Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 1, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESULTS REGARDING THE VALORIZATION OF WASTEWATER IN IRRIGATION OF GRAIN SORGHUM CULTIVATED ON SANDY SOILS

Reta DRĂGHICI, Iulian DRĂGHICI, Mihaela CROITORU, Maria Florentina BĂJENARU, Alina Nicoleta PARASCHIV

Research Development Station for Plant Culture on Sands Dabuleni, Romania, 217 Petre Banita Street, Dabuleni, Dolj County, Romania

Corresponding author email: retadraghici@yahoo.com

Abstract

Studies conducted on sorghum cultivation, located in the conditions of sandy soils in southern Oltenia, followed the influence of fertigation with filtered waste water, with a content of 221 mg total nitrogen/liter compared to classical fertilization and irrigation with normal water from surface water sources. The results of the biometric determinations highlight differences depending on the fertilizer wastewater doses applied, on the plant height, stem diameter and leaf area. The production results obtained showed yields between 4167-7667 kg/ha, noting the variant fertilized with $N_{80}P_{80}K_{80}$, applied at preparation of the germination bed + N70, in vegetation, provided by fertigation with filtered waste water, applied fractionally in doses of 25% + 25% + 25 % + 25% (7667 kg/ha). The grain production obtained from sorghum grains in the different fertigation variants was positively correlated significantly with the weight of 1000 grains.

Key words*: fertigation-sorghum-treated water-stress resistance-productivity.*

INTRODUCTION

Climate change, unpredictable weather conditions and drought contribute significantly to the availability of freshwater resources. The growing demand for water and the discharge of a large amount of untreated wastewater is a major challenge for the management of water resources in an integrated manner.

Agriculture is a sector that consumes large amounts of water and can use lower quality water compared to the industrial sector or drinking water for human consumption (Ayer and Wescot, 1989). Direct reuses of untreated wastewater, as well as the use of freshwater resources polluted with agricultural wastewater, are very common in urban and peri-urban areas. Therefore, wastewater and biosolids are important resources that can help in the fight against water, food and energy crises (Lazarova and Bahri, 2004). Kretschmer et al., (2003) describe the advantages of using wastewater by: conserving freshwater resources, recharging aquifers, reducing the use of fertilizers.

The use of wastewater for irrigation depends largely on climatic conditions, physical properties of the soil, salt tolerance of the cultivated plant and management practices (Pescod, 1992). It is suggested to study and design the use of treated wastewater in agriculture, as part of the approach of a water circuit, which allows connecting different problems, different areas of some disciplines, in a logical and gradual framework (Huibers and Van Lier, 2005). The results obtained by Wang et al., 2002 showed that the use of sewage sludge increased the content of nitrogen, phosphorus and organic matter in the soil, thus being advantageous for the growth and development of crops. Wastewater contains the main plant nutrients (N, P, K) and also trace elements (Ahmed, 2009).

The results of the study conducted by Vijayasatya et al., (2019), showed that treated wastewater can be successfully used for the cultivation of bioenergetic sorghum in arid region. Sorghum is one of the crops with a high adaptability to unfavorable ecological conditions (poor soils, arid climate), due to the high capacity to efficiently capitalize on natural resources and increased drought tolerance (Matei, 2018, 2016, Draghici, 2019).

In the current climate arid conditions, the identification of agricultural practices with the potential to mitigate the impact of climate

change on the security of agricultural production is of increasing interest.
In this context, the orientation towards drought-resistant crops and finding an alternative to water scarcity was the objective of the present study.

MATERIALS AND METHODS

The study was carried out in the conditions of sandy soils in southern Oltenia, aiming at the influence of fertigation with an effluent obtained by wastewater treatment (treated water), compared to classical fertilization and irrigation with normal water from surface water sources. The treated water was obtained by the National Research-Development Institute for Environmental Protection, Bucharest, with the help of a wastewater treatment plant, within the complex project 27PCCDI / 2018, in order to use them for fertigation of energy crops. The experiment was performed in vegetation vessels, filled with sand with low natural fertility, with a low total nitrogen content (0.044%-0.085%) and a medium supply of extractable phosphorus (27-35 ppm) and exchangeable potassium (45-80 ppm). When filling the vessels with sand, it was fertilized with complex fertilizers type $N_{15}P_{15}K_{15}$, in a dose of $N_{80}P_{80}K_{80}$/ha (3.2 g for the vessel with an area of 0.06154 m^2).
The experiment was placed according to the method of randomized blocks, taking into account 6 experimental variants on irrigation of sorghum for grains with an effluent obtained by wastewater treatment, compared to irrigation with water from the street network, quality parameters being given in Table 1.
Irrigation with water from the street network was experimented on two variants of sorghum fertilization: $N_{80}P_{80}K_{80}$, $N_{150}P_{80}K_{80}$, the dose of N_{70} being applied in vegetation, in the phenophase of 5-7 leaves of the plant, in the form of ammonium nitrate, in a dose of 1.3 g vessel, representing 0.43078 g nitrogen active substance / vessel. Irrigation with effluent obtained by wastewater treatment, which had a total nitrogen content of 221 mg / l, was tested in 4 variants of application in vegetation of the dose of N_{70} (0.43078 g N / vessel), on the agrofound of $N_{80}P_{80}K_{80}$, used in the preparation of the germination bed.

Table 1. Water quality used to irrigate the sorghum crop

No.	Water quality indicators	Value of Quality Indicators	
		Treated water	Normal water
1	$N\text{-}NH_4$	189 mg/l	0.06 mg/l
2	$N\text{-}NO_2$	0.05 mg/l	0
3	$N\text{-}NO_3$	8.2 mg/l	0.61 mg/l
4	P total	0.9 mg/l	0
5	Al	3 mg/l	0
6	Ca	19.6 mg/l	73.4 mg/l
7	Mg	31.1 mg/l	44.5 mg/l
8	Na	226.1 mg/l	22 mg/l
9	HCO_3	1156 mg/l	400 mg/l
10	CO_3	72 mg/l	0
11	Chlorides	264 mg/l	25.5 mg/l
12	Conductivity	3.5 mS/cm	0.57 mS/cm
13	K	150 mg/l	0
14	CBO_5	100 mg/l	0
15	Sulphates	176 mg/l	30

There were 4 variants of achieving the dose of N_{70}, by using treated water, as follows: in 4 stages of 25% of the nitrogen dose, in 3 stages of 33% of the nitrogen dose, in 2 stages of 50 % of the nitrogen dose and in a single step, in a dose of 100%. The dose of 100% was applied in the phase of 5-7 leaves of the plant, and the other doses were applied weekly, until the flowering of the plant.
During the vegetation period of the plant, were performed: morphological, biometric, physiological and productivity determinations. From a physiological point of view, in the flowering phase of the plant, the following were analyzed: diurnal variation of photosynthesis and foliar perspiration, using the LC Pro+ device. Also determined were: water forms and dry matter from the leaves by gravimetric method, using the Venticell oven for drying the samples. At harvest, the following were determined: biomass production, grain yield in panicle, grain production and a thousand grains weight (TGW).
The obtained results were analyzed and interpreted by analysis of variance (ANOVA) and with the help of mathematical functions.

RESULTS AND DISCUSSIONS

The obtained results showed a differentiation of the growth rate of sorghum plants, depending on the fertigation variants applied. Thus, in the first two weeks after emergence, when the plants have developed up to 5-7 leaves, there was a uniform growth, with slightly higher values (1.1-1.2 cm / day) in the variant fertilized with $N_{80}P_{80}K_{80}$, when preparing the germination bed. In the period between the phenophase of 5-7 leaves / plant and the bellows phase of the panicle, the growth rate of the plant intensified, reaching values of 2.2-3.6 cm / day, with the maximum value in the variant fertilized with $N_{80}P_{80}K_{80}$, at preparation of the germination bed + N_{70}, applied fractionally in vegetation, by fertigation with treated water, in doses of 25% + 25% + 25% + 25%. In the period between the phenophase of the panicle bellows and the phenophase of the appearance of the panicle, the vegetative growth rate was reduced to 1.6-3.1 cm / day, during this period being more intense the process of generative development of the sorghum plant. The highest values of the growth rate were registered in the period between the exit of the panicle and the flowering phase of the panicle, the increases being between 5.2-6.4 cm / day, with the maximum value for the variant fertilized with $N_{80}P_{80}K_{80}$, at the preparation germination bed + N_{70} in vegetation, by fertigation with treated water, applied fractionally in doses of 25% + 25% + 25% + 25% (Figure 1).

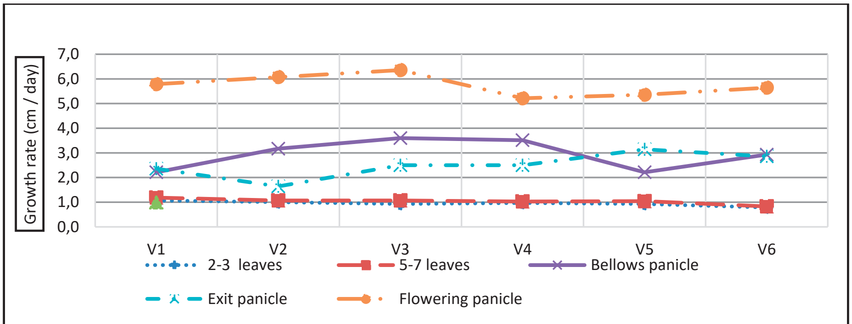

Figure 1. Influence of wastewater fertigation on sorghum plant growth rate

Biometric determinations on the growth and development of sorghum plants showed a plant height between 98.5 - 110 cm, the highest value being recorded for fertilization with $N_{80}P_{80}K_{80}$, for the preparation of the germination bed + N_{70}, in vegetation, by fertigation with treated water, applied fractionally in doses of 25% + 25% + 25% + 25%.

The diameter of the stem showed high values (15.99 mm) for the variants fertilized with $N_{80}P_{80}K_{80}$, for the preparation of the germination bed + N_{70}, in vegetation, in vegetation, by fertigation with treated water, applied fractionally in doses of 25% + 25% + 25% + 25%.

Good results of the stem diameter (15.84 mm) were also recorded for fertigation with treated water, applied fractionally in doses of 33% + 33% + 33%, on the same NPK agrofond.

The index of the leaf surface varied between 4.7-7.8, with the highest value (7.8) achieved when applying a fertilization with $N_{80}P_{80}K_{80}$, for the preparation of the germination bed + N_{70}, in vegetation, by fertigation with treated water, applied fractionally in doses of 25% + 25% + 25% + 25% (Table 2).

Table 2. Influence of wastewater fertigation on the development of grain sorghum plants

No.	Fertilization / Fertigation variant	Plant height (cm)	Panic length (cm)	Stem diameter (mm)	Leaf area index
V1	$N_{80}P_{80}K_{80}$	98.5	24.25	13.55	4.7
V2	$N_{80}P_{80}K_{80}$ + N_{70} from ammonium nitrate	104	25	15.54	6.5
V3	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 25% + 25% + 25% + 25%	110	29.5	15.99	7.8
V4	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 33% + 33% + 33%	106.5	23	15.84	6.8
V5	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 50% + 50%	103	26.5	13.76	7.3
V6	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 100%	103.5	27	14.79	5.9

The water content of the leaves is a measure of the plant's fight against stress conditions, and severe decreases can contribute to structural disruptions of important biological functions in plants that lead to tissue damage or death (Devnarain, 2016). The results on dry matter and water forms in the leaves showed that they are influenced by fertigation with wastewater. The percentage of dry matter in the leaves of sorghum plants was between 20.17–24.22% with the maximum value (24.22%) in plants fertilized with $N_{80}P_{80}K_{80}$, in the preparation of the germination bed + N_{70}, in vegetation, by treated water fertigation, applied in a dose of 100%. The free water showed values between 71.65 - 76.07%, higher values being registered for the variant fertilized with $N_{80}P_{80}K_{80}$, when preparing the germination bed. The plants from the version fertilized with $N_{80}P_{80}K_{80}$, when preparing the germination bed + N_{70}, in vegetation, ensured by a phase fertilization with ammonium nitrate, registered the highest content of bound water 4.63%. The concentration of vacuolar juice, which is a reaction of plants to defend themselves under stress conditions, had values in the range of 9.9-14%, the maximum value being recorded in the variant fertilized with $N_{80}P_{80}K_{80}$, in the preparation of the germination bed + N_{70}, in vegetation, by fertigation with treated water, applied fractionally in doses of 33% + 33% + 33% (Table 3). Sorghum [Sorghum bicolor (L.) Moench], a C4 photosynthetic plant, is the fifth most important cereal plant in the world in terms of world production and one of the most drought tolerant and efficient in terms of of water consumption, grown in semi-arid environments (Blum, 2004, Rooney 2004).

Table 3. Influence of fertirigării with treated water on the physiological indices grain sorghum

No.	Fertilization / Fertigation variant	Dry matter %	Total water %	Free water %	Bound water %	Vacuolar juice concentration %
V1	$N_{80}P_{80}K_{80}$	20.17	79.83	76.07	3.76	11.4
V2	$N_{80}P_{80}K_{80}$ + N_{70} from ammonium nitrate	22.06	77.94	73.31	4.63	10.6
V3	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 25% + 25% + 25% + 25%	22.24	77.76	73.44	4.32	9.9
V4	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 33% + 33% + 33%	22.77	77.23	72.77	4.46	14
V5	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 50% + 50%	20.70	79.30	75.23	4.07	10.7
V6	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 100%	24.22	75.78	71.65	4.13	11.6

The analysis of the values registered by the active radiation in photosynthesis and the temperature at the level of the foliar apparatus, underlines significant differences during the day, which had a decisive role in the development of the physiological processes of the plant (Table 4).

Table 4. Climatic conditions recorded with the LC Pro + device at the time of physiological determinations

Time of day	Active solar radiation in photosynthesis ($\mu mol/m^2/s$)	Temperature (°C)	Atmospheric pressure (hPa)
9 o'clock	800-870	24-26	1011
12 o'clock	1444 – 1689	38.7 – 39.7	1011
15:30 o'clock	100 – 111	31.1 – 32.2	1010

In grain sorghum, the diurnal variation of photosynthesis presented a unimodal curve, with the maximum values recorded at noon, in all variants analyzed (Figure 2).

The highest average daily accumulation rate of CO_2 in the process of photosynthesis was recorded at fertilization with $N_{80}P_{80}K_{80}$, at the preparation of the germination bed + N70, in vegetation, applied by fertigation with treated water, divided into 3-4 doses (18, 24-18,61 ($\mu mol\ CO_2 / m^2 / s$).

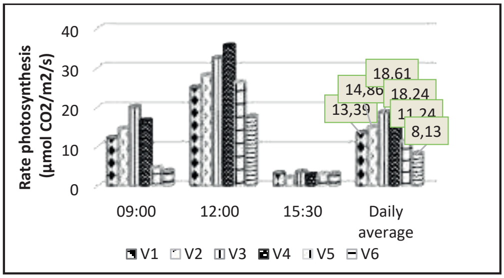

Figure 2. Diurnal variation of the photosynthesis process in grain sorghum

Between the process of foliar perspiration,, with average daily values between 1.90-3.33 mmol H_2O / m^2 / s and the photosynthesis process, with values in the range of 8.13-18.61 $\mu mol\ CO_2 / m^2 / s$, it was established a positive correlation, distinctly significant, which emphasizes the efficient recovery of water lost through foliar perspiration. The values of foliar perspiration increased in direct proportion to the intensity with which the photosynthesis process took place, the best results registering the variants fertilized with $N_{80}P_{80}K_{80}$, at the preparation of the germination bed + N_{70}, in vegetation, by fertigation with treated water, applied fractionally 3-4 doses (Figure 3).

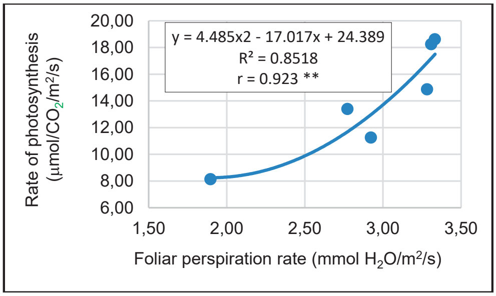

Figure 3. Correlation between foliar perspiration and photosynthesis in grain sorghum

Improving the efficiency of perspiration, especially in dry environments, can have a major impact on improving sorghum yield because high efficiency of perspiration will allow plants to either delay the symptoms of water stress or produce more biomass from the same amount of soil moisture available. or a combination of both (Xin et al., 2008, Thapa et al., 2017).

The production results, recorded for grain sorghum, showed an increase in productivity compared to the control variant, depending on the application of different doses of fertigation with treated water (Table 5). The best production results (6823-7667 kg / ha) and the weight of one thousand grains (33.2-33.6 g) were noted, the variants in which the dose of 70 kg N / ha, required in vegetation, was ensured by irrigating the sorghum with treated water divided into 3 doses of 33% or 4 doses of 25%, starting with the phase of 5-7 leaves, on an agrofund of $N_{80}P_{80}K_{80}$. Similar results were obtained on the sandy soils from Tâmburești, where grain sorghum achieved maximum yields at fertilization with a dose of $N_{150}P_{80}K_{80}$ (Matei Gh., 2011).

Table 5. Production results obtained from sorghum grains in different fertilization / fertigation variants

No. Var..	Fertilization / Fertigation variant	Biomass production (t/ha)	Grain yield / panicle %	Grain yield (kg/ha)	Significance	(TGW) (g)
V1	$N_{80}P_{80}K_{80}$	24	72.5	4147	Mt.	31.3
V2	$N_{80}P_{80}K_{80}$ + N_{70} from ammonium nitrate	24.5	89.3	5708	-	32.8
V3	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 25% + 25% + 25% + 25%	32	83.5	7667	**	33.6
V4	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 33% + 33% + 33%	35	85.1	6823	*	33.2
V5	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 50% + 50%	26.6	76.8	5613	-	33.2
V6	$N_{80}P_{80}K_{80}$, + N_{70} from treated water, in doses of 100%	27.1	75	5519	-	31.9
LSD 5% = 2238 kg/ha ; LSD 1% = 3510 kg/ha; LSD 0,1% = 5976 kg/ha						

The biomass production registered values between 24-35 t / ha, highlighting with the highest values the fertilization with $N_{80}P_{80}K_{80}$, at the preparation of the germination bed + N_{70}, in vegetation, ensured by fertigation with treated water, applied fractionally in doses of 33 % + 33% + 33%. The results of the surveys performed by Jerbi et al. (2020) and Fakhroddin et al. (2020), showed increases in production of various irrigated crops with wastewater. The grain production obtained from sorghum grain in the different fertigation variants was positively correlated, insignificantly with the grain yield on the panicle and positively significant with the weight of one thousand grains (Figure 4).

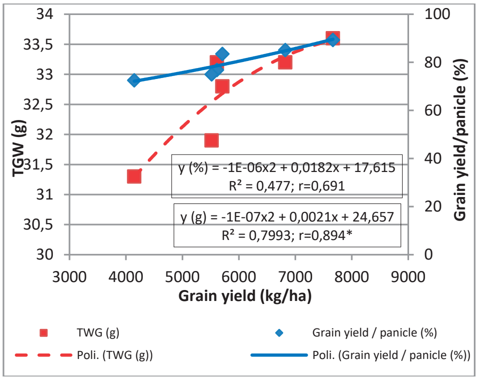

Figure 4. Correlation between grain yield, one thousand grain weight and grain yield / panicle

CONCLUSIONS

The obtained results highlighted the role of fertigation with an effluent obtained by wastewater treatment on the results obtained from grain sorghum grown in sandy soil conditions.

The index of the leaf surface varied between 4.7-7.8, with the highest value achieved when applying a fertilization with $N_{80}P_{80}K_{80}$, when preparing the germination bed + N_{70}, in vegetation, by fertigation with treated water, applied fractionally in doses of 25% + 25% + 25% + 25%.

The concentration of vacuolar juice, which is a reaction of plants to defend themselves under stress conditions, had values in the range of 9.9-14%, the maximum value being recorded in the variant fertilized with $N_{80}P_{80}K_{80}$, in the preparation of the germination bed + N_{70}, in vegetation, by fertigation with treated water, applied fractionally in doses of 33% + 33% + 33%.

The highest average daily rate of CO_2 accumulation in the process of photosynthesis was the fertilization with $N_{80}P_{80}K_{80}$, at the preparation of the germination bed + N_{70}, in vegetation, applied by fertigation with purified water, divided into 3-4 doses (18,24-18, 61 (μmol CO_2 / m^2 / s).

The best results regarding the production (6823-7667 kg / ha) and the weight of one thousand grains (33.2-33.6 g) were noted, the variants in which the dose of 70 kg N / ha, required in vegetation, was ensured by irrigating the sorghum with purified water divided into 3 doses of 33% or 4 doses of 25%, starting with the phase of 5-7 leaves

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation CCDI - UEFISCDI, Project Innovative technologies for irrigation of agricultural crops in arid, semiarid and subhumid-dry climate, PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III.

REFERENCES

Ahmed, K.A.S.M., (2009). *Effect of Using Treated Wastewater with Urea Fertilization on the Quality and Yield of Sorghum Forage (Sorghum bicolor)* Doctoral dissertation, University of Khartoum.

Ayers, R.S., Westcott, D.W. (1989). Water quality for Agriculture, Irrigation and Drainage. Paper 29 rev. 1. FAO. Blum A. (2004): Sorghum physiology. In: Nguyen H.T., Blum A. (eds): *Physiology and Biotechnology Integration for Plant Breed*ing. New York, Basel, Marcel Dekker, 141–223.

Blum, A. (2004). Sorghum physiology. In: Nguyen H.T., Blum A. (eds): *Physiology and Biotechnology Integration for Plant Breeding*. New York, Basel, Marcel Dekker, 141–223.

Devnarain, N., Crampton, B.G., Chikwamba, R., Becker J.V.W., Kennedy, M.M.O. (2016). Physiological responses of selected African sorghum landraces to progressive water stress and re-watering. *South African Journal of Botany*, *103*. 61–69. https://doi.org/10.1016/j.sajb.2015.09.008

Drăghici, I., Drăghici, R., Constantinescu, M., Croitoru, M., Stoica, M.M., Paraschiv, A., Băjenaru, M.F., (2019). Research on fertirigation implications on grain sorghum cultivated under thermohydric stress conditions. ISB-INMA TEH, Agricultural and Mechanical Engineering, 724–731.

Fakhroddin, G.S., Omolbani, M., Masoomeh, D., Abbas Khashei, S., Henk, R., Ali, Ch. (2020). Effect of utilization of treated wastewater and seawater with Clinoptilolite-Zeolite on yield and yield components of sorghum. *Agricultural Water Management*, *234*. https://doi.org/10.1016/j.agwat.2020.106117.

Frans, P., Huibers, Jules B. Van Lier (2005). Use of wastewater in agriculture: the water chain approach. *Irrigation and Drainage*, *54*. https://doi.org/10.1002/ird.181

Jerbi, A., Brereton, N.J.B., Sas, E., Amiot, S., Lachapelle-T, X., Comeau, Y., Pitre, F.E., Labrecque, M. (2020). High biomass yield increases in a primary effluent wastewater phytofiltration are associated to altered leaf morphology and stomatal size in Salix miyabeana. *Science of The Total*

Environment, *738*. https://doi.org/10.1016/j.scitotenv.2020.139728

Kretschmer, N., Ribbe, L., Gaeses, H. (2003). Wastewater reuse for agriculture. *Technology Ressource Management & Development - Scientific Contributions for Sustainable Devel*opment, *2*. 37–64.

Lazarova, V.a, Bahri, A. (2005). Water Reuse for Irrigation. *Agriculture, Landscapes and Turf Grass*. 6–7.

Matei, Gh. (2011). Research on some technological measures for increasing the yields on grain sorghum cultivated on sandy soils from Tâmburești. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series*, *41*(1), 235–239.

Matei, Gh., Vlăduț, V.N., Pânzaru, R.L., Săvescu, P., Sălceanu, C. (2018). Study on the influence of mineral fertilization on the yield of grain sorghum cultivated in the Caracal Plain. I*nternational Symposium, ISB-INMA TEH' 2018, Agricultural and mechanical engineering, Bucharest, Romania*. 1021–1026.

Matei, Gh. (2016). Study on yield features of sweet sorghum hybrids grown in south west of Romania. *16th International Multidisciplinary Scientific GeoConference SGEM 2016, www.sgem.org, SGEM2016 Conference Proceedings,* Book6 Vol. 1, 783–790. DOI: 10.5593/SGEM2016/B61/S25.104

Pescod, M.B. (1992). Wastewater treatment and use in agriculture- FAO *Irrigation and Drainage*. 47.

Rooney, W.L. (2004). Sorghum improvement – Integrating traditional and new technology to produce improved genotypes. *Advances in Agronomy*, *83.* 37–109.

Thapa, S., Stewart, B., Xue, Q. (2017). Grain sorghum transpiration efficiency at different growth stages. *Plant soil and environment*, *63*. 70–75. https://doi.org/10.17221/796/2016-pse

Vijayasatya, N., Chaganti, Girisha Ganjegunte, Genhua Niu, April Ulery, Robert Flynn, Juan M. Enciso, Manyowa N. Meki, James R. Kiniry, (2019), Effects of treated urban wastewater irrigation on bioenergy sorghum and soil quality. *Agricultural Water Management,* 228. https://doi.org/10.1016/j.agwat.2019.105894.

Wang, Xin & Chen, Tao & Liang, Renlu & Zhou, Qixing, (2002). Effects of land utilization of sewage sludge on crops and soils. *The journal of applied ecology / Zhongguo sheng tai xue xue hui, 13*(2), 163–166.

Xin, Z., Franks, C., Payton, P., Burke, J.J. (2008). A simple method to determine transpiration efficiency in sorghum. *Field Crops Research.*, *107*. 180–183.