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The Effect Of Cultivation Methods Of The Summer Rape In Intermediate Sowings On The Yield Of "Winter Crop-Summer Rape" Crop Rotation In The Middle Pre-Urals.

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ABSTRACT

The results of the study of the effect of the summer rape cultivation methods in intermediate sowings on the yield of the "winter crop-summer rape" crop rotation performed on the turfic-podzolic heavy loamy soils in the middle Pre-Urals are presented. The development of cultivation methods of summer rape in intermediate sowings with the aim to attain 2-3 harvests per year for farms of the Perm region is in great demand. The investigated winter crops are found to be equivalent. The advantage of using summer crops as the hay and grain crops is highlighted. It is found that the highest yield of summer rape is attained when sown after winter rye. The top yield of summer rape is attained with sowing after harvesting the leftover winter green fodder crops. The increase of the seeding density from 2 to 4 million seeds per hectare leads to increasing yields of summer rape. It is found that the primary crop has equal effect on both parts of the "winter crop-summer rape" crop unit productivity. The comparison of types of the intermediate sowing of summer rape has shown that the highest yield is attained in the case of the hay and grain crops. The seeding density of 4 million seeds per hectare is found to be the most cost- and energy-effective case of the "winter crop-summer rape" crop unit cultivation.
Keywords: winter triticale, winter rye, summer rape, intermediate sowing, productivity, seeding density.

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INTRODUCTION

The intensive exploitation of soils in many regions of Russia allows to attain the 2-3 harvests rate of forage crops per year. This is achieved by employing the intermediate sowing technique. By extending the intermediate sowing areas it is possible to increase the forage crop yield and free more areas for cereal crops, technical crops etc. [1-8]. The most important part of the intermediate crops cultivation technology is a choice of the optimum sowing date and the sowing density. The sowing date is primarily determined by the crop's biological requirements on the main environmental factors, cultivation purpose as well as the specific year's climatic conditions [9]. Only the optimally-sown plants are able to fully utilize all the required factors for its growth and development [10]. Soil and climatic peculiarities of the middle Pre-Urals as well as biological properties of summer rape permit its usage in various intermediate sowings. As stated by certain authors [11-15], rape is the leading summer after mowing and after harvesting sowing crop due to its frigostability and low seeding density. It also stated that the late rape sowings can be the source of supply of the green fodder for livestock right until the onset of the snow cover thanks to its good restoration of productivity after harvesting. Depending on the cultivation area, sowing date and fertility of the soil the rape is able to accumulate up to 9 tons of dry biomass per hectare [16]. According to V.A.Kubarev [17] the cultivation of rape in intermediate sowings allows to fill the lack of full-fledged green fodder in summer and autumn seasons and fill the needs of animal industry in feed protein.

Therefore our aim is to develop the elements of cultivation technology of summer rape in intermediate sowings in combination with various winter-sown crops in the middle Pre-Urals.

METHODOLOGY

In order to archive the goals a series of field exercises on the turfic-podzolic heavy loamy soils was performed over a period of 2011-2014 years on the basis of Perm Agricultural Academy. The arable layer of the exercise soil is characterized by the average content of humus, close-to-neutral pH, very high content of labile phosphorus, above average content of exchange potassium.

The objects of research were the winter rye of the "Falenskaya 4" variety and the winter triticale of the "Izhevskaya 2" variety. The general guidelines for scientific and research institutions were adhered during the exercises. Three series of experiments were performed over the period of 2011-2013 years. The experiment scheme: factor A – main culture in intermediate sowing: A_1 – winter rye, A_2 – winter triticale; factor B – type of intermediate sowing of summer rape, purpose of use: B_1 – green fodder, after mowing, B_2 –hay and grain, after mowing, B_3 –grain, after harvesting; factor C – summer rape sowing density (million seeds per hectare): C_1 – 2; C_2 – 3; C_3 – 4; C_4 – 5; C_5 – 6. The plot placement pattern is systematic with splitting. Four sowings are made per variant. The plot square is 32,4 m^2.

The agrotechnics employed complies to local agricultural guidelines, recommended for the Pre-Urals. The winter crop sowing is performed by the SZ-3.6 seed driller in a row fashion with 15 cm. spacing between rows. The sowing density is 6 mil. seeds per hectare, the planting depth is 4-5 cm. The summer rape sowing is performed by the SSNP-16 seed driller with the sowing density set according to the experiment plan and planting depth is 2-3 cm. The green fodder and hay and grain cutting is performed by the KRN-2.1 mower (mowing height is 5-6 cm.), grain cutting is performed on the complete grain ripeness stage in single run by the SK-5 "Niva" combine harvester.

There where substantial differences in meteorological conditions over the experimental period. The sowing and germination periods were moderately dry and cold in years 2011-2012 and moderately warm with sufficient moistening in year 2013. Compared to the region's climate data the vegetation period of the year 2012 was more damp and warm than average while year 2013 was dry warm and year 2014 appeared to be damp cold.

RESULTS

Table 1 represents the results of yield accounting of winter cultures over the years 2012-2014. The yields are conveniently presented for the dry material.

The three year experiment has shown that the investigated winter cultures are generally equivalent in terms of the yield with 3.80 tons per hectare for winter rye and 4.11 tons per hectare for winter triticale (considering the HCP_{05} equal to 0.98 tons per hectare for main effects of the factor A). The comparison of winter crops revealed the advantage of hay and grain crop purpose of use over the other uses with average yield of 5.50 tons per hectare.

Table 1: The winter cultures yield in intermediate sowing, in tons/hectare, years 2012-2014.

Crop (A)	Purpose of use (B)	Yield, tons/hectare	Averaged A	Averaged B
Winter rye	B_1 – green fodder, after mowing	2.43	3.80	2.73
	B_2 –hay and grain, after mowing	5.30		5.50
	B_3 –grain, after harvesting	3.66		3.63
Winter triticale	B_1 – green fodder, after mowing	3.03	4.11	
	B_2 –hay and grain, after mowing	5.71		
	B_3 –grain, after harvesting	3.60		

HCP_{05}	Discrepancies	Main effects
factor A	1.71	0.98
factor B	1.02	0.72

The comparison of the studied factors over the three year period revealed the comparable data for the yield. In the after mowing case the attained yields are 2.43 tons per hectare for winter rye and 3.03 tons per hectare for winter triticale. In the hay and grain case the yields are 5.30 and 5.71 tons per hectare, correspondingly. The results for the grain harvesting case are similar, no yield advantage is revealed.

Table 2: Summer rape yield with respect to the purpose of use of the main culture, type of intermediate sowing and sowing density, in tons/hectare, years 2012-2014.

Main crop (A)	Purpose of use (B)	Seeding density, mil./hectare (C)					Avg. A	Avg. B
		2	3	4	5	6		
Winter rye	B_1 – green fodder, after mowing	1.57	1.71	2.09	2.01	1.86	1.21	1.77
	B_2 –hay and grain, after mowing	1.05	1.26	1.46	1.20	1.19		0.99
	B_3 –grain, after harvesting	0.37	0.56	0.61	0.60	0.61		0.46
Winter triticale	B_1 – green fodder, after mowing	1.56	1.55	1.80	1.83	1.67	0.94	
	B_2 –hay and grain, after mowing	0.69	0.74	0.79	0.79	0.76		
	B_3 –grain, after harvesting	0.32	0.35	0.43	0.38	0.37		
Averaged C		0.69	0.77	0.90	0.85	0.81		
Averaged B/C	B_1 – green fodder, after mowing	1.56	1.63	1.95	1.92	1.77		
	B_2 –hay and grain, after mowing	0.87	1.00	1.13	1.00	0.97		
	B_3 –grain, after harvesting	0.34	0.46	0.52	0.49	0.49		

HCP_{05}	Discrepancies	Main effects
factor A	0.95	0.25
factor B	0.94	0.30
factor C	0.17	0.07

The data analysis has revealed that for the case of winter rape the highest yield is attained when sown after harvesting the winter rye (see Table 2). The attained yield is 1.21 tons per hectare which is 0.27 tons per hectare higher than for the case of sowing after harvesting the winter triticale (HCP_{05} for main effects is 0.25). The substantial yield variety for intermediate sowing type of summer rape is obtained. The after mowing rape sowing performed after the green fodder harvesting of winter cultures presented the highest yield of 1.77 tons per hectare of dry biomass thanks to attained 2-3 harvests per year. The after mowing sowing performed after the hay and grain harvesting of winter cultures as well as the after harvesting of winter cultures lead to yield decrease. For example, the after mowing sowing of summer rape performed after the hay and grain harvesting

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of winter cultures in July yielded 0.99 tons per hectare which is 0.78 tons per hectare lower that in the after mowing case. The lowest attained yield was for the case of after harvesting sowing with a mere 0.46 tons per hectare.

The seeding density also contributed to the yield. The increase in the seeding density from 2 to 4 mil. seeds per hectare has shown the increase in the yield. The highest yield was attained with the 4-6 mil. seeds per hectare seeding density.

The primary parameters of the energy value of food are the feed value and the metabolizable energy. The nutritiousness of the dry biomass for winter rape varied with the main culture. The obtained feed value for the case of sowing after the winter triticale is 0.85 1/Kg compared to 0.83 1/Kg for the case of sowing after the winter rye. There is also effect of intermediate sowing type on the dry biomass composition. The farther the sowing date of the date off the first year's sowing date the more feed value and metabolizable energy is obtained. The highest values of 10.3-10.4 MJ/Kg for the metabolizable energy and 0.86-0.89 1/Kg for the feed value were obtained for the after harvesting sowing cases while the lowest values of 9.9-10.0 MJ/Kg and 0.78-0.80 1/Kg, correspondingly, were obtained for the green fodder after mowing sowing case. The seeding density also influenced the values: by increasing the density the corresponding values of 10.2 MJ/Kg and 0.85 1/Kg were obtained. Likewise, decreasing the sowing density leads to the decrease of the values.

The highest yield of feed value and metabolizable energy was obtained when grown after winter rye. The comparison of the cases of intermediate sowing has revealed the following differences: the highest yield of feed value and metabolizable energy obtained for the case of sowing after the green fodder after mowing of either winter rye or triticale is $(1177.7\text{-}1558.9)\cdot 10^3$ 1/hectare and 14.4-19.3 GJ/hectare, correspondingly. The least productive are the after harvesting sowing cases with the $(577.6\text{-}715.2)\cdot 10^3$ 1/hectare and 6.8-8.5 GJ/hectare corresponding values.

Table 3 presents the per kilogram nutritiousness of the dry biomass per hectare. The assessment of cultivation effectiveness of summer rape in intermediate sowing is presented with respect to the productivity parameters of the "winter crop – summer rape" crop rotation.

Table 3: Overall productivity of the "winter crop – summer rape" crop rotation with respect to the main crop purpose of use, intermediate sowing type and seeding density over years 2012-2014.

Main crop (A)	Purpose of use (B)	Summer rape seeding density, mil./hectare (C)					Avg. A	Avg. B
		2	3	4	5	6		
Winter rye	B_1 – green fodder, after mowing	2.89	3.04	3.38	3.31	3.16	3.99	3.33
	B_2 –hay and grain, after mowing	4,50	4,66	4,89	4,68	4,66		4.72
	B_3 –grain, after harvesting	3.99	4.16	4.20	4.18	4.20		4.20
Averaged A/C		3.79	3.95	4.15	4.06	4.00	4.17	
Winter triticale	B_1 – green fodder, after mowing	3.29	3.38	3.61	3.65	3.57		
	B_2 –hay and grain, after mowing	4.70	4.73	4.77	4.80	4.77		
	B_3 –grain, after harvesting	4.20	4.24	4.29	4.25	4.24		
Averaged A/C		4.06	4.12	4.22	4.23	4.19		
Averaged C		3.93	4.03	4.19	4.14	4.10		
Averaged B/C	B_1 – green fodder, after mowing	3.09	3.21	3.49	3.48	3.37		
	B_2 –hay and grain, after mowing	4.60	4.70	4.83	4.74	4.71		
	B_3 –grain, after harvesting	4.09	4.20	4.25	4.22	4.22		
HCP_{05}	Discrepancies			Main effects				
factor A	3.39			0.87				
factor B	1.79			0.57				
factor C	0.16			0.07				

The three year study has shown that the main crop posed no effect on the food value yield of the "winter crop – summer rape" crop rotation. The obtained yield is (3.99-4.17)·10^3 1/hectare (HCP_{05} of main factors is 0.87).

As for the intermediate sowing type, the lowest food value yield obtained in case of greed fodder after mowing sowing with 3.33·10^3 1/hectare which is significantly lower than in cases of after harvesting and hay and grain after mowing sowing. The yield for the latter cases is 4.20·10^3 1/hectare and 4.72·10^3 1/hectare, correspondingly.

Considering the effect of seeding density on food value yield of the "winter crop – summer rape" crop rotation the lowest yield is obtained for the case of 2 mil./hectare density (3.93·10^3 1/hectare); by increasing the seeding density of 4 mil./hectare the yield of 4.19·10^3 1/hectare is attained.

The comparison of the studied factors has shown that the hay and grain after mowing in use of both winter crops leads to increase of the yield of the entire "winter crop – summer rape" crop rotation with similar yield values obtained in all cases. Generally it can be stated that all cases appear to comparable in terms of yield.

The development of the cultivation methods of summer rape in intermediate sowing implies the increase in both productivity of the crop rotation and economic efficiency.
The comparison of the crop rotations has shown that the lowest total production cost (2.76-2.96 roubles per feed value) is attained in case of summer rape sown after the after mowing hay & grain winter crops (Table 4). The attained profitability is 103-107%.

Table 4: Economic efficiency of the "winter crop – summer rape" crop rotation with respect to the main crop purpose of use, intermediate sowing type and seeding density over years 2012-2014.

Main crop (A)	Purpose of use (B)	Seeding density, mil./hectare	Yield, 10^3 1/hectare	Price, rouble/hectare	Expenses, rouble/hectare	Prod. Cost, roubles	Net income, rouble/hectare	Profitability, %
Winter rye	B_1 – green fodder, after mowing	2	2.89	17.63	13.88	4.81	3.75	27
		4	3.37	20.55	14.36	4.25	6.19	43
		6	3.16	19.23	14.44	4.58	4.80	33
	B_2 –hay & grain, after mowing	2	4.50	26.98	13.09	2.91	13.88	106
		4	4.89	29.32	13.49	2.76	15.83	117
		6	4.66	27.93	13.59	2.92	14.34	105
	B3 –grain, after harvesting	2	3.98	23.91	13.38	3.36	10.54	79
		4	4.30	25.83	13.89	3.23	11.95	86
		6	4.30	25.83	14.08	3.27	11.75	83
Winter triticale	B_1 – green fodder, after mowing	2	3.40	20.43	15.53	4.56	4.90	32
		4	3.61	21.66	15.86	4.39	5.81	37
		6	3.60	21.61	16.15	4.49	5.46	34
	B_2 –hay & grain, after mowing	2	4.74	28.47	13.83	2.92	14.63	106
		4	4.84	29.04	14.13	2.92	14.91	105
		6	4.83	28.99	14.31	2.96	14.68	103
	B3 –grain, after harvesting	2	4.10	24.64	13.80	3.36	10.84	79
		4	4.28	25.68	14.15	3.31	11.53	81
		6	4.20	25.21	14.09	3.35	11.13	79

It is important to analyze the energy consumption and energy factors of the cultivated crops which show the total energy expenses and energy accumulation and ultimately the overall energy efficiency of the plant production.

Considering the energy efficiency of the "winter crop – summer rape" crop rotation the advantage of the after mowing sowing after hay and grain rye and triticale is shown. (Table 5). The low level of energy consumption made it possible to attain the high level of energy efficiency. The obtained energy efficiency factor for rye and triticale is 3.7-3.9 and 3.4-3.6, correspondingly. The lowest energy consumption is attained in case of 4 mil./hectare sowing density.

Table 5: Energy balance of the "winter crop – summer rape" crop rotation with respect to the main crop purpose of use, intermediate sowing type and seeding density over years 2012-2014.

Main crop (A)	Purpose of use (B)	Seeding density,mil./hectare	Yield, 10^3/hectare	Consumed energy, MJ/hectare	Accumulated energy, MJ/hectare	Specific energy consumption, MJ	Energy efficiency factor
Winter rye	B_1 – green fodder, after mowing	2	2.89	32061.4	71753.0	11.1	2.2
		4	3.37	32631.6	81710.1	9.7	2.5
		6	3.16	32699.4	76864.0	10.4	2.4
	B_2 –hay and grain, after mowing	2	4.50	30402.6	113371.4	6.8	3.7
		4	4.89	30871.8	121053.2	6.3	3.9
		6	4.66	30971.2	115971.5	6.7	3.7
	B3 –grain, after harvesting	2	3.98	31308.9	54181.1	7,9	1.7
		4	4.30	31925.7	60806.2	7,4	1.9
		6	4,30	32141.9	60497.6	7,5	1.9
Winter triticale	B_1 – green fodder, after mowing	2	3.40	35975.5	96656.0	10.6	2.7
		4	3.61	36355.5	100709.2	10.1	2.8
		6	3.60	36914.8	100159.1	10.3	2.7
	B_2 –hay and grain, after mowing	2	4.74	33162.2	119406.6	7.0	3.6
		4	4.84	33508.2	121286.4	6.9	3.6
		6	4.83	33696.6	115371.2	7.0	3.4
	B3 –grain, after harvesting	2	4.10	32621.7	73530.3	7.9	2.3
		4	4.28	33036.2	77053.0	7.7	2.3
		6	4.20	33168.2	75423.8	7.9	2.3

Considering the results summarized in Tables 4-5 the "winter crop – summer rape" crop rotation in case of after mowing rape sowing with the seeding density of 4 mil./hectare after the hay and grain winter crops is the most energy and economy efficient case.

CONCLUSIONS

According to experiment results the following conclusions statements can be made:

- The winter crops are equivalent in terms of green biomass and grain yields.
- Winter rye and winter triticale in case of hay and grain purpose of use have an advantage over the green fodder and grain purposes of use with respect to the dry biomass yield.
- Considering the effect of the main crop (rye and triticale) on the yield of summer rape the advantage of rye is revealed. The highest yield of summer rape is attained in the case of after mowing sowing after the green fodder usage of main crop thanks to attainable harvest rate of 2-3 harvests per year.
- Over the entire experimental period the increase of the seeding density from 2 to 4 mil. per hectare led to increase of the rape yield.
- Over the three year experimental period the main crop poses the equal effect on the yield of "winter crop – summer rape" crop rotation. The highest yield of the crop rotation is attained in case of the after mowing rape sowing after the hay and grain winter crops.
- The "winter crop – summer rape" crop rotation in case of after mowing rape sowing with the seeding density of 4 mil./hectare after the hay and grain winter crops is the most energy and economy efficient case.

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