THE EFFECTS OF TREATED AND COMPOSED SEWAGE SLUDGE IN AGRICULTURAL PRODUCTION

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ABSTRACT

The main objective of this research was to investigate the effect of the treated and composed solid sludge from waste water treatment stations on the yield and quality of tobacco. Quality characteristics of the sludge were analyzed, as well as its impact on improving the soil properties as unrivaled environment in agricultural production. Field experiments were set for three consecutive years (2011-2013), in two locations with four variants as follows: variant without fertilization (control), fertilized variants with 10 t/ha, 20 t/ha and 30 t/ha. According to analysis of the sludge it was found that it contains a high percentage of organic matter (>20%) as a good basis for improving lean and poor in organic matter agricultural soils. After three years of the field experiment it can be concluded that sludge has a positive impact on soil quality characteristics. It slightly increases the content of humus and pH of soil, and maintains the content of available phosphorus and potassium. The yield of tobacco was increased so thus the average price and the revenue from the unit area. Usage of the sludge does not deteriorate the quality properties of the produced raw tobacco.

***Key words**: sewage sludge, soil, tobacco, yield, quality*

INTRODUCTION

It is generally known that sludge as result of the treatment of the municipal and industrial waste water is one of the most urgent problems in contemporary life. Besides inorganic composition, sludge contains a large percentage of organic substances, mainly proteins, carbohydrates, fats and oils, synthetic organic materials in smaller quantities, bound in a wide range of compounds, pathogenic micro-organisms and substances characteristic for enzymatic reactions [1]. Waste water sludge, in terms of disposal on dry fields, represents a real ecological bomb for the environment and human health. That is why much is done and still is working on resolution of this problem. In that direction,during the period of 2009-2011 in the Republic of Macedonia we were working on the project "Treatment and processing of waste sludge from the wastewater treatment plant Vranishta - Struga". Research on this project was grouped into two phases. The objective in the first phase was to find technical and technological procedure for obtaining microbiologicaly clean waste material that through further treatment, processing and composting as organo-mineral fertilizer will get its use in agricultural production. Second phase includes laboratory analysis on the quality properties of the obtained product and its effects on the agricultural production. Part of the obtained results are presented in the paper entitled: Waste sludge from municipal wastewater tretment plant and its valorization in agricultural production [1], where the main objective are quality properties of treated sludge. Data presented in this paper will finalize the second research phase of this project. Obtained results are based on the triennial field trials with small leaf tobacco variety P-23 in Prilep and Bitola tobacco production regions. The main objective of the research is to investigate the continued effect of the waste sludge used on agricultural soil, the yield and quality characteristics of the tobacco material.

MATTERIALS AND METHODS

Studies were performed in 2011, 2012 and 2013 in the Prilep production area at the field at the Scientific Tobacco Institute - Prilep with oriental tobacco and in Bitola production area at the municipality Dobrushevo. The experiment was set up in randomized complete block design in three 3 replications, with four variants as follows:

1. First ∅ - unfertilized-control
2. Variant fertilized with 10 t/ha
3. Variant fertilized with 20 t/ha
4. Variant fertilized with 30 t/ha

The experiment area is 160 m^2. Each parcel has 6 rows, 4 for harvesting and two for protection, with 41 strands in order and distance of transplanting 40 x12 cm. The main plowing was done in fall, and also two times in spring. Appropriate amount of waste sludge was uniformly distributed on the surface of the parcel and it was incorporated into the soil before transplanting. All indispensable agro-technical and plant protection practices were applied during the vegetation period of tobacco. During the three years research we studied the impact of waste sludge on the changes of soil quality and agronomic properties of tobacco (yield, average price and the earned income per unit area). Tobacco quality was determinated with following chemical parameters: nicotine, total nitrogen, proteins, soluble sugars, mineral matter and reducing sugars content by Schmuk. Laboratory analyses are done by standard methods in accredited laboratories of Scientific Tobacco Institute – Prilep.

RESULTS AND DISCUSSION

Average soil samples were taken to examine the effect of waste sludge on agrochemical properties of soil from both locations, before setting up the experiment in 2011 and after completion of field trials at the end of the vegetation in year 2013. Results are presented in Table 1. A positive trend of the obtained data can be seen from tested parameters that reflect soil fertility. The high percentage of organic matter in the fertilizer correlates with increasement of soil organic matter. As it can be seen in Table 1, content of organic matter is soil increased from 1.36 to 1.95 % (Locality Prilep) and 1.37 to 1.82 % (Locality: municipality of Dobrushevo). Also, there can be seen increase in the content of available phosphorus and potassium, soil reaction and clay content. The increasement of the selected parameters follows the tendency of increasing the amount of fertilizer (from variant with 10t/ha to variant with 30t/ha).

Numerous authors point out that the yield and quality of tobacco is undoubtedly influenced on soil where it is cultivated [7,14,11,16 and other].

Oriental tobacco can be grown on all soil types which are suitable for cultivation of other cultivated plants. But only in certain soil and climatic conditions it is possible to obtain a tobacco with certain yield and quality. Small leaf oriental tobacco with good quality is grown on soils with light mechanical composition and structure, loose soils that are characterized by good water-air and heat regime, that has good aeration and water permeability and that are easily heated [14]. It is thought that high-quality tobacco is produced on poor soils with low content of organic matter.

Table 1. Agrohemical properties of the soil treated with ogano-mineral fertilizer

variants	Humus %		Total nitrogen %		pH				mg/100 g				Clay %	
					H_2O		KCl		P_2O_5		K_2O			
	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013
Locality: Prilep														
Ѳ	1.36	1.18	0.068	0.059	6.76	6.65	5.56	5.83	22.11	21.81	16.89	18.80	28.70	27.90
10 t	-	1.48	-	0.074	-	7.30	-	6.39	-	22.15	-	17.88	-	29.91
20 t	-	1.70	-	0.083	-	7.75	-	6.92	-	23.61	-	18.63	-	30.41
30 t	-	1.95	-	0.098	-	7.80	-	7.16	-	27.39	-	20.01	-	30.40
Locality: municipality of Dobrushevo														
Ѳ	1.37	1.30	0.069	0.066	7.08	7.15	5.93	5.91	4.74	5.28	16.25	15.92	26.70	28.00
10 t	-	1.51	-	0.071	-	7.12	-	6.23	-	6.78	-	17.07	-	29.50
20 t	-	1.73	-	0.083	-	7.29	-	6.66	-	8.29	-	17.52	-	29.89
30 t	-	1.82	-	0.087	-	7.43	-	6.94	-	7.54	-	17.54	-	29.63

Given that tobacco is a culture that draws large amounts of nutrients from the soil (100 kg dry tobacco extracts about 4 kg of nitrogen, 2 kg phosphorus, 10.6 kg potassium and 6.3 kg calcium), it becomes clear that if we do not return the stated amounts of nutritious elements in tobacco fields we put the yield and quality of tobacco into question [4]. It is known that tobacco is quite often grown as a monoculture, which contributes into extraction of nutrients that leans the soil.

The authors that studied tobacco agrees on that the most precious fertilizer for tobacco cultivation is organic fertilizer because of the right proportion of nutrients for tobacco development and positive effect on physical properties of soil [7,14,4,5], point out that the best fertilizer is organo-mineral or mineral fertilizers should be applied in the combination with lower rates of well burnt organic manure (200-500 kg/acre).

There are sufficient amounts of organic fertilizer in tobacco producing areas in Macedonia, so treated waste sludge is an excellent substitute for organic manure. The results of the impact of treated waste sludge on the agronomic and chemical properties of tobacco are presented in Tables 2-5.

Table 2. Impact of organo-mineral fertilizer on the average yield of tobacco

N°	variant	2011		2012		2013		Average (2011-2013)	
		kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Locality: Prilep									
1	Ѳ	2878	100.00	3624	100.00	2034	100.00	2845	100.00
2	10 t	3069	106.64	3931	108.47	2418	118.88	3139	110.33
3	20 t	3105	107.89	3890	107.34	2454	120.65	3150	110.72
4	30 t	3179	110.46	4015	110.79	2537	124.73	3244	114.02
Locality: Dobrushevo									
1	Ѳ	3136	100.00	3524	100.00	2001	100.00	2887	100.00
2	10 t	3110	99.17	4013	113.88	2411	120.48	3178	110.07
3	20 t	3236	103.19	3957	112.29	2383	119.09	3192	110.56
4	30 t	3283	104.69	3884	110.22	2388	119.34	3185	110.32

LSD	Locality- Prilep kg/ha	Locality- Dobrushevo kg/ha
0.05 =	90.93	201.76
0.01 =	137.75	305.66
0.001 =	221.44	491.34

Based on the data (Table 2), lowest yield is noticed at the unfertilized control (variant 1) and it follows the trend of increasing quantities of fertilizer. In the locality of Prilep the yield is increased for 10.33-11.02 % and in Dobrushevo all three variants have yield increasement of around 10 %). Statistical analysis of the data showed a significant difference in the yield from all variants relative to the control. According to the presented results it can be concluded that a significant impact on the yield have and meteorological conditions of the year. The highest yield in all variants has been achieved in the harvest of 2012.

The achieved average price reflects the organoleptic tobacco quality. The lowest average price was obtained from the control variant, 126.5 den/kg ie 127.8 den/kg, and the highest average price is obtained from the variant fertilized with10 t/ha organo-mineral fertilizer. Average price from this variant is 137 den/kg, that is for 8.70 % higher than unfertilized control from Prilep area, and 146.3 den/kg or 14.44 % respectively in Dobrushevo. According to the statistical analyses there is statistical significance for average cost for all variants compared to the control.

Table 3. Impact of organo-mineral fertilizer on the average price of tobacco

N°	Variant	2011		2012		2013		Average (2011-2013)	
		den/kg	%	den/kg	%	den/kg	%	den/kg	%
Locality: Prilep									
1	Ѳ	135.5	100.00	110.9	100.00	133.1	100.00	126.5	100.00
2	10 t	142.4	105.09	128.7	116.05	139.9	105.16	137.0	108.30
3	20 t	140.2	103.47	128.3	115.68	136.5	102.57	135.0	106.71
4	30 t	140.6	103.76	125.2	112.89	137.1	103.00	134.3	106.16
Locality: Dobrushevo									
1	Ѳ	131.8	100.00	121.9	100.00	129.7	100.00	127.8	100.00
2	10 t	154.7	117.37	140.8	115.50	143.3	110.48	146.3	114.44
3	20 t	157.5	119.50	139.9	114.76	141.8	109.32	146.4	114.55
4	30 t	157.9	119.80	131.4	107.79	137.1	105.70	142.1	111.21

LSD	Locality Prilep den/kg	Locality Dobrushevo den/kg
0.05 =	5.89	7.76
0.01 =	8.92	11.75
0.001 =	14.35	18.90

The lowest average price was obtained from the control variant, 126.5 den/kg ie 127.8 den/kg, and the highest average price is obtained from the variant fertilized with10 t/ha organo-mineral fertilizer. Average price from this variant is 137 den/kg, that is for 8.70 % higher than unfertilized control from Prilep area, and 146.3 den/kg or 14.44 % respectively in Dobrushevo. According to the statistical analyses there is statistical significance for average cost for all variants compared to the control.

Gross income in agricultural production is an important parameter that reflects the economic impact of unit area.

In our research the highest gross income of 432 503 den/ha has been achieved in the variant with the highest amount of fertilizer from the experiment in Prilep. Results from Dobrushevo indicate that third variant, fertilized with 20 t, gross income is 467054 den/ha, that is for 27.10 % higher than the control. Statistical significance of the results for this parameter is at level of 0.001 or 99.9 %.

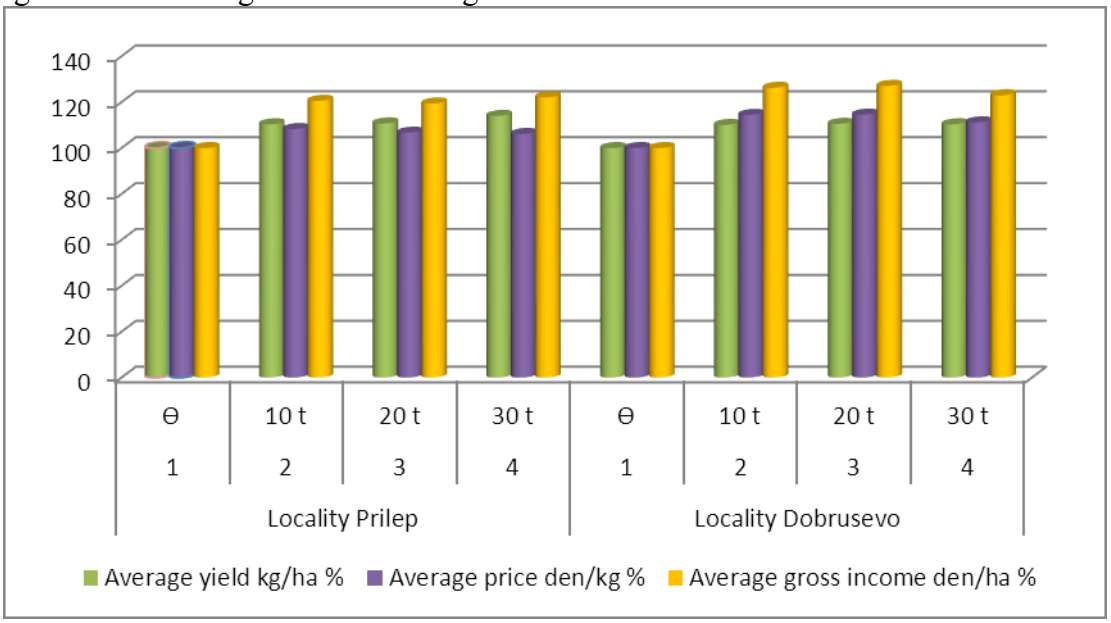
Table 4. Impact of organo-mineral fertilizer on gross income from tobacco (2011-2013)

N°	Варијанта	2011		2012		2013		Average (2011-2013)	
		den/ha	%	den/ha	%	den/ha	%	den/ha	%
Locality: Prilep									
1	Ѳ	389969	100.00	402105	100.00	270742	100.00	354272	100.00
2	10 t	437026	112.07	505896	125.81	338467	125.01	427130	120.56
3	20 t	435321	111.63	499010	124.10	335059	123.76	423130	119.43
4	30 t	446967	114.61	502718	125.02	347823	128.47	432503	122.08
Locality: Dobrushevo									
1	Ѳ	413325	100.00	429500	100.00	259530	100.00	367452	100.00
2	10 t	481117	116.40	565207	131.60	345496	133.12	463940	126.25
3	20 t	509670	123.31	553584	128.89	337909	130.20	467054	127.10
4	30 t	518386	125.42	510357	118.83	327395	126.14	452046	123.02

LSD	Locality Prilep den/ha	Localitet Dobrushevo den/ha
0.05 =	22709	36881
0.01 =	34403	55872
0.001 =	55303	89815

The average values of the agronomic characteristics of tobacco in both localities are presented in Figure 1..

Figure 1. The average values of the agronomic characteristics of tobacco in both localities



The chemical composition of tobacco is the main component of the dry matter that has a large influence on the smoking characteristics of tobacco. Quality of tobacco depends on the ratio of individual chemical components [12]. The contents of the chemical components of tobacco is not type characteristic but is influenced on the conditions on which is grown, the way it is grown, as well as doses of fertilizers [6,3].

Table 5. Impact of organo-mineral fertilizer on the chemical composition of tobacco

Variant	Nicotine		Total N		Proteins		Soluble sugars		Mineral matter		Shmuk number	Indeks
	%	Indeks	%	Indeks	%	Indeks	%	Indeks	%	Indeks		
Locality: Prilep												
Θ	1.48	100.00	2.05	100.00	6.01	100.00	19.67	100.00	11.83	100.00	3.27	100.00
10t	1.45	97.97	2.02	98.38	6.09	101.27	20.82	105.83	11.23	94.90	3.42	104.50
20t	1.64	113.33	2.31	112.66	6.68	109.69	18.21	92.58	12.27	103.66	2.73	83.34
30t	2.25	136.92	3.13	152.60	7.78	129.43	8.81	44.79	15.37	129.89	1.13	34.60
Locality: Dobrushevo												
Θ	1.51	100.00	2.35	100.00	6.23	100.00	16.77	100.00	12.83	100.00	2.69	100.00
10t	1.33	88.11	1.94	82.55	6.46	103.69	16.51	98.47	10.14	79.01	2.56	94.96
20t	1.45	108.50	2.09	88.94	6.84	109.79	15.87	94.65	10.46	81.51	2.32	86.21
30t	2.14	147.93	2.86	121.70	7.65	122.79	8.40	50.12	13.39	104.34	1.10	40.82

Impact of organo-mineral fertilizer on the chemical composition of dry fermented tobacco raw material from both experiment location is given in Table 5. According to obtained data, it can be concluded that by increasing the amount of fertilizer from 10 t to 30 t, content of nicotine, total nitrogen, protein and minerals are increased. This is in accordance with a number of other researches [10,15,13]. Highest content of soluble sugars have samples at both experiment fields in variants fertilized with the lowest rate (20.82% and 16.51%, Table 5). Soluble sugar content is substantially reduced at variant fertilized with the highest fertilizer rate (8,81% and 8,40% at both sampling places, Table 5). Shmuk number that represents the ratio between soluble sugars and proteins is a relative indicator of tobacco quality. Highest content of soluble sugars is determined in the samples from the variant fertilized with 10 t of treated sludge (Table 5). This parameter has very low values at variant fertilized with 30 t, which indicates that by increasing the amount of fertilizer, quality of raw tobacco is decreased.

CONCLUSIONS

- Organo-mineral fertilizer from treated waste sludge shows a positive impact on the quality characteristics of the soil for tobacco cultivation as well as agronomic characteristics of tobacco.
- By increasing the doses of organo-mineral fertilizer after the third year we can note a slight increase of the content of agrochemical parameters that affect the quality or soil fertility.
- Organo-mineral fertilizer has significant effect on increasing the yield, the average price and gross income per unit area. Yields and gross income increases, while average price decreases by increasing the fertilizer doses.
- Tobacco raw material samples from variant fertilized with 10 t/ha has most harmonious chemical composition characteristic for small-leaf tobacco of aromatic variety.
- Overall, based on all tested parameters we can conclude that the variant fertilized with 10 t/ha organo-mineral fertilizer is best and the most economically justified.

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