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Determination of the effect of biodiesel blends on agricultural tractor during real time measurement

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ABSTRACT : An experiment was carried out to determine the physico-chemical properties of selected blends of karanja biodiesel with petro-diesel *viz.,* B_0, B_{20}, B_{40} and B_{60} and to study the effect of these blends on specific draft, drawbar power, fuel consumption and fuel efficiency of 50 hp (2WD Mahindra 585DI) tractor and analyzed the emission characteristics of the tractor at three selected forwards *viz.,* 2.5, 3.5 and 4.5 km h^{-1} during ploughing operation. The results indicated that the kinematic viscosity, specific gravity, flash and fire points and free fatty acids of biodiesel blends were decreased with increased percentage of biodiesel in petro-diesel while their calorific value was decreased. The performance parameters like specific draft and drawbar power of tractor were not affected by the blends of biodiesel but these were significantly affected by the speed of operation. Whereas, both the blends of biodiesel and forward speeds showed significant effect on fuel consumption and fuel efficiency. The fuel consumption of tractor was increased by 7.69 per cent for B_{60} blend as compared to petro-diesel at forward speed of 3.5 km h^{-1}. The CO and CO_2 emission were decreased with the increase in blends of biodiesel as compared to petro-diesel while, the NOx emission was increased during ploughing operation. Among the blends tested, B_{20} performed comparably with petro-diesel in terms fuel consumption, fuel efficiency and NOx emission. The fuel consumption and NOx emission increased and fuel efficiency decreased with increased percentage of biodiesel beyond B_{20}. Hence, B_{20} blend of karanja biodiesel may be recommended to use in tractor for ploughing operation.

KEY WORDS : Agricultural tractor, Biodiesel, Exhaust emission, Fuel efficiency, Specific draft

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The main energy source of agricultural tractor engines is diesel fuel. All the modern tractors are equipped with multi cylinder diesel engine in which diesel is used as fuel. Due to the possibility of depletion of oil reserves in this century, usage of renewable energy sources are being considered as alternative energy sources. The price of crude oil was 26.65 dollars per barrel in 2001 but the current oil prices has reached more than 85.09 dollars per barrel in international market (Anonymous, 2011). Another drawback of petro-diesel was environmental pollution caused by its abundant usage in all the sectors. Concerns about oil supply and energy security have motivated many countries to find an alternative fuel source to petro-diesel such as biodiesel.

The developed countries are producing biodiesel from sunflower, peanut, palm and several other feed stocks which are essentially edible in Indian context. Hence, it is not possible to divert these edible oil sources for biodiesel production in India. Therefore, the developing country like India is producing biodiesel from non-edible oil sources which can be extensively grown in the waste lands. It has been reported that non-edible oils available in India are karanja, jatropha, rubber, simarouba, etc. (Anonymous, 2003 and Belum *et al.*, 2008). If 5 per cent biodiesel fuel is blended with petro-diesel to the present diesel consumption in India would save about Rs. 4000 crore a year in foreign exchange (Misra and Murthy, 2011). As India's economy is mostly depend on agriculture, the use of biodiesel with petro- diesel will create a new demand in the export market, thus it will help to strengthen India's position as a leading producer and exporter of biodiesel. The blends of biodiesel with mineral diesel fuel can be used in diesel engines (Pramanik, 2003 and Forson *et al.,* 2004).

In the majority of previous studies, biodiesel was usually tested on single-cylinder engines under laboratory test conditions. Ejilah *et al.* (2010) evaluated the performance of 2.43 kW IC engine fuelled with blends of jatropha biodiesel in proportion of B_5, B_{10}, B_{15} and B_{20} and reported that the break power and break mean effective pressure generated by jatropha biodiesel blends were comparable to diesel while, the fuel consumption of B_5, B_{10}, B_{15} and B_{20} blends were 1.63, 3.06, 0.03 and 0.514 per cent higher than diesel fuel, respectively. Milan *et al.* (2010) studied the application of different methyl ester blends 90:10, 80:20, 70:30, 50:50, 25:75 and 0:100 obtained from mixture of 75 per cent sunflower oil and 25 per cent cooking oil used in agricultural tractor (Kubota) of a rated horsepower of 19.7 kW. They reported that there is no significant reduction in power output and torque with blends smaller than 50 per cent, however, fuel consumptions with biodiesel were higher than that of diesel except the blends up to 30 per cent. Most of the research on biodiesel use and exhaust emissions was conducted in laboratories using dynamometers to apply a constant load and speed, or simulate a real operation by applying a predetermined load cycle. Most test engines were heavy-duty highway engines, but little attention was given to off-road engines, especially in real-time in-use conditions (Anonymous, 2002). Although many studies have been conducted on performance of biodiesel derived from various sources of bio-oils and most of them have reported on stationery engines, there is virtually no documentation on exhaust emissions from either petroleum or biodiesel fuel use in agricultural application (Li *et al*., 2006). Very few investigations have been carried out in agricultural and forestry tractors that's to be in real field conditions.

Keeping the above facts in view, a study was conducted to determine the physico-chemical properties of selected blends of karanja biodiesel and to analyze their effect on performance and emission characteristics of 50 hp agricultural tractor at different forward speeds during ploughing operation.

METHODOLOGY

The karanja biodiesel was procured from Indus Biodiesel Plant of Shimoga District, Karnataka, India and blended with petro-diesel on volume basis in varying proportions *viz.,* 20:80, 40:60 and 60:40 and designated as B_{20}, B_{40} and B_{60} while petro-diesel as B_0. The physico-chemical properties *viz.,* calorific value, kinematic viscosity, specific gravity, flash and fire point free fatty acids of prepared blends were determined by using ASTM standard procedure in Farm Machinery and Power engineering laboratory of College of Agricultural Engineering of UAS, Raichur. A 50 hp (2WD Mahindra 585DI) agricultural tractor was selected to study the effect of selected blends of biodiesel in performance and emission level during ploughing operation with two bottom mouldboard plough. An auxiliary fuel tank and system of valves were installed on the tractor to allow switching of premixed blends of biodiesel during field operation.

The experiment was carried out at the Krishi Vignyan Kendra (KVK) farm, University of Agricultural Sciences, Raichur of Karnataka state, India. Located at 16° 15' North latitude and 77° 20' east longitude and is at an elevation of 389 m above mean sea level (MSL). The selected field was having black clay loam soil. The pigeonpea crop was grown previous year in test site and the residues were shredded and the field was left fallow with stalks of the plant which was grown previous year. Prior to performing the ploughing operation, the field was irrigated to get desired condition. The single rectangular plot was selected to avoid much variation in field condition.

The selected tractor was evaluated for selected blends at three different forward speeds *viz.,* 2.5 (S_1), 3.5 (S_2) and 4.5 (S_3) km h^{-1}. Each treatment was tested on an area of 0.09 hectares (10×90 m^2) laid randomly in the field as per two factorial Complete Randomized Block Design and it was divided into three main blocks for experiment as shown in experimental layout Fig. A.

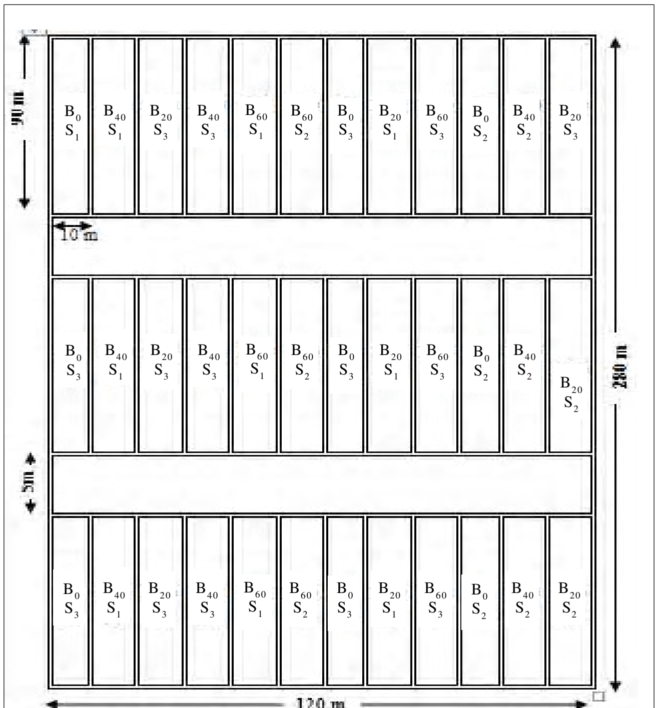

Fig. A: Field experimental layout

Before testing each blend at different speed, the forward speed of tractor was calibrated for required speed for individual blend of biodiesel. These forward speeds were achieved by adjusting engine throttle position and gear setting and the depth of operation was maintained constant by setting hydraulic position in order to avoid much variation in load. The fuel consumption of tractor was measured by filling up the fuel tank before starting each trial then after finishing the trial tank was refilled again using a one litre graduated cylinder. The total quantity of fuel needed to refill the tank was recorded and considered as fuel consumption of tractor. After each trial the tractor engine was run at idle for about 15 minutes to purge the fuel filters with the new blend of biodiesel. The performance of tractor in terms of specific draft, drawbar power, fuel consumption and fuel efficiency were determined as per the standard test procedure recommended by RNAM Technical series-12 (1983). The exhaust gas emission characteristics of tractor were analyzed by using a KM900 Plus analyzer (M/s Nevco Pvt. Ltd. India) in terms of CO, CO_2 and NOx emissions. The data were stastically analyzed by using design expert version 7.

RESULTS AND DISCUSSION

The physico-chemical properties of selected blends of biodiesel are presented in Table 1. The kinematic viscosity of all selected blends of karanja biodiesel were found to be higher than that of petro-diesel which was found highest for B_{60} (4.2 cSt) among the selected blends Similarly the specific gravity of petro-diesel was 0.824 g cc^{-1} while it was 0.892 g cc^{-1} for B_{60}. It was increased as the per cent of biodiesel increased in petro-diesel. The flash point of selected blends of biodiesel varied from 65 to 104 ºC and the flash and fire points were increased as the per cent of biodiesel increased in petro-diesel, which is safe for storage and handling. The free fatty acids of selected blends of biodiesel varied from 0.266 to 0.566 per cent and it was absent in petro-diesel. The addition of biodiesel increased the free fatty acid content of the fuel. The calorific value of B_{60} blend was found to be 37.42 MJ kg^{-1} which was 11.08 per cent lesser than the calorific value of petro-diesel (42.43 MJ kg^{-1}). As the percentage of biodiesel in the blends increased, the calorific value decreased.

The selected experimental plot had clay loam soil, which was examined prior to the field experiment and the soil parameters such as moisture content, bulk density and cone index were recorded. The mean soil moisture content in field at the time of tillage operation was 11 per cent at 20 cm of depth. The bulk density of soil varied from 1.62 to 1.65 g cm^{-3}. Similarly the cone index at a depth of 0-10 cm was 1.8 to 2.1 kg cm^{-2} while at depth of 10-20 cm it was in the range of 3.5 to 3.7 kg cm^{-2}.

The performance of the tractor was evaluated in terms of specific draft, drawbar power, fuel consumption and fuel efficiency during ploughing operation.

The variation in specific draft with respect to blends of biodiesel and forward speed are presented in Table 2. It varied from 7.38 to 12.29 N mm^{-1} for all the selected blends of biodiesel at varying forward speeds. The analysis of the data showed that the speed of operation individually influenced on the specific draft whereas, the effect of blends of biodiesel and its interaction with speeds were not significant at 5 per cent level. This may be due to the fact that the specific draft was affected only by the implement type, width of cut, depth of cut and corresponding soil implement interaction (Li *et al.,* 2006).

The maximum drawbar power of 12.14 kW was recorded at B_0S_3 while it was minimum (4.05 kW) for B_20S_1 (Table 3). The variation in the drawbar power at same speed was mainly due to the field condition. The statistical analysis of drawbar power showed that the forward speed significantly affected on the drawbar power while, the blends of biodiesel and its interaction with speeds not significantly affected at 5 per cent level of significance.

Table 1 : Physico-chemical properties of petro-diesel and selected blends of biodiesel

Types of blends	Calorific value (MJ kg^{-1})	Kinematic viscosity (cSt)	Specific gravity (g cc^{-1})	Flash point (ºC)	Fire point (ºC)	Free fatty acids (%)
B_0	42.43	1.97	0.824	65	70	--
B_{20}	38.65	2.44	0.847	71	73	0.266
B_{40}	37.98	3.17	0.868	88	95	0.433
B_{60}	37.42	4.22	0.892	104	110	0.566

Table 2 : Effect of blends of biodiesel and forward speeds on specific draft

Blends of biodiesel	Forward speed (km h^{-1})		
	S_1	S_2	S_3
B_0	7.51	9.67	12.29
B_{20}	7.38	9.49	12.08
B_{40}	7.5	9.77	12.23
B_{60}	7.44	9.55	12.27
	B	S	B*S
S.E.±	0.124	0.107	0.214
C.D.	0.363	0.314	0.629

The drawbar power of tractor was varied due to variation in draft of the implement and speed of operation (Kheiralla *et al.*, 2004) and the fuel type did not shown any effect on this.

The results pertaining to the fuel consumption are presented in Table 4. The fuel consumption of tractor during ploughing varied from 3.06 to 4.54 l h^{-1} at different forward speeds for selected blends of biodiesel. It was maximum for $B_{60}S_3$ (4.54 l h^{-1}) while minimum (3.06 l h^{-1}) for B_0S_1. The analysis showed that the effect of both the factors (B and S) were significant on fuel consumption at 5 per cent level of significance. Also the individual influence of factor B and S on fuel consumption was significant at 5 per cent level of significance. Among the selected blends, B_{20} blend of biodiesel performed comparably with the petro-diesel. The fuel consumption of tractor was increased with increase per cent of biodiesel in petro-diesel which may be due less calorific value of biodiesel blends compared to petro-diesel (Li *et al.*, 2006).

The effect of selected blends of biodiesel and forward speed on fuel efficiency are presented in Table 5. The maximum fuel efficiency of 10.32 MJ l^{-1} was obtained at S_3 speed for B_0, while it was minimum (4.34 MJ l^{-1}) at S_1 speed for B_{60} blend of biodiesel.

The fuel efficiency differed significantly for all the selected blends of biodiesel and forward speeds and the combined effect was not significant at 5 per cent level of significance. It was observed that as the blends of biodiesel increased fuel efficiency decreased while it increased with increased in forward speeds of tractor, which may be due high drawbar power produced by tractor at higher speeds (Li *et al.*,

Table 3 : Effect of blends of biodiesel and forward speeds on drawbar power

Blends of biodiesel	Forward speed (km h^{-1})		
	S_1	S_2	S_3
B_0	4.12	7.43	12.14
B_{20}	4.08	7.29	12.07
B_{40}	4.11	7.50	11.93
B_{60}	4.05	7.33	12.12
	B	S	B*S
S.E.±	0.107	0.092	0.185
C.D.	0.314	0.272	0.544

Table 4 : Effect of blends of biodiesel and forward speeds on fuel consumption

Blends of biodiesel	Forward speed (km h^{-1})		
	S_1	S_2	S_3
B_0	3.06	3.55	4.24
B_{20}	3.15	3.62	4.36
B_{40}	3.23	3.77	4.44
B_{60}	3.39	3.85	4.54
	B	S	B*S
S.E.±	0.003	0.003	0.006
C.D.	0.010	0.009	0.018

Table 5 : Effect of blends of biodiesel and forward speeds on fuel efficiency

Blends of biodiesel	Forward speed (km h^{-1})		
	S_1	S_2	S_3
B_0	4.85	7.53	10.32
B_{20}	4.62	7.26	9.87
B_{40}	4.58	7.17	9.79
B_{60}	4.34	6.86	9.6
	B	S	B*S
S.E.±	0.094	0.081	0.162
C.D.	0.275	0.238	0.477

2006). Among the tested blends B_{20} performed comparable with petro-diesel at all the selected speeds.

The emission levels of tractor during ploughing operation were analyzed in terms of CO, CO_2 and NOx and the results are presented.

The variation of carbon monoxide emission of tractor during ploughing operation was depicted in Fig.1. The highest CO emission was recorded at B_0S_3 (1499 ppm) while, it was lowest at $B_{60}S_1$ (823 ppm). The CO emission increased as forward speed increased for all the blends tested. While, it decreased as per cent of biodiesel increased in petro-diesel which may be due to more number of oxygen molecules present in biodiesel as compared to petro-diesel. Similarly the Fig. 1 shows the NOx emissions of selected blends of biodiesel were higher than diesel under all the speeds. The NOx emission of the tractor varied from 279 to 596 ppm for the selected blends of biodiesel (Fig. 1). It was observed that the NOx emissions are a direct function of blends of biodiesel and speed of operation.

The variations in CO_2 emission of tractor during ploughing operation fuelled with blends of biodiesel at different forward speeds. The maximum CO_2 emission was observed as 9.93 per cent for B_0S_3 which was at par with all the blends tested at S_3 whereas the minimum of 4.5 per cent was observed at S_1 for B_{60} blend (Fig.2). It was observed that the

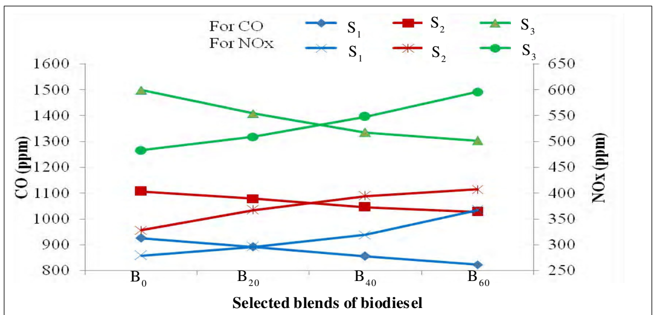

Fig. 1: Effect of forward speeds on CO and NOx emission for petro-diesel and selected blends of biodiesel during ploughing operation

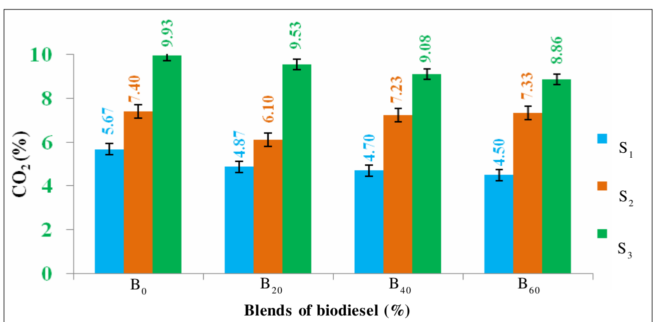

Fig. 2 : Effect of forward speeds on CO_2 emission for petro-diesel and selected blends of biodiesel during ploughing operation

CO_2 emission increased with increase in forward speed of tractor whereas it decreased as blend increased.

Conclusion :

The results of physico-chemical properties showed that the calorific value (MJ kg^{-1}), kinematic viscosity (cSt), specific gravity (g cc^{-1}), flash and fire points (ºC) and free fatty acid (%) of B_{20} blend of karanja biodiesel relatively closer to that of petro-diesel.

The specific draft and drawbar power of tractor during ploughing operation were not affected by the fuel type while the fuel consumption and fuel efficiency were significantly affected by it whereas the forward speed affected significantly all the performance parameters. Similarly, the emission of CO and CO_2 were decreased as blends of biodiesel increased, whereas the NOx emissions increased with increased blends of biodiesel.

Among the blends tested, B_{20} performed comparably with petro-diesel in terms fuel consumption, fuel efficiency and NOx emission. The fuel consumption and NOx emission increased and fuel efficiency decreased with increased percentage of biodiesel beyond B_{20}. Hence, B_{20} blend of biodiesel may be recommended for use in agricultural tractor for ploughing operation. However, the long duration trials should be conducted to study the effect of blends of biodiesel on various components of the tractor engine and their performance under the field conditions.

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