2nd VegOil

Demonstration of 2nd Generation Vegetable Oil Fuels in Advanced Engines

Workpackage 5

Engine Demonstration

Deliverable N° 5.9:

Support to field tests by VWP

Publishable summary

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List of acronyms

DPF	Diesel Particle Filter
ECU	Engine Control Unit
FRCUMA	Fédération Régionale des CUMA Rhône-Alpes
IBMER	Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa
IBC	Intermediate Bulk Container
IBDI	regineering, Ingenieurbüro Duft Innerhofer
JDWM	John Deere Werke Mannheim
MFDA	Multi Functional Diesel Additive
PRV	Pressure Regulating Valve
PTO	Power Take Off
Q.A.	Quality Assurance
RPM	Revolutions per Minute
VWP	Vereinigte Werkstätten für Pflanzenöle

1 Summary

This interim report D5.9 shall give a first impression of the field tests of tractors running on 100% 2nd generation pure vegetable oil (2G-PVO) within the 2ndVegOil project. Such tests have already been executed in Austria, Poland and France. Based on the first results, all actions concerning the field test parameters and the documentation of the operations will be reviewed and further improved for the remaining field testing. Support of field test data and feedback from local partners are incorporated as well.

Above all, the field testing shall demonstrate a stable and good engine performance with very low emission levels while running the vehicles with 2G-PVO and blends of different 2G-PVOs over a 22 month testing period. The aim of the whole field test is to demonstrate that the combination of

- the fuel developed within this project (WP3)
- the developed plant oil engine technology (WP2)
- the developed engine lubricant (WP4)

works together without technically failures and is suitably for a daily custom use.

Conclusions from field testing following the double strategy of adapting engines as well as the fuel will follow. First test results even show trends that this combination may achieve a high engine performance at minimum fuel consumption compared to diesel driven tractors while fitting with the emission limits.

- In the following chapters, the field testing parameters will be first explained along the tractor masterplan, then, the monitoring guidelines, partners, oil sorts, lubricants and tractors.
- After that information about the sources that can be used for the evaluation as log-books, fault reports, fuel supply and monitoring reports is provided.
- Based on this material, a validation will be worked out. A short introduction into the validation work is given.
- At least field testing conclusions are made.

2 Field testing parameters

2.1 Design of experiments

A major aim of the experiments is to obtain data from converted tractors running with pure 2G-PVO. Throughout the testing period, the testing participants report all relevant experiences to the project by use of logbooks, fault reports and any feedbacks.

The **tractor masterplan** describes the planned use and further conversions of the vehicles during the 2ndVegOil project period. It is the main document to organize and update the 2ndVegOil project field test. It is build up as a life cycle overview. Different background colours shall help to identify the concerned task and field test status of each tractor.

2.2 Monitoring guideline / Training documentation

VWP published a documentation for training purposes relating to the EU 2ndVegOil project field trials on John Deere tractors. Therein, guidelines for the correct servicing and operating of the tractors are described. The intention is to give every partner and participant of field testing best information about technical specifications and methods how to maintain the modified vehicles correctly and how to prevent damages. As well fault diagnosis techniques are introduced. Technical risks shall be reduced to a minimum.
Over all the main aspect of the field testing is to gain repeatable results. Only based thereon correct conclusions can be elaborated. The securing of servicing will be granted by workshops supported by VWP and local partners as well as by the logbooks and Fault reports.

2.3 Selection of local partners

All tractors were sold to the local farmers by John Deere. The local partners were identified with the focus on their skills and neighbourhood as close as possible around the same maintenance office/ John Deere Dealer. Additionally, “customer informations” were handed out to brief the operators on the technical changes of tractors due to the use of 2G-PVO fuels.

2.4 Tested oil sorts (fuels) and Q.A.

The development of 2ndVegOil treatment achieves better results in steady operating and durability of engines and filter elements over all seasons. To extend the possible basis of renewable raw materials, not only Pure Rape Seed Oil, but other pure oils shall be developed and tested, too. The following table provides the complete overview of the oils and the denotation system used in the project:

Code for seed	Code for oil	Type of oil
RS	2G-PVO-RS	2nd generation pure vegetable oil based on rape seed
SF	2G-PVO-SF	2nd generation pure vegetable oil based on sunflower
CS	2G-PVO-CS	2nd generation pure vegetable oil based on camelina sativa
MG	2G-PVO-MG	2nd generation pure vegetable oil based on maize germ
JA	2G-PVO-JA	2nd generation pure vegetable oil based on jatropha
blend	-	mixture of 2G-PVO-RS and 2G-PVO-CS

These different 2G-PVOs have all a higher quality standard then up-to-date used fuel oils of vegetable origin. They and blends of them will be used for testing purposes. Among others the 2G-PVOs contain less minerals compared to 1st generation pure vegetable oils (fuel oils corresponding e.g. to the German pre-norm DIN 51605). The main fuel is 2G-PVO-RS, the 2nd generation pure vegetable oil based on rape seed oil. All tractors in task T5.9 only used 2G-PVO-RS fuels produced by the partner Waldland until now. In the second phase of task T5.9, the other 2G-PVOs shall be used too. The results obtained with these fuels will be reported in the final deliverable D5.9.

According to the aims of WP3, fuel development, additives developed and produced by John Deere and Lubrizol are admixed to the 2G-PVO. The additives are so called Multi functional Diesel Additives (MFDA). They optimize the combustion and prevent the injection system to get affected by combustion residuals.
Waldland also delivers the test fuels. Quality assurance will be reached through a closed delivery chain from the oil press into the tractors´ fuel tanks. Oil samples of every batch are tested.

Only oil with a suitable quality (sum of P, Ca and Mg < 1,5 mg/kg), will be filled into intermediate bulk containers (IBC) for transportation. At participants place, solely extra filling stations that are connected to the IBC directly, are used for the 2G-PVO fuels. The participants also have to assure, that the IBCs are sheltered and secured from direct sun light. These measures shall prevent biological reactions of the 2G-PVO. For more information about 2G-PVO fuels please see the deliverables of WP3, fuel development.

IBC with mounted filling station

2.5 Engine lubricants

There are 2 different engine lubricants used in the project. They differ concerning ash forming behaviour. Oils with the specifications ACEA E7 and ACEA E9 are used (see table below). The partner Lubrizol provides the needed lubricants and monitors the tractors directly with regard to the lubricant performance and impact on the engine. For further information please see reports of WP4, Engine oil development.

Typical Chemical & Physical Results for Engine Lubricants

Oil Code		OS TBD	OS240946
Viscosity Grade		15W-40	15W-40
Formulation		**ACEA E7**	**ACEA E9**
DI		12.6% Lubrizol® 4986E	10.0% Lubrizol® 4980A
Booster		-	6.5% Lubrizol® 48007E
NDVM		7.7% Lubrizol® 7077	6.1% Lubrizol® 7075F
PPD		0.3% Lubrizol® 6662	0.2% Lubrizol® 6662
Base Oil		59.4% ExxonMobil 150N (Group I)	71.1% Chevron 220R (Group II)
Base Oil		20.0% ExxonMobil 600N (Group I)	6.1% Chevron 600R (Group II)
Typical physical & chemical properties			
Viscosity @ 100°C	cSt	14.40	16.30
Viscosity @ 40°C	cSt	107.2	-
Cold cranking @ -20°C	cP	6820	6685
HTHS	cP	4.02	4.08
Total base number	mgKOH/g	9.1	8.3
Sulphated ash	%	1.15	0.97
Phosphorus content	%	0.11	0.11
Sulphur content	%	0.66	0.4
Magnesium content	%	<0.001	<0.001
Calcium content	%	0.28	0.23
Potassium	%	<0.001	<0.001
Sodium	%	<0.001	<0.001
Zinc	%	0.12	0.12

Table source: Lubrizol Corporation

2.6 Tractor and engine types

For the fleet demonstration in the 2ndVegOil project, certain tractor models were selected. These models are the 6830 Premium, 6930 Premium, 7430 Premium and 7530 Premium tractors of John Deere. They are powered by the 6068 Powertech Plus engine at different power levels. The 6830 Premium and 6930 Premium tractors have got the CD6068HL481 engine and the 7430 Premium and 7530 Premium the CD6068HL482.

The two engine models differ in the stability of the crankshaft for instance, but not in major technological properties like air or fuel system. The different power levels are implemented by different ECU software versions. The 6068 Powertech Plus engines are four-valve engines with a high pressure common rail system for fuel injection. They are turbocharged and have an external exhaust gas recirculation (EGR) system including cooler to control NOx emissions.

Those tractor models were selected as they are the largest and most powerful tractors produced at the John Deere Werke Mannheim (JDWM). After evaluation of the market demand it is clear that mostly owners of large tractors with numerous operating hours demand a plant

oil powered tractor. In that case the highest saving potential is achieved and the investment in the engine technology is profitable.

3 Assessment of monitoring data

3.1 Tractor logbooks

VWP published logbooks that shall record the status of each tractor and the effected jobs. They have to be filled by the operator every day the tractor has been used. The documents are used for analysing each vehicle and to compare its behaviour with the rest of the fleet. Additionally, damages shall be prevented by checking the correct intervals and reading the trends e.g. history of consumption and oil levels. All partners are forced to check the continuous keeping of the logs. Especially, IBDI asks for missing results monthly as well as to improve the form if new knowledge requires so during the field test period.

3.2 Fault reports (tractors)

Each tractor is by default equipped with a command center that shows the most important operation parameters. Among others, failure indications can be read out here. Specific failure codes give notice of an unusual status of the tractor and indicate engine failures as well as general failures. Only the engine specific failure codes (ECU failure codes) are reported in the logbooks. All the same attention is to be given to damages of engine parts, being influenced by the use of 2G-PVO.

3.3 Fuel supply

The program partner Waldland leads the Work package 3, fuel development. Also the fuel supply will be granted and quality assured by Waldland by controlling development, production and delivery of the 2G-PVOs. The quality analysis reports, tractor logbooks as well as other reports are given to VWP to make conclusions.

3.4 Monitoring reports D5.7 from IBMER, Waldland, FRCUMA

Task 5.7 describes Milestone M5.9: “Monitoring results from IBMER, FRCUMA and Waldland. Targets are indicated when the 250 hours’ maintenance interval is met, engine power output is stable, engine oil analysis is okay, engine oil level stays stable. Material durability is okay if there are no visible leaks. (Month 36)”

The project partners support the preparation of the monitoring reports that compile all relevant data of the field testing. Each tractor is reviewed and evaluated in terms of:

- amount of filled fuels/ oils
- fuel consumption in relation to the effected job

- cold start behaviour
- achieved power performance
- history of engine oil level
- tested fuels and additives
- service intervals
- failure codes, errors and malfunctions
- achieved emission levels
- effects related to DPF
- effects to engine concerning deterioration and sedimentation due to combustion

4 Validation

The work package 5 objectives designate: *"Good engine performance will be considered to be achieved and indicated if the tractor's electronic engine control system shows zero failure on the original John Deere service advisor."* (only failure codes concerning engine operations will be noticed). And further on: *"The stable combustion and emission quality will be considered to be achieved if the monitored level of engine oil does not grow within the respective maintenance intervals. The target of maintenance interval for engine oil change and fuel filter change is 250 hours which will be proven by an engine oil analysis."*
Achieving these main targets will be evaluated based on tractor logbooks and service protocols. Therefore, the following data will be charted for test fleet tractors:

- Operating hours
- Operating hours per fuel filter change
- Operating hours per oil filter change
- Amount of used 2G-PVO
- Amount of added diesel

To get more detailed information for technical development new charts will be calculated as:

- Performance profile versus load levels
- Performance profile for different operating modes
- Engine oil level as a function of operating hours
- Load level development against operating hours
- Average fuel consumption against operating hours

4.1 Validation of basic data

Based on reported logbooks, the basic monitoring data were transferred into an excel sheet form. This sheet was especially developed for the concerns of this field test. The focus was on maintaining transparency of the raw data material and the possibility to crosscheck data entries with other sources like fuel-delivery reports or operation hour documentation in service protocols e.g.

To evaluate the tractors' history of consumption and oil level as well as to make it comparable to others, the operation modes (work no.) were divided into groups such as high load, medium load, low load and special OP mode 16. The classification is shown in the table below and based on following sources:

- „Erfahrungssätze für überbetriebliche Maschinenarbeiten 2009", Landwirtschaftskammer NRW
- www.llh-hessen.de/landwirtschaft/bw_vtec/text63.htm loadlevels (on 22.Dec.2009)

work	load level	consumption		
no.		L/h	%	
1	Plough	23	100%	high load
12	Forage loader	21	91%	
10	Mower	21	91%	
14	Manure Spreader	20	87%	
13	Slurry tank	19	83%	
8	Seeder (crop)	18	78%	
3	Disc harrow	16	70%	
7	Power harrow	14	61%	medium load
9	Baler	13	57%	
11	Tedder, windrower	13	57%	
5	Spreader	13	57%	
[8]	Seeder (maize)	12	52%	
4	Transport (on road)	12	52%	
2	Cultivator	10	43%	
6	Sprayer	6	26%	low load
15	Front loader work	5	22%	
16	OP mode 16 (others)			mode 16 load

Based thereon, calculations and diagrams could be made as follows:

- performance profile of tractors
- average fuel consumption (only over all applicable due to reporting modus)
- time between filter changes (up to now not correctly reported, not applicable)
- history of oil level

4.2 Power measurements

Before delivery of the 10 tractors of the task T5.9 phase 1, they were tested on the PTO test bench at John Deere in Mannheim. All measured powers showed to be in an acceptable range.

PTO - power measurement at JDWM (2009)

4.3 Overview field testing

Statistics and graphs will find out potentials of the field testing and will allow taking a closer look on fleet trends and single vehicles status.

4.4 Local test fleets

10 tractors are tested by project partners in France, Poland and Austria. Further tractors are tested in Germany. The project partners are FRCuma (France), IBMER (Poland), Waldland (Austria) and JDWM (Germany).

4.5 Conclusions

Finally, this interim view on the status of the field testing shows that the demonstration is ongoing as planed with only less discrepancies compared to the anticipated performance. Each tractor can be described as technically working. It is the base for the up-coming work of work package WP5.

The supply with 2G-PVO-RS was very good. Concerning the effects of additives to the behaviour of 2G-PVO-RS, no results can be reported yet. Monitoring the engine lubricants is arranged and will be revised by Lubrizol according to work package WP4.

The annual operating hours can be noticed as planed for the whole test fleet. Each tractor will reach a minimum of 500 operating hours a year.

The reported logbook entries showed some deficiencies and mistakes that could be noticed and at least discussed at the 3rd progress meeting in Lyon (27 January 2010). New logbook forms and additional briefing shall help to improve reporting for the remaining field testing period. Due to this learning process, a working report structure is build up to get information faster and as of good quality as for comparable result needed.

A final deliverable report D5.9 will follow in month 36. Further results can be expected.

5 References

- „Erfahrungssätze für überbetriebliche Maschinenarbeiten 2009“, Landwirtschafts-kammer NRW
- www.llh-hessen.de/landwirtschaft/bw_vtec/text63.htm loadlevels (on 22.Dec.2009)