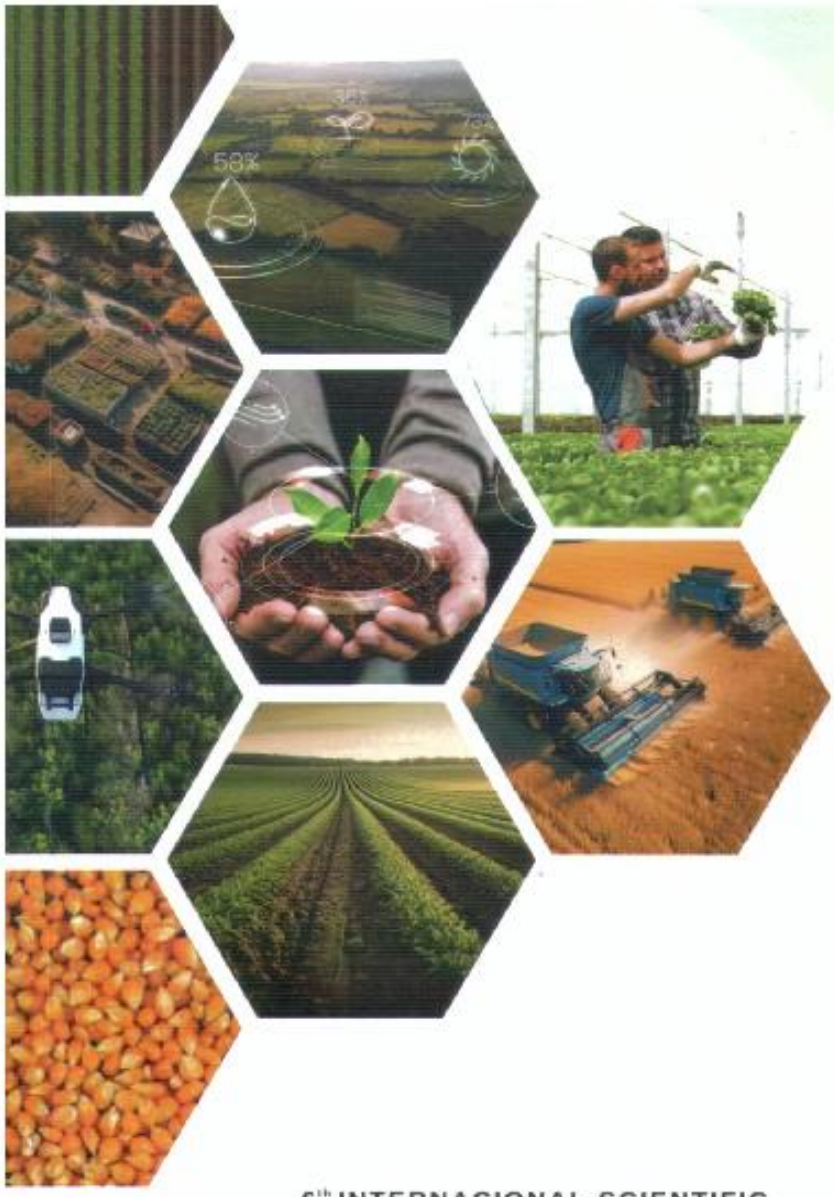

BOOK OF PROCEEDINGS

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VILLAGE AND AGRICULTURE

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INFLUENCE OF DIGESTATE ON THE PRODUCTIVITY OF OATS IN DIFFERENT ENVIRONMENTAL CONDITIONS

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Abstract

Thanks to the grain's high energy and nutritional value, oats are of great economic importance. The paper analyzed the productivity of oats on fertile soil, chernozem in a two-year period and in two variants of feeding: control (variants without feeding) and in the variant with digestate. Oat productivity parameters were analyzed: number of ears per panicle, grain mass per panicle and compared with grain yield per hectare. The results showed that year and digestate had a statistically significant effect on the number of spikelets per panicle of oats and that higher values of grain weight per panicle were achieved in the digestate variant compared to the control variant. The digestate had a significant effect on the increase in oat productivity parameters and its application in the oat crop is justified.

Key words: oats, seed storage, production year, digestate, productivity parameters

Introduction

Oats (*Avena sativa* L.) is a true cereal that has a smaller area of distribution due to less tolerance to frost and drought. Thanks to the grain's high energy and nutritional value, oats are of great economic importance. Hulled grain is used in human nutrition and unhulled grain and above-ground biomass as food for domestic and farmed animals. Oats are known as natural functional food. Oats for human consumption are responsible for numerous health benefits in addition to basic nutrition (Burić et al., 2023). In human nutrition, peeled oat grain is used in the form of oatmeal, semolina and oat flour, which is mixed with wheat flour to make bread and other bakery - bread products (Figure 1a-c). In the diet of domestic animals, oats can be used in two basic ways, as concentrated and voluminouse fodder. Oat grain has 8.18% digestible proteins, has higher nutritional value than corn and 1.02 nutritional units (Glamočlija et al., 2015; Lakić et al., 2018; Rajičić & Terzić, 2022; Burić et al., 2022).In our country, it is grown more as a fodder plant in mixtures with buttercups, and less for grain.

If it is grown for grain, the unpeeled fruits are used as animal feed, and the peeled fruits are used for the industrial preparation of finished food products of high nutritional value. Secondary products are harvest residues (whose percentage share in the total biomass yield is higher than in other grains), followed by chaff, poorly grains and bran that remain after grain milling.

Despite its great economic importance and diverse application in nutrition and industrial processing, the area sown under oats in some countries, which were the largest producers, decreased, but increased in South America and some European countries, especially where the grain is increasingly used in feed people. The trend of decreasing areas in the last decades of the last century was greatly influenced by the weak competitiveness of oats with other more productive types of grain and a significant decrease in the number of horses for which oat grain served as the main concentrated feed.

For most types of soil in Serbia conditions, to achieve high yield and good grain quality, on average, should be applied 60-90 kg ha^{-1} of N, 60-90 kg ha^{-1} of P_2O_5 and 40-60 kg ha^{-1} of K_2O pure nutrients. Phosphorus and potassium fertilizers are introduced in winter oats 50% in the basic tillage and 50% before sowing, while in spring oats all phosphorus and potassium quantities are introduced in autumn under basic tillage. In more humid regions, the amount of nitrogen for fertilization is added early in the spring during intense tillering (the first fertilization with half of the anticipated amount) and the second fertilization at the beginning of stem elongation with the remaining amount of nitrogen. In the case of spring oats in arid regions, the entire amount of nitrogen is given before basic treatment or pre-sowing preparation, i.e. without top dressing (Rajičić et al., 2020; 2021). The aim of this study was to investigate the effect of digestate on oat productivity on chernozem.

Materials and Methods

In this study, the analysis of oat production in the world (FAO 2023) as well as the influence of digestate on oat productivity on black soil was monitored. The experiments were carried out in Kovin, Pančevo municipality during 2021 and 2022, on chernozem type soil in three repetitions. The elementary plot was 25m2. Sejana is a spring oat variety of NS Dunav. Precrop was soybeans. Soil cultivation was carried out according to standard methods for spring crops. Instead of fertilization, digestate was applied as a nutrient and a control variant was without digestate. The entire amount of digestate was given in the pre-sowing preparation. Sowing was done in mid-February, Harvesting was done in early August with a harvester for experiment. The following parameters were analyzed: Number of spikelets per panicle of oats and mass (yield) of grain per panicle (g). The yield was measured on the day of harvest and converted to 14% moisture. The economic importance of oats is reflected in the quality of its grain from which high-quality products are obtained, Figure 1a-c. Oats are

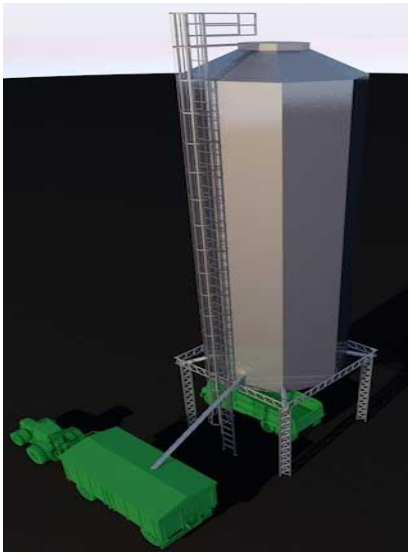
harvested at technological maturity, Figure 1a. Oat seed is dried to 14-15% moisture, Figure 1b, and stored in storage silos, Figure 2.

a) b) c)

Figure 1. Oat crop (a), oat seed (b) and oat products (c)

Seed storage

Seed storage is the final work operation in the oat production process. There are several types of storage: normal storage, storage with drying or additional drying of products and storage with preservation of products. When storing oats, the most important condition during storage is maintaining humidity at optimal values. Oat grain with a higher percentage of water after harvesting is dried in dryers or directly poured into a silo that has an innovative mixing propeller that works with the help of SMART-THINGS, i.e. with the help of sensors as shown in Figure 2. The sensors are monitoring the humidity of the oat grain, reporting to the central sensor that automatically blows moist or dry air directly with the help of the unit, depending on the need, in order to maintain optimal conditions for storing oat seeds.



a)

b)

Figure 2. Silos for storing oats, a.)Designed by Ristić&Popović, 2023; seed, b.)

Meteorological Conditions

During the investigation, meteorological data, temperature and precipitation were very variable. Crop production is highly sensitive to climate, which means that climate change significantly affects crop production (Popović et al., 2011; 2020a; 2020b; 2022). The meteorological conditions, monthly precipitation and air temperatures for 2021 and 2022 during the trial were taken from the Hydro-meteorological service of the Republic of Serbia, situated in Pančevo (Table 1).

Table 1. Average monthly temperatures and amounts of precipitation for the oat vegetation period during 2021 and 2022 in Pančevo

Parameter	**Temperature (^{0}C)**						
Month	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Average**
2021	13,2	16.04	21.60	25.30	22.00	17.00	19.25
2022	9.89	17.14	21.70	25.28	22.04	17.87	19.03
Parameter	**Precipitation (mm)**						
Month	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Total**
2021	44.0	73.3	31.1	110	48.3	21.7	328.4
2022	54.6	63.1	41.7	142	38.3	11.7	351.4

Average temperatures in the growing season in 2021 were 19.25 °C and were higher by 0.22 °C compared to the growing season of 2022, while total precipitation in 2022 was higher by 23 mm, but with an unfavorable schedule, especially in critical stages for oats. Precipitation and temperature have a decisive influence on the yield (Ljubičić et al., 2021; 2023; Milunović et al., 2022).

Results and Discussion

Oat production in the world

The area under oats has been reduced in the past decades in the world at the expense of more productive grains, and according to FAO data, in 2022 oats was grown on 9,562,497ha (mostly in the countries of Eastern and Northeastern Europe), Table 2. According to FAO statistical data in the world in 2022 there were 9,562,497 ha under oats. The average grain yield was 2,360 kg ha^{-1}, and the total production was 22,571,618 tons. The largest areas under oats by continent were Europe with 5,390,227 ha or 56.37% and America with 2,387,873 ha or 24.97%. Europe recorded the highest average grain yield of 2,526 kg ha^{-1} with a total production of 13,614,876 tons, while America recorded an average grain yield of 2,380 kg ha^{-1} and total production was 5,683,700 tons, table 2.

Table 2. Areas, yields and production of oats in the world in 2022.

Parameter	Area, ha	Yield, kg ha^{-1}	Production, t	Share area,%
World	9,562,497	2,360	22,571,618.53	100.00
Europe	5,390,227	2,526	13,614,876.00	56.37
America	2,387,873	2,380	5,683,700.71	24.97
Oceania	1,075,574	1,788	1,922,794.62	11.25
Asia	581,092	2,036	1,183,130.74	6.08
Africa	127,731	1,308	167,116.45	1.34
EU	2,553,510	2,933	748,848.00	26.70
Source: FAO, 2023				

In our country, according to data for 2021, oats are grown on an area of 14,503 ha. In total, 44,176 tons of grains were produced. Average grain yields of 3,046 kg ha^{-1} are 20.58% higher than the average of European countries, or about 30% higher than the average world yields. In lowland areas, especially on areas next to large buildings of domestic ruminants, oats are mostly grown in fodder mixtures for fresh biomass that is used fresh or for the preparation of silage and haylage. Grain production is mainly concentrated in the hilly and mountainous areas of the central part of Serbia.

Productive characteristics of oat varieties in Serbia

The average value of the number of spikelets per panicle was 24.52. The values of the number of spikelets per panicle varied from 22.25 in the control variant to 26.20 in the variant with digestate.

Year and variety had a statistically significant influence on the values of the number of spikelets per panicle. The interaction of the examined factors had no statistical significance for the examined factor, tables 3, 4 and 5, graphs 1a and 2.

The average value of grain weight per panicle was 1.47 g. The values of grain mass per panicle varied from 1.36 g in the control variant to 1.58 g in the variant with digestate. Year and variant and the interaction of the examined factors had no statistical significance for the examined factor, tables 6 and 7, graphs 1b and 2.

Table 3. Productivity parameters of oats in the control and in the variant with digestate

Parameter	Varijant	2021.	2022	Average	IV
Number of spikelets per panicle	Control	24,53	21,17	22,85	3,36
	Digestat	26,90	25,50	26,20	1,40
	Average	**25,72**	**23,34**	**24,52**	**2,38**
Mass of grains per panicle	Control	1,20	1,51	1,36	0,31
	Digestat	1,57	1,58	1,58	0,01
	Average	**1,39**	**1,55**	**1,47**	**0,16**

LSD	No. of spikelets per panicle			Mass of grains per panicle		
	Year	Variant	Yx Var.	Year	Variant	Y x Variant
0,5	1,336	1,337	6,135	0,303	0,304	4,297
0,1	6,308	6,308	8,922	0,442	0,442	6,253

Tabela 4. Anova for number of spikelts per panicle

Parametar	SS	Degr. of Freedom	MS	F	p
Number of spikelts per panicle	7217,708	1	7217,708	680,4878	0,000000
	17,041	1	17,041	1,6066	0,240616
	33,667	1	33,667	3,1742	0,112671
	2,901	1	2,901	0,2735	0,615170
	84,853	8	10,607		

Table 5. Number of spikelts per panicle of oats

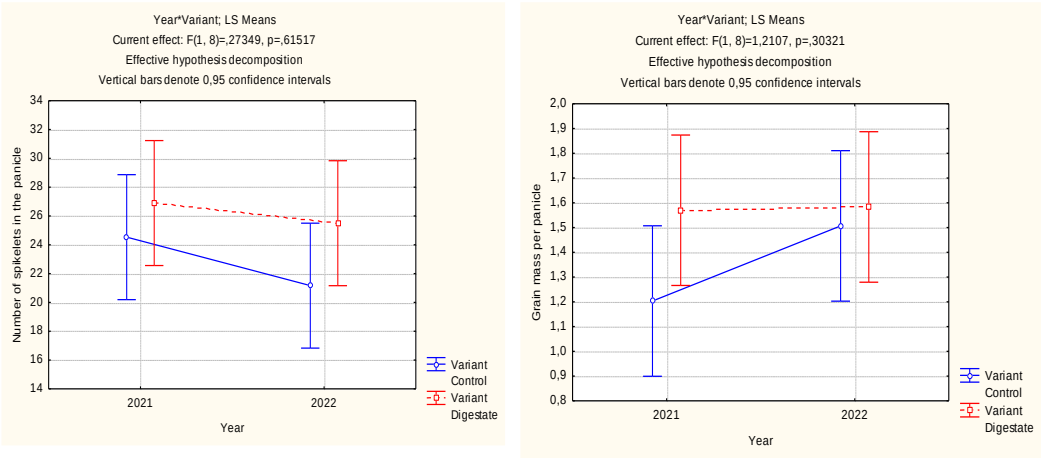
Effect	Level of factor	Level of factor	N	Mean	Std. Dev.	Std. Error	-95,0%	+95,0 %
Total			12	24.53	3.547	1.024	22.270	26.779
Year	2021		6	25.72	4.151	1.694	21.360	30.073
Year	2022		6	23.33	2.655	1.084	20.546	26.119
Variant	Control		6	22.85	4.280	1.747	18.358	27.341
Variant	Digestate		6	26.20	1.625	0.663	24.494	27.905
Year x Variant	2021	Control	6	24.53	5.970	3.446	9.702	39.364
Year x Variant	2021	Digestate	6	26.90	1.800	1.039	22.420	31.371
Yearx Variant	2022	Control	6	21.17	1.286	0.742	17.973	24.361
Year xVariant	2022	Digestate	6	25.50	1.374	0.794	22.084	28.915

Tabela 6. Anova for mass of grains per panicle of oats

Parametar	SS	Degr. of Freedom	MS	F	p
Mass of grains per panicle	25.784	1	25.784	494.894	0.000000
	0.075	1	0.075	1.4435	0.263927
	0.147	1	0.147	2.8293	0.131060
	0.063	1	0.063	1.2107	0.303206
	0.416	8	0.052		

Table 7. Mass of grain per panicle of oats

Effect	Level of factor		N	Mean	Std. Dev.	Std. Error	-95,00 %	+95,00 %
Total			12	1.465	0.25	0.073	1.305	1.626
Year	2021		6	1.386	0.27	0.110	1.103	0.669
Year	2022		6	1.545	0.23	0.094	1.304	1.785
Variant	Control		6	1.355	0.27	0.109	1.075	1.634
Variant	Digestate		6	1.576	0.21	0.082	1.366	1.787
Year x Variant	2021	Control	6	1.203	0.21	0.124	0.669	1.737
Year xVariant	2021	Digestate	6	1.570	0.18	0.107	1.106	2.034
Year x Variant	2022	Control	6	1.506	0.25	0.143	0.889	2.125
Year x Variant	2022	Digestate	6	1.583	0.25	0.147	0.948	2.218



a. b.

Graph. 1. Interaction Y x V for number spikelets in panicle (a) and grain mass per panicle (b)

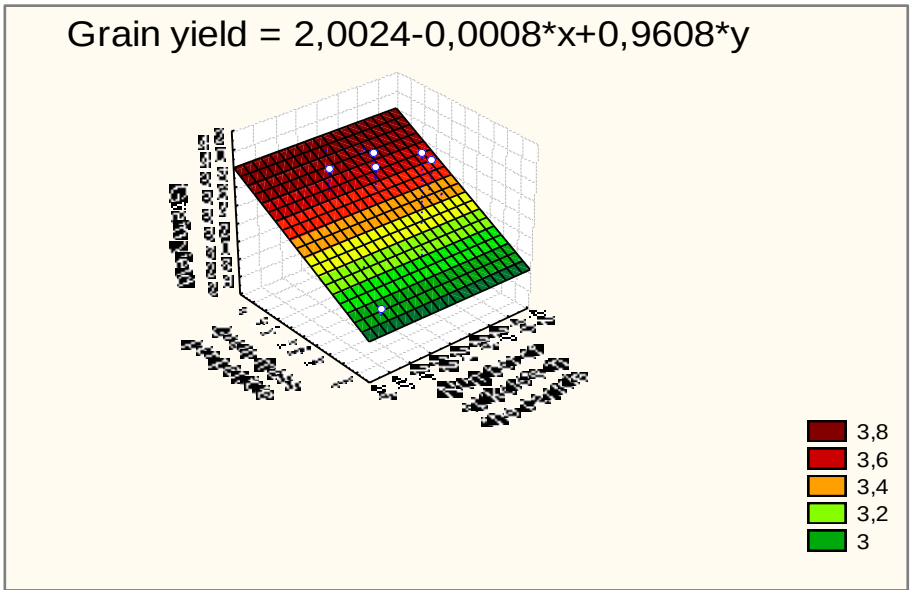
Correlation analysis of the studied oat traits

Correlation coefficients based on all traits tested during 2021-2022 had positive values (Table 8). Over a two-year study period, highly significant positive correlation coefficients were found between grain yields and grain mass per panicle (r=0.50**).

Table 8. Correlations between the analyzed traits

Traits	GY	NSP	GMP
Grain yield - GY	1.00	0.14	0.50**
Number spikelets in panicle - NSP	0.14	1.00	0.30
Grain mass per panicle - GMP	0.50*	0.30*	1.00
* significant at 0.05; **significant at 0.01			

Significant positive correlations were found between Number spikelets in panicle - NSP and grain mass per panicle (r=0.411*). A strong positive correlation between small yields and grain weight has been found by many researchers (Terzic et al., 2018), medium (Đekić et al., 2014, Güngör et al., 2017), while weak positive dependence has been identified by Rajičić et al. (2020).



Graph. 2. 3 D for GY- yield, grain mass per panicle and number spikelets in panicle

Oats nutritional value

Oat genotypes (winter and spring) differ in the chemical composition of the grain, especially in protein content. The protein content of oat grains is 16.9g, fat content 6.9g, crude fiber content 12.1g, Table 9.

Table 9. Oats nutrution value

Nutrient	**Amount per 100g of oats** (% of recommended daily intake)
Protein, g	16.9
Total fat, g	6.9
Saturated fat, g	1.2
Monounsaturated fat	2.2
Sodium, mg	6.0
Total Carbohydrate, g	57.1
Dietary Fiber, g	12.1
Sugar, g	1.1
Potassium, mg	310.1
Calcium, mg	48.1
Iron, mg	4.2

Jordanovska et al. (2018) points out that the protein content of oat grains varied from 12-15%, fat content from 4-6.5%, crude fiber content from 12.2-12.5%.

There was a significant effect ($p<0.001$) of both the variety and environment on protein, oil and β-glucan contents which, averaged over all varieties, ranged from 7.77 to 12.33%, 6.48 to 7.83% and 3.16 to 4.88%, respectively, across environments (Howarth et al., 2021).

Conclusion

Oat grain is used for food, non-food and feed products due to its unique grain qualities. Known as a natural functional food, oats for human consumption are responsible for numerous health benefits beyond basic nutrition.

Over a two-year study period, highly significant positive correlation coefficients were found between grain yields and grain mass per panicle ($r=0.50^{**}$). Significant positive correlations were found between Number of spikelets in panicle - NSP and grain mass per panicle ($r=0.411^{*}$).

The results showed that year and digestate had a statistically significant effect on the number of ears per panicle of oats and that higher values of grain weight per panicle were achieved in the digestate variant compared to the control variant. The digestate had a significant effect on the increase in oat productivity parameters and its application in the oat crop is justified.

By improving the quality of oat varieties for food, non-food and fodder products through plant breeding, new opportunities will be created for the future of this culture.

Acknowledgments

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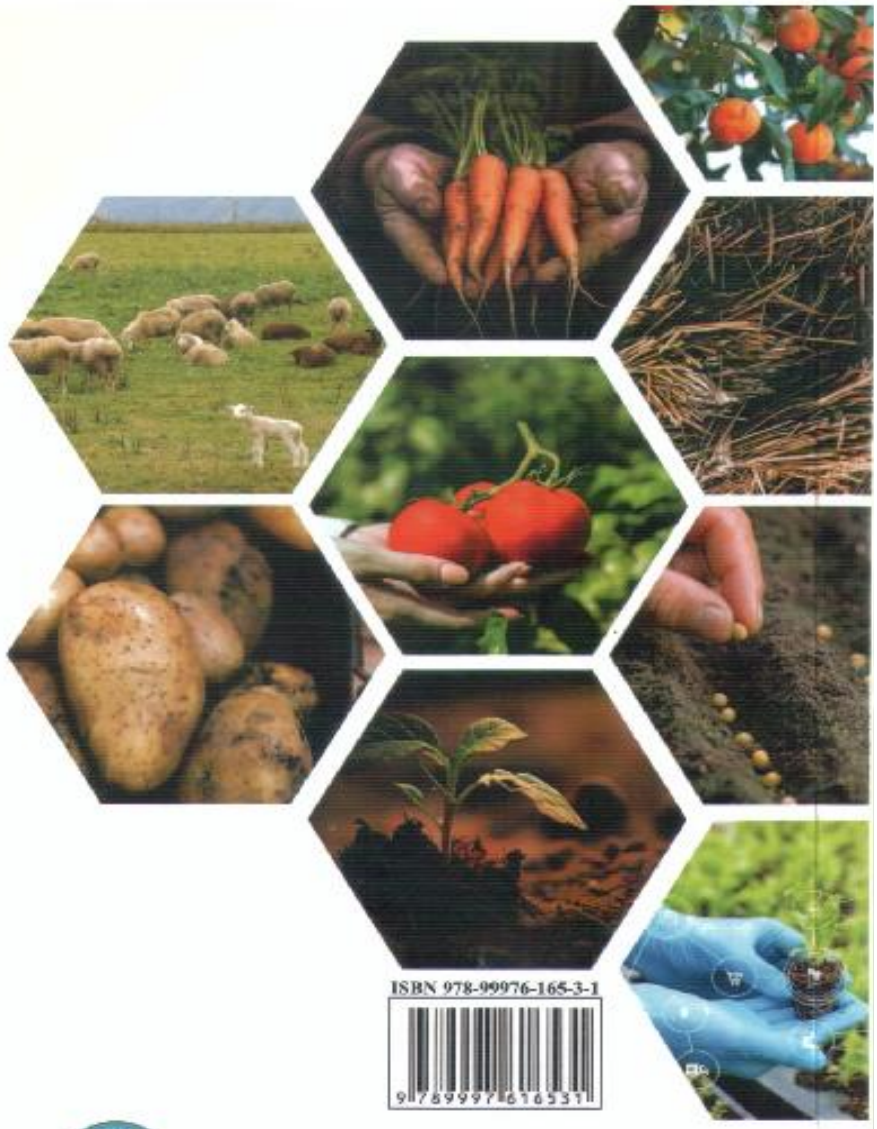

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