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RICE STRAW AND HUSKS AS A RAW FOR BIOFUELS PRODUCTION DEPENDING ON FERTILIZATION AND SEEDING RATES

Introduction. Energy deficit is a daunting challenge recently faced by humanity which urges scientists to actively search for effective alternatives of conventional energy sources. One of the most promising ways of obtaining energy is its accumulating by biomass. The effectiveness of producing alternative biological fuels is determined by rational selection of plants types and how intensively the plants form biomass of the necessary chemical composition [1]. Considering the dependence on gas imports, which price has tripled over the past five years for Ukraine, it's necessary to search for alternative energy sources and implement strong energy policy and energy saving. A number of programs and regulations developed and adopted in this country aim to search for alternative energy sources and introducing energy intensive technologies under the Energy Strategy of Ukraine till 2030. Currently, the country imports 60% of energy, and by 2030 this dependence should be reduced to 11% [2].

Farm production in Ukraine has significant potential of biomass available for producing energy. Its main components are the energy crops and agricultural residues. Among the latter, the greatest energy potential is offered by the residues of sunflower production (stalks, husks), somewhat less – by residues of buckwheat and rice production [1].

Analysis of recent publications. Favorable climate of Southern Ukraine and availability of rice irrigation systems provide the chances to obtain good yields of high quality rice grain, leaving, at the same time, the significant amounts of by-products in the form of straw, husk and bran which are sources of raw materials for solid biofuel [3].

In Ukraine, with 22-25 ha rice cultivation area, the gross harvests of paddy rice in 2010 amounted to 150.1 thousand tones, and in 2011 – 169.9 thousand tones. The harvest of rice straw is about 170 thousand tones; should it be used as a source of alternative energy, the rice regions of Ukraine could get heat energy equivalent to the amount released during combustion of 62 million m^3 of gas [4]. In Kazakhstan, the technology of producing biofuel from the rice straw consists of grinding dried raw material and pressing the obtained powder into briquettes under high pressure. The products manufactured in this way are three times cheaper than diesel fuel [5]. An integral part of the rice grain is the husk which is separated from the grain during processing. In the weight part, the portion of husk makes 15-20% of the total mass of rice grain. Thus, we observe the annual growth of a large amount of valuable energetic plant raw materials which have not yet found an effective application. Considering the quite long list of ways to use the by-product of rice cultivation, the problem of wastes recycling should not arise; however, due to a number of reasons stemmed from economic and social factors, most of them find no practical application [6, 7]. But the fundamental reason is the lack of technology package that would consider the local conditions; at the same time, a fairly large volume of information on many manufacturing processes is easily accessible; also, development of technological parameters of production requires relatively small amount of data.

Aim of research. Establishing optimal and cost-based levels of fertilization and seeding rates for rice varieties ensuring production of high-quality groats and usage of the byproducts as raw material for biofuels.

Research methodology. To establish the influence of the main agronomic cultivation techniques of modern rice varieties in the South of Ukraine on the qualitative characteristics of grain and raw materials for biofuels, the field experiments were conducted in 2011-2012 in the fields of Institute of rice of NAAS at Krasnoznam'yanska irrigation system area. The experiment crop management practices met the recommendations of Institute of rice of NAAS, the land treatment and mechanization rate were typical for rice farms in the South of Ukraine except for the factors of interest. The soil at test plots was meadow-chestnut, moderately loamy, residual alkaline. The top soil contained humus 2.27%, lightly hydrolyzed nitrogen by method of Tyurin & Kononova – 4.8 mg/100 g soil, labile phosphorus – 3.9, potassium – 31 mg/100 g soil by method of Machygin, pH of aqueous recovery – 7,9. The rice seeds were planted by ‘Klen 1,5C’ seeder. The harvest was collected by direct combine harvesting by ‘Yanmar’ small-sized combine followed by adjusting the grain to the standard characteristics: 100% purity and 14% humidity.

The experiments were carried out as follows:

Factor A – variety:	Factor B – fertilizers doze:	Factor C – seeding rate:
1. Vikont;	1. $N_0P_0K_0$;	1. 5 million seeds/ha;
2. Premium	2. $N_{90}P_{30}K_0$;	2. 7 million seeds/ha;
	3. $N_{180}P_{60}K_0$	3. 9 million seeds/ha

The results of the experiments were calculated by analysis of variance using the application software MSExsel and Statistica 5.0 [8].

Research results. Assessment of bioenergy potential of rice varieties showed that by-products (straw and husk) of Vikont and Premium breeds demonstrate the highest values of energy output; these varieties were studied to establish how the agronomic factors affect the formation of rice productivity with the final products meant for food and straw and husk being a source of bioenergy plant material as a solid biofuel.

On average, over the two years of the experiment, the yields ranged from 3,53-9,01 t/ha (Table 1); it should be noted that Vikont variety formed larger harvests compared to Premium variety, an average of the experiment being 7.13 and 5.71 t/ha, respectively. According to our data, the crop yield of the researched rice varieties was in direct proportion to the use of mineral fertilizers and seeding rates.

Thus, the lowest value of this rate was observed at minimal values of the studied factors – 4.53 and 3.53 t/ha respectively for Vikont and Premium breeds. The increase of the seeding rate of Vikont rice variety with $N_0P_0K_0$ led to decrease in grain yield, but the difference between options remained within the research. When seeding the rice of Premium variety at the rate of 9 million seeds/ha with applied $N_{90}P_{30}K_0$, the 0.79 t/ha decrease in the yield was observed compared to the usual seeding rate of 9 million seeds/ha. The biggest yields were obtained under applied $N_{180}P_{60}K_0$ with seeding rate of 9 million seeds/ha for Vikont and Premium breeds at the levels of 9 and 8 t/ha, respectively.

Table 1

Crop yield of rice grains depending on the variety, fertilization and crop seeding rates, t/ha (average for 2011-2012)

Variety (factor A)	Seeding rates, million seeds per ha (factor C)	Doze of fertilizers (factor B)			Average (factor A)	Average (factor C)
		$N_0P_0K_0$	$N_{90}P_{30}K_0$	$N_{180}P_{60}K_0$		
Vikont	5	4,53	6,98	7,25	7,13	5,70
	7	6,37	7,50	8,27		6,67
	9	6,29	7,95	9,01		6,89
Premium	5	3,53	5,50	6,38	5,71	
	7	4,39	5,92	7,59		
	9	4,86	5,13	8,09		
Average (factor B)		5,00	6,50	7,77		

LSD (5%):
2011 p.: A – 0,29; B – 0,35; C – 0,35; AB – 0,50; AC – 0,50; BC – 0,61; ABC – 0,87
2012 p.: A – 0,25; B – 0,31; C – 0,31; AB – 0,44; AC – 0,44; BC – 0,54; ABC – 0,76

The key features of cereal qualities of rice grain may vary depending on growing conditions, methods of harvesting, processing and storage, but they keep the varietal character.

Establishing of rice grain quality showed that for two years of research, the average weight of 1000 grains was the greatest for the Premium variety with seeding rate of 5 million seeds/ha under applied $N_{180}P_{60}K_0$ – 31.2 g, and the least – with seeding rate of 9 million seeds/ha under applied $N_{90}P_{30}K_0$ – 28.3 g. For the Vikont variety, the weight of 1000 grains was greatest with seeding rate of 5 million seeds/ha under applied $N_0P_0K_0$ – 30.1 g, and the least – with seeding rate of 9 million seeds/ha under applied $N_{90}P_{30}K_0$ was 28.8 g.

The largest output of cereal was demonstrated by Vikont variety at the seeding rate of 9 million seeds/ha under applied $N_{90}P_{30}K_0$ – 68.8%; the same variety, however, showed the lowest output at seeding rate of 7 million similar seeds per the area unit under applied $N_{180}P_{60}K_0$ – 66.1%. The biggest output of whole kernel was demonstrated by Vikont variety - 77.9% with seeding rate of 9 million seeds/ha under applied $N_{90}P_{30}K_0$, and the lowest proportion of whole kernels in total cereal output was in Vikont variety – 62.2% with seeding rate of 9 million seeds/ha without fertilizers.

It was found that the amount of rice by-products is proportional to the amount of the yield obtained. The average amount of straw in experiment made 9.11 t/ha for two years, with its highest value of 16.08 t/ha for Vikont variety, and 10.18 t/ha for Premium variety (Table 2).

Table 2

Amount of straw obtained in the experiment variants, t/ha (average for 2011-2012)

Variety (factor A)	Seeding rates, million seeds/ha (factor C)	Doze of fertilizers (factor B)			Average (factor A)	Average (factor C)
		$N_0P_0K_0$	$N_{90}P_{30}K_0$	$N_{180}P_{60}K_0$		
Vikont	5	5,16	8,71	11,71	10,50	7,85
	7	8,95	8,97	13,57		9,35
	9	9,47	11,91	16,08		10,16
Premium	5	5,57	7,62	8,32	7,73	
	7	6,12	8,32	10,18		
	9	6,75	6,56	10,16		
Average (factor B)		7,00	8,68	11,67		

LSD (5%):
2011 p.: A – 0,32; B – 0,39; C – 0,39; AB – 0,55; AC – 0,55; BC – 0,68; ABC – 0,95
2012 p.: A – 0,25; B – 0,31; C – 0,31; AB – 0,44; AC – 0,44; BC – 0,54; ABC – 0,76

It is worth to mention that increased fertilization led to increased amount of straw for both studied varieties of rice: on average, 1.4 times for Vikont variety and 1.3 times for Premium variety. Increased seeding rates for Vikont variety under applied $N_{90}P_{30}K_0$, $N_{180}P_{60}K_0$ led to increase of amount of straw on average by 14%; however, this increase was insignificant for Premium variety, except for $N_{90}P_{30}K_0$ option with seeding rate of 9 million seeds/ha which resulted in 27% decrease of the amount of straw.

Rice growing and next grain processing generate heavytonnage wastes in the form of husk. The analysis of rice grain determined the amount of husk and its sensitivity to various agronomic factors.

According to two-year data, the amount of husk was in range of 0.98-2.20 t/ha for Vikont variety and 0.77-1.88 t/ha for Premium variety (Table 3), with the highest

Table 3

Amount of husk obtained in the experiment variants, t/ha (average for 2011-2012)

Variety (factor A)	Seeding rates, million seeds/ha (factor C)	Doze of fertilizers (factor B)			Average (factor A)	Average (factor C)
		$N_0P_0K_0$	$N_{90}P_{30}K_0$	$N_{180}P_{60}K_0$		
Vikont	5	0,98	1,67	1,63	1,68	1,28
	7	1,61	1,79	1,86		1,58
	9	1,44	1,91	2,20		1,63
Premium	5	0,77	1,31	1,31	1,31	
	7	1,02	1,39	1,81		
	9	1,14	1,18	1,88		
Average (factor B)		1,16	1,54	1,78		

LSD (5%):
2011 p.: A – 0,24; B – 0,29; C – 0,29; AB – 0,41; AC – 0,41; BC – 0,51; ABC – 0,71;
2012 p.: A – 0,22; B – 0,27; C – 0,27; AB – 0,38; AC – 0,38; BC – 0,47; ABC – 0,66

rates observed under high fertilization with the seeding rate of 9 million seeds/ha, which is obviously explained by the formation of bigger amount of biomass per area unit due to high doses of nitrogen fertilizers. The essential difference in amounts of husk between fertilization options is observed only at lower fertilization rates for Vikont variety; for Premium variety, the difference remains within research. This value was less influenced by seeding rates: for instance, the output of husk from both rice varieties was almost at the same level with the seeding rates of 7 and 9 million of similar grains per area unit, except for Vikont variety under applied $N_{180}P_{60}K_0$.

The results of the researches of 2011-2012 suggest that the optimal combination of rice farming techniques leads to high yields of the crop, and at the same time, to significant amounts of by-products suitable for further use.

To assess the influence of agronomic factors on the rice production technology, we made the economic evaluation that results from field researches and provides initial phase of introducing these results into production. The profit from the sale of grain and by-products ranged from 0.32 to 7.9 thousand UAH per area unit for cultivation of Vikont a variety, and from 0.60 to 3.81 thousand UAH for Premium variety. It should also be noted that there are three unprofitable options for Premium variety: under applied $N_0P_0K_0$ with seeding rate of 5 and 7 million seeds/ha and under applied $N_{90}P_{30}K_0$ with seeding rate of 9 million of similar seeds per hectare.

Institute of rice of NAAS and its Experimental farm have developed and introduced to the production the program of transition from the traditional energy sources (natural gas) for drying grain and seeds and heating office premises and technical facilities to non-traditional ones which use biomass originating from cultivating of crops.

When using the straw as a source of energy, the fuel costs are reduced by 10.3 times compared to the natural gas necessary to dry 1 ton of grain. The transition from gas heat generators to the biomass heat generators leads to annual cost cutout of 192.3 thousand UAH, and the payback period is 1.14 year.

An important element of the implementation of the energy-saving program is the use of rice husk. The administrative offices, schools, cultural centers, kindergartens and other buildings can be heated by boilers with power from 15 kW to 500 kW.

To become suitable for fuel, the rice husk is to be briquetted. The screw press helps to obtain square briquettes without binding components. The principle of the press operation is based on continuous extrusion process, its output passes through the following stages: extrusion, forming, surface annealing which gives the briquette the dark brown color. Influenced by pressure and temperature, the natural compound lignin – is plasticized and secreted to the briquette surface creating a protective shell. The press output is 4 tons of briquetted raw materials per hour, i.e. a 7-hour-shift can produce 2 tons of high-quality environmentally friendly solid fuel. The using of fuel briquettes instead of the natural gas for heating premises leads to annual cost cutout of 237.9 thousand UAH, and the payback period is 1.6 year.

Conclusions. The biggest yields of rice grains were obtained under applied mineral fertilizers $N_{180}P_{60}K_0$ with seeding rate of 9 million of similar seeds per hectare for Vikont and Premium breeds at the levels of 9 and 8 t/ha, respectively. Thus, the optimal combination of rice farming techniques leads to high yields of the crop, and at the same time, to significant amounts of by-products suitable for further use.

From the economic point of view, it is profitable to grow rice and use the by-products of Vikont and Premium varieties under applied fertilizers $N_{180}P_{60}K_0$ and with seeding rate of 9 million of similar seeds per area unit.

Should the rice straw be used as a source of alternative energy, the rice regions of Ukraine could get heat energy equivalent to the amount released during combustion of 62 million m^3 of natural gas. The economic effect of the transition from gas heat generators to the biomass heat generators leads to annual cost cutout of 192.3 thousand UAH, and the payback period is 1.14 year.

An additional source of alternative energy in rice farming is the rice husk. The payback of launcing a rice husk briquetting line is 1.6 year.

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Анотація

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Рисова солома і лузга як сировина для виробництва біопалива залежно від удобрення та норми висіву насіння

Встановлено вплив основних агротехнічних факторів на формування продуктивності сортів рису. Обґрунтовано ефективність вирощування культури з урахуванням господарської, економічної та енергетичної ефективності для використання в якості біопалива.

Ключові слова: *рис, урожайність, солома, лузга, біопаливо*

Аннотация

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Рисовая солома и лузга как сырье для производства биотоплива в зависимости от удобрения и нормы высева семян

Установлено влияние основных агротехнических факторов на формирование продуктивности сортов риса. Обоснована эффективность выращивания культуры с учетом хозяйственной, экономической и энергетической эффективности для использования в качестве биотоплива

Ключевые слова: *рис, урожайность, солома, лузга, биотопливо*