the viscosity property (in centi-strokes) of various blends of Neem Oil with Diesel is shown.

Various Blends/ Properties	N20	N30	N40	N50	N60	N70	N80	N90	N100
Viscosity (centistokes)	16.93	19.23	25.25	27.06	37.32	55.9	57.74	70.9	105.66

Table 2: Variation of Viscosity with temperature of Diesel Blended Neem Oil.

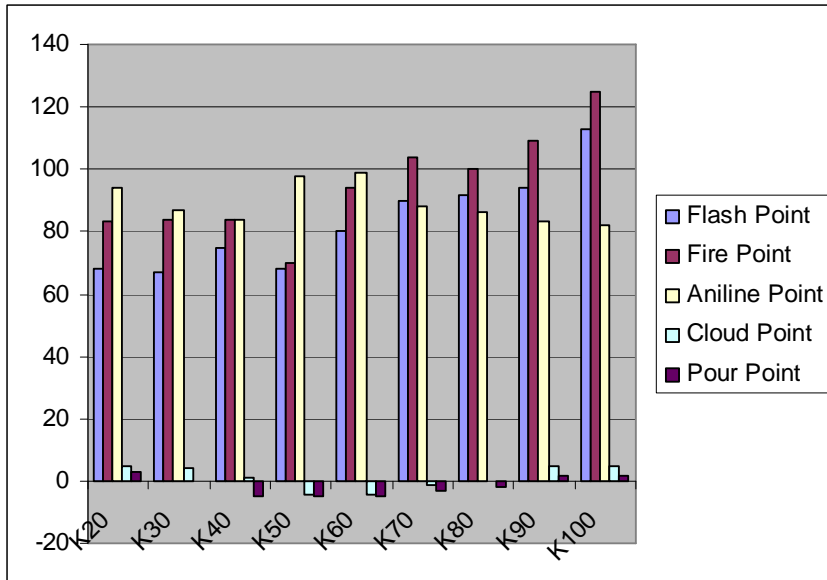


2.2 Karanja and its various blends

In the following table the properties of Karanja Oil of various blends (with diesel) have been shown. Blends of Karanja Oil starts from K20 and then go high upto K100 at an interval 10% increase of blend of Karanja Oil.

Various Blends/ Properties	K20	K30	K40	K50	K60	K70	K80	K90	K100
Flash Point	68	67	75	68	80	90	92	94	113
Fire Point	83	84	84	70	94	104	100	109	125
Aniline Point	94	87	84	98	99	88	86	83	82
Cloud Point	5	4	1	-4.5	-4	-1	0	5	5
Pour Point	3	0	-5	-5	-5	-3	-2	2	2

Table 3: Variation of Physical Properties of Diesel Blended Karanja Oil with Temperature ($^{\circ}\text{C}$).

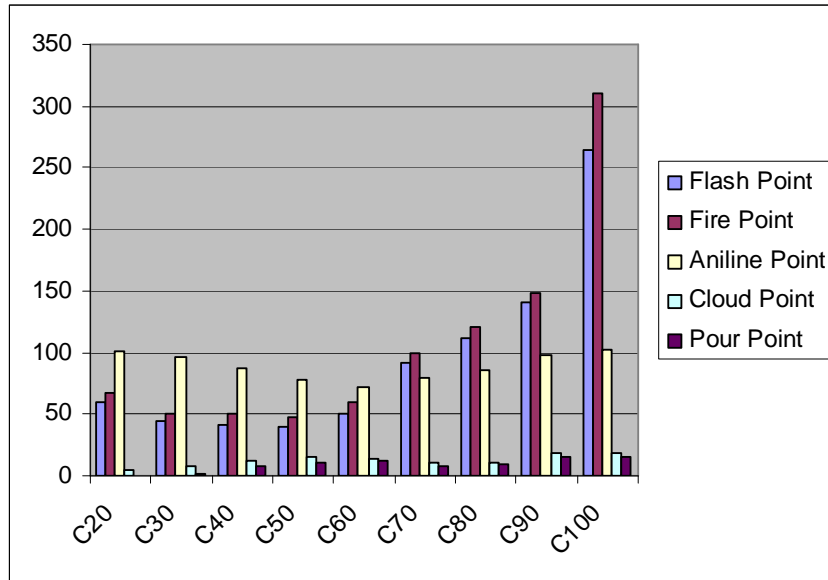


2.3 Castor and its various blends

In the following table the properties of Castor Oil of various blends (with diesel) have been shown. Blends of castor Oil starts from C20 and the go high upto C100 at an interval 10% increase of blend of Castor Oil.

Various Blends/ Properties	C20	C30	C40	C50	C60	C70	C80	C90	C100
Flash Point	59	45	42	40	50	92	112	140	265
Fire Point	68	51	50	47	60	100	120	148	310
Aniline Point	101	95.6	86.6	77.6	72	79	86	98.4	102
Cloud Point	5	7	12	15	14	10	10	19	19
Pour Point	0	2	7	10	12	7	9	15	16

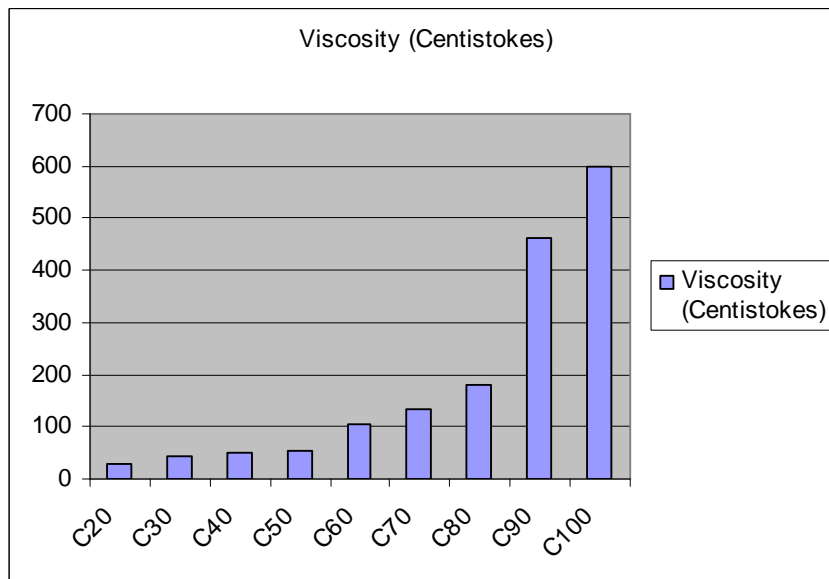
Table 5: Variation of Physical Properties of Diesel Blended Castor Oil with Temperature ($^{\circ}\text{C}$).



In the following table the viscosity property (in centi-stokes) of various blends of castor Oil with diesel is shown.

Various Blends/ Properties	C20	C30	C40	C50	C60	C70	C80	C90	C100
Viscosity (Centistokes)	27.33	42.66	51.68	55.63	105.39	134.12	180.28	461.5	598

Table 6: Variation of viscosity with temperature of diesel Blended Castor Oil.



2.4 Mahua Oil & its various Blends

In the following table the properties of Mahua Oil of various blends (with diesel) have been shown. Blends of Mahua Oil starts from M20 and then go high up to M100 at an interval 10% increase of blend of Mahua Oil. Here M20 means 20% Mahua Oil is mixed with 80% mineral diesel, M100 means pure Mahua Oil.

Various Blends/ Properties	M20	M30	M40	M50	M60	M70	M80	M90	M100
Flash Point	35	38	40	51	58	73	76	97	202
Fire Point	37	40	45	58	60	78	116	120	212
Aniline Point	92	94	95	90	96	97	97	103	108
Cloud Point	-2.0	-2.0	-0.5	1.0	3	4	7	9	13
Pour Point	-4.0	-4.5	-4.0	0	2	3.5	4	6	8

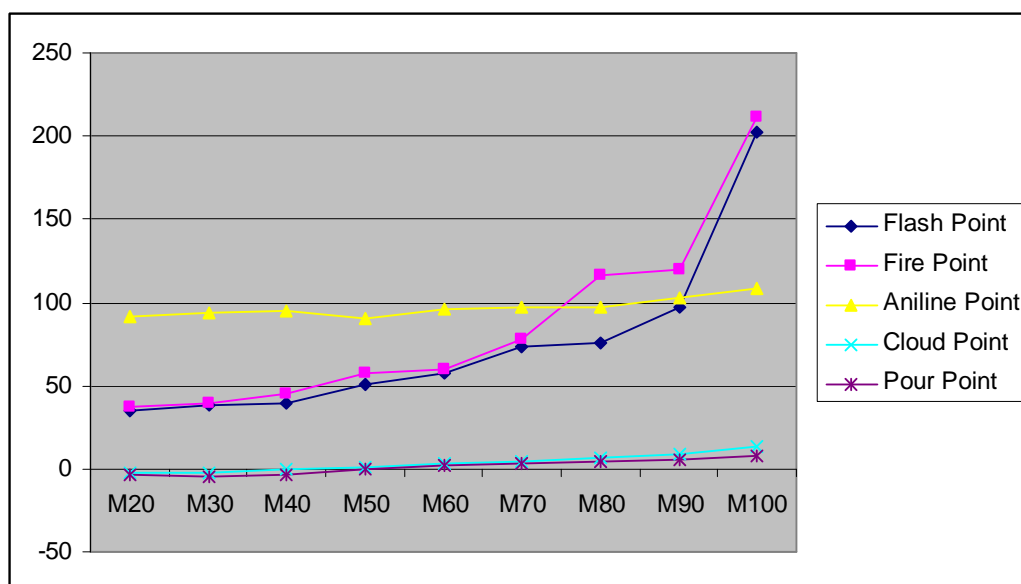
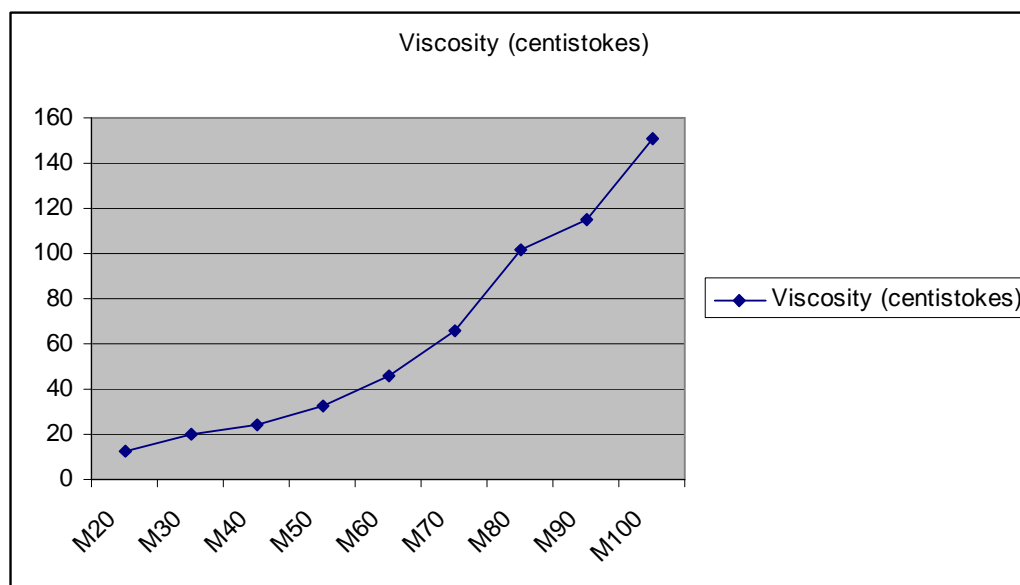


Table 7: Variation of Physical Properties of diesel Blended Mahua Oil with Temperature (°C).

In the following table the viscosity property (in centi stokes) of various blends of Mahua Oil with diesel is shown.

Various Blends/ Properties	M20	M30	M40	M50	M60	M70	M80	M90	M100
Viscosity (centistokes)	12.15	20	24	32.5	45.8	65.5	102	115	151

Table 8: Variation of viscosity with temperature of Diesel Blended Mahua Oil.

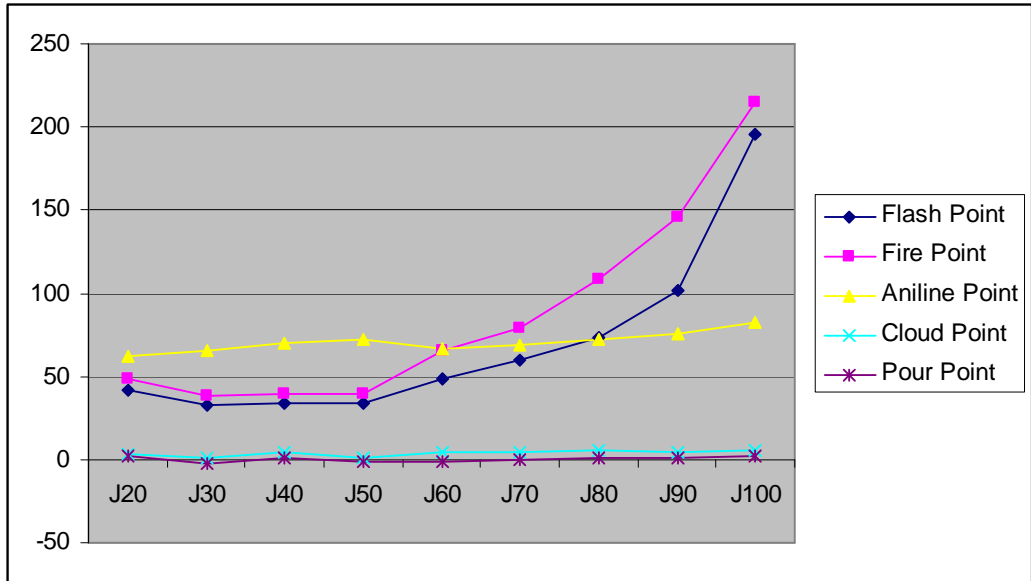


2.4 Jatropha and its various blends

In the following table the properties of Jatropha Oil of various blends (with diesel) have been shown. Blends of Jatropha Oil starts from J20 and then go high upto J100 at an interval 10% increase of blends of Jatropha Oil.

Various Blends/ Properties	J20	J30	J40	J50	J60	J70	J80	J90	J100
Flash Point	42	33	34	34	49	60	73	102	196
Fire Point	48	38	39	39	65	79	109	146	215
Aniline Point	62	65	70	72	67	69	72	76	82
Cloud Point	3	1	4	1.5	4	4.5	5	4	5
Pour Point	2	-3	1	-1	-1	-0.5	1	1	2

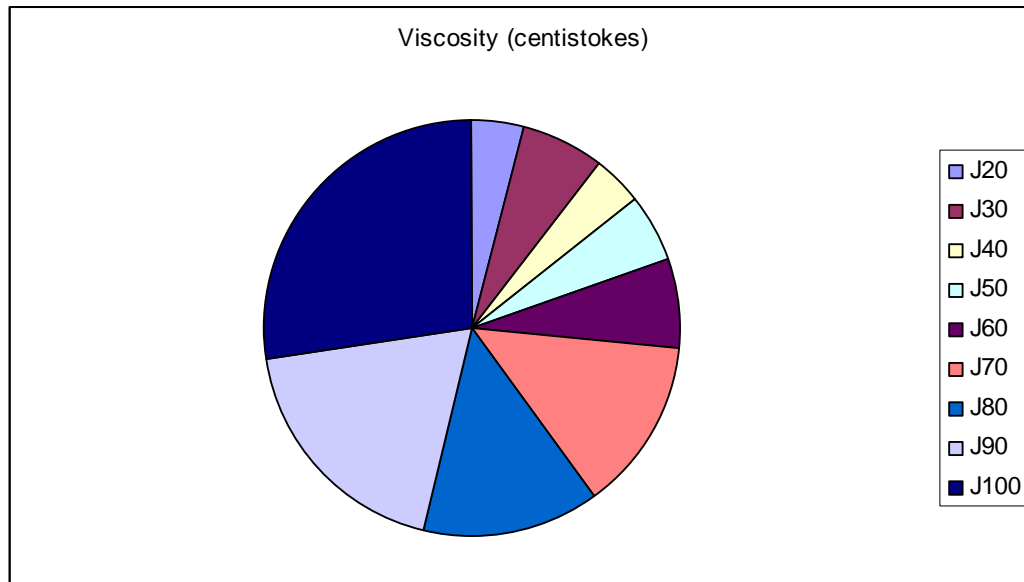
Table 9: Variation of Physical Properties of Diesel Blended Jatropha Oil with Temperature ($^{\circ}\text{C}$).



In the following table the viscosity property (incentistokes) of various blends of Jatropha Oil with Diesel is shown.

Various Blends/ Properties	J20	J30	J40	J50	J60	J70	J80	J90	J100
Viscosity (centistokes)	22.67	33.5	21.2	29.0	37.4	71.0	73.8	101	148.2

Table 10: Variation of viscosity with temperature of Diesel Blended Jatropha Oil.



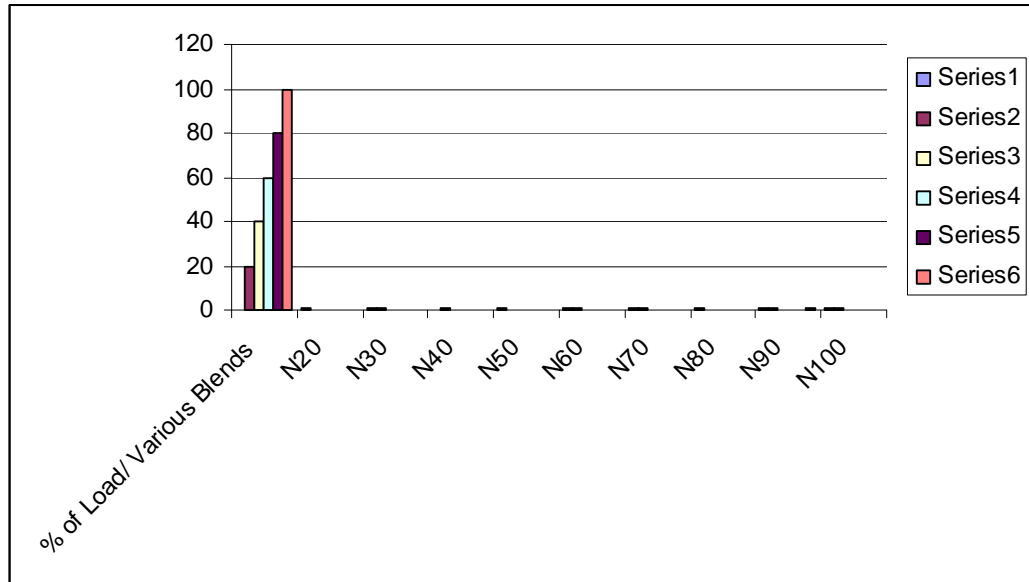
3. Performance Study

3.1 Performance study of Neem Oil and its Blends

1.1 The following table shows the specific fuel consumption (kg/kwh) of various Neem-Diesel at various load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
N20	0.81	0.294	0.18	0.18	0.216	0.286
N30	0.62	0.444	0.277	0.259	0.249	0.317
N40	0.114	0.466	0.271	0.221	0.228	0.296
N50	0.866	0.404	0.247	0.267	0.259	0.318
N60	1.164	0.476	0.320	0.261	0.276	0.356
N70	0.977	0.468	0.351	0.264	0.257	0.310
N80	1.023	0.425	0.322	0.273	0.256	0.322
N90	0.895	0.477	0.358	0.318	0.298	0.439
N100	0.900	0.600	0.360	0.289	0.300	0.328

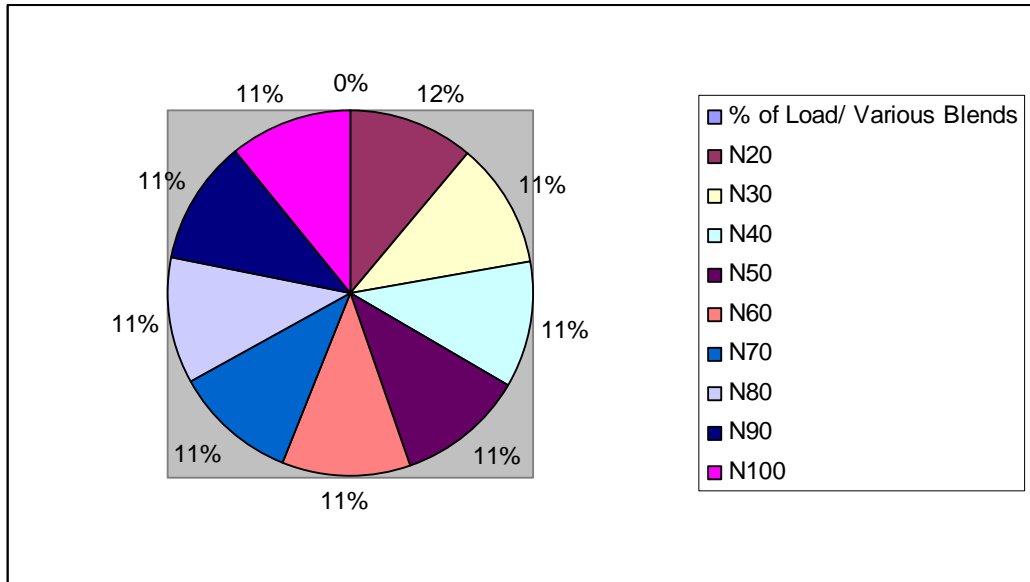
Table : 11 Specific fuel consumption of various Neem Oil Blends at different Load (KW).



3.1.2 The following table shows the r.p.m of various Neem-Diesel Blends at various Load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
N20	1497	1460	1430	1405	1390	1350
N30	1480	1450	1420	1398	1385	1355
N40	1510	1497	1459	1425	1390	1365
N50	1526	1502	1450	14141	1406	1380
N60	1520	1480	1432	1410	1390	1355
N70	1465	1430	1415	1390	1365	1520
N80	1500	1455	1425	1410	1390	1350
N90	1495	1450	1405	1395	1382	1345
N100	1450	1410	1390	1382	1365	1335

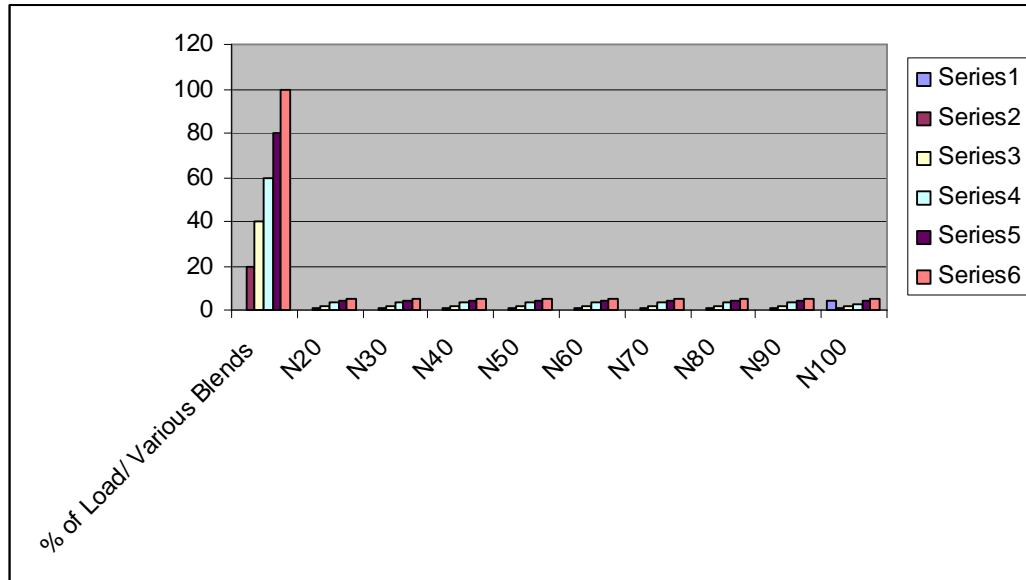
Table 12: r.p.m of various Neem Oil Blends at different load (kw)



3.1.3. The following Table shows the break power of various Neem- Diesel Blends at various Load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
N20	0.4	1.1	2.1	3.0	4.0	4.9
N30	0.4	1.0	2.0	3.0	4.0	4.9
N40	0.4	1.1	2.1	3.1	4.0	5.0
N50	0.4	1.0	2.1	3.1	4.0	4.9
N60	0.4	1.1	2.0	3.1	4.0	4.9
N70	0.4	1.0	2.0	3.1	4.1	4.9
N80	0.4	1.1	2.0	3.0	4.1	4.9
N90	0.4	1.0	2.0	3.0	4.0	4.9
N100	4.0	1.0	2.0	2.9	4.0	4.9

Table 13 Break Power of various Neem Oil Blends at different Load (kw).

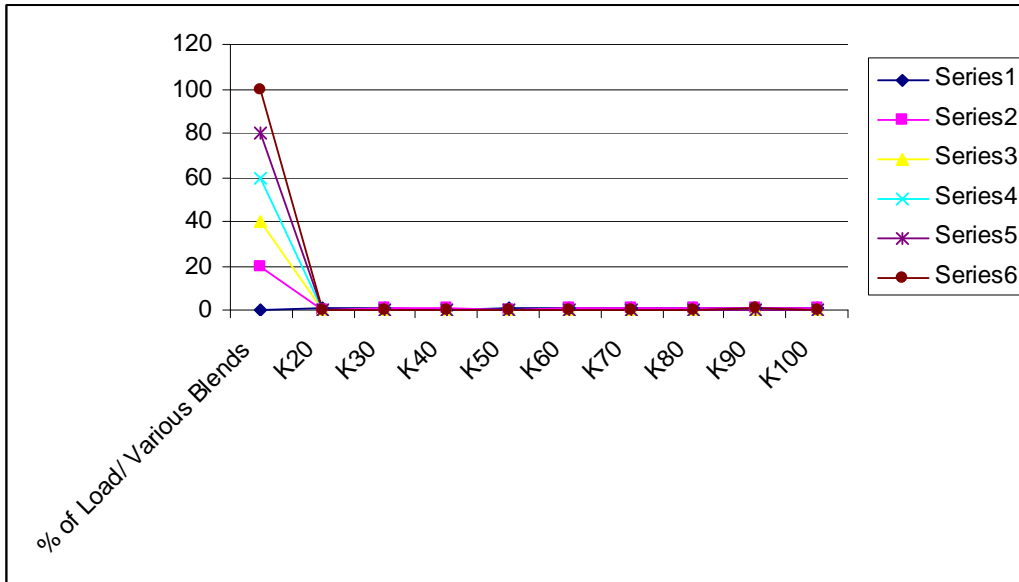


3.2 Performance study of Karanja Oil and its Blends.

3.2.1 The following table shows the specific fuel consumption (kg/kwh) of various Karanja-Diesel at various load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
K20	0.900	0.301	0.190	0.190	0.230	0.290
K30	0.568	0.451	0.278	0.261	0.251	0.320
K40	0.118	0.471	0.278	0.225	0.231	0.301
K50	0.871	0.410	0.251	0.271	0.261	0.325
K60	1.172	0.481	0.330	0.271	0.281	0.362
K70	0.901	0.512	0.362	0.271	0.262	0.330
K80	1.101	0.431	0.328	0.278	0.261	0.328
K90	0.921	0.482	0.361	0.322	0.312	0.443
K100	0.921	0.625	0.367	0.292	0.312	0.335

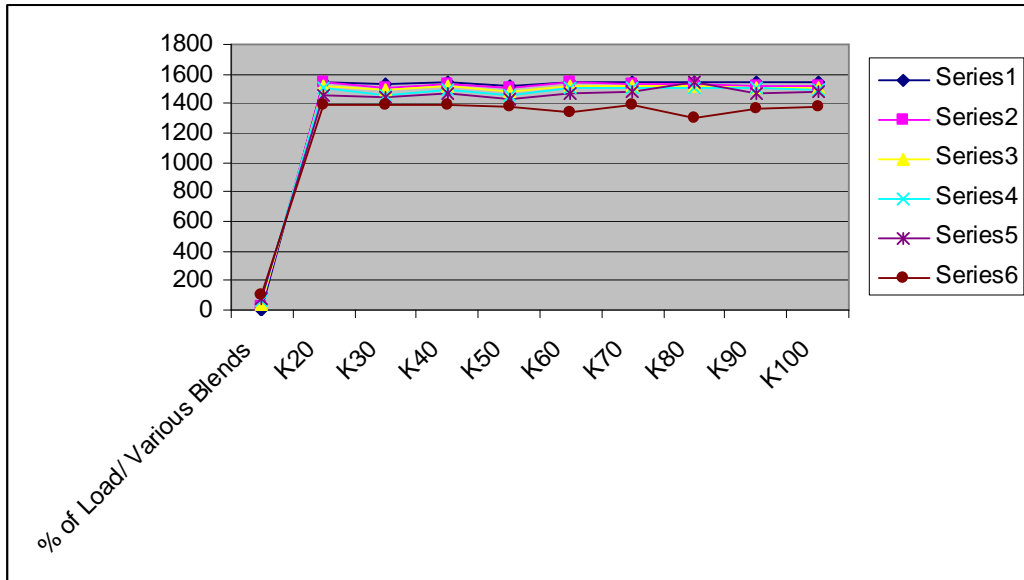
Table 14 : Specific fuel consumption of various Karanja Oil Blends at different load (kw).



3.2.2. The following table shows the r.p.m. of various Karanja-Diesel Blends at various load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
K20	1548	1540	1525	1510	1455	1390
K30	1530	1510	1490	1460	1440	1395
K40	1545	1534	1515	1497	1463	1390
K50	1525	1505	1485	1455	1435	1385
K60	1548	1540	1525	1505	1470	1342
K70	1545	1530	1518	1500	1475	1389
K80	1547	1530	1515	1504	1540	1304
K90	1542	1525	1510	1500	1470	1370
K100	1540	1520	1505	1495	1475	1375

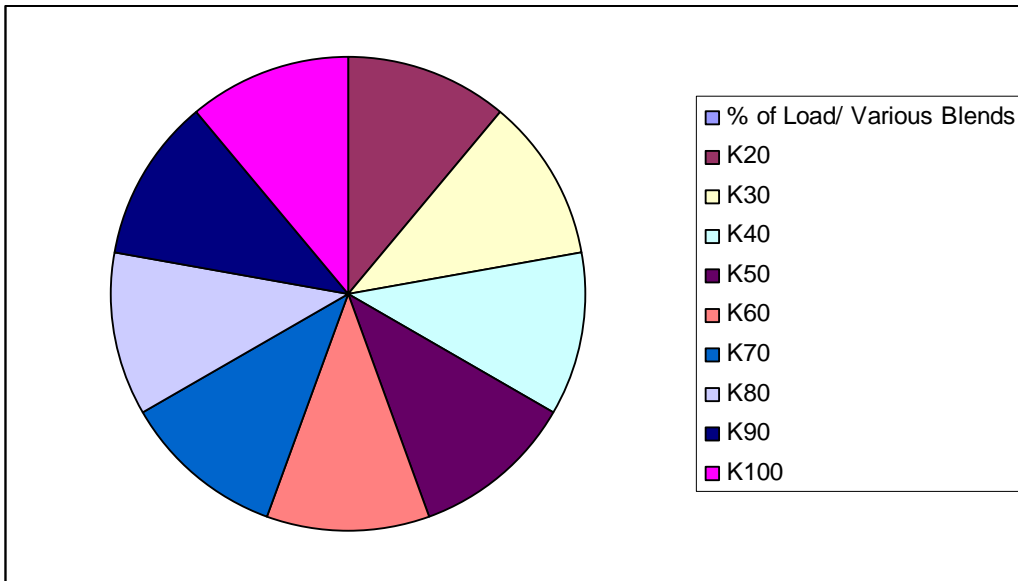
Table 15 : r.p.m. of various karanja Oil Blends at different Load (kw).



3.2.3. The following table shows the break Power of various Karanja-Diesel Blends at various Load conditions

% of Load/ Various Blends	0	20	40	60	80	100
K20	0.4	1.1	2.1	3.1	4.0	4.8
K30	0.4	1.1	2.0	3.0	4.1	4.8
K40	0.4	1.1	2.1	3.1	4.2	4.8
K50	0.4	1.1	2.0	3.0	4.1	4.8
K60	0.4	1.1	2.1	3.0	4.2	4.8
K70	0.4	1.1	2.1	3.1	4.1	4.8
K80	0.4	1.1	2.1	3.1	4.2	4.7
K90	0.4	1.1	2.1	3.0	4.1	4.8
K100	0.4	1.1	2.1	3.1	4.2	4.7

Table 16: Break Power of various Karanja Oil Blends at different load (kw).

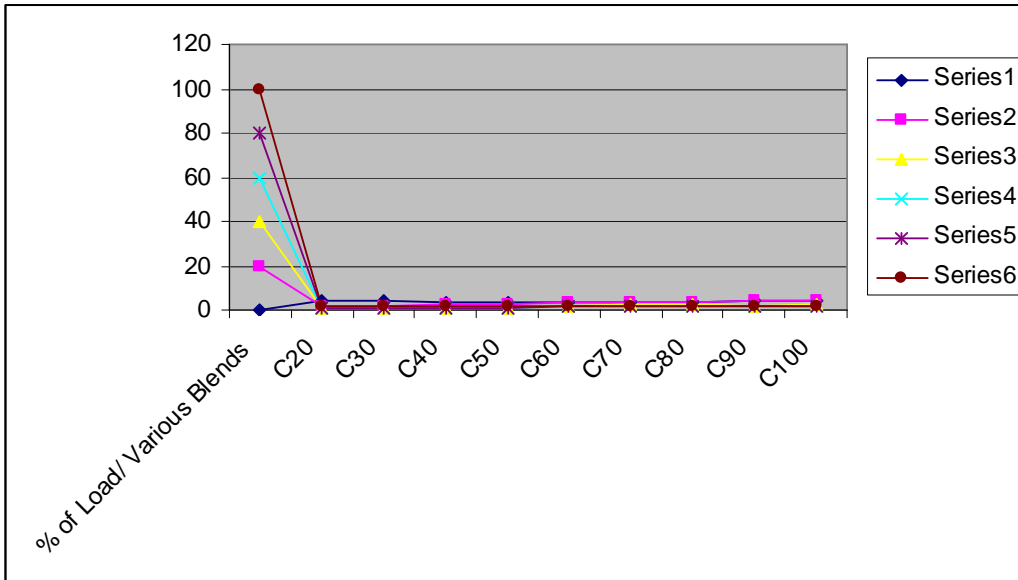


3.3. Performance study of Castor Oil and its Blends.

3.3.1. The following table shows the specific fuel consumption (kg/kw) of various Castor-Diesel at various Load conditions

% of Load/ Various Blends	0	20	40	60	80	100
C20	3.90	1.73	1.02	1.17	1.20	1.37
C30	3.85	2.10	1.11	1.15	1.25	1.42
C40	3.45	2.80	1.20	1.10	1.22	1.48
C50	3.44	2.80	1.20	1.10	1.22	1.48
C60	3.22	3.40	1.92	1.81	1.87	1.91
C70	3.65	3.25	2.25	1.67	1.75	1.70
C80	3.82	3.75	2.29	1.59	1.70	1.71
C90	3.87	3.87	2.11	1.77	1.75	1.68
C100	3.96	3.89	2.17	1.88	1.65	1.61

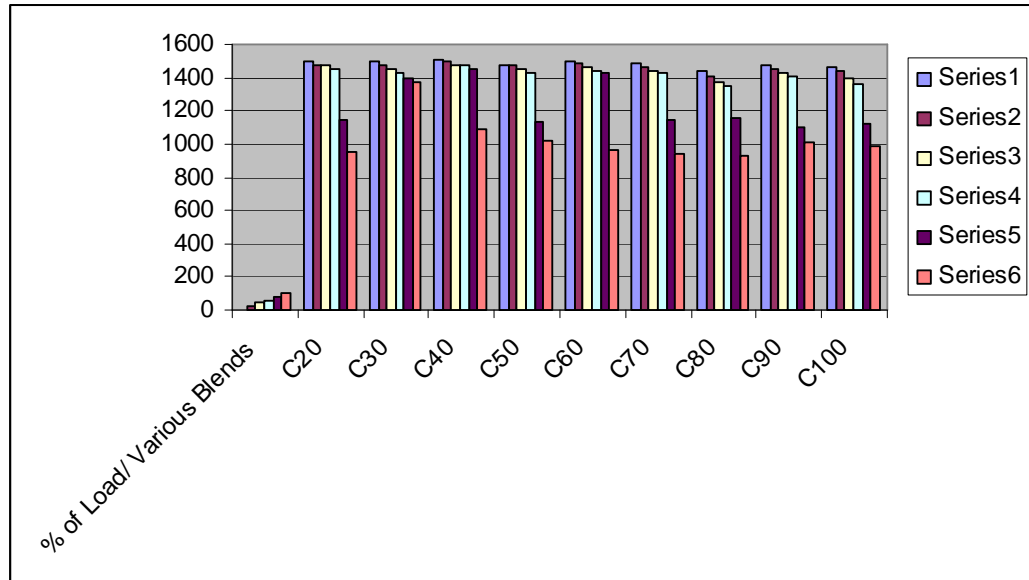
Table 17 : Specific fuel consumption of various Castor Oil Blends at different load (kw)



3.3.2. The following table shows the r.p.m. of various Castor-Diesel Blends at various Load condition.

% of Load/ Variou Blends	0	20	40	60	80	100
C20	1495	1480	1470	1450	1150	950
C30	1495	1470	1450	1430	1395	1370
C40	1505	1495	1480	1470	1450	1090
C50	1480	1470	1450	1435	1138	1020
C60	1497	1485	1465	1440	1425	970
C70	1485	1460	1440	1425	1150	940
C80	1440	1410	1370	1350	1160	930
C90	1470	1450	1425	1405	1105	1010
C100	1465	1440	1395	1360	1125	985

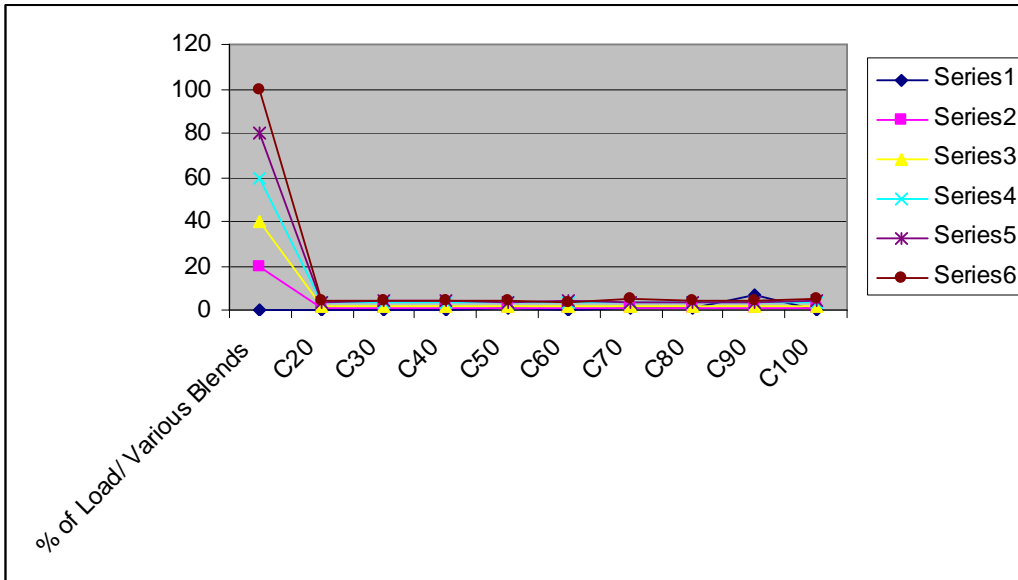
Table 18: r.p.m. of various castor oil at different load (kw).



3.3.3 The following table shows the break power of various Castor-Diesel at various load condition.

% of Load/ Various Blends	0	20	40	60	80	100
C20	0.4	0.8	2.1	3.0	3.8	4.2
C30	0.4	1.1	2.0	3.0	3.9	4.0
C40	0.4	1.1	2.1	3.1	4.1	4.3
C50	0.6	0.9	2.1	3.0	3.4	4.5
C60	0.4	1.0	2.1	3.1	4.1	3.5
C70	0.5	0.8	2.0	3.0	3.8	4.7
C80	0.5	0.9	2.1	3.0	3.7	4.6
C90	6.4	0.8	2.1	3.0	3.8	4.3
C100	0.3	0.9	2.1	3.0	3.9	4.7

Table 19: Break power of various Oil blends at different load (kw).

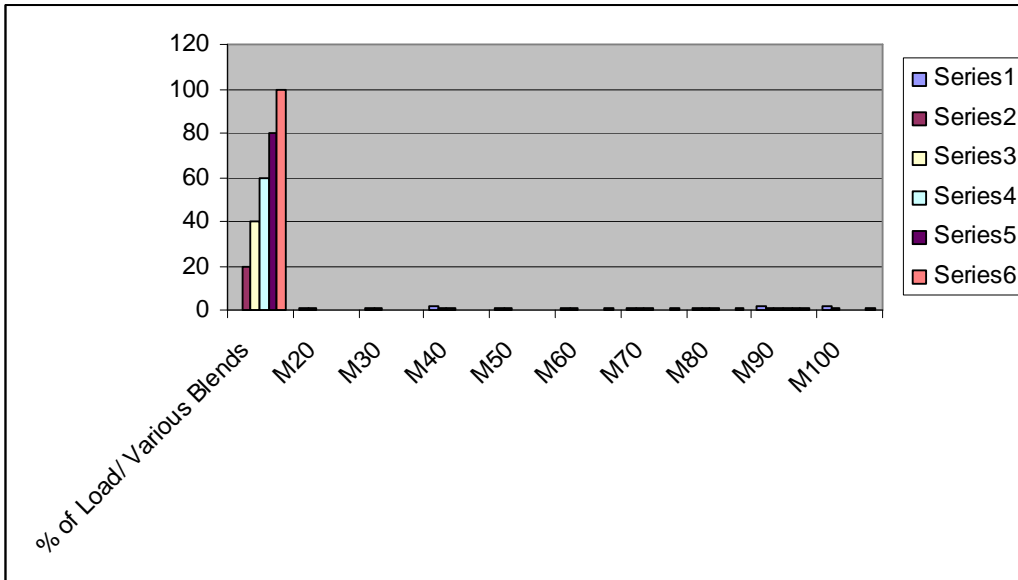


3.4 Performance study of Mahua Oil and its blends

3.4.1. The following table shows the specific fuel consumption (kg/kwh) of various Mahua-Diesel at various load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
M20	1.20	0.48	0.30	0.28	0.29	0.34
M30	1.15	0.45	0.21	0.32	0.35	0.36
M40	1.72	0.59	0.47	0.42	0.39	0.39
M50	0.956	0.510	0.318	0.340	0.318	0.390
M60	0.92	0.78	0.42	0.36	0.35	0.44
M70	0.85	0.71	0.49	0.25	0.34	0.51
M80	0.73	0.65	0.55	0.37	0.31	0.59
M90	1.52	0.92	0.85	0.80	0.78	0.53
M100	1.425	0.641	0.392	0.403	0.356	0.436

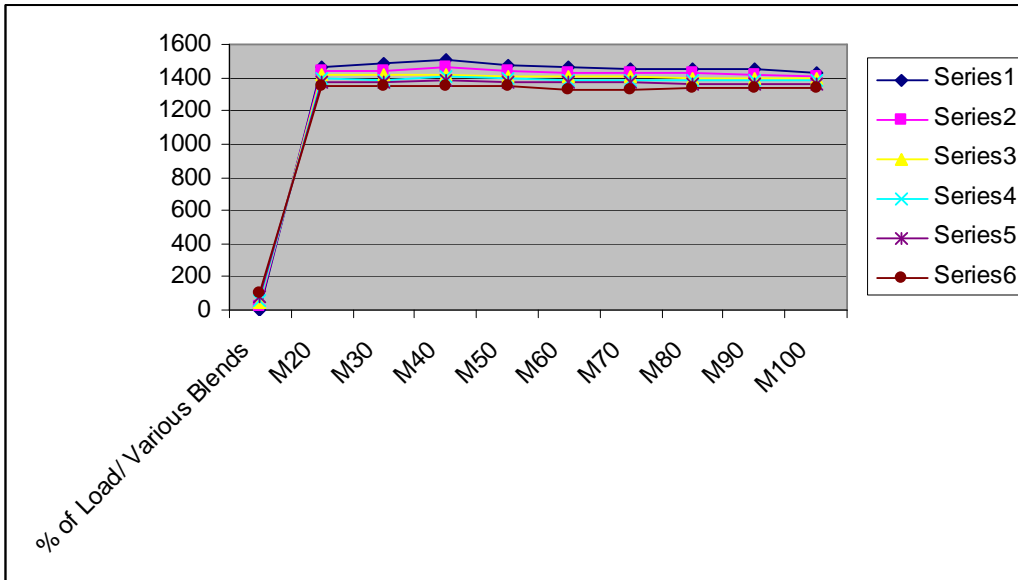
Table 20 : Specific fuel consumption of various Mahua-Oil blends at different load (kw)



3.4.2. The following table shows the r.p.m. of various Mahua Diesel blends at various load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
M20	1465	1445	1415	1395	1375	1350
M30	1490	1445	1415	1390	1370	1355
M40	1505	1465	1420	1405	1385	1350
M50	1470	1440	1410	1395	1370	1345
M60	1465	1435	1410	1390	1370	1330
M70	1450	1430	1410	1390	1370	1330
M80	1455	1430	1400	1385	1365	1340
M90	1450	1420	1395	1380	1365	1340
M100	1430	1410	1395	1380	1365	1335

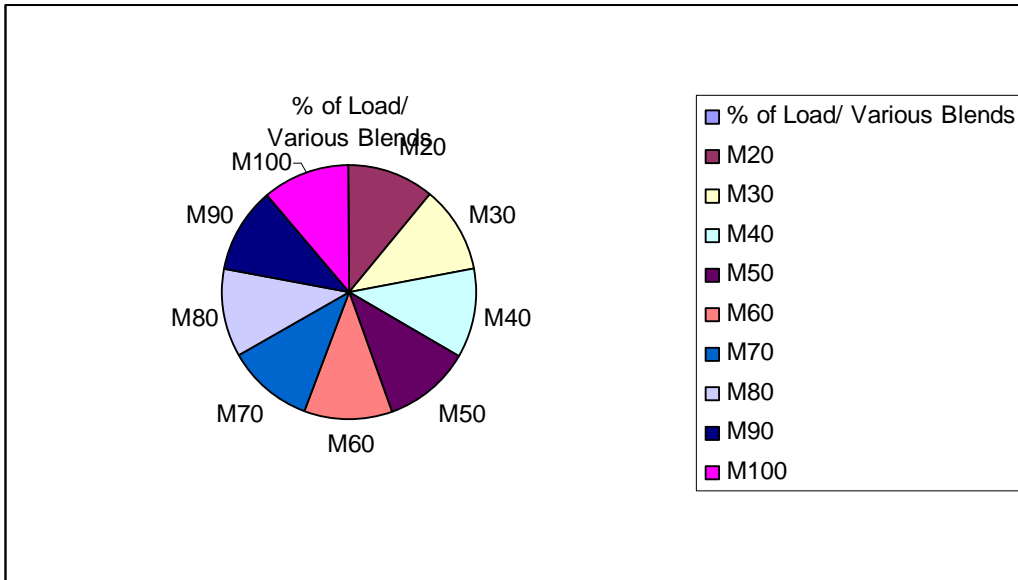
Table 21: r.p.m. of various Mahua Oil at different load (kw).



3.4.3. The following Table shows the break power of various Mahua-diesel at various load conditions.

% of Load/ Various Blends	0	20	40	60	80	100
M20	0.4	1.0	2.0	3.0	4.0	4.9
M30	0.4	1.0	2.0	3.0	4.0	5.0
M40	0.4	1.0	2.0	3.0	4.0	4.9
M50	0.4	1.0	2.0	3.0	4.0	4.9
M60	0.4	1.0	2.1	3.1	4.0	4.8
M70	0.4	1.0	2.0	3.2	4.0	4.8
M80	0.4	1.0	2.0	3.0	4.0	4.9
M90	0.4	1.0	2.0	3.0	4.0	4.9
M100	0.4	1.0	2.0	3.0	4.0	4.9

Table 22: Break power of various Mahua-oil blends at different load (kw)



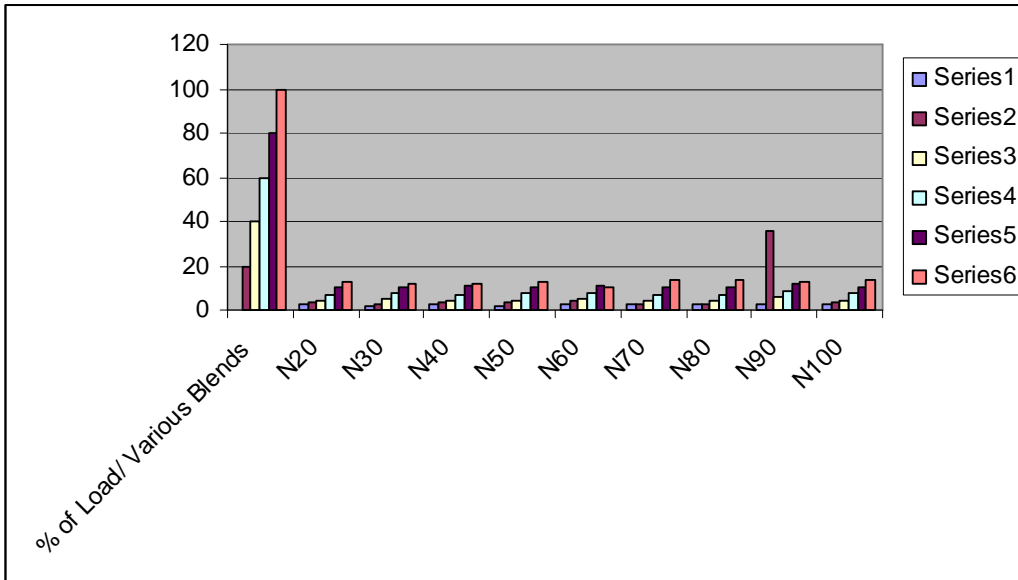
4. Emission studies of Neem, Karanja, Castor and Mahua oil and their blends

4.1. Emission studies of Neem oil and its blends

4.1.1 Carbon dioxide emission

% of Load/ Various Blends	0	20	40	60	80	100
N20	2.2	3.2	4.6	6.9	10.3	13.1
N30	2.0	2.7	4.8	7.5	10.1	11.5
N40	2.2	3.2	4.6	7.1	10.8	11.9
N50	2.1	3.0	4.5	7.4	10.4	12.5
N60	2.5	4.3	5.2	7.7	11.1	10.4
N70	2.3	2.7	4.5	6.9	9.9	13.3
N80	2.2	2.7	4.6	7.0	10.1	13.3
N90	2.6	36.	6.2	8.2	11.7	13.1
N100	2.3	3.2	4.5	7.3	10.1	13.2

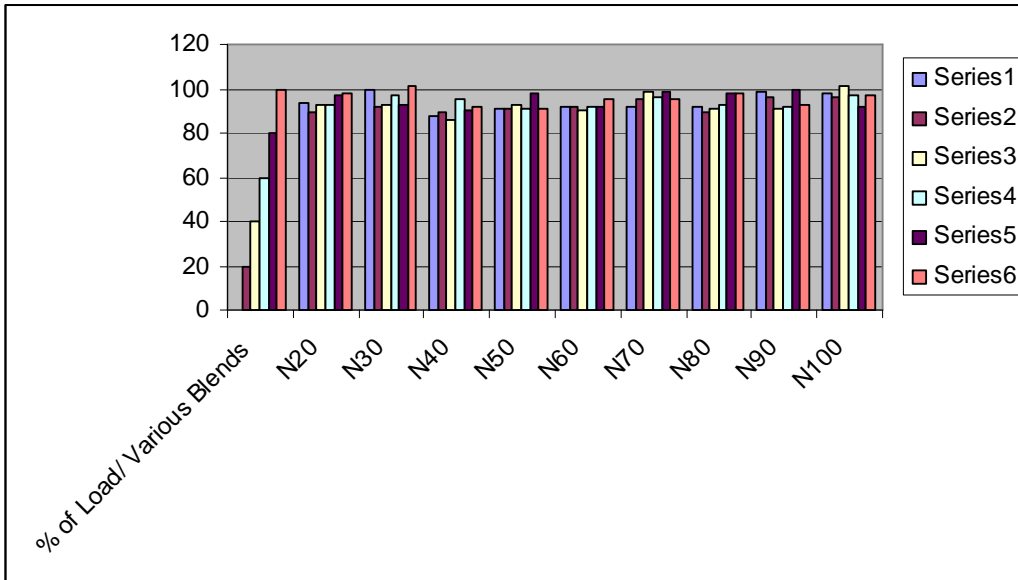
Table 23 : Carbondioxide at different loads of various Neem blends



4.1.2. Exhaust Gas temperature ($^{\circ}\text{C}$)

% of Load/ Various Blends	0	20	40	60	80	100
N20	94	89	93	93	97	98
N30	100	92	93	97	93	101
N40	88	89	86	95	90	92
N50	91	91	93	91	98	91
N60	92	92	90	92	92	95
N70	92	95	99	96	99	95
N80	92	89	91	93	98	98
N90	99	96	91	92	100	93
N100	98	96	101	97	92	97

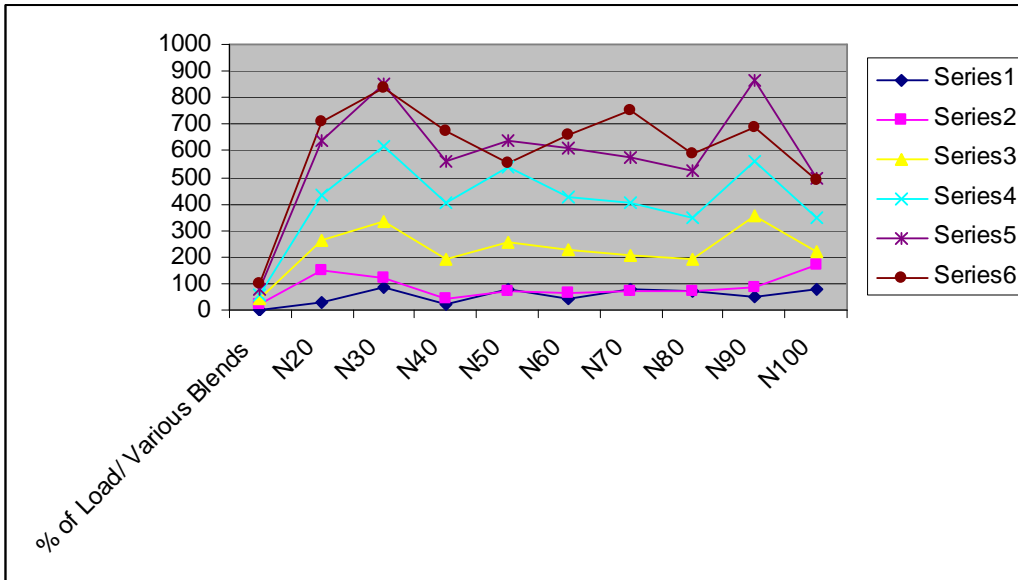
Table 24 : Exhaust Gas temperature of various Neem blends at different load (kw).



4.1.3. NO_x emission.

% of Load/ Various Blends	0	20	40	60	80	100
N20	30	147	264	436	637	708
N30	84	123	330	619	850	834
N40	20	44	193	407	558	674
N50	77	73	254	536	636	550
N60	42	65	229	425	611	660
N70	77	74	203	404	571	754
N80	74	74	193	346	524	592
N90	53	83	357	558	863	690
N100	75	169	223	350	499	491

Table 25: NO_x emission of various Neem blends at different load (kw).



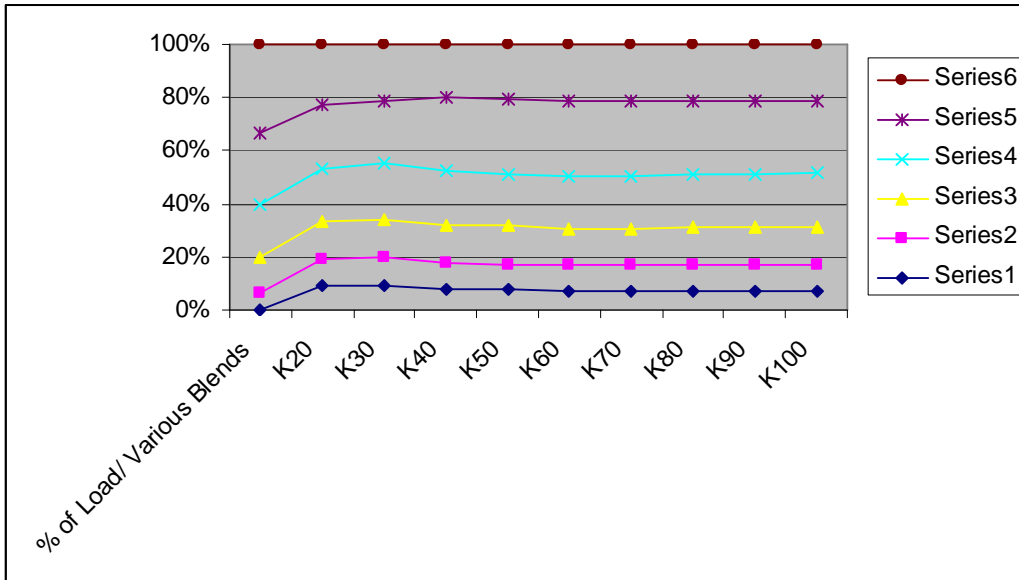
4.2 Emission studies of Karanja oil and its blends

4.2.1 CO₂ emission

4.2.2

% of Load/ Various Blends	0	20	40	60	80	100
K20	4.30	5.00	6.70	9.50	11.50	10.90
K30	4.0	4.70	6.30	9.20	10.50	9.20
K40	3.40	4.30	6.40	8.90	12.30	8.70
K50	3.30	4.20	6.20	8.50	12.20	9.00
K60	3.20	4.10	6.00	8.40	12.40	9.20
K70	3.10	4.15	6.05	8.50	12.20	9.15
K80	3.20	4.20	6.10	8.60	12.0	9.10
K90	3.05	4.10	6.05	8.50	11.80	9.0
K100	3.0	4.0	6.0	8.40	11.20	8.95

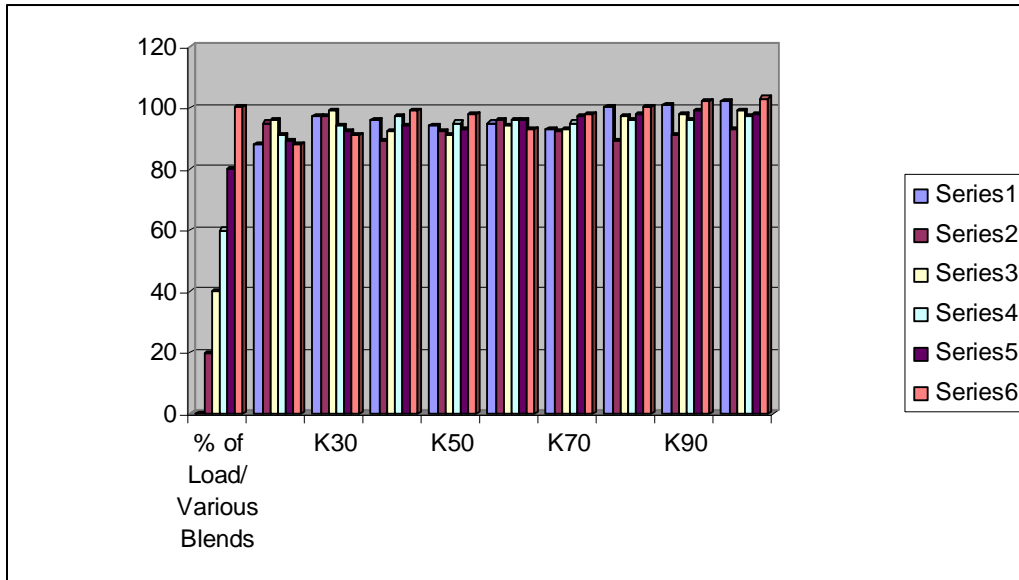
Table 26: CO₂ at different load at various Karanja blends.



4.2.2. Exhaust Gas Temperature (O_c)

% of Load/ Various Blends	0	20	40	60	80	100
K20	88	95	96	91	89	88
K30	97	97	99	94	92	91
K40	96	89	92	97	94	99
K50	94	92	91	95	93	98
K60	95	96	94	96	96	93
K70	93	92	93	95	97	98
K80	100	89	97	96	98	100
K90	101	91	98	96	99	102
K100	102	93	99	97	98	103

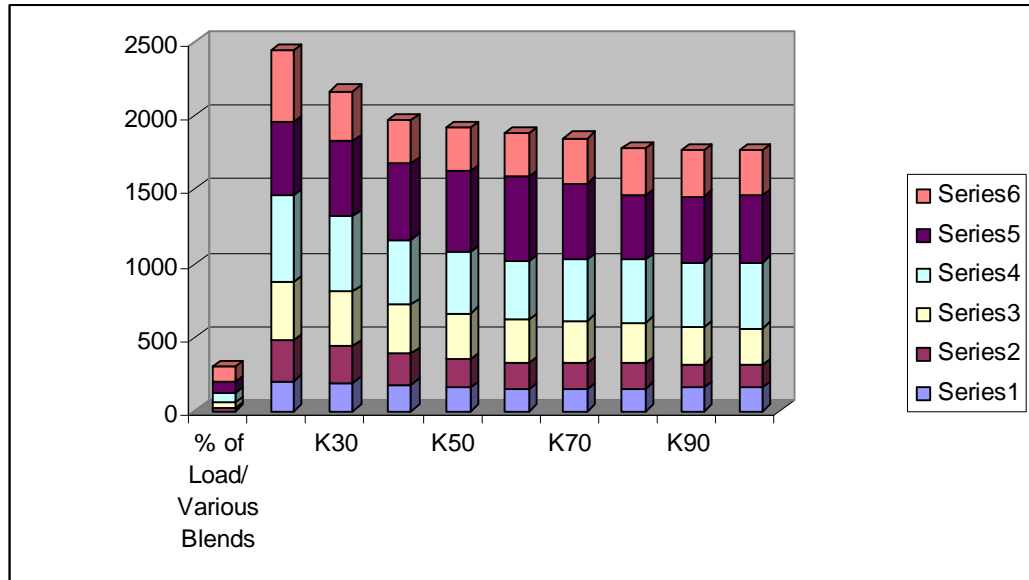
Table 27 : Exhaust Gas temperature of various Karanja blends.



4.2.3. NO_x Emission

% of Load/ Various Blends	0	20	40	60	80	100
K20	205	277	390	592	499	481
K30	192	251	363	512	510	341
K40	179	212	333	436	520	294
K50	161	192	309	415	545	295
K60	142	179	299	395	575	296
K70	148	176	289	415	515	307
K80	153	174	273	426	437	315
K90	158	162	252	435	446	310
K100	162	149	249	448	451	305

Table 28 : NO_x emission of various Karanja blends at different load (kw).

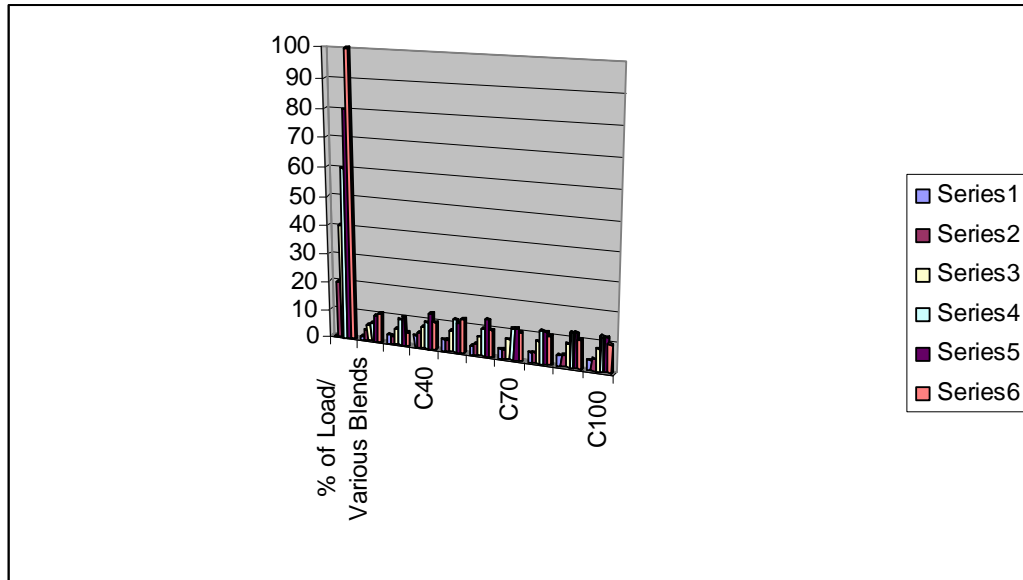


4.3 Emission studies of castor Oil and its blends.

4.3.1 CO₂ emission.

% of Load/ Various Blends	0	20	40	60	80	100
C20	1.50	3.90	5.90	6.60	9.40	10.30
C30	3.20	2.90	5.60	9.10	10.40	4.90
C40	4.30	5.30	7.80	9.40	12.80	9.70
C50	4.10	4.00	7.70	11.60	10.70	12.20
C60	3.20	4.20	6.60	9.50	12.90	9.60
C70	3.50	3.50	7.20	11.10	11.30	10.20
C80	3.60	3.70	7.80	11.50	11.40	10.10
C90	3.80	4.10	8.00	12.10	12.30	10.00
C100	3.70	4.00	7.90	12.00	12.10	9.80

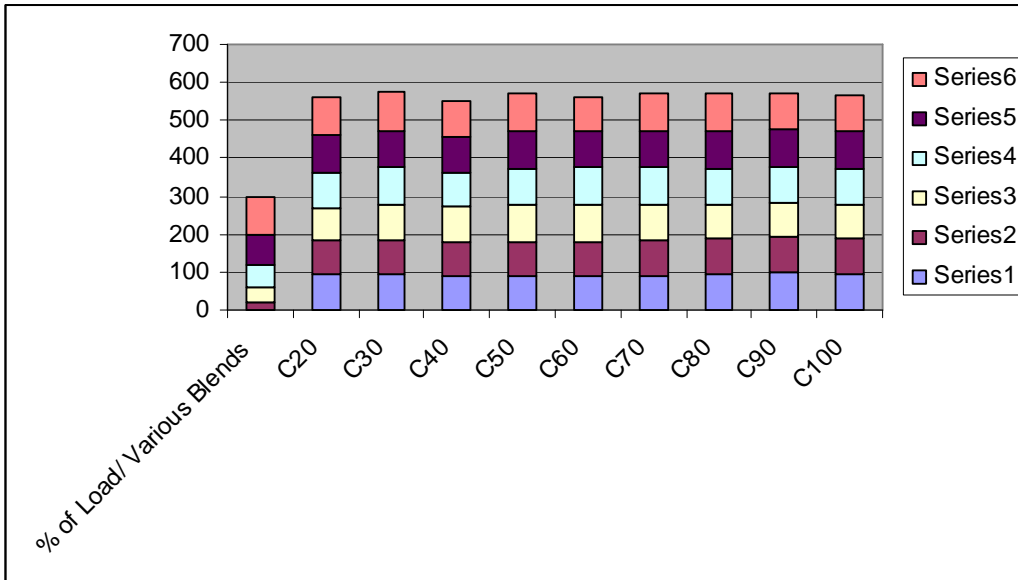
Table 29 : CO₂ at different load of various Castor blends.



4.3.2 Exhaust Gas temperature ($^{\circ}\text{C}$)

% of Load/ Various Blends	0	20	40	60	80	100
C20	93	92	83	93	99	100
C30	93	90	97	96	98	102
C40	88	91	95	86	96	93
C50	88	92	97	94	99	101
C60	91	90	98	98	95	90
C70	91	93	96	95	97	99
C80	93	94	93	93	98	98
C90	97	96	91	94	99	96
C100	95	93	92	93	97	98

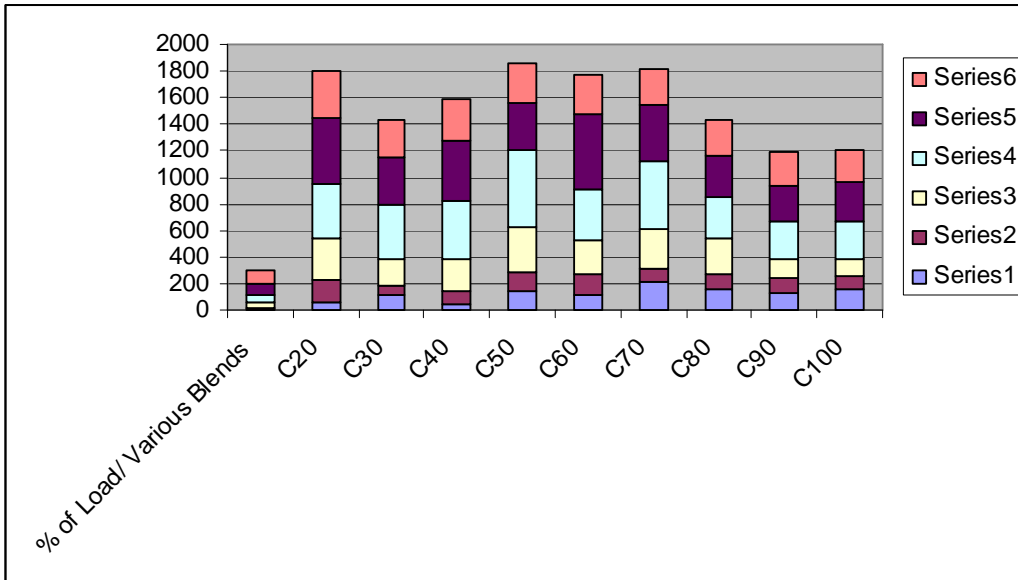
Table 30 : Exhaust Gas temperature of various castor blends at different load (kw).



4.3.3. NO_x emission

% of Load/ Various Blends	0	20	40	60	80	100
C20	52	180	303	413	499	350
C30	116	63	199	422	345	293
C40	42	99	236	439	461	315
C50	147	132	349	576	356	299
C60	110	161	253	390	568	292
C70	206	111	300	506	418	275
C80	162	109	270	312	310	271
C90	124	122	134	293	265	260
C100	152	101	131	282	295	250

Table 31 : NO_x emission of various castor blends at different load (kw).



4.4 Emission studies of Mahua oil and its blends

4.4.1. CO₂ emission

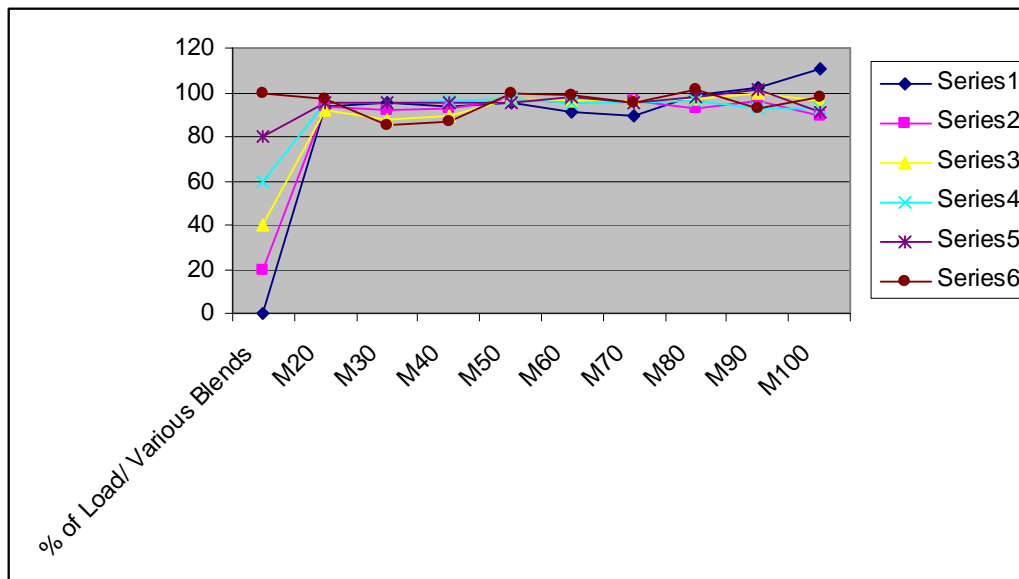
% of Load/ Various Blends	0	20	40	60	80	100
M20	2.20	2.90	4.20	1.40	9.70	12.80
M30	1.30	2.80	4.40	6.70	9.70	12.50
M40	2.10	2.98	4.70	6.90	9.89	12.20
M50	2.30	3.10	5.00	7.40	10.80	11.90
M60	2.30	3.20	5.00	7.70	11.20	12.00
M70	2.70	3.30	5.40	7.70	12.00	8.80
M80	2.00	3.60	5.10	7.80	11.60	6.50
M90	2.50	3.30	5.70	7.50	10.80	7.90
M100	2.60	3.50	5.30	7.40	10.90	11.90

Table 32 : CO₂ at different load at various Mahua blends.

4.4.2. Exhaust Gas Temperature (°C)

% of Load/ Various Blends	0	20	40	60	80	100
M20	94	94	92	95	95	97
M30	95	92	88	95	95	85
M40	94	93	89	96	95	87
M50	95	97	97	97	95	100
M60	91	95	96	95	98	99
M70	89	96	96	95	95	95
M80	99	93	97	96	98	101
M90	102	96	100	93	101	93
M100	111	89	96	93	91	98

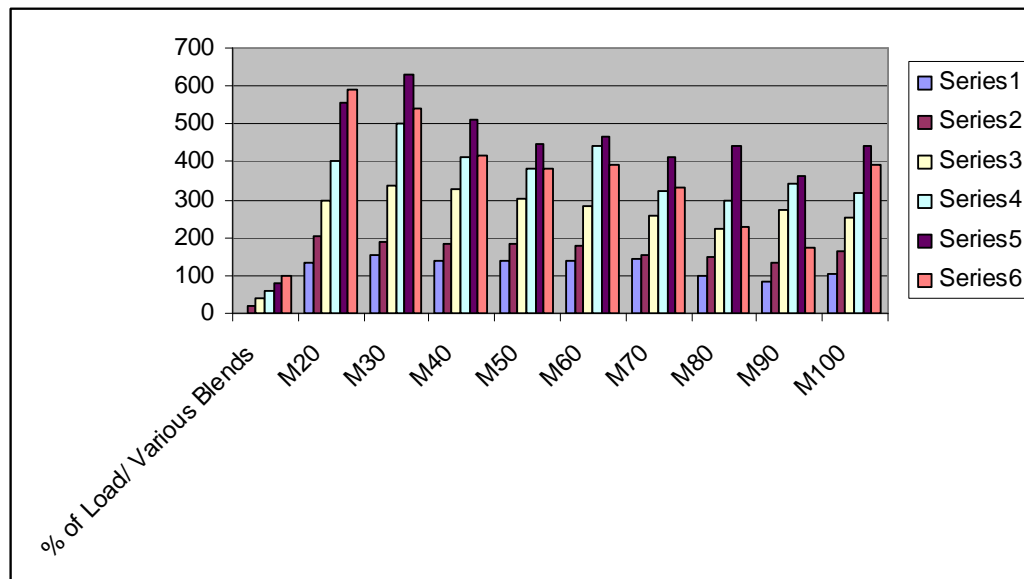
Table 33: Exhaust Gas temperature of various Mahua blends at different load (kw).



4.4.3. NO_x emission

% of Load/ Various Blends	0	20	40	60	80	100
M20	133	203	299	402	554	590
M30	154	189	337	501	629	541
M40	141	186	326	412	512	415
M50	138	182	302	383	448	384
M60	138	178	283	442	467	391
M70	145	155	256	325	411	331
M80	101	148	222	298	443	229
M90	83	134	273	344	363	176
M100	106	164	251	320	441	393

Table 34: NO_x emission of various Mahua blends at different load (kw).



Conclusions

Based on the studies conducted so far, the following conclusions may be arrived at

1. Vegetable oil is an environmentally and technically feasible fuel for diesel engine.
2. Apart from lower emissions, it has benefits like better safety, lubricity and low temperature feasibility.
3. Engine Durability can be ensured if the fuel quality is maintained through good process control.
4. Issues concerning fuel quality and engine durability has to be adequately resolved.
5. Poor oxidation stability of vegetable oil is a cause for worry. Further research is needed to improve oxidation stability.
6. The performance and emission tests are conducted with diesel and blends of vegetable oil at different loads. From experimental results obtained, vegetable oil is found to be a promising alternative fuel for compression ignition engines. It can be directly used of straight vegetable oil as a replacement of diesel fuel and do not require any major modification in the engine. Emission parameters are found to have increased with increasing proportion of vegetable oil in the blends compared to diesel. Therefore, either heating or blending the vegetable oil can be used in compression ignition engines in rural areas of agriculture, irrigation and electricity generation.