

Ministry of Education and Science of Ukraine  
Mykolaiv National Agrarian University

ISSN 2313-092X  
E-ISSN 2411-9199

**Вісник аграрної науки** ————— Том 27, № 4  
**Причорномор'я**

*Науковий журнал*

**Ukrainian Black Sea Region**  
**Agrarian Science**

*Scientific Journal*

Volume 27, No. 4

Year of establishment: 1997  
Publication frequency: Four times a year

Mykolaiv  
2023

DOI: 10.56407/2313-092X/2023-27(4)

**Рекомендовано до друку та поширення  
через мережу Інтернет Вченою радою  
Миколаївського національного аграрного університету  
(протокол № 5 від 12 грудня 2023 р.)**

**Свідоцтво про державну реєстрацію  
друкованого засобу масової інформації  
Серія: KB № 25119-15059 ПР від 21 лютого 2022 р.**

**Журнал входить до переліку наукових фахових видань України категорії «Б»:**

з економічних, технічних, сільськогосподарських, ветеринарних наук за спеціальностями 051 – Економіка, 071 – Облік і оподаткування, 072 – Фінанси, банківська справа та страхування, 073 – Менеджмент, 075 – Маркетинг, 076 – Підприємництво, торгівля та біржова діяльність, 181 – Харчові технології, 183 – Технології захисту навколишнього середовища, 201 – Агрономія, 202 – Захист і карантин рослин, 204 – Технологія виробництва і переробки продукції тваринництва, 205 – Лісове господарство, 207 – Водні біоресурси та аквакультура, 208 – Агроінженерія, 281 – Публічне управління та адміністрування (Наказ Міністерства освіти і науки України від 07 травня 2019 р. № 612; від 11 липня 2019 р. № 975)

**Журнал представлено у наукометричних базах даних, репозитаріях:**

Google Scholar, Open Academic Journals Index,  
Національна бібліотека України імені В. І. Вернадського, IJIFACTOR,  
Directory of Research Journals Indexing | DRJI, Crossref,  
Фахові видання України, Dimensions, AGRIS, EBSCO

Вісник аграрної науки Причорномор'я : наук. журн. / [редкол.: В. С. Шибанін (голов. ред.) та ін.]. – Миколаїв : Миколаївський національний аграрний університет, 2023. – Т. 27, № 4. – 100 с.

**Адреса редакції:**

Миколаївський національний аграрний університет  
54008, вул. Георгія Гонґадзе, 9, м. Миколаїв, Україна,  
тел.: +38(0512) 70-93-54  
E-mail: [info@bsagriculture.com.ua](mailto:info@bsagriculture.com.ua)  
www: <https://bsagriculture.com.ua/uk>

**Recommended for printing and distribution  
via the Internet by the Mykolaiv National Agrarian University**  
(Minutes No. 5 of December 12, 2023)

**Certificate of state registration of the print media**  
Series: KB No. 25119-15059 PR of February 21, 2022

**The journal is included in the list of professional publications of Ukraine of category “B”:**

Economic, technical, agricultural, veterinary sciences by specialty 051 – Economics,  
071 – Accounting and taxation, 072 – Finance, banking and insurance, 073 – Management, 075 – Marketing,  
076 – Entrepreneurship, trade and exchange activity, 181 – Food technologies,  
183 – Environmental protection technologies, 201 – Agronomy, 202 – Protection and quarantine of plants,  
204 – Technology of production and processing of livestock products, 205 – Forestry,  
207 – Water bioresources and aquaculture, 208 – Agricultural engineering,  
281 – Public management and administration  
(Order of the Ministry of Education and Science of Ukraine of May 7, 2019 No. 612; of July 11, 2019 No. 975)

**The journal is presented at scientometric databases, repositories:**

Google Scholar, Open Academic Journals Index,  
National Library of Ukraine named after V. I. Vernadskyi, IJIFACTOR,  
Directory of Research Journals Indexing | DRJI, Crossref,  
Professional Editions of Ukraine, Dimensions, AGRIS, EBSCO

Ukrainian Black Sea Region Agrarian Science / Ed. by V. S. Shebanin (Editor-in-Chief) et al. Mykolaiv: Mykolaiv National Agrarian University, 2023. Vol. 27, No. 4. 100 p.

**Publishing Address:**

Mykolaiv National Agrarian University  
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine  
tel.: +38(0512) 70-93-54  
E-mail: [info@bsagriculture.com.ua](mailto:info@bsagriculture.com.ua)  
www: <https://bsagriculture.com.ua/en>

## Редакційна колегія

### Головний редактор

В'ячеслав Шебанін | д-р техн. наук, професор, ректор, Миколаївський національний аграрний університет, м. Миколаїв, Україна

### Національні члени редколегії

<b>Ірина Ксьонжик</b>	д-р екон. наук, професор, завідувач кафедри обліку і оподаткування, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Анастасія Полторак</b>	д-р екон. наук, доцент, завідувач кафедри менеджменту та маркетингу, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Наталя Сіренко</b>	д-р екон. наук, професор, завідувач кафедри фінансів, банківської справи та страхування, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Олена Зайцева</b>	канд. екон. наук, доцент, професор кафедри маркетингу, Державний торговельно-економічний університет, м. Київ, Україна
<b>Зоряна Мацук</b>	д-р екон. наук, професор, завідувач кафедри фінансів, Івано-Франківський національний технічний університет нафти і газу, м. Івано-Франківськ, Україна
<b>Альона Ключник</b>	д-р екон. наук, професор, завідувач кафедри публічного управління та адміністрування і міжнародної економіки, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Наталя Потриваєва</b>	д-р екон. наук, професор, професор кафедри обліку і оподаткування, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Олена Шебаніна</b>	д-р екон. наук, професор, декан факультету менеджменту, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Михайло Федорчук</b>	д-р с.-г. наук, професор, професор кафедри рослинництва та садово-паркового господарства, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Катерина Давиденко</b>	канд. с.-г. наук, доцент, старший науковий співробітник, завідувач відділу ентомології, фітопатології та фізіології, Український орден «Знак Пошани», науково-дослідний інститут лісового господарства і агролісомеліорації ім. Г.В. Висоцького, м. Харків, Україна
<b>Віталій Любич</b>	д-р с.-г. наук, професор, професор кафедри харчових технологій, Уманський національний університет садівництва, м. Умань, Черкаська область, Україна
<b>Олександр Жуков</b>	д-р біол. наук, професор, професор кафедри ботаніки та садово-паркового господарства, Мелітопольський державний педагогічний університет імені Богдана Хмельницького, м. Мелітополь, Запорізька область, Україна
<b>Ігор Коваленко</b>	д-р біол. наук, професор, декан факультету агротехнологій та природокористування, Сумський національний аграрний університет, м. Суми, Україна
<b>Віталій Пічура</b>	д-р с.-г. наук, професор, завідувач кафедри екології та сталого розвитку імені професора Ю.В. Пилипенка, ДВНЗ «Херсонський державний аграрно-економічний університет», м. Херсон, Україна
<b>Лідія Міщенко</b>	д-р біол. наук, професор, провідний науковий співробітник ННЦ «Інститут біології та медицини», Київський національний університет імені Тараса Шевченка, м. Київ, Україна
<b>Валентина Гамаюнова</b>	д-р с.-г. наук, професор, завідувач кафедри землеробства, геодезії та землеустрою, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Раїса Вожегова</b>	д-р с.-г. наук, професор, академік Національної академії аграрних наук України, директор Інституту зрошуваного землеробства Національної академії аграрних наук України, м. Херсон, Україна
<b>Сергій Крамаренко</b>	д-р біол. наук, професор, професор кафедри генетики, годівлі тварин та біотехнології, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Сергій Рубан</b>	д-р с.-г. наук, професор, завідувач кафедри генетики, розведення та біотехнології тварин, Національний університет біоресурсів і природокористування України, м. Київ, Україна
<b>Віктор Балацький</b>	д-р с.-г. наук, професор, завідувач лабораторії генетики, Інститут свинарства і агропромислового виробництва Національної академії аграрних наук України, м. Полтава, Україна

<b>Богдан Гутий</b>	д-р вет. наук, професор, професор кафедри фармакології та токсикології, Львівський національний університет ветеринарної медицини та біотехнологій ім. С.З. Гжицького, м. Львів, Україна
<b>Тетяна Димань</b>	д-р с.-г. наук, професор, проректор з освітньої, виховної та міжнародної діяльності, Білоцерківський національний аграрний університет, м. Біла Церква, Київська область, Україна
<b>Сергій Луговий</b>	д-р с.-г. наук, професор, завідувач кафедри генетики, годівлі тварин та біотехнології, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Антоніна Панфілова</b>	д-р с.-г. наук, професор, завідувач кафедри рослинництва та садово-паркового господарства, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Володимир Кондратенко</b>	канд. наук з прикл. матем., Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Віталій Ніценко</b>	д-р екон. наук, професор, професор кафедри підприємництва та маркетингу, Івано-Франківський національний технічний університет нафти і газу, м. Івано-Франківськ, Україна
<b>Ольга Яценко</b>	д-р екон. наук, професор, професор кафедри міжнародної торгівлі і менеджменту, Київський національний економічний університет імені Вадима Гетьмана, м. Київ, Україна
<b>Олена Петрова</b>	канд. с.-г. наук, доцент, в.о. завідувача кафедри переробки продукції тваринництва та харчових технологій, Миколаївський національний аграрний університет, м. Миколаїв, Україна
<b>Наталія Болгова</b>	канд. с.-г. наук, доцент кафедри технологій та безпечності харчових продуктів, Сумський національний аграрний університет, м. Суми, Україна
<b>Світлана Халатур</b>	д-р екон. наук, професор, завідувач кафедри фінансів, банківської справи та страхування, Дніпровський державний аграрно-економічний університет, м. Дніпро, Україна
<b>Михайло Сичов</b>	д-р с.-г. наук, професор, завідувач кафедри годівлі тварин та технології кормів ім. П.Д. Пшеничного, Національний університет біоресурсів і природокористування України, м. Київ, Україна
<b>Віталій Бех</b>	д-р с.-г. наук, професор, завідувач кафедри аквакультури, Національний університет біоресурсів і природокористування України, м. Київ, Україна
<b>Антоніна Дробітько</b>	д-р с.-г. наук, професор, декан факультету агротехнологій, Миколаївський національний аграрний університет, м. Миколаїв, Україна

#### **Міжнародні члени редколегії**

<b>Анна Бжозовська</b>	д-р екон. наук, професор кафедри бізнес-інформатики, Ченстоховський технологічний університет, м. Ченстохова, Польща
<b>Джулія Олбрехт</b>	д-р філософії, професор, професор кафедри харчування та медичних наук, Університет Небраски-Лінкольн, м. Лінкольн, Сполучені Штати Америки
<b>Борис Боінчан</b>	д-р с.-г. наук, професор, директор Державної установи Науково-дослідницький інститут польових культур «Селекція», м. Бельці, Республіка Молдова
<b>Ісаак Рашаль</b>	д-р біол. наук, професор, Інститут біології, Латвійський університет, м. Саласпілс, Латвія
<b>Антоніна Калініченко</b>	д-р с.-г. наук, професор Інституту технічних наук, Опольський університет, м. Опольце, Польща
<b>Віджай Вирендра</b>	PhD, професор, керівник, Центр розвитку сільських районів та технологій, Індійський технологічний інститут Делі, м. Делі, Індія
<b>Теодора Попова</b>	PhD, професор, Інститут зоотехнії Болгарської сільськогосподарської академії, м. Костинброд, Болгарія
<b>Астріда Міцейкене</b>	д-р екон. наук, професор, Університет Вітаутаса Великого, м. Каунас, Литва
<b>Мануела Тваронавічене</b>	PhD, професор, Даугавпілський університет, м. Даугавпілс, Латвія
<b>Інга Ковалевська</b>	Західнопоморський технологічний університет, кафедра генетики, факультет біотехнології та тваринництва, м. Щецин, Польща
<b>Василь Черлінка</b>	д-р біол. наук, доцент, університет Павла Йозефа Шафарика, м. Кошице, Словаччина

---

## Editorial Board

---

### Editor-in-Chief

Viacheslav Shebanin | Doctor of Technical Sciences, Professor, Rector, Mykolaiv National Agrarian University, Mykolaiv, Ukraine

### National Members of the Editorial Board

<b>Iryna Ksyonzhik</b>	Doctor of Economics, Professor, Professor of Accounting and Taxation, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Anastasiia Poltorak</b>	Doctor of Economics, Associate Professor, Head of the Department of Management and Marketing, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Natalia Sirenko</b>	Doctor of Economics, Professor, Head of the Department of Finance, Banking and Insurance, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Olena Zaitseva</b>	PhD in Economics, Associate Professor, Professor of the Department of Marketing, State University of Trade and Economics, Kyiv, Ukraine
<b>Zoriana Matsuk</b>	Doctor of Economics, Professor, Head of the Department of Finance, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
<b>Alyona Klyuchnik</b>	Doctor of Economics, Professor, Head of the Department of Public Administration and International Economics, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Natalia Potryvaieva</b>	Doctor of Economics, Professor, Professor of Accounting and Taxation, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Olena Shebanina</b>	Doctor of Economics, Professor, Dean of the Faculty of Management, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Mychailo Fedorchuk</b>	Doctor of Agriculture, Professor, Professor of the Department of Plant Breeding and Horticulture, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Kateryna Davydenko</b>	PhD in Agriculture, Associate Professor, Head of the Department of Entomology, Phytopathology and Physiology, Ukrainian Order "Badge of Honor", Research Institute of Forestry and Agroforestry named after H.V. Vysotskyi, Kharkiv, Ukraine
<b>Vitalii Liubych</b>	Doctor of Agriculture, Professor, Professor of the Department of Food Technologies, Uman National University of Horticulture, Uman, Cherkasy Region, Ukraine
<b>Olexander Zhukov</b>	Doctor of Biological Sciences, Professor, Professor of the Department of Botany and Horticulture, Melitopol State Pedagogical University named after Bohdan Khmelnytskyi, Melitopol, Zaporizhzhia Region, Ukraine
<b>Ihor Kovalenko</b>	Doctor of Biological Sciences, Professor, Dean of the Faculty of Agrotechnology and Nature Management, Sumy National Agrarian University, Sumy, Ukraine
<b>Vitalii Pichura</b>	Doctor of Agriculture, Associate Professor, Head of the Department of Ecology and Sustainable Development named after Professor Yu.V. Pilipenko, Kherson State Agrarian and Economic University, Kherson, Ukraine
<b>Lidiya Mishchenko</b>	Doctor of Biological Sciences, Professor, Leading Research Fellow, NSC "Institute of Biology and Medicine", Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
<b>Valentina Gamayunova</b>	Doctor of Agriculture, Professor, Head of the Department of Agriculture, Geodesy and Land Management, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Raisa Vozhehova</b>	Doctor of Agriculture, Professor, Academician of the National Academy of Agrarian Sciences of Ukraine, Director of the Institute of Irrigated Agriculture National Academy of Agrarian Sciences of Ukraine, Kherson, Ukraine
<b>Sergei Kramarenko</b>	Doctor of Biological Sciences, Professor, Professor of Genetics, Animal Feeding and Biotechnology, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Sergey Ruban</b>	Doctor of Agriculture, Professor, Acting Head of the Department of Genetics, Breeding and Biotechnology of Animals, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine

<b>Viktor Balatsky</b>	Doctor of Agriculture, Senior Researcher, Head of the Laboratory of Genetics, Institute of Pig Breeding and Agroindustrial Production of National Academy of Agrarian Sciences of Ukraine, Poltava, Ukraine
<b>Bogdan Gutyj</b>	Doctor of Veterinary Sciences, Professor, Professor of Pharmacology and Toxicology, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Lviv, Ukraine
<b>Tetyana Dyman</b>	Doctor of Agriculture, Professor, Vice-Rector for Educational, Educational and International Activities, Bila Tserkva National Agrarian University, Bila Tserkva, Kyiv Region, Ukraine
<b>Serhiy Luhovyy</b>	Doctor of Agriculture, Professor, Head of the Department of Genetics, Animal Feeding and Biotechnology, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Antonina Panfilova</b>	Doctor of Agriculture, Professor, Head of the Department of Plant Breeding and Horticulture, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Volodymyr Kondratenko</b>	PhD in Applied Mathematics, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Vitalii Nitsenko</b>	Doctor of Economics, Professor, Department of Entrepreneurship and Marketing, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
<b>Olha Yatsenko</b>	Doctor of Economics, Professor, Department of International Trade and Management, Kyiv National Economic University named after Vadym Hetman, Kyiv, Ukraine
<b>Olena Petrova</b>	PhD in Agriculture, Associate Professor, Acting Head of the Department of Livestock Product Processing and Food Technologies, Mykolaiv National Agrarian University, Mykolaiv, Ukraine
<b>Natalia Bolgova</b>	PhD in Agriculture, Associate Professor of the Department of Technology and Food Safety, Sumy National Agrarian University, Sumy, Ukraine
<b>Svitlana Khalatur</b>	Doctor of Economics, Professor, Head of the Department of Finance, Banking and Insurance, Dnipro State Agrarian and Economic University, Dnipro, Ukraine
<b>Mykhailo Sychov</b>	Doctor of Agriculture, Professor, Head of the Department of Animal Feeding and Feed Technology named after P.D. Pshenychnyj, National University of Environmental Sciences of Ukraine, Kyiv, Ukraine
<b>Vitaliy Bekh</b>	Doctor of Agriculture, Professor, Head of the Department of Aquaculture, National University of Environmental Sciences of Ukraine, Kyiv, Ukraine
<b>Antonina Drobitko</b>	Doctor of Agriculture, Professor, Dean of the Faculty of Agricultural Technology, Mykolaiv National Agrarian University, Mykolaiv, Ukraine

#### **International Members of the Editorial Board**

<b>Anna Brzozowska</b>	Doctor of Economics, Professor of Business Informatics, Czestochowa University of Technology, Czestochowa, Poland
<b>Albrecht Julie</b>	Doctor of Philosophy, Professor, Professor of the Department of Nutrition and Medical Sciences, University of Nebraska-Lincoln, Lincoln, United States of America
<b>Boris Boincean</b>	Doctor of Agriculture, Professor, Director of the State Institution Scientific Research Institute of Field Crops "Seleksiia", Bălți, Republic of Moldova
<b>Isaak Rashal</b>	Doctor of Biological Sciences, Professor, Institute of Biology, University of Latvia, Salaspils, Latvia
<b>Antonina Kalinichenko</b>	Doctor of Agriculture, Professor of the Institute of Technical Sciences, Opole University, Opole, Poland
<b>Vijay Virendra</b>	PhD, Professor, Head, Center for Rural Development and Technology, Delhi Indian Institute of Technology, Delhi, India
<b>Teodora Popova</b>	PhD, Professor, Institute of Animal Science Bulgarian Agricultural Academy, Kostinbrod, Bulgaria
<b>Astrida Miceikienė</b>	Doctor of Economics, Professor, Vytautas Magnus University, Kaunas, Lithuania
<b>Manuela Tvaronavičienė</b>	PhD, Professor, Daugavpils University, Daugavpils, Latvia
<b>Inga Kowalewska-Luczak</b>	West Pomeranian University of Technology, Department of Genetics, Faculty of Biotechnology and Animal Breeding, Szczecin, Poland
<b>Vasyl Cherlinka</b>	Doctor of Biological Sciences, Associate Professor, Pavel Josef Šafarik University, Kosice, Slovakia

## ЗМІСТ / CONTENTS

<b>А. В. Дробітько, Т. В. Качанова</b> Агроекологічне обґрунтування технологій вирощування зернових та зернобобових культур в умовах Південного Степу України.....	9
<b>A. Drobitko, T. Kachanova</b> Agroecological substantiation of technologies for growing grain crops in the conditions of the Southern Steppe of Ukraine.....	9
<b>Д. В. Бабенко, Н. А. Доценко, О. А. Горбенко, І. В. Бацуrowsька</b> Дослідження характеру руху подрібненої маси по поверхні решіт сепаратора насіння овочевих та баштанних культур .....	18
<b>D. Babenko, N. Dotsenko, O. Gorbenko, I. Batsurovska</b> Study of the nature of the movement of the crushed mass on the surface of the sieves of the vegetable and melon seed separator .....	18
<b>М. І. Гиль, О. І. Каратєєва, М. М. Тимофіїв</b> Біотехнологія регуляції відтворювальних функцій порід <i>Bos primigenius taurus</i> .....	36
<b>M. Gill, O. Karatieieva, M. Tymofiv</b> Biotechnology of regulation of reproductive functions of <i>Bos primigenius taurus</i> .....	36
<b>О. Г. Афанасьєва, Л. М. Голосна, Г. М. Лісова, А. І. Кривенко, Р. В. Соломонов</b> Ефективні джерела стійкості пшениці озимої в селекції на імунітет.....	52
<b>O. Afanasyeva, L. Golosna, G. Lisova, A. Kryvenko, R. Solomonov</b> Use of effective sources of winter wheat resistance in breeding for immunity.....	52
<b>О. С. Садовий, О. І. Савенков, І. М. Сидорика, Ю. Г. Щербак, А. А. Кондратьєва</b> Підвищення ефективності машин і механізмів агропромислового комплексу застосуванням підшипників ковзання з криволінійними твірними внутрішньої циліндричної поверхні.....	60
<b>O. Sadovoy, O. Savenkov, I. Sydoryka, Yu. Shcherbak, A. Kondratieva</b> Increasing the efficiency of machines and mechanisms of the agro-industrial complex using sliding bearings with curvilinear generators of the internal cylindrical surface.....	60
<b>В. М. Польовий, М. Г. Фурманець, О. В. Сніжок, Л. А. Ященко</b> Вплив побічної продукції за різних способів обробітку ґрунту на врожайність ріпаку озимого в умовах Західного Лісостепу.....	71
<b>V. Poliovyi, M. Furmanets, O. Snizhok, L. Yashchenko</b> Influence of by-products under different methods of soil cultivation on the yield of winter rape in the Western Forest-Steppe.....	71
<b>В. Б. Рябошапка, Р. Д. Лисенко</b> Проблеми та перспективи створення сучасних сільськогосподарських газодизелів: літературний огляд .....	81
<b>V. Ryaboshapka, R. Lysenko</b> Problems and prospects of creating modern agricultural gas diesel engines: A literature review.....	81
<b>О. І. Трембіцька, С. В. Богдан</b> Оцінка впливу дефекату та органічних добрив на продуктивність буряків цукрових в умовах Поділля.....	90
<b>O. Trembitska, S. Bohdan</b> Evaluation of the effect of sugar mud and organic fertilizers on the productivity of sugar beets in the conditions of Podillia .....	90



## Problems and prospects of creating modern agricultural gas diesel engines: A literature review

### Vadym Ryaboshapka

PhD in Technical Sciences, Senior Lecturer  
Vinnytsia National Agrarian University  
21008, 3 Sonyachna Str., Vinnytsia, Ukraine  
<https://orcid.org/0000-0003-1812-1030>

### Roman Lysenko\*

Master  
Vinnytsia National Agrarian University  
21008, 3 Sonyachna Str., Vinnytsia, Ukraine  
<https://orcid.org/0009-0007-9867-5581>

**Abstract.** In conditions of constant growth in the cost of traditional oil products and their shortage, the issue of using alternative fuels becomes urgent. The purpose of the article is to identify ways of using alternative types of fuel for the operation of diesel engines. Research methods – analysis and verification of data obtained from scientific publications, which are part of the world-famous scient metric databases, for the relevance of the subject of research. The research results reveal the advantages and disadvantages of dual-fuel engines operating on gaseous fuel with diesel fuel additive, the impact of this type of engine on emissions and toxicity of exhaust gases, in particular nitrogen oxides  $NO_x$ . The application of the so-called gas nozzle and the cross-section of the holes of its nozzles are substantiated. It was analysed and established that the most economically expedient is the use of liquefied petroleum gas for the operation of diesel engines by implementing the gas-liquid cycle; it was found that the most promising for this is gas cylinder equipment of the so-called 4th generation. A retrospective analysis of studies of internal combustion engines with gas cylinder equipment showed an increase in motor resource when using gaseous fuels, as well as the negative side of using gaseous fuels, which consists in reduced power when converting carburettor engines, however, the use of these fuels for the operation of diesel engines completely eliminates this disadvantage. Based on the research analysis, the influence of the ignition dose, when the engine is operating on the gas-diesel cycle, on the performance at different loads was also established, and a recommendation was found to switch to the diesel cycle from the gas-diesel cycle at loads less than 30% of the nominal one. The optimal scheme for the implementation of the gas-diesel cycle, which is relevant and promising for more widespread energy and transport vehicles, has been substantiated and selected. Based on the analysed schemes, it was established that the scheme that can be taken as a basis for further research in this direction is the scheme of the DG-Flex BOSCH gas-diesel system. The practical value of the work lies in the justification of complex conversion with partial replacement of diesel fuel with liquefied petroleum gas as the most rational way of converting serial diesel engines into dual-fuel engines

**Keywords:** transport; liquefied petroleum gas; gas cylinder equipment; power supply system

### Article's History:

Received: 27.07.2023  
Revised: 07.11.2023  
Accepted: 12.12.2023

### Suggested Citation:

Ryaboshapka, V., & Lysenko, R. (2023). Problems and prospects of creating modern agricultural gas diesel engines: A literature review. *Ukrainian Black Sea Region Agrarian Science*, 27(4), 81-89. doi: 10.56407/bs.agrarian/4.2023.81.

\*Corresponding author



## INTRODUCTION

In the conditions of an increase in the share of fuel costs, many commercial transport operators are thinking about the possibility of compensating for the increase in prices by switching to gas. However, such radical methods as converting diesel engines to gas engines have their drawbacks. In the search for an optimal solution, an alternative option is often considered – the use of a gas-diesel engine, which combines the advantages of a traditional diesel and gas cylinder equipment (HBO) (Kabeyi & Olanrewaju, 2023; Liu *et al.*, 2023). Gas-diesel engines at the beginning of the 21<sup>st</sup> century (Shyamkishore *et al.*, 2023) are considered as a separate type of engines that are widely used in many sectors of the economy, in particular in agriculture, and which also have environmental advantages over traditional fuels (Emaish *et al.*, 2021). A dual-fuel gas-diesel engine is a power plant, which is additionally equipped with equipment for work involving gas (Sain *et al.*, 2018). The principle of operation of such an installation consists in the simultaneous supply of two types of fuel to the combustion chamber. The main fuel is gas of various origins, and the additional fuel is diesel oil. In this case, diesel fuel is supplied in a much smaller volume than usual. In the gas-diesel design (Zhu & Fan, 2022), diesel fuel acts as a kind of ignition for the air-gas mixture. The supply of diesel fuel is due to the fact that the ignition temperature of gas is higher than that of diesel fuel, and that is why at the moment of compression, in the combustion chamber, the gas itself cannot ignite. For its ignition during the compression stroke, a small amount of diesel fuel is fed into the combustion chamber. Based on the above, it can be concluded that the gas-diesel dual-fuel engine retains the ability to work only on diesel fuel, but is not capable of working on one gas. The use of gas-diesel engines in agriculture is a rather promising direction for the development of agricultural engineering, which preserves all the advantages of a diesel engine in terms of energy capabilities and improving environmental and economic parameters when using gas fuel (Mathur *et al.*, 2022; Saleem, 2022). The existing data of scientific research by scientists for the year 2022 (Bagagiolo *et al.*, 2022; Kutkovetska *et al.*, 2022) allow us to state the prospects for the development of the use of gas-diesel engines, but today there is no systematic approach to the use of this type of fuel equipment in agriculture.

The purpose of the work was to assess the prospects of using the gas-diesel engine system in agriculture. For this purpose, an analysis of modern scientific data on the use of auto-tractor diesel engines with the involvement of liquefied petroleum gas (LPG) was carried out. A search for scientific sources was conducted

in the Google Scholar, Scopus, Web of Science databases of publications for the period 2000-2023 according to the set goal. Publications that lacked statistical justification, duplicated results, or contained data that could not be further verified were excluded from further analysis.

## GAS-DIESEL ENGINES: PROBLEMS OF THEIR MODIFICATION AND OPERATION

Attention is drawn to the use of the term in the world scientific literature for an engine that uses both conventional diesel fuel and liquefied gas – “liquefied gas and diesel dual-fuel engine” (Ashok *et al.*, 2015). In publications from 2010-2020, dual-fuel LPG engines are modified diesel engines that use LPG as the primary fuel and diesel as the secondary fuel (Pielecha & Sidorowicz, 2021; Pham *et al.*, 2022). Dual-fuel LPG engines have good thermal efficiency at high power, but performance is lower at part-load conditions due to poor utilization of the energy potential of the combined fuel. This problem can be overcome by using a variety of factors such as fuel injection rate, injection timing, gaseous fuel composition and intake charge conditions to improve the performance, combustion and emissions of dual-fuel engines. However, the question of the most effective way to transfer a diesel engine to dual-fuel mode remains open (Bennour, 2021).

Several publications (Murthy *et al.*, 2021; Al-Dawody *et al.*, 2022) review the results of studies conducted to improve the performance, combustion parameters, and emissions of LPG and diesel engines. The data of the work showed that the use of liquefied gas in a diesel engine is one of the effective methods of reducing toxic emissions, but at the same time, under conditions of partial load, there is a drop in the efficiency and effective power of the diesel engine. Specifically, a diesel fuel blend with 10% LPG (Liquefied Petroleum Gas) is shown to produce a 5.35% reduction in  $NO_x$ , while diesel with 20 and 30% LPG emits 9.05 and 16.5% less  $NO_x$ , respectively. Increasing the percentage of LPG in diesel results in lower soot concentrations because LPG has a lower carbon to hydrogen ratio. The lowest ability to emit smoky combustion is found for fuel with 30% LPG, where a reduction of 7.4% is achieved. It was concluded that the optimal mixing ratio is 30% LPG.

One of the main problems of combining diesel fuel with LPG is the gas density, which is very low under ambient conditions (Anisimov *et al.*, 2016). This affects the fuel supply system, and to inject the required mass of fuel, a much larger cross-sectional area of the fuel injector is required than that of a diesel injector.

In modern units, the operation of gas cylinder equipment (HBO) on a diesel engine is performed according to the principle of the 4th generation of HBO gasoline engines with a slight difference in the fuel supply system (Semenov *et al.*, 2015). If in the gasoline analogue, the engine starts working on gasoline, and then uses only gas, then HBO on a diesel engine uses both types of fuel at the same time, feeding it to the cylinders in turn at different strokes (Kalinichenko *et al.*, 2019). The principle of operation of gas in a diesel engine is based on the fact that both types of fuel alternate in supply. The launch is carried out only on diesel fuel. In the first stroke, a portion of gas fuel mixed with air enters the cylinders, which is then compressed, and at the end of the compression stroke, an igniting dose of diesel fuel is supplied, which self-ignites from compression and ignites the gas-air mixture. The lower the octane number of gas fuel, the faster the gas burns with less heat release, and accordingly, the more it can replace diesel fuel (Poliakov *et al.*, 2015).

In 2010, the use of natural gas in a compressed form became the most widespread in cars with engines with external mixture formation and forced (spark) ignition (Melnyk *et al.*, 2018; Singh *et al.*, 2021). Usually, cylinders for storing natural gas under high pressure, gas reducers, electromagnetic valves and other gas equipment are additionally installed on a car with a carburetor engine, which ensures the possibility of engine operation on gas. The versatility of the power supply of such a vehicle (gasoline or natural gas) is also its disadvantage, since the full potential of the high detonation resistance of natural gas is not used (Lopatin, 2020). At the beginning of the 2020s, carburetor engines in agriculture recede into the background, due to their obsolescence and inefficiency, as well as unsatisfactory environmental parameters (Hua, 2021). However, there are publications about the experience of gas cars manufactured in the USSR (Union of Soviet Socialist Republics) running on compressed natural gas (CNG), which revealed a number of positive aspects (Poliakov & Mariyanko, 2014). The researchers established an increase in the motor resource of the converted engine by 35-40, an extension of the term of use of candles by 30-40%, as well as a reduction in engine oil consumption by postponing the replacement by 2-3 times. However, the same researchers noted a number of disadvantages of using the dual-fuel mode, in particular – a decrease in power by 18-20%, which leads to a decrease in maximum speed by 5-6%, respectively, and an extension of the acceleration time by 24-30%, a decrease in the maximum angles overcome by the climb and mileage limits at one gas station. At the same time, the carrying capacity decreases significantly

(9-14%) due to the increase in the weight of the car due to the gas cylinder equipment.

The difficulty of using gas fuel in diesel engines is related to their poor flammability, low cetane number, and high ignition temperature (Zaharchuk & Zaharchuk, 2020). Therefore, to organize the operation of a diesel on natural gas, the gas-diesel process is used, which consists in feeding a dose of flammable diesel fuel into the cylinders, which ensures the ignition of the gas-air mixture (Kryshchuk *et al.*, 2018). Gas-diesel engine start-up and idling work only on diesel fuel. In other modes, an increase in engine power is achieved by increasing the gas fuel supply. The amount of incendiary dose delivery is 15-20% of the total fuel consumption.

### LPG AS A PROMISING GAS-DIESEL ENGINE COMPONENT

In addition to liquid fuel – diesel, gaseous fuels such as hydrogen, compressed natural gas (CNG), diesel methyl ether (DME), biogas, and LPG are used in combination (Caban *et al.*, 2013; Kumar *et al.*, 2018). Liquefied petroleum gas (LPG) and CNG turned out to be the most popular among gas fuels in 2010-2020 due to the availability and simplicity of units for their use (Wei & Geng, 2016; Singh *et al.*, 2020). LPG fuel can be used as gas or liquid phase in diesel engines. In the gas phase, air from the intake is fumigated and an LPG-air mixture is formed in the intake manifold (Mueller & Guenther, 2023). When LPG is a liquid, it is mixed with diesel fuel at a pressure above 0.5 MPa. LPG is mixed with diesel fuel under pressure by a high-pressure pump. A high-pressure pump supplies a mixture of diesel fuel and gas to the injector. The liquid phase of LPG is injected either as a mixture of LPG with diesel fuel at the same time by an injector or separately by a second injector (Vo *et al.*, 2022).

In gas-phase LPG diesel engines, vaporized LPG is fed into the cylinder with intake air and the LPG-air mixture is compressed as in a conventional diesel engine. The LPG-air mixture is not self-igniting due to the high auto-ignition temperature. A small amount of diesel fuel, called pilot, is injected to ignite the LPG-air mixture. Pilot diesel fuel injected by conventional diesel injection equipment only reduces a small fraction of engine power output (Canelada & Tischer, 2007). The use of LPG in the gas phase is quite well studied in many scientific works (Saleh, 2008; Ciniviz, 2010; Mohsen *et al.*, 2023). It was concluded that this combination leads to better engine efficiency, reduction of emissions of solid particles and smoke.

M. Ciniviz (2010) carried out a study of the effectiveness of the use of dual fuel (diesel / LPG) in a diesel engine on power and emissions. A gas control valve

system was designed to supply liquefied gas at a rate of 30% to the intake manifold. The experimental results showed that the engine power, engine torque and specific fuel consumption were improved due to the dual fuel supply. As a result of the use of dual-fuel engines, compared to single-fuel engines, torque and engine power increased by 5.8%, and  $NO_x$  emissions and excess air ratio decreased by 5.9 and 1/9%, respectively. Furthermore,  $CO_2$  emissions were shown to be lower than in single-fuel mode, as  $CO$  emissions cannot be converted to  $CO_2$  in dual-fuel mode.

Also P. Stålhammar *et al.* (2011) studied the performance and emissions of a 100% LPG direct injection diesel engine. They added di-tert-butyl peroxide (DTBP) and aliphatic hydrocarbon (AHC) to LPG fuel to increase the cetane number. The stable operation of the diesel in a wide range was demonstrated. The engine load range has been extended with the improvement of LPG cetane number. Several different LPG mixtures were obtained by varying the concentration of DTBP and AHC. LPG and only AHC fuel blends increased  $NO_x$  emissions compared to diesel operation. The results of the experiment showed that the thermal efficiency of a diesel engine running on liquefied gas was similar in basic parameters to running on pure diesel fuel. From the point of view of emissions of exhaust gases, their reduction was ascertained when using different mixtures of LPG, DTBP and AHC.

Attempts to convert YaMZ-240 GD and YaMZ-240 H1-GD diesels to gas diesel were carried out by a group of researchers from Ukraine (Kovbasenko *et al.*, 2016). The obtained data indicate the prospects of this type of conversion using the regulation of the starting ignition volume of a diesel engine with an electromagnet. Regulation of fuel supply to both diesel and gas in this case is carried out by separate screws. It is planned to switch to purely diesel mode when the load in the combined cycle is reduced below 20-30% of the maximum, which establishes the use of gas-diesel mode as the basic one. Also, the same scientists noted the improvement of environmental characteristics in the dual-fuel mode of engine operation in the form of a certain decrease in the content of carbohydrates and carbon monoxide, as well as the smokiness of exhaust gases. With the proposed mechanism of conversion to gas-diesel, slight differences in the emission of carbon oxides were noted in the two modes of engine operation. As for nitrogen oxide, the researchers even found an increase in the content of this compound when operating in gas-diesel mode. There are also significant disadvantages of this system in the form of an increase in the engine design due to the hydraulic amplifier of the gas dispenser drive and the impossibility of correcting the volume of

flammable diesel fuel, which limits the amount of replacement of diesel with gas. When using a gas-diesel installation on a YAMZ-236 GD engine with mechanical multi-mode rotation control, the ignition dose of diesel fuel was 30%. The above results of scientists from Ukraine coincide with the conclusions of researchers from other countries and indicate the prospects for further development of gas-diesel engines, however, the very scheme of conversion to gas-diesel requires further improvement.

Also, work on the creation of engines with a gas-diesel type of power supply is carried out both in scientific institutions and by commercial companies in many countries of the world. In particular, as a good example of this is the development of the Bosch company Diesel-Gas System – Bosch (DG-Flex) (D'Agosto *et al.*, 2014). However, data on its installation on agricultural machinery has not been found. As standard, DG-Flex consists of sensors: detonation, air temperature, coolant temperature, phase, crankshaft, gas temperature and pressure, as well as a lambda probe and an electronic gas supply control unit. The use of the Diesel-Gas System – Bosch (Fontaras *et al.*, 2012; Gopalakrishnan & Tischer, 2014) leads to a significant improvement in environmental characteristics in the form of a six-fold reduction in solid emissions and nitrogen oxide volume compared to the diesel cycle. Also, a positive effect is saving money and reducing the volume of fuel consumption. However, some scientists (Owczuk *et al.*, 2019) point to the imperfection of this design in the form of the complexity of the system itself, a mixed method of power regulation with a throttle and a complicated control algorithm of this system.

#### **PROBLEMS AND PROSPECTS OF USING A GAS-DIESEL ENGINE IN AGRICULTURE**

The main problem in the practical application of a gas-diesel engine in agriculture is the choice of the principle of rebuilding the power system for the conversion of serial tractor engines (Mattarelli *et al.*, 2019; Giorgi *et al.*, 2020). Fundamental in this case is the difference in the two concepts of converting diesel engines to a gas-diesel power model. The most radical method is the complete replacement of fuel, which is accompanied by spark ignition of the gas-air mixture (Mattarelli *et al.*, 2021). This method involves complete disassembly of the diesel fuel equipment followed by reprogramming of the compression ratio, reducing it to 11-14 units, and at the end, the system is equipped with gas equipment (ignition system, cylinder, gas pipeline). The technical parameters of this conversion method correspond to the parameters of the engine



before the rebuild, and the environmental indicators are significantly improved, since in general this engine runs on gas fuel (Kabeyi & Olanrewaju, 2022). After the conversion, the engine can no longer run on diesel fuel, the reverse operation is economically impractical. Experiments were conducted by researchers M. Kabeyi & O. Olanrewaju (2022) to study the efficiency of a diesel engine with natural gas and diesel fuel in dual fuel mode with different proportions of diesel fuel 10-100% at 10% intervals. The results show that the overall efficiency of using CNG was lower than that of 100% diesel. At lower loads the efficiency was significantly lower and at higher outputs the performance was much better but still lower than when the diesel was running at 100%. The specific fuel consumption of the engine at 1.1 kW when operating on a mixture with 90% CNG was 68% higher than when the engine was operating in purely diesel mode. However, at 2.8 kW, the specific fuel consumption of the engine when running on 90% CNG was only 7% higher. Exhaust gas emissions show that in gas-liquid mode  $CO_2$  and smoke emissions were lower due to the lower carbon to hydrogen ratio in CNG.  $CO$  emissions were higher due to the lower air-to-fuel ratio, as the injection of LNG into the intake air replaced some of the air in the intake tract.

The next option is the dual-fuel mode of rebuilding the diesel engine. In general, it is a variant of the standard gas-diesel engine with the predominant use of gas as the base fuel and diesel for the ignition of the gas mixture (Dasappa & Sridhar, 2011). However, the use of a specific ratio of diesel and gas in this scheme is a rather variable indicator that primarily depends on the type of gas fuel, individual design features of both the diesel engine and the gas plant. An important factor in this version of the gas-diesel engine is the possibility of using a full-fledged purely diesel mode, which is carried out by the operator himself.

In view of the energy crisis, many alternative fuels have been tested worldwide for use in internal combustion engines (Wang *et al.*, 2022; Das *et al.*, 2022). The conducted review indicates the perspective of conducting research on the use of natural gas as an alternative fuel, corresponds to the trend of finding new types of fuel with improved environmental performance and preservation of the technical characteristics of the diesel engine. Taking into account the above data, one of the promising types in terms of economy is the use of a diesel engine with an LPG system in agriculture. An increase in the number of publications on the study of optimal conversion schemes of diesel engines using biogas and LPG is attracting attention (Wei & Geng, 2016; Singh *et al.*, 2020). Analysis of the publications of scientists from Ukraine on this issue

indicates that most of the research is devoted to the conversion of outdated engines or the use of biogas, which is quite debatable regarding the availability of this type of fuel in Ukraine (Zhuk, 2022).

Gas-diesel engines in agriculture can be rebuilt by completely replacing diesel fuel with gas, which leads to environmental improvement, but the loss of the ability to use diesel fuel. On the other hand, a dual-fuel mode can be applied, where gas is used as the base fuel, but diesel remains for ignition, giving greater flexibility of use.

## CONCLUSIONS

The conducted review indicates the relevance of developing new schemes for conversion of serial diesel engines to dual-fuel mode using alternative fuel mixtures. Alternative types of gaseous fuels available on the market, such as hydrogen, CNG, diesel methyl ether, biogas and LPG have significant differences in the implementation of engine conversion and technical characteristics after modification. There are several options for converting a diesel engine to work in dual-fuel mode, but there are no generally accepted schemes for modifying diesel engines in agriculture. The diesel engine conversion schemes proposed for 2010-2020 are technically quite complex and require significant intervention in the engine layout, which increases the cost of this manipulation. It was established that the use of dual-fuel engines has a significant thermal efficiency at high power, but at the same time they are characterized by lower performance under partial load conditions due to insufficient use of the energy potential of the combined fuel. They are trying to overcome this problem by optimizing the power and combustion parameters. The optimal way to modify a diesel engine into a dual-fuel mode remains a debatable issue, which prevents serial conversion. Taking into account the available opportunities in Ukraine regarding the availability of various types of gaseous fuel, the most economically feasible type of gaseous fuel when converting a diesel engine is the use of liquefied petroleum gas. Taking into account the available schemes, the scheme of the DG-Flex BOSCH fuel supply system, which provides for the supply of liquefied petroleum gas to the intake manifold and its mixing with air on the intake stroke, and the supply of an ignition dose of diesel fuel, using modern diesel fuel equipment, is promising for the operation of a dual-fuel engine according to the gas-diesel cycle Common Rail. However, the existing schemes need to be improved, taking into account the existing shortcomings in the form of software and maintenance complexity, as well as a multi-level throttle control system. As a result of this

review, the existence of the problem of developing energy-efficient and environmentally safe gas-diesel systems, in particular, for use in the agriculture of Ukraine, was established, which requires further research with the aim of implementation in practical activities. None.

## ACKNOWLEDGEMENTS

## CONFLICT OF INTEREST

## REFERENCES

- [1] Al-Dawody, M.F., Al-Chlahawi, K.K.I., & Al-Farhany, K.A. (2022). Numerical simulation of the effect of LPG blending on the characteristics of a diesel engine. *Heat Transfer*, 51(2), 1918-1938. doi: [10.1002/htj.22381](https://doi.org/10.1002/htj.22381).
- [2] Anisimov, V., Ryaboshapka, V., & Ivanovs, S. (2016). Calculation of the performance indicators of machine and tractor aggregates using biofuel. *Journal of Research and Applications in Agricultural Engineering*, 61(3), 16-20. Retrieved from <https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-a64917a2-d68a-4e5f-8c73-97f953e35735>.
- [3] Ashok, B., Ashok, S.D., & Kumar, C.R. (2015). LPG diesel dual fuel engine - a critical review. *Alexandria Engineering Journal*, 54(2), 105-126. doi: [10.1016/j.aej.2015.03.002](https://doi.org/10.1016/j.aej.2015.03.002).
- [4] Bagagiolo, G., Vigoroso, L., De Paolis, G., Caffaro, F., Cavallo, E., & Pampuro, N. (2022). Barriers to adoption of alternative fuels for agricultural machinery: A study on a group of Italian farmers. *SAE Technical Paper*, 2022-24-0028. doi: [10.4271/2022-24-0028](https://doi.org/10.4271/2022-24-0028).
- [5] Bennour, M. (2021). *LPG-diesel dual fuel engine: Literature review and CFD analysis*. Retrieved from <http://repository.enp.edu.dz/jspui/handle/123456789/10357>.
- [6] Caban, J., Gniecka, A., & Holeša, L. (2013). Alternative fuels for diesel engines. *Advances in Science and Technology. Research Journal*, 7(20), 70-74. doi: [10.5604/20804075.1073063](https://doi.org/10.5604/20804075.1073063).
- [7] Canelada, M.M., & Tischer, F. (2007). DualFuel system, diesel and natural gas - optimizing the concept. *SAE Technical Paper*, 2007-01-2616. doi: [10.4271/2007-01-2616](https://doi.org/10.4271/2007-01-2616).
- [8] Ciniviz, M. (2010). Full load performance and emission characteristics of a LHR diesel engine for different insulation levels. *Technological Applied Sciences*, 5(2), 40-50. Retrieved from <https://dergipark.org.tr/en/pub/nwsatecapsci/issue/20180/213935>.
- [9] D'Agosto, M. de A., Oliveira, C.M., & Assumpção, F. do C. (2014). Energy alternatives for urban public transportation in Rio de Janeiro: A Life Cycle Inventory (LCI) analysis. *TRANSPORTES*, 22(1), 76-97. doi: [10.14295/transportes.v22i1.736](https://doi.org/10.14295/transportes.v22i1.736).
- [10] Das, A.K., Sahu, S.K., & Panda, A.K. (2022). Current status and prospects of alternate liquid transportation fuels in compression ignition engines: A critical review. *Renewable and Sustainable Energy Reviews*, 161, 112358. doi: [10.1016/j.rser.2022.112358](https://doi.org/10.1016/j.rser.2022.112358).
- [11] Dasappa, S., & Sridhar, H.V. (2011). Performance of a diesel engine in a dual fuel mode using producer gas for electricity power generation. *International Journal of Sustainable Energy*, 32(3), 1-16. Retrieved from <https://www.researchgate.net/publication/239792335>.
- [12] Emaish, H., Abualnaja, K.M., Kandil, E.E., & Abdelsalam, N.R. (2021). Evaluation of the performance and gas emissions of a tractor diesel engine using blended fuel diesel and biodiesel to determine the best loading stages. *Scientific Reports*, 11(1), 9811. doi: [10.1038/s41598-021-89287-0](https://doi.org/10.1038/s41598-021-89287-0).
- [13] Fontaras, G., Manfredi, U., Martini, G., Dilara, P., & Deregibus, G. (2012). Experimental assessment of a Diesel-LPG dual fuel supply system for retrofit application in city busses. *SAE Technical Paper*, 012-01-1944. doi: [10.4271/2012-01-1944](https://doi.org/10.4271/2012-01-1944).
- [14] Giorgi, C., Teimuraz, K., & Romanov, T. (2020). The possibility and analysis of using gas as an alternative fuel in the diesel engine. *Trans Motauto World*, 5(2), 68-70. Retrieved from <https://stumejournals.com/journals/tm/2020/2/68>.
- [15] Gopalakrishnan, M., & Tischer, F.P. (2014). Torque model for a dual fuel engine. *SAE Technical Paper*, 2014-01-2417. doi: [10.4271/2014-01-2417](https://doi.org/10.4271/2014-01-2417).
- [16] Hua, Y. (2021). Ethers and esters as alternative fuels for internal combustion engine: A review. *International Journal of Engine Research*, 24(1), 178-216. doi: [10.1177/14680874211046480](https://doi.org/10.1177/14680874211046480).
- [17] Kabeyi, M., & Olanrewaju, O. (2023). Diesel to gas engine power plant conversion: A review and preliminary design for an operating power plant. *Journal of Energy Management and Technology*, 7(2), 103-115. doi: [10.22109/JEMT.2022.292982.1312](https://doi.org/10.22109/JEMT.2022.292982.1312).

- [18] Kabeyi, M.J.B., & Olanrewaju, O.A. (2022). Feasibility of conversion from diesel engine to natural gas power plants. In *IECON 2022 - 48th Annual Conference of the IEEE Industrial Electronics Society* (pp. 1-7). doi: [10.1109/IECON49645.2022.9968428](https://doi.org/10.1109/IECON49645.2022.9968428).
- [19] Kalinichenko, A., Havrysh, V., & Atamanyuk, I. (2019). The acceptable alternative vehicle fuel price. *Energies*, 12(20), 3889. doi: [10.3390/en12203889](https://doi.org/10.3390/en12203889).
- [20] Kovbasenko, S., Nazarenko, M., Petrenko, V., & Golyk, A. (2016). Prospects for the use of natural gas by vehicle engines in Ukraine. In *Systems and means of motor transport: Selected problems* (Vol. 7; pp. 159-164). Rzeszow: Oficyna Wydawnicza Politechniki Rzeszowskiej.
- [21] Kryshchop, S., Panchuk, M., Kozak, F., Dolishnii, B., Mykytii, I., & Skalatska, O. (2018). Fuel economy raising of alternative fuel converted diesel engines. *Eastern-European Journal of Enterprise Technologies*, 4(8), 6-13. Retrieved from [http://www.irbis-nbuv.gov.ua/cgi-bin/irbis\\_nbuv/](http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/).
- [22] Kumar, N., Sonthalia, A., & Pali, H.S. (2018). Alternative fuels for diesel engines: New frontiers. In *Diesel and gasoline engines*. London: IntechOpen. doi: [10.5772/intechopen.80614](https://doi.org/10.5772/intechopen.80614).
- [23] Kutkovetska, T.O., Kravchenko, V.V., & Petrychenko, E.A. (2022). Prospects for the development of gas-diesel power tools in modern agricultural production. *Scientific Notes of the Tavrida V.I. Vernadsky National University. Series: Technical Sciences*, 33(6), 13-16. Retrieved from <https://lib.udau.edu.ua/handle/123456789/9497>.
- [24] Liu, L., Zhang, M., & Liu, Zh. (2023). A review of development of natural gas engines. *International Journal of Automotive Manufacturing and Materials*, 2(1), 16. doi: [10.53941/ijamm0201004](https://doi.org/10.53941/ijamm0201004).
- [25] Lopatin, O.P. (2020). Natural gas combustion in diesel engine. *IOP Conference Series: Earth and Environmental Science*, 421(7), 072019. doi: [10.1088/1755-1315/421/7/072019](https://doi.org/10.1088/1755-1315/421/7/072019).
- [26] Mathur, S., Waswani, H., Singh, D., & Ranjan, R. (2022). Alternative fuels for agriculture sustainability: Carbon footprint and economic feasibility. *AgriEngineering*, 4(4), 993-1015. doi: [10.3390/agriengineering4040063](https://doi.org/10.3390/agriengineering4040063).
- [27] Mattarelli, E., Rinaldini, C.A., & Savioli, T. (2019). Dual fuel (natural gas diesel) for light-duty industrial engines: A numerical and experimental investigation. In K. Srinivasan, A. Agarwal, S. Krishnan, & V. Mulone (Eds.), *Natural gas engines* (pp. 297-328). Singapore: Springer. doi: [10.1007/978-981-13-3307-1\\_11](https://doi.org/10.1007/978-981-13-3307-1_11).
- [28] Mattarelli, E., Rinaldini, C.A., Savioli, T., & Scignoli, F. (2021). Optimization of a high-speed dual-fuel (natural gas-diesel) compression ignition engine for gen-sets. *SAE International Journal of Engines*, 14(3), 369-386. Retrieved from <https://www.jstor.org/stable/27039294>.
- [29] Melnyk, V., Voytsevivska, T., & Sumer, A. (2018). Studying main technical-operating characteristics of the alternative fuels for diesel internal combustion engines. *Scientific Works of Vinnytsia National Technical University*, 2. Retrieved from <https://works.vntu.edu.ua/index.php/works/article/view/540>.
- [30] Mohsen, M.J., Al-Dawody, M.F., Jamshed, W., El Din, S.M., Abdalla, N.S.E., Abd-Elmonem, A., ... Shah, H.H. (2023). Experimental and numerical study of using of LPG on characteristics of dual fuel diesel engine under variable compression ratio. *Arabian Journal of Chemistry*, 16(8), 104899. doi: [10.1016/j.arabjc.2023.104899](https://doi.org/10.1016/j.arabjc.2023.104899).
- [31] Mueller, F., & Guenther, M. (2023). Comparison of premixed fuel and premixed charge operation for propane-diesel dual-fuel combustion. *SAE Technical Paper*, 2023-24-0059. Retrieved from <https://www.sae.org/publications/technical-papers/content/2023-24-0059/>.
- [32] Murthy, K., Srinivas, V.G., & Kumar, S. (2021). Modeling and prediction of  $NO_x$  emission in an LPG-diesel dual-fuel CI engine. *Heat Transfer*, 50(7), 6847-6867. doi: [10.1002/htj.22206](https://doi.org/10.1002/htj.22206).
- [33] Owczuk, M., Matuszewska, A., Kruczyński, S., & Kamela, W. (2019). Evaluation of using biogas to supply the dual fuel diesel engine of an agricultural tractor. *Energies*, 12(6), 1071. doi: [10.3390/en12061071](https://doi.org/10.3390/en12061071).
- [34] Pham, Q., Park, S., Agarwal, A.K., & Park, S. (2022). Review of dual-fuel combustion in the compression-ignition engine: Spray, combustion, and emission. *Energy*, 250, 123778. doi: [10.1016/j.energy.2022.123778](https://doi.org/10.1016/j.energy.2022.123778).
- [35] Pielecha, I., & Sidorowicz, M. (2021). Effects of mixture formation strategies on combustion in dual-fuel engines - a review. *Combustion Engines*, 184(1), 30-40. doi: [10.19206/CE-134237](https://doi.org/10.19206/CE-134237).
- [36] Poliakov, A.P., & Mariyanko, B.S. (2014). Study of the effect on gas-diesel performance of improving the power supply system using a gas release device. *Scientific Works of Vinnytsia National Technical University*, 2. Retrieved from <http://ir.lib.vntu.edu.ua/bitstream/handle/123456789/4793/405.pdf?sequence=3>.
- [37] Poliakov, A.P., Galushchak, O.O., & Galushchak, D.O. (2015). Technique of motor vehicle indices calculation while transition of its engine for operation at the mixture of diesel and biodiesel fuels. *TEHNOMUS - New Technologies and Products in Machine Manufacturing Technologies*, 22, 76-81. Retrieved from <http://inmad.vntu.edu.ua/portal/static/OAA9A0E8-0C4E-484D-BFAC-4C2CF5DF8066.pdf>.

- [38] Sain, M., Kaur, M., Singh, M., & Kumar, S. (2018). Development of a dual fuel system to operate tractor on biogas. *International Journal of Pure & Applied Bioscience*, 6(1), 1710-1720. doi: [10.18782/2320-7051.8065](https://doi.org/10.18782/2320-7051.8065).
- [39] Saleem, M. (2022). Possibility of utilizing agriculture biomass as a renewable and sustainable future energy source. *Heliyon*, 8(2), E08905. doi: [10.1016/j.heliyon.2022.e08905](https://doi.org/10.1016/j.heliyon.2022.e08905).
- [40] Saleh, H.E. (2008). Effect of variation in LPG composition on emissions and performance in a dual fuel diesel engine. *Fuel*, 87(13-14), 3031-3039. doi: [10.1016/j.fuel.2008.04.007](https://doi.org/10.1016/j.fuel.2008.04.007).
- [41] Semenov, V.G., Komaha, V.P., & Ryaboshapka, V.B. (2015). The simulation of the combustion process in a tractor and combine diesel engines running on different fuels by using more refined models I.I. Vibe, based on the approximation experimental data. *Technology, Energy, Transport of Agricultural Industry*, 1(91), 52-58. Retrieved from <http://socrates.vsau.org/repository/getfile.php/10269.pdf>.
- [42] Shyamkishore, I., Mundra, S., & Bhande, R. (2022). Alternative transportation fuels. *World Journal of Advanced Engineering Technology and Sciences*, 7(2), 044-053. doi: [10.30574/wjaets.2022.7.2.0123](https://doi.org/10.30574/wjaets.2022.7.2.0123).
- [43] Singh, A.P., Mustafi, N.N., Sharma, Y.C., & Agarwal, A.K. (2020). Introduction to alternative fuels and their utilization strategies in internal combustion engines. In *Fuels and their utilization strategies in internal combustion engines* (pp. 3-6). Singapore: Springer. doi: [10.1007/978-981-15-0418-1\\_1](https://doi.org/10.1007/978-981-15-0418-1_1).
- [44] Singh, G., Dogra, D., Ramana, R., Chawla, J., Sutar, P.S., Sagare, V.S., ... Thipse, S.S. (2021). Development of dual fuel (diesel + CNG) engine for off-road application. *SAE Technical Paper*, 2021-26-0119. doi: [10.4271/2021-26-0119](https://doi.org/10.4271/2021-26-0119).
- [45] Stålhammar, P., Erlandsson, L., Willner, K., & Johannesson, S. (2011). *Demonstration and evaluation of dual-fuel technology*. Malmo: Svenskt Gastekniskt Center. Retrieved from <https://www.osti.gov/etdeweb/servlets/purl/1035259>.
- [46] Vo, T.C., Tran, D.L., Sy, N.Q., Khai, C.Q., Nhan, N.T., & Hao, L.V.M. (2022). A study on LPG injection based speed regulator for dual fuel diesel engine. *Journal of Technical Education Science*, 72A, 1-9. doi: [10.54644/jte.72A.2022.1264](https://doi.org/10.54644/jte.72A.2022.1264).
- [47] Wang, Y., Cao, Q., Liu, L., Wu, Y., Liu, H., Gu, Z., & Zhu, C. (2022). A review of low and zero carbon fuel technologies: Achieving ship carbon reduction targets. *Sustainable Energy Technologies and Assessments*, 54, 102762. doi: [10.1016/j.seta.2022.102762](https://doi.org/10.1016/j.seta.2022.102762).
- [48] Wei, L., & Geng, P. (2016). A review on natural gas/diesel dual fuel combustion, emissions and performance. *Fuel Processing Technology*, 142, 264-278. doi: [10.1016/j.fuproc.2015.09.018](https://doi.org/10.1016/j.fuproc.2015.09.018).
- [49] Zaharchuk, V., & Zaharchuk, O. (2020). Indexes of gas engine converted from a tractor diesel. *Trans Motauto World*, 5(2), 71-73. Retrieved from <https://stumejournals.com/journals/tm/2020/2/71>.
- [50] Zhu, Y., & Fan, L. (2022). Fuel delivery system for alternative fuel engines: A Review. In A.K. Agarwal, & H. Valera (Eds.), *Potential and challenges of low carbon fuels for sustainable transport* (pp. 67-95). Singapore: Springer. doi: [10.1007/978-981-16-8414-2\\_4](https://doi.org/10.1007/978-981-16-8414-2_4).
- [51] Zhuk, G.V. (2022). Prospects for the production of alternative automotive fuel in Ukraine: Transcript of the report at the meeting of the Presidium of the National Academy of Sciences of Ukraine on June 8, 2022. *Visnyk of the National Academy of Sciences of Ukraine*, 8, 19-24. doi: [10.15407/visn2022.08.019](https://doi.org/10.15407/visn2022.08.019).



## Проблеми та перспективи створення сучасних сільськогосподарських газодизелів: літературний огляд

### Вадим Борисович Рябошапка

Кандидат технічних наук, старший викладач  
Вінницький національний аграрний університет  
21008, вул. Сонячна, 3, м. Вінниця, Україна  
<https://orcid.org/0000-0003-1812-1030>

### Роман Дмитрович Лисенко

Магістр  
Вінницький національний аграрний університет  
21008, вул. Сонячна, 3, м. Вінниця, Україна  
<https://orcid.org/0009-0007-9867-5581>

**Анотація.** В умовах постійного зростання вартості традиційних нафтопродуктів та їх дефіциту, актуальним постає питання використання альтернативних палив. Метою статті є виявлення шляхів використання альтернативних видів палива для роботи дизельних двигунів. Методи досліджень – аналіз та верифікація даних отриманих з наукових публікацій, що входять до всесвітньо відомих наукометричних баз, на актуальність предмету досліджень. Результатами досліджень є виявленні переваги й недоліки двопаливних двигунів, що працюють на газоподібному паливі з присадкою дизельного палива, вплив цього типу двигунів на викиди та токсичність відпрацьованих газів, зокрема окисів азоту  $NO_x$ . Обґрунтовано застосування так званої газової форсунки та поперечного перерізу отворів її розпилювачів. Проаналізовано та встановлено, що найбільш економічно доцільним є використання для роботи дизельних двигунів зрідженого нафтового газу шляхом реалізації газорідного циклу; виявлено, що найбільш перспективним для цього є газобалонне обладнання так званого 4-го покоління. Ретроспективний аналіз досліджень двигунів внутрішнього згорання з газобалонним обладнанням, показав збільшення моторесурсу при використанні газоподібних палив, а також негативну сторону використання газоподібних палив, яка полягає у зниженні потужності при переобладнанні карбюраторних двигунів, однак використання цих палив для роботи дизелів повністю нівелює цей недолік. На основі аналізу досліджень, встановлено також вплив запальної дози, при роботі двигуна по газодизельному циклі, на показники роботи при різних навантаженнях та знайдено рекомендацію переходити на дизельний цикл з газодизельного при навантаженнях менших за 30 % від номінального. Обґрунтовано та вибрано оптимальну схему реалізації газодизельного циклу, що є актуальною і перспективною для більш розповсюджених енергетичних та транспортних засобів. Виходячи з проаналізованих схем, встановлено, що схемою, яку можна взяти за основу при подальших дослідженнях цього напрямку – це схема газодизельної системи DG-Flex BOSCH. Практична цінність роботи полягає в обґрунтуванні комплексного переобладнання з частковим заміщенням дизельного пального зрідженим нафтовим газом як найбільш раціонального способу переведення серійних дизельних двигунів в двопаливні

**Ключові слова:** транспорт; зріджений нафтовий газ; газобалонне обладнання; система живлення

# ВІСНИК АГРАРНОЇ НАУКИ ПРИЧОРНОМОР'Я

*Науковий журнал*

**Том 27, № 4. 2023**

Заснований у 1997 р.  
Виходить чотири рази на рік

Оригінал-макет видання виготовлено у видавничому відділі  
Миколаївського національного аграрного університету

**Відповідальний редактор:**

Д. Чохленко

**Редагування англomовних текстів:**

С. Воровський, К. Касьянов

**Комп'ютерна верстка:**

О. Глінченко

Підписано до друку 12 грудня 2023 р.

Формат 60\*84/8

Умов. друк. арк. 11,7

Наклад 300 прим.

**Адреса видавництва:**

Миколаївський національний аграрний університет  
54008, вул. Георгія Гонґадзе, 9, м. Миколаїв, Україна,

тел.: +38(0512) 70-93-54

E-mail: [info@bsagriculture.com.ua](mailto:info@bsagriculture.com.ua)

www: <https://bsagriculture.com.ua/uk>

# UKRAINIAN BLACK SEA REGION AGRARIAN SCIENCE

*Scientific Journal*

**Volume 27, No. 4. 2023**

Year of establishment: 1997  
Publication frequency: Four times a year

The original layout of the publication was made in the Publishing Department  
of Mykolaiv National Agrarian University

**Managing Editor:**

D. Chokhlenko

**Editing English-language texts:**

S. Vorovsky, K. Kasianov

**Desktop publishing:**

O. Glinchenko

Signed for print of December 12, 2023  
Format 60\*84/8  
Conventional printed pages 11.7  
Circulation 300 copies

**Publishing Address:**

Mykolaiv National Agrarian University  
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine  
tel.: +38(0512) 70-93-54  
E-mail: [info@bsagriculture.com.ua](mailto:info@bsagriculture.com.ua)  
www: <https://bsagriculture.com.ua/en>