INTERNATIONAL SCIENTIFIC JOURNAL

MECHANIZATION IN AGRICULTURE & CONSERVING OF THE RESOURCES

Issue 6
2016

Year LXII, ISSN print 0861-9638, ISSN web 2534-8450

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
BULGARIAN ASSOCIATION OF MECHANIZATION IN AGRICULTURE

PUBLISHERS

SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING

BUGLARINA ASSOTIOATION OF AGRICULTURAL MACHINERY

ISSN PRINT 0861-9638, ISSN WEB 2534-8450
YEAR LXII ISSUE 6 / 2016

The journal “Mechanization in agriculture & Conserving of the resources” is continuer of the journals “Mechanized farming” (1948-1957), “Mechanization and electrification of agriculture” (1959-1980), “Mechanization of agriculture” (1981-1991) and “Mechanization in agriculture” (1991-2016)

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OPTIMIZATION OF BIOGAS PRODUCTION FROM LIGNOCELULOSIC MATERIALS BY DIFFERENT METHODS OF SUBSTRATE TREATMENT

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Abstract: *One of the most used types of biofuels is the biogas, produced during the process of anaerobic digestion of organic waste. The current project aims utilization of plant biomass waste, used to produce energy in the form of biogas, after proper pretreatment, in order to enhance energetic value and yield. Proper resource and method of pretreatment will be chosen, in order to obtain high biogas yields. The chosen technology will be tested in a plug-flow bioreactor to optimize the technical parameters.*

Keywords: BIOGAS, ANAEROBIC DIGESTION, BIOMASS, LIGNOCELULOSIC MATERIAL, BIOREACTOR

1. Introduction

Biofuels represent a great share of the energy carriers of the modern developed society. They are considered an alternative to the traditional energy sources such as oil, coal and nature gas. Biofuels stands for ethanol, produced from plants, biodiesel, produced from nature lipids and biogas, produced through anaerobic digestion of plant and animal waste.

Biogas is widely used fuel in economically developed countries, as well as in the countries from 3rd world. It has many applications. Among the most important ones are as fuel for both thermal power plants, national gas grid and as a fuel in various types of vehicles, including passenger cars, trucks, small and midsize boats and aircrafts. The main source to produce biogas is manure. Some of the disadvantage of producing biogas, is the low content of methane (50 60%), as well as the presence of sulfuric compounds. In the current case, our aim is to investigate the possibilities of optimizing the methods and conditions for biogas production from vegetal waste.

Series of periodic experiments on biogas production from vegetal waste have been carried out in the Institute of Chemical Engineering (BAS). In each one of them, coniferous material was mixed with manure. Pretreatment of manure and coniferous material was conducted in some of the experiments. Most commonly, the treatment involved acid hydrolysis of the coniferous material, autoclaving applying electrical field in the reactors containing coniferous material and manure. After both materials were treated in the corresponding way, they were subjected to mesophilic anaerobic digestion in sealed glass vessels. Biogas was collected and stored above water in gas-holders. Biogas yields were checked and samples for analyze were taken daily.

During the experiments, we used a coniferous material from type *Picea excelsa L*. The first part of treatment focused on the lignocellulosic material. The branches and leaves were shredded and then collected in a beaker. After that, their weight was measured. In the next step, the material was mixed with water or acid. Then, the material was autoclaved for 20 min at 121 °C. In the meantime, the second part of the treatment was carried out. A specific amount of organic waste (cow/cattle manure) was taken, and then it was mixed with water. After that, the slightly liquefied manure was treated in various ways. One of them included passing an electrical current through the mixture for some time. After that, the lignocellulosic material and the organic waste were mixed. Then the mixture was poured in air insulated glass vessels. The vessels were installed in water bath, where the temperature was kept at around 35 °C. Each experiment included different ways of treatment, mixing and autoclaved material.

Experiment 1 has no additional treatment of the two materials used (coniferous and manure). It serves as a base experiment.

Experiment 2 Sample A contains cattle manure only. Sample B includes coniferous material mixed with acid and autoclaved. Then it was mixed with cattle manure.

Experiment 3 Sample A contains coniferous material mixed with water and then cattle manure was added. Sample B contains coniferous material treated the same way, but before adding, the cattle manure was treated with electricity for ½ hour.

Experiment 4 Sample A contains coniferous material mixed with acid and autoclaved, then before adding, the manure was treated with electricity for ½ hour. Sample B contains coniferous material mixed with water and then autoclaved. Before adding, the cattle manure was treated with electricity for 1 hour.

Experiment 5 Sample A contains coniferous material which was treated by method called “steam explosion”. Then it was mixed with manure. Sample B has the same treatment, only before adding, the manure was treated with electricity for ½ hour.

Fig. 1 *Outlook of the small scale bioreactor*

2. Results and Discussion

During the first part of the project, it was investigated the possibility to produce biogas by using different waste materials, which include lignocellulose, pretreated in various ways (including hydrolysis, enzymes, electrochemical processes) and kept in defined conditions (temperature – 35 °C). The materials used were mainly from plant, animal, and/or industrial waste (wasted glycerol from biodiesel production). Their treatment included different schemes of mixing, use of digestion compounds (acid hydrolysis, water autoclave, electrical treatment).

Table 1: *Biogas daily yield – Samples A and B. Results from burning test.*

	Biogas yield Samples A, mL	Biogas yield Samples B, mL	Total amount of burning biogas, mL
Experiment 1	2285	1691	A-2075; B-1691
Experiment 2	70	325	A-0; B-325
Experiment 3	3345	210	A-0; B-210
Experiment 4	2100	1005	A-0; B-1005
Experiment 5	328	388	A-0; B-303

In the conducted experiments, we have found out that, the treatment of the waste material with electric current leads to improvement in the ingredients of produced biogas, expressed mainly in higher methane content (reaching in some cases 95 – 98 % (vol.) in a comparison with most commonly observed 50 – 75%). It is important, as the higher methane content in the produced biogas, means better fuel properties. Therefore, the accumulated biogas (containing 95 – 98% methane), could be directly used as a fuel in public transport, or to be supplied into the national gas grid system without additional treatment, as it is in the case with biogas with lower methane content. Then additional treatment is required, when the biogas will be used as fuel in public vehicles or the injection into the national gas grid. The treatment includes compressing, drying the biogas and separating the remaining CO_2 and sulfuric compounds (hydrogen sulfide and mercaptans). This leads to higher energetic and economic expenditure and therefore producing less amount of methane.

In the present case electric current as pretreatment method avoids the necessity of additional treatment of the produced biogas.

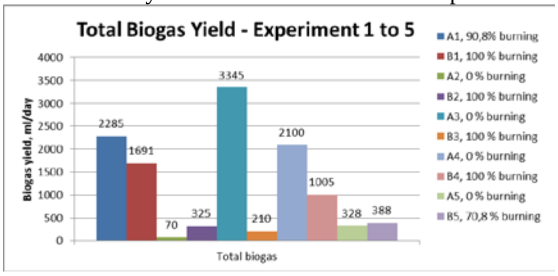

***Fig.2** Biogas yield in experiments 1 to 5*

Fig. 2 shows the combined results from 5 experiments. Each experiment contains two samples, named A and B. In the some of the samples, the burning is 100 %, which means that all the collected for the day biogas burnt. In others, the percentage is lower, because not all taken samples were burning (when the methane content in the taken sample drops to below 50 %, vol). Sample A3 gave the highest quantity of biogas, but there was no burning, while B3 gave much less biogas quantity, but with 100 % burning.

Fig. 3 to Fig. 6 show the corresponding biogas results for each experiment. It can be noticed that in most of the experiments, Samples A show higher amount of biogas, but has lower content of methane, while Sample B show lower amount of biogas, but higher methane content.

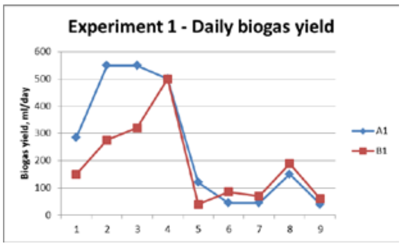

***Fig.3** Biogas yield Experiment 1*

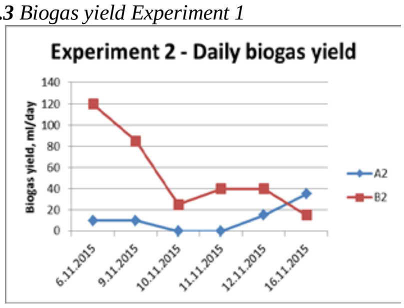

***Fig.3** Biogas yield Experiment 2*

In Experiment 2, Sample A contains manure only, while Sample B contains acid hydrolyzed (with 1 % H_2SO_4) coniferous material mixed with manure. (Acid treatment was applied to the plant material only.

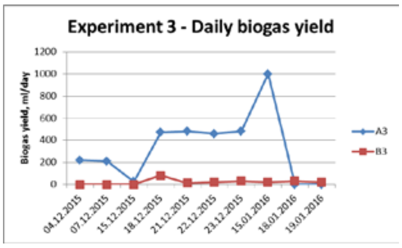

***Fig.4** Biogas yield Experiment 3*

In Experiment 3, Sample A contains water autoclaved coniferous material, later mixed with manure, and Sample B contains the same way treated coniferous material, plus additional treatment of the manure – charged with electrical current for 30 min.

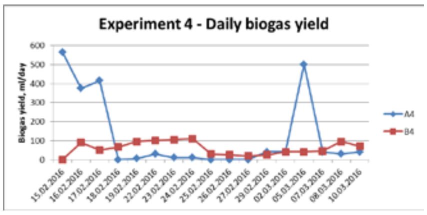

***Fig.5** Biogas yield Experiment 4*

In Experiment 4, the coniferous material was treated with 1% H_2SO_4 and the manure was treated with electrical current for 30 min (Sample A). Sample B was treated the same way, with the only difference – the manure was treated with electricity for 1 hour.

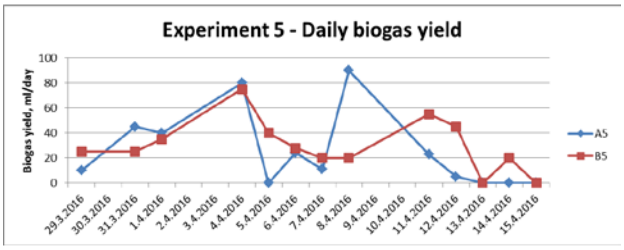

***Fig. 6** Biogas yield Experiment 5*

In Experiment 5, the coniferous material from Sample A and B was treated by method called steam explosion. It was believed that such treatment would make the organic compounds more accessible for the microorganisms present in the anaerobic digestion process. Then the exploded coniferous material was mixed with untreated manure (Sample A), and a treated with electrical current for 30 min manure.

3. Conclusion

According to the results obtained from our experiments, we have noticed that treatment did improve the quantity and quality of the collected biogas. While some of the treatments gave more biogas quantity with slightly less amount of CH_4, others gave slightly lower amount of biogas, but with higher content of CH_4.

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DETERMINING THE LEVEL OF RELIABILITY OF SELF-PROPELLED AGRICULTURAL MACHINERY USING THE METHOD OF INSTANTANEOUS OBSERVATIONS

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Summary: *To solve the tasks related to the operational management of the technical condition of self-propelled agricultural equipment the method of momentary observations to quickly assess the level of reliability of self-propelled agricultural equipment was improved.*
A comparative study of the reliability of the self-propelled agricultural machinery / harvesters / classic method and the method of current observation, and it has been found that the accuracy of the results obtained by the method of current observation satisfy the requirements for practical usage.
KEYWORDS: *REFUSAL, WORK TILL REFUSAL, THE FLOW RATE OF REFUSALS, SCHEDULED MAINTENANCE, PLANNED REPAIRS, MATHEMATICAL MODEL, RELIABILITY, COEFFICIENT OF READINESS.*

Used test methods in the theory and practice of reliability are of long duration and to conduct accelerated testing usually require special stands and expensive measurement equipment. Meanwhile tasks regarding the operational management of the technical condition of the machines, require the development of express methods for assessing the level of reliability.
When the machines are working it is possible in operating order to organize observation at certain times and to establish what their condition is. We accept that we have N machines that will be used till manufacture of t_n (Fig. 1). During the operation they refuse at time moments t^j_i ($\forall i = \overline{1,N}$ and $j = \overline{1,m}$), and their performance was recovered in the moments $t^j_{b_i}$ where j is the number of refused and *i* - the number of machine. At certain times t_{M_k} the technical condition of the machine is determined – we establish in what condition it is, capable or incapable of working (in a state of refusal) [3].
When there is a sufficient number of objects N, from Figure 1, the likelihood to establish that the first machine is in working condition is proportional to the time being in this state:

$$P = \frac{n_1}{N} = \frac{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{m} t^j_i}{Nt}, \tag{1}$$

Where n_1 is the number of machines found in working condition;
N - total number of machines which are monitored;
m - the number of refusals in the i-th machine.
Similarly, the probability of failure is determined by the following relationship:

$$F(t) = 1 - P(t) = \frac{n_2}{N} = \frac{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{m} t^j_{bi}}{Nt} \tag{2}$$

Where n_2 is the number of machines present in the non-operational.
From the ratio

$$\frac{n_1}{n_2} = \frac{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{m} t^j_i}{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{m} t^j_{b\,i}} \tag{3}$$

After conversion we get that

$$t_{cp} = \frac{n_1}{n_2} t_b \ ;\ n_2 \neq 0, \tag{4}$$

Where t_{cp} is average work out till failure;
$t_в$ - average time to restore the performance of the objects.

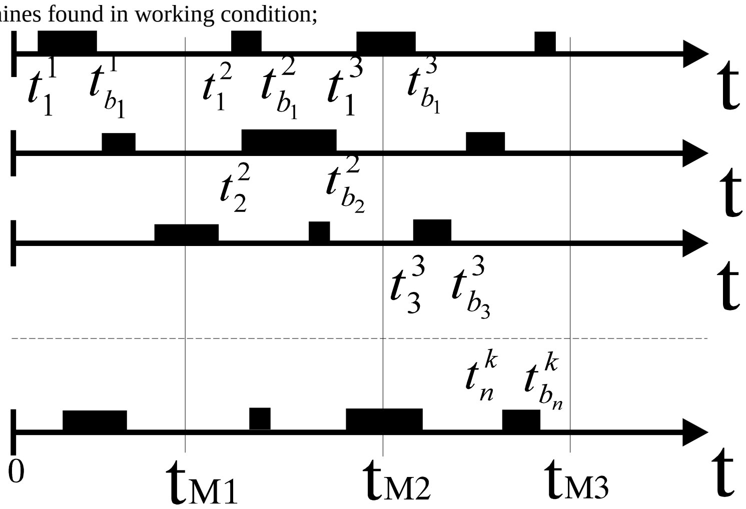

Fig. 1. *Scheme of using the current live observations*

From this ratio will readily determine by the famous formula $Kr = \dfrac{t_{cp}}{t_{cp} + t_b}$, then substitution of (4) we get

$$Kr = \frac{\frac{n_1}{n_2} t_b}{\frac{n_1}{n_2} t_b + t_b} = \frac{n_1}{(n_1 + n_2)} \tag{5}$$

Similarly, the coefficient of technical use will be

(6) $$K_{TK} = \frac{n_1}{n_1 + n_2 + n_3 + n_4}$$

Where n_3 is the number of machines that are in scheduled maintenance;

n_4- the number of machines located in planned repair.

The parameter of refusals flow ω(t) in stationary proses (t→∞) was determined by the dependency $\omega(t) = \frac{1}{t_{cp}}$, then:

(7) $$\omega(t) = \frac{n_2}{n_1 t_b}$$

And the average number of failures at time t is

(8) $$m_{cp}(t) = \omega(t).t = \frac{n_2}{n_1 t_b}.t$$

Similarly, the expression (4) can determine the average resource of the machine:

(9) $$T_{cp} = \frac{n_1}{n_5} t_p$$

Where t_p is the average time in which the machine spends in major renovation;

n_5- number of machines in overhaul.

It is known that the moments of occurrence of refusals and time to remove them are random magnitude and momentary observations are conducted per plan, at set intervals. Then the probability that the observer will begin monitoring during the recovering if the object's performance is allocated under the law of uniform distribution. Here mathematical expectation of time from the beginning of occurrence of refusal till observer's fixing it is:

(10) $$t_b^H = \frac{1}{2}\sum_{i=1}^{n_2} t_{bi}$$

Thus, the average observation time of the machine in a state of refusal is equal to half of the average time of recovery of its working capacity. Then

$$t_b = 2.t_b^H$$

i. e., the average recovery time of the object is equal to double the time from the beginning of the failure of products until its fixing in a state of refusal. For practical calculations it is appropriate to use the following formula

(11) $$t_b = \frac{2\sum_{i=1}^{n_2} t_{bi}^H}{n_2}$$

Where t_b^H is the time from the beginning of occurrence of the i-th refusal until its fixing at the time of monitoring.

The required number of momentary observation, i. E. Fixed the machine operable or non-operational, is based on the formula for the accuracy of an assessment [1,2]

(12) $$\varepsilon = t_\beta \sqrt{\frac{P(1-P)}{n}}$$

where P is the probability of occurrence of a random event A, determining the state of the research object;

t_β - the argument of the differential distribution function of Student;

n - number of current observations.

From here $n = t_p^2 P(1-P) / \varepsilon^2$

The expression (12) is correct in a single instantaneous monitoring of machines. Therefore, when the number of momentary observations has to be greater than the number of machines (n> N), then (12) takes the following form:

(13) $$\varepsilon = t_\beta \sqrt{\frac{P(1-P)}{\ell N}}$$

where ℓ is the number of re-monitored machinery.

The formula (13) is true when the frequency of conduction of current observations (τ) greater than the maximum time for removal of failures $t_{\text{вmax}}$. ($\tau > t_{\text{вmax}}$). Otherwise for repeated monitoring of denials whose time for removal of failures is greater than the frequency of current observations ($t_в > \tau$) will again be included in the number of refusals. The probability of such failures is defined by $F(\tau) = \int_\tau^\infty \psi(t)dt$ where ψ(t) is the density of distribution of recovery time.

Then the number of failures is re-registered

$$m_n = N\int_\tau^\infty \psi(t)dt$$

From here

(14) $$\varepsilon = t_\beta \sqrt{\frac{P(1-P)}{\ell N(1-F(\tau))}}$$

The expression (14) allows to find the necessary frequency for conducting the instantaneous observations. If the time allotted for assessing the reliability $t_0 > t_{\text{вmax}}$, the frequency is selected equal to $t_{\text{вmax}}$ and the number of current observations are determined by formula (13), meaning:

$$N = \frac{t_\beta^2 P(1-P)}{\ell \varepsilon^2}$$

Otherwise, the frequency of momentary observations is found by converting the formula (14) taking into account that the recovery time is distributed by the exponential law, and $\tau = t_0 / \ell$. Then

$$\tau = \frac{t_0 N\varepsilon^2(1-e^{-\lambda\tau})}{t_\beta^2 P(1-P)}$$ but since

$$e^{-\lambda\tau} = 1 - \frac{\lambda\tau}{1!} + \frac{(\lambda\tau)^2}{2!} - - \to \infty$$ and we take the first two terms,

(15) $$\tau = \frac{t_0 N\varepsilon^2}{(1-\lambda)t_\beta^2 P(1-P)}$$

In the period from 2005-2006, a study was conducted over the reliability of 10 combine harvesters, in the conventional way and by momentary observations. There were conducted 450 momentary observations and registered 403 cases of operational and 59 - non-operational. The aggregated data are given in Table 1.

To calculate the difference between the estimates as a benchmark, other results were used from prolonged observation. From the analysis of the accuracy of the result we come to the conclusion that the accuracy of the test method of momentary observations is sufficient for practical use.

***Table 1**: Characteristics of indicators of reliability of combine harvesters*

Characteristics	Methods of evaluation		
	continuous observation	momentary observation	Difference %
Work out –till-refusal	8.97	9.47	5.5
Ratio of readiness	0.866	0.872	0.69
Parameter of refusal flow, 10^{-3}	111	106	5.6
Work out till refusal in groups of complexity:			
I	20.71	18.54	10.5
II	17.20	16.90	1.7
III	196.75	190.08	3.4

Conclusions:

1. The method of instantaneous observations used to quickly assess the level of reliability of self-propelled agricultural equipment is improved.
2. A comparative study was conducted of the reliability of self-propelled agricultural machinery / harvesters / in a classic method and the method of instantaneous observations.
3. It has been found that the accuracy of the results obtained by the method of momentary observation satisfy the requirements for practical usage.

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BIOCHAR EFFECTS ON MAIZE PHYSIOLOGY AND WATER CAPACITY OF SANDY SUBSOIL

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Abstract:
Sandy soils facilitate maize growth in cold regions. However, Danish coarse sands have poor water and nutrient retention capacity which may constrain crop growth during dry spells. A greenhouse maize experiment was conducted in which straw biochar was applied to the subsoil at concentrations of 0, 1, 2, and 3%. All the plants were fully irrigated until flowering. Thereafter, half of the plants were subjected to drought until 76% of soil water content at field capacity was depleted in the control. Plant height and number of leaves were not significantly different at flowering although significantly lower for 3% biochar at stem elongation stage. Leaf water potential, stomatal conductance as well as photosynthesis and transpiration were maintained in biochar 2 and 3% during the drying cycle reflecting the increase in soil water holding capacity. In the drought treatments, plant biomass tended to be greater for biochar 2% but decreased for biochar 1 and 3%. Cob biomass was increased by biochar 3% but decreased by 1 and 2 %. Biochar however decreased plant biomass and cob biomass under irrigation.

KEYWORDS: DEFICITIRRIGATION, LEAF WATER POTENTIAL, STOMATAL CONDUCTANCE, COB BIOMASS, STRAW BIOCHAR, PHOTOSYNTHESIS

1. Introduction

The impacts of global climate change may result in drought in many areas with drought disaster affected areas projected to increase from 15.4% to 44% by 2100 (Li et al., 2009). Drought can result in significant grain yield reduction in maize especially during tasseling and or ear formation (Çakir, 2004). During drought, maize roots that detect drying of the soil communicate this change to the shoots (Blackman and Davies, 1985), as root derived abscisic acid eventually lower the stomatal conductance and thereby reduce transpiration and photosynthesis. This is particularly serious in sandy soils because of their low capacity for plant available water and their shallow rooting depth (Andersen and Aremu, 1991; Andersen et al., 1992).

Biochar is emerging as a solution to enhance crop growth, increase water and nutrient retention as well as increase soil carbon sequestration. It is a carbon-rich product formed when biomass such as wood, manure, or crop residues is heated in a closed container with little or no oxygen (Lehmann and Joseph, 2009). They are highly recalcitrant (Cheng et al., 2008) due to the condensed aromatic ring structure (McBeath et al., 2014) with an estimated mean residence time of between 90-1600 years (Singh et al., 2012). The key characteristic of biochar, depending on the pyrolysis treatment (Lee et al., 2010), is the cation exchange capacity due their large negatively charged surface area (Liang et al., 2006). In addition to the pyrolysis conditions biochar characteristics also depend on the type of feedstock. For instance, Jindo et al. (2014) have shown that biochar obtained from rice materials have unique chemical properties because of the incorporation of silica elements into its chemical structure. On the other hand, biochar produced from wood materials showed high carbon content and absorption character. This varied nature of biochar may be responsible for the differences and sometimes contrasting effects that have been reported in literature.

Danish coarse sandy soils restrict root growth and have poor water and nutrient retention (Bruun et al., 2014) with rooting depth limited to about 60 cm (Rasmussen, 1999). They pose a constraint on crop development because they have a high risk of drought in the dry seasons and of nitrate leaching from the root zone in the wet seasons (Bruun et al., 2014). In cold regions, sandy soil facilitates maize growth due to higher soil temperature than loamy soils (Odgaard et al., 2011). In Denmark cultivation of maize started increasing in the 1980´s (Olesen and Bindi, 2004). It is mostly for silage to feed cattle during winter, as this can be produced from maize vegetative parts and immature cobs (Andersen, 2000) as cited in Odgaard et al. (2011). Maize in Denmark is grown between May and October. There is some risk of some dry spells during summer which may be a major constraint for maize planted in sandy soils.

Several studies have shown that biochar application to soils increases soil water retention, root growth and yield (Abel et al., 2013; Abiven et al., 2015; Akhtar et al., 2014; Sun et al., 2014). A study by Bruun et al. (2014) showed that biochar increased water retention, and possibly improved root penetration and density in a Danish coarse sandy soil. Uzoma et al. (2011) observed significant increases in maize yield and nutrient uptake when they applied cow manure biochar to sandy soil. To the best of our knowledge, there is very limited literature on the effect of biochar amendment to coarse sandy soils under drought conditions and its implications for maize yield and crop physiological processes.

In the present study we therefore investigated the effect of biochar amendment to subsoil on crop physiological processes and yield of maize comparing irrigated and drought conditions.

2. Materials and Methods

2.1. Study location and Soil & Biochar

The study was conducted at Foulum Research station of Aarhus University, Denmark with soil collected from the Jyndevad research station. Soil materials were collected from 0 – 25 cm and 25 – 100 cm depth to represent topsoil and subsoil respectively. Information on the textural composition is presented in Table 1.

Table 1. Physical properties of soil used

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Organic matter (%)	Bulk density (g/cm^3)	Plant available water (%)
0-30	5.8	2.1	90.7	1.9	1.41	10.2
30-70	5.9	0.5	92.7	0.7	1.46	6

Source: (Ahmadi et al., 2009)

Wheat straw biochar from a commercial company, Frich A/S, Denmark was used for the experiment. It was produced by slow pyrolysis at a temperature of 500°C. Biochar properties are shown in Table 2.

2.2. Experimental set up

The pots used for this experiment had a dimension of diameter: 36 cm; length 70 cm. The soil columns were prepared under a shed in at AU-Foulum.To prevent root growth along the sides, the inside of the pots were coated with subsoil mixed with water insoluble wallpaper glue (Bostik Hernia Vaadrumslim) as done by Bruun et al. (2014) before filling the soil. The soil was filled in three layers. The layer at the bottom from 50 – 70 cm depth was filled with subsoil only.

Table 2. Some of the properties of the biochar used

Total C: 79.3 %, Total N: 0.7%, pH: 8.4, PAH: <0.50 mg/kg							
Nutrients							
NH_4 (mg/L)	NO_3-N (mg/L)	P_2O_5 (%)	K_2O (%)	MgO (%)	Na (mg/kg)	CaO (%)	S (%)
1.39	<5.0	1.1	5.3	0.44	996	1.81	0.12
Heavy metals (mg/kg)							
Cu	Fe	Mn	Zn	Pb	Cd	Cr	Ni
14.3	1300	86.1	81.4	<3.0	<0.20	19.9	32.0

It was then followed by subsoil with or without added biochar at the 20 – 50 cm depth. The topmost layer was filled with only topsoil at a depth of 8 – 20 cm. Prior to filling the pots, the soil and biochar were weighed to get the desired dry weight and proportion, and mixed for 5 minutes in a mechanical mixer. The soil was packed at a bulk density of 1.2 kg/m^3 and 1.3 kg/m^3 in the topsoil and subsoil sections, respectively. Packing was done by pressing the soil down with fingers followed by surplus irrigation and letting the soil settle to a "natural" bulk density, which was determined after harvest of the plants. TDR probes of 60 cm were placed in each pot for determining soil water content for irrigation scheduling. After filling all the pots, they were placed on an area with moist and lose soil to which peat had been added and irrigated in excess. The pots were then allowed to drain for three days after which field capacity was determined with time-domain reflectometry (TDR).

2.3. Treatments

Biochar was mixed with the subsoil in the following concentrations 0, 1, 2 and 3% on dry weight basis. With regards to irrigation, all the pots were initially fully irrigated and irrigation was carried out each time the soil water deficit exceeded 25% of the available soil water content. Drying cycle 1 was initiated at BBCH stage 5 (tasseling) at day 60 after planting (DAP). In the drying cycle, half of the pots were fully irrigated while the others were exposed to drought until an average soil water deficit of 76% was reached in the pots without biochar. Drying cycle 2 was initiated at BBCH stage 7 (fruit development) on day 78 after planting. This resulted in 8 treatments with 8 replicates shown in Table 3.

Table 3: Treatment combinations

Biochar Conc. (%)	Irrigation Level	Designation
0	Full	BC01
0	Drought	BC00
1	Full	BC11
1	Drought	BC10
2	Full	BC21
2	Drought	BC20
3	Full	BC31
3	Drought	BC30

2.4. Planting and growth conditions

Maize was sown on 7th May, 2015 under the shed. Three seeds were planted per pot at a depth of 5 cm and a distance of 2 cm between seeds. The pots were moved into the greenhouse on 11th May, 2015. The pots were arranged in four rows in the greenhouse in a completely randomized design. The plants were thinned after emergence to one plant per pot twelve days after planting. The growth condition of the greenhouse was a maximum temperature of 28 ºC during the day and 10 ºC at night. Plants were subjected to natural lightening with no artificial lamp. Recommended amount of Garta liquid NPK fertilizer with chelated micro minerals corresponding to 160 kg N/ha 26.6 kg P/ha and 127 kg K/ha was applied in two doses at leaf development stages 12 and 15. The plants were harvested 104 days after planting (19th August, 2015) at BBCH stage 85.

2.5. Plant physiological measurements

Growth stage of the plants was recorded weekly according to the BBCH scale for maize and plant height was measured with a ruler. Leaf area was scanned non-destructively using the Licor Li-3000 portable area meter (LI-COR Inc, NE, USA) for leaves numbers 4, 6, 8, 10 when they were fully developed.

Stomatal conductance (g_s) and photosynthetic rate (A_n) were measured weekly with a portable photosynthesis system (CIRAS-2, PP systems, MA, USA). Measurements were performed between 12.00 – 16.00 at 400 – 420 ppm CO_2 and with PAR set to 1500 μmol m^2 s^{-1} and the humidity close to the humidity of the air in the green-house. The measurements were conducted on the last fully developed leaf from leaf stage 3 to the stem elongation stage. From the flowering stage onwards, the measurements were carried out on the fourth leaf from the top.

Leaf water potential measurements were made during the drying cycle in connection with the gas-exchange measurements. A leaf was enclosed in a plastic bag and cut off using a razor. The leaf with the plastic bag was then inserted in the pressure chamber (Soil Moisture Corp. CA, USA), and the pressure increased slowly. The equilibrium pressure was read, as soon as water flow from the cut mid-vein of the leaf was observed through a binocular microscope.

After harvest, the fresh weight of the cobs and the other shoot parts was determined. The dry weight was determined after drying at 60 ^{o}C to a constant weight.

2.6. Sap flow

Transpiration was measured by the sap flow technique (Dynagage, Tx, USA) in treatments that were either: fully irrigated with and without biochar; drought stressed without biochar; and drought stressed with 2 % addition of biochar. Eight heat balance sensors were mounted so that they surrounded the maize stems and monitored and recorded 10 minute values of sap flow with a CR1000 data logger (Campbell Scientific, Logan, UT, USA).

2.7. Soil water measurement

Soil water content was measured three times per week with the Campbell TDR-100 system connected to a handheld computer.

2.8. Statistical analysis

The data analysis was done with SigmaPlot 11 (Systat Software, San Jose, CA). All data were tested for normality. In case of normal distribution and equal variance, one way Analysis of Variance (ANOVA) was used. Otherwise, the Kruskal-Walis test was used. P values of less or equal to 0.05 indicate statistical difference.

3. Results

3.1. Soil water content

Volumetric water content at field capacity is shown in Fig 1. There was significant increase (P=0.001) with the highest biochar concentration of 3%. There was also an increase with 2% but a decrease with 1% biochar, however the latter differences were not statistical significant. The trend of volumetric soil water content during the growing season under irrigation and drought is shown in Fig 2. The trend was the same for both irrigation schemes before day 60 when drying was initiated.

Under drought, the trend shows a steep fall when the water content was depleting and a rise when the plants were irrigated at the end of the drying cycles.

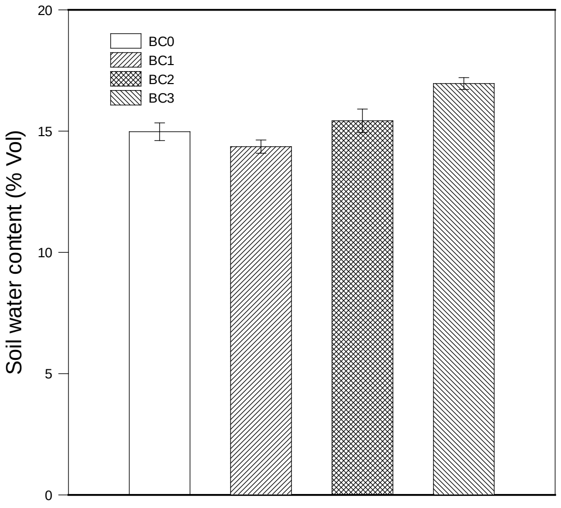

Fig. 1. *Soil water content with different biochar concentration at field capacity.*

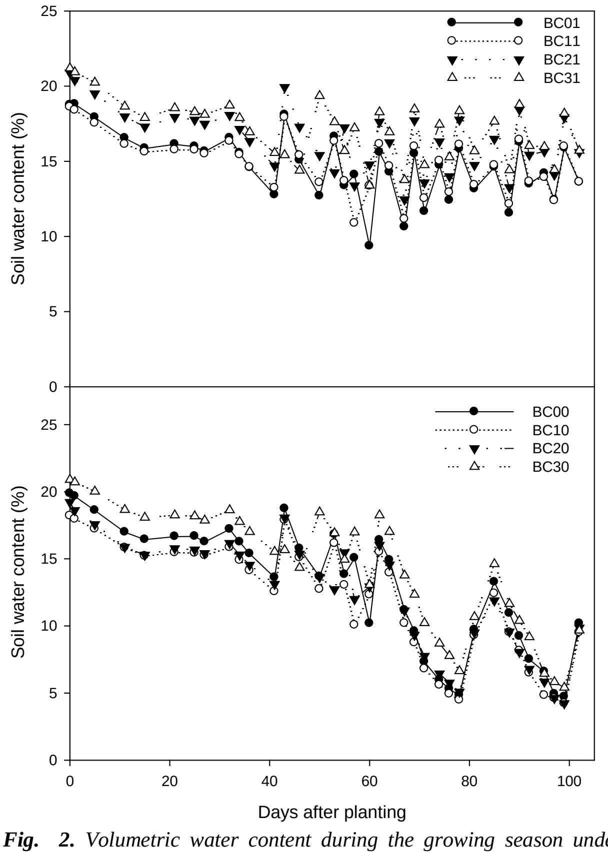

Fig. 2. *Volumetric water content during the growing season under full irrigation (upper) and drought (lower)*

3.2. Plant physiology measurements

The treatments showed similar trend for plant height and number of leaves shown in Fig. 3. The application of biochar had no significant effect on plant height until growth stage 3 (stem elongation) when the biochar 3% plant height was significantly lower than the remaining treatments (P=0.001). However, at growth stage 6 (flowering) there was no statistical difference between the treatments, (P = 0.094). Similar trend was observed for the number of leaves, showing a significant decrease for biochar 3% at stage 3 (P=0.013) and not significant at stage 6 (P=0.08).

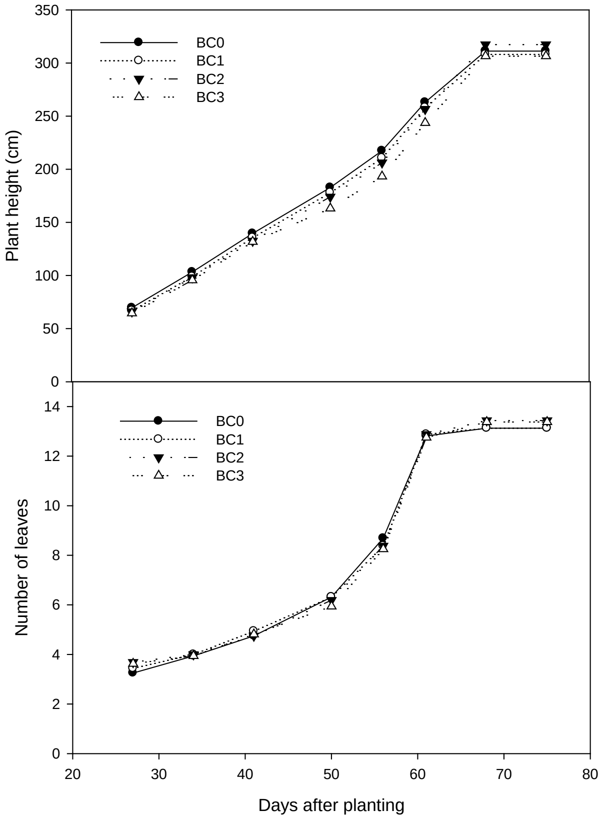

Fig. 3. *Weekly plant height (upper) and number of leaves (lower)*

Biochar tended to decrease the leaf area (Fig. 4) of leaves numbers 4, 6 and 8 with a less clear trend in leaf 10. The decrease was observed in the order of BC1, BC2 and BC3. The differences observed were however not statistically significant.

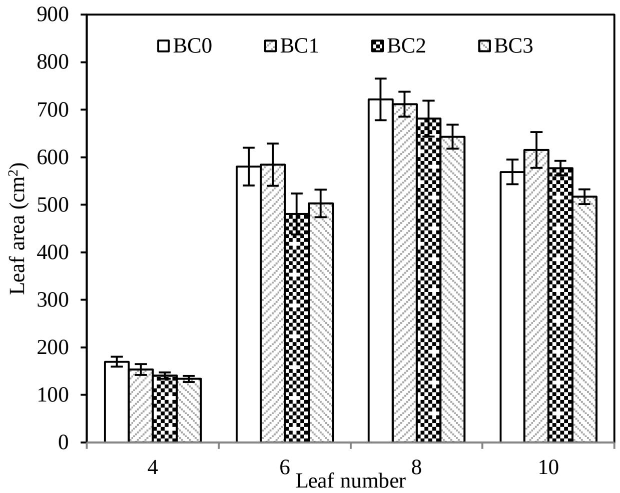

Fig. 4*. Leaf area for leaves numbers 4, 6, 8 and 10 when fully developed*

Net photosynthetic rate (A_n) (Fig. 5) and stomatal conductance (g_s) (graph not shown) decreased with an increasing rate of biochar prior to flowering (DAP 60). There was a strong correlation between A_n and g_s as shown in Fig 6. After flowering, biochar generally increased the A_n and g_s under both full irrigation and drought conditions. Under full irrigation, the trend continued until yield formation (DAP 92) when lower A_n and g_s were observed for biochar 2% than the control.

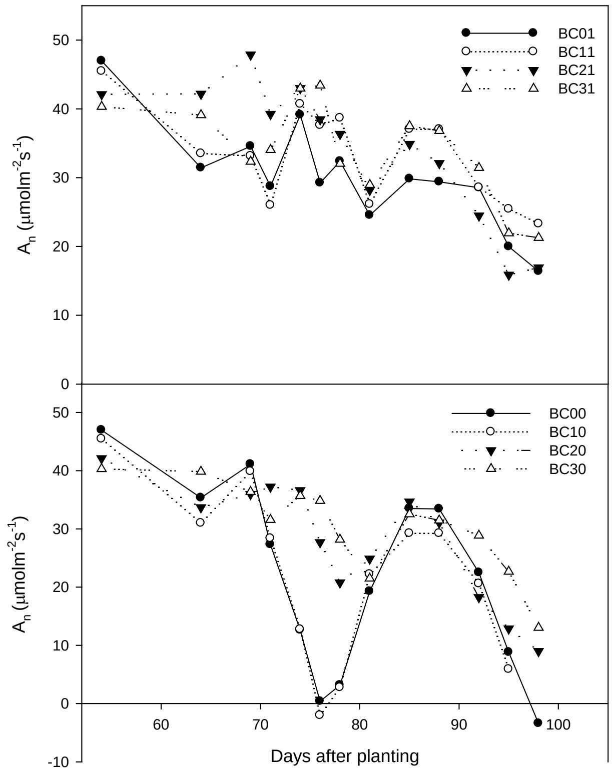

Fig.5. Photosynthetic rate under full irrigation (upper) and drought (lower)

At DAP 98, the lowest and similar values were observed for both control and 2% indicating ripening and approaching senescence. Under drought conditions, biochar generally increased the A_n and g_s after the initiation of dry cycle 1 (DAP 60). A steep downward decrease of A_n and g_s is observed at day 9 in drying cycle 1 (DAP 69) for the control and biochar 1%. Lowest A_n values of 0.04 and -2.03 µmol $m^{-2}s^{-1}$ were recorded for control and biochar 1% respectively indicating that leaves of the latter treatment had higher respiration than gross photosynthesis. The control and biochar 1% responded to irrigation at the end of dry cycle 1. Similar trends were observed for A_n and g_s in drying cycle 2.

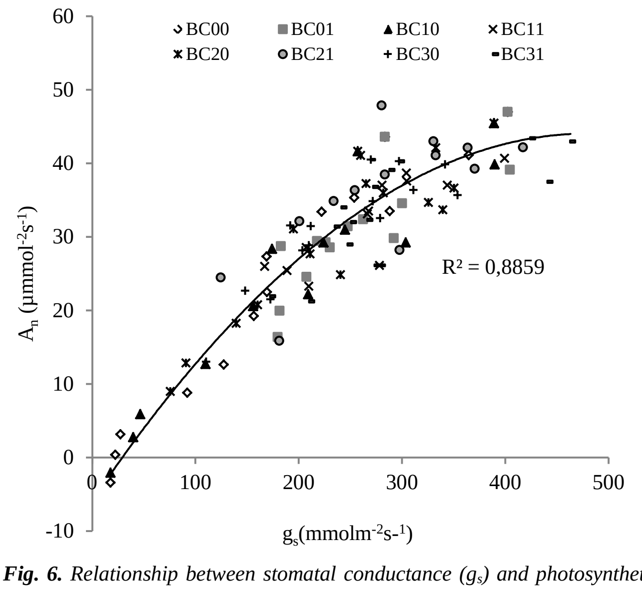

Fig. 6. *Relationship between stomatal conductance (g_s) and photosynthetic rate (A_n)*

The trend for the leaf water potential during the drying cycles is presented in Fig. 7. Under drought, biochar increased the LWP as the drying cycle progressed. At the peak of the drying cycle the highest LWP (i.e. least negative) was recorded in the highest biochar level of 3% followed by 2%. Biochar level 1% on the contrary showed lower LWP than the control. Under full irrigation, biochar generally decreased the LWP except on DAP 69 and 81. This could be due the fact that the soil water deficit before irrigating on those days was much higher for the control than for the biochar treatment (Fig. 2 upper).

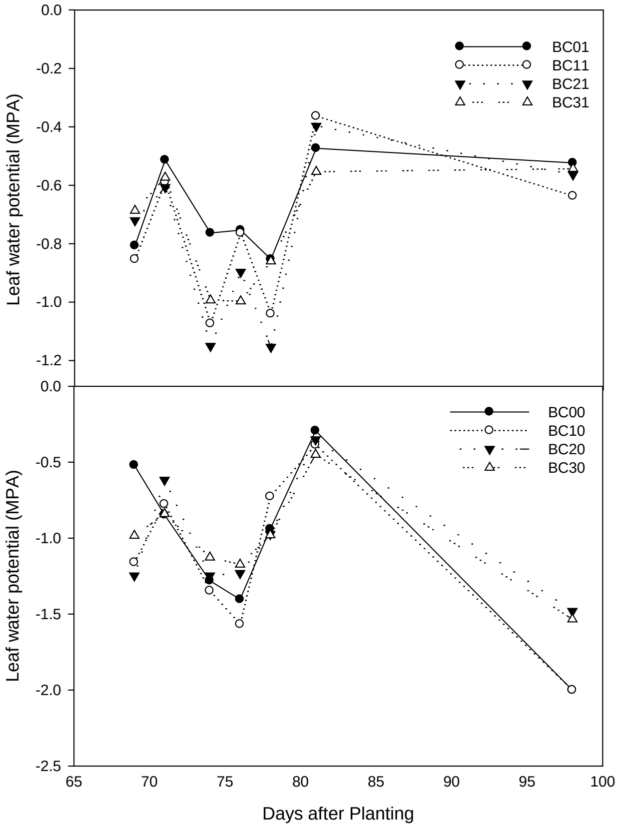

Fig. 7*.Leaf water potential during drying cycle under full irrigation (upper) and drought (lower)*

3.3 Transpiration

The transpiration of each plant was normalized by expressing it as percent of the plants transpiration 94 DAP as shown in Figure 11. Drought treatments with biochar maintained transpiration during the drought periods, while the one without biochar did not.

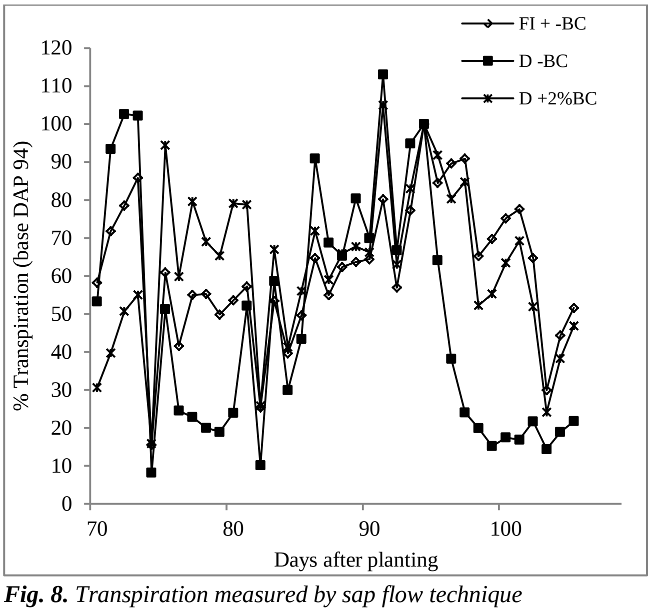

Fig. 8. *Transpiration measured by sap flow technique*

3.4. Maize yield

The maize yields are presented in Fig. 9. The total above ground biomass was divided into the cob biomass and the remaining biomass is referred to as plant biomass. Biochar increased plant biomass in the 2% treatment. The application at the 1% and 3% levels however, resulted in a decrease. This trend was observed under both irrigation and drought conditions. The differences were not statistically significant with P values of P = 0.120 and 0.190, under irrigation and drought respectively. Cob biomass was decreased by the addition of biochar under full irrigation. The decrease was however not significant at biochar levels 2 and 3%. On the contrary, it was statistically significant at biochar 1% (P=0.048). Under drought the cob biomass was increased by biochar 3%. Cob biomass of 1 and 2% were lower than the control, however the differences were not statically significant (P=0.594).

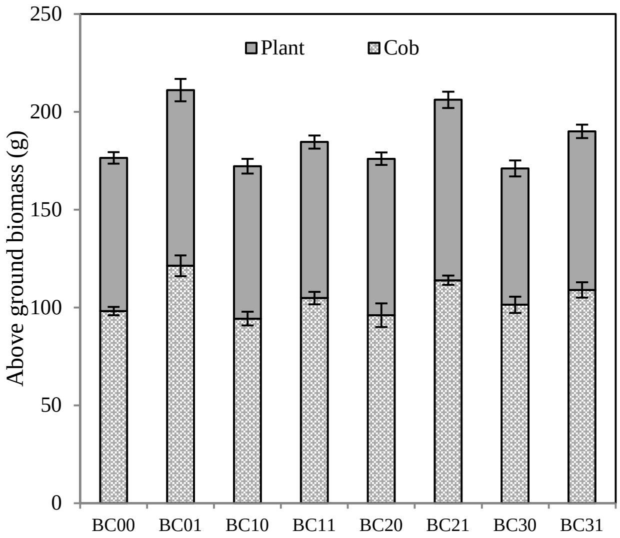

Fig. 9. *Aboveground biomass at harvest*

4. Discussion

4.1. Soil water content

The incorporation of straw biochar 2 and 3% increased the soil water content at field capacity. This result is consistent with findings from other studies on Danish coarse sandy soils (Bruun et al., 2014; Hansen et al., 2016). The increased water content can be attributed to the increased specific surface area (Glaser et al., 2002), the decrease in bulk density and increase in pore volume (Abel et al., 2013) of soil after biochar amendment. Our determination of bulk density after the experiment indicated a decrease of bulk density with increasing biochar concentration at the 30 cm and 50 cm. Biochar 1% however tended to decrease the soil water holding capacity.

4.2. Plant physiology

The number of leaves and plant height followed a similar trend. The similarity in the trend at the different growth stages was also reported by Uzoma et al. (2011). Contrary, to their results which showed a significant increase in maize height and number of leaves with the addition of biochar, our results indicate that there was no significant effect of biochar on height and leaves except at the growth stage 3 (stem elongation) when biochar 3% resulted in significantly lower height and number of leaves. Simultaneously at this stage, it was observed that some of the roots of this treatment lost their geotropism and grew upwards after entering the top soil (Fig. 10).We suspect ethylene gas might have been the cause of this effect. Ethylene is a plant hormone that regulates many aspects of plant growth and development (Sisler and Yang, 1984) and in high concentration it can negatively impact plant growth. Several studies have shown that ethylene in soil can accumulate under anaerobic conditions (e.g. Rigler and Zechmeister-Boltenstern, 1999). Neljubow (1901) as cited in (Fulton et al., 2013) was the first to demonstrate that ethylene affects tropism. Recent studies by (Fulton et al., 2013) have reported that fresh biochar can emit significant concentrations of ethylene. They recommend that biochar should be stored for three months in the open to allow ethylene stored in fresh biochar to degas before using. In our experiment the bags with biochar were only opened when it was used to mix with soil and the soil-biochar mix was planted one week after filling the pot. The loss of geotropism in the 3% biochar treatment and general decrease of leaf area with increasing biochar concentration could be due to ethylene emitted directly by the biochar we used which was further compounded by anaerobic conditions most likely created in the biochar 3% treatment. Biochar consists of a labile fraction and the recalcitrant fraction. Decomposition of the carbon takes up oxygen and in the case of biochar 3% the very high labile fraction means that the oxygen could be depleted, leaving the soil in an anaerobic condition. Since there was no significant difference between the leaf number and plant height at flowering, we assume the ethylene to have dissipated at that time.

Drought stress has been shown to decrease photosynthesis, stomatal conductance, leaf water potential and transpiration. The reduction of LWP and A_n that occurred in the late drying period is consistent with results by Bahrun et al. (2002).Our results show a decrease in A_n. g_s, LWP and T during the drying cyles for the control and biochar 1%. To the best of our knowledge there is no study of the effect of biochar on physiological processes on sandy soil with maize so it was not possible to compare these results. However, when compared for grapes on sandy-clay-loam (Baronti et al., 2014) the improved soil water status was associated with increased photosynthesis, stomatal conductance and leaf water potential in biochar treatments, results which are consistent with our findings. Similar results were also reported by (Hansen et al., 2016) who showed a decrease in stomatal conductance of barley on coarse sandy soil under drought conditions.

Fig. 10. *Roots of 3% biochar treatment growing out of topsoil*

Our results showed that drought reduced the yields of maize in all treatments irrespective of the biochar concentration compared to their fully irrigated counterparts. Under full irrigation biochar reduced both cob and plant biomass. Reported effects of biochar on yield have been rather mixed. Whiles some studies e.g. Uzoma et al. (2011) have reported an increase in yield of up to 150% when they used cow manure biochar, other studies such as Major et al. (2010) observed no significant increase in maize yields in the first year of application of wood biochar but significant increases over the next three years. In temperate soils, the use of pure biochar has often shown moderately-negative to -positive yield effects (Kammann et al., 2015). Even though we observed that biochar maintained photosynthesis in our drought treatments, there was no significant increase of yield. This could be due to the concomitant reduction of leaf area of the plants, which was generally reduced by biochar.

Thus the photosynthesis per plant integrated over time and leaf area may not have been enhanced by biochar, which may be the reason for no yield increase even under drought.

5. Conclusion

Biochar increased soil water content in Danish coarse sandy soil. Under drought, photosynthesis, leaf water potential and transpiration were maintained by 2 and 3% biochar addition to the subsoil. Thus, the use of biochar has the potential to enhance agricultural productivity in drought prone areas. However, some negative effects and the lack of corresponding increase in yield requires further studies of long term effects after the suspected short term toxicity of the biochar has subsided.

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THE ECONOMIC EFFICIENCY OF IRRIGATED AGRICULTURE LAND USE IN KAZAKHSTAN

ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ ЗЕМЕЛЬНЫХ РЕСУРСОВ В ОРОШАЕМОМ ЗЕМЛЕДЕЛИИ КАЗАХСТАНА

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Abstract: *Irrigated agriculture plays an important role in agricultural production in Kazakhstan. In case of optimal use of land and water resources irrigated agriculture could become a significant driving force of agricultural production. Strategically important crop products such as cotton, rice, sugar beet, tobacco, vines, melons are grown only on irrigated lands of Kazakhstan.*
KEYWORDS: *LAND RESOURCES, IRRIGATION, EFFICIENCY, PROFITABILITY, INVESTMENTS.*

1. Introduction

Irrigated agriculture occupies 2 335 thousand hectares or 7% of the total cultivated area of agricultural production in Kazakhstan. In case of optimal use of land and water resources irrigated agriculture could become a reliable sector of agricultural production and provide up to 30% gross output of all crop production. Meanwhile, strategically important for the country crop products such as cotton, rice, sugar beet, tobacco, vines, melons are grown only on irrigated lands.

2. Methods and study results

Indicators of economic efficiency of land use in irrigated agriculture were defined on the basis of data collected from the water and agricultural organizations, farms and cooperative farms, as well as pilot studies in production conditions.

Irrigated agriculture is stringently an economic reason. On irrigated and ameliorated lands cost per unit increases sharply. So in the cotton zone of irrigated farming expenses per 1 ha of irrigated land, including development costs, reach 12 thousand US dollars. The specific working conditions on those lands increase spending on agricultural development and intensification of production in order to reach the level corresponding to the potential of improved land. Also increase labor costs. The existing surface irrigation technology increases labor costs to maintain irrigation network and water costs, compared with rainfed agriculture, from 15% (for crops) up to 50-60% (industrial crops). [1] In general, per unit investments in 1 ha of irrigated areas agriculture are 4 times greater than on non-irrigated land, and capital-labor ratio nearly 2.7 times.

On the other hand, irrigated agriculture demonstrates accelerated cost recovery compared with rainfed agriculture as land productivity sharply increases, as well as the proportion of high-performance technical and other crops which have high commodity output and provide a significant increase in revenues for farms per unit of area. Thus the irrigated land productivity is 5.3-8.7 times higher than rainfed agriculture. (Table 1)

Table 1. *Gross output from 1 ha of irrigated and non-irrigated crops in arid zones*

Years	Output in US dollars		Increase, number of times
	irrigated	rainfed	
2008	1210.4	224.1	5.4
2009	1231.1	141.5	8.7
2010	1230.2	273.3	4.5
2011	1308.7	278.4	4.7
2012	1350.5	164.6	8.2
2013	1340.3	216.2	6.2
2014	1351.8	237.1	5.7
2015	1360.8	256.7	5.3

On average the productivity of irrigated land in the arid zones of the Republic of Kazakhstan over 6 years constituted 1346.8 US dollars per hectare, while between regions the range is from 1230.2 to 1434.0 US dollars per hectare. In southern regions of Kazakhstan where 82% of all irrigated lands are concentrated productivity is 1438.0 US dollars per hectare, in the eastern and western regions 1230.2 US dollars per hectare.

The development of irrigation in Kazakhstan is shaped not only by the social transformations that have taken place in the Republic of Kazakhstan, but also its rich and extremely diverse natural landscapes. The vast territory, significant land resource reserves allow to develop diversified agricultural production and increase its profitability, despite the dry climate on most areas, especially in southern and south-eastern parts.

The leading crops in the farm irrigated zone of Kazakhstan are winter wheat, rice, barley and rye, which occupy 75-85% of all grain crops.

For such crops as spring wheat, oats, millet, and buckwheat small areas are assigned. Data on the yield of winter wheat in the south and south-east of Kazakhstan are shown in Table 2, the coefficient of production efficiency is 1.6.

Table 2. *Efficiency of winter and spring wheat production on irrigated lands in the south and south-east of Kazakhstan*

Region	Winter wheat				Spring wheat			
	Yield, t / ha		Effectiveness ratio	Water consumption m^3 / t	Yield, t / ha		Effectiveness ratio	Water consumption m^3 / t
	Irrigated	Rainfed			Irrigated	Rainfed		
Almaty	1.80	1.12	1.6	1171	1.72	0.70	2.46	1319
Zhambyl	1.59	0.94	1.69	1108	1.59	0.62	2.56	1176
South Kazakhstan	2.19	0.81	2.71	1473	1.77	0.58	3.05	1330
Kyzylorda	0.81	-	-	2023	1.49	0.21	7.12	2002
Total for south and south-east	1.92	0.11	2.00	1294	1.43	0.53	3.80	1457

Particular note can be taken of the South Kazakhstan and Zhambyl regions, where year after year high and stable grain yields are obtained. These regions employ a range of agricultural practices. The forerunner of winter wheat, almost everywhere is a beet or maize. After harvesting of forerunner crop farmers conduct before plowing watering to trap moisture. Then introduce phosphate fertilizer at the rate of 0.205 t/ha and plowing to a depth of 22.25 cm with harrow. Typically in September from 15 to 30 sowing of certified seed, close-drilled, at the rate of sowing 220-260 kg/ha.

The economic efficiency of irrigated crops in Zhambyl region in the period from 2010 to 2015 can be judged from the following data: the yield of sugar beet increased from 17.54 to 20.32 t/ha, melons from 9.61 to 15.83 t/ha, vegetables from 10.93 to 15.02 t/ha, potatoes from 13.72 to 15.93 t/ha and grain from 1.26 to 2.07 t/ha. On the scale of districts virtually all cultivated crops demonstrate increase in productivity.

Concerning potato yields the greatest growth was obtained in Korday District 151.2% and the lowest in Moyinkum District 102.2%. The highest yield 20.0-24.0 t/ha were achieved in Zhualynskiy and Kordai Districts.

Vegetables yields have significantly increased in Talas District (202.2%) and amounted to 20.4 t/ha, while in Shu District decreased by 8.8%.

Concerning sugar beet Merke District in 2015 achieved yield of 30.09 t/ha which an increase of 67% compared to 2010.

Rice is one of the leading crops of irrigated agriculture in the south of Kazakhstan, it has great economic importance, contributes to soil desalinization.

Rice is cultivated in Kyzylorda, Almaty and South Kazakhstan regions which have favorable soil and climatic conditions, water and land resources.

However, the efficiency of rice cultivation is not identical everywhere. It motivates to maximize the internal reserves, which are now available in every farmland cultivating rice.

Experience shows that rice-growing farms with carefully leveled land with engineered irrigation network have significantly higher rice yields. So, in 2015 in Kyzylorda region on carefully leveled land with engineered irrigation network rice yield was 4.83 t/ha and on primitive -3.56 t/ha. At individual farms the difference is even greater. (Table 3)

Table 3. *Economic indicators of rice production on the irrigated lands of Kazakhstan (2010-2015)*

Region	Sown area, hectare	Yield, t/ha	Unit price, US dollars per tonne of rice	Profit (+) loss (-) t/ha USD per hectare	Profitability,%	Water consumption, m^3/t
Almaty	12900	2.83	258	2890.4	39.5	9434
South Kazakhstan	2232	3.430	346.5	4631.0	3.8	8090
Kyzylorda	68777.5	3.53	249.8	3896.7	44.1	7507
Total for Kazakhstan	83909.5	3.42	253.6	3650.6	42.0	7768

Heightening investment in rice production and more efficient land use will lead to the rational agriculture, introduction of sophisticated agricultural machinery, reduction of irrigation costs, will allow farmers to employ the huge opportunities that are provided by nature in the south Kazakhstan. [2]

Functioning irrigation and drainage network, high-quality layout of rice fields will increase rice yield and reduce the cost of 1 ton of rice. The minimum cost of raw rice is 340.0 US dollars per 1 ton of rice is achieved under permanent flooding condition, with the change of water on rice field once during the germination of rice plants. This irrigation technology of rice provide yield of 5.93 t/ ha, irrigation rate - 26000 m^3/ha, the consumption of water per ton of rice - 4390 m^3/t, drainage runoff - 2300 m^3/ha. With the decrease in rice yield, its cost increases (Figure 1).

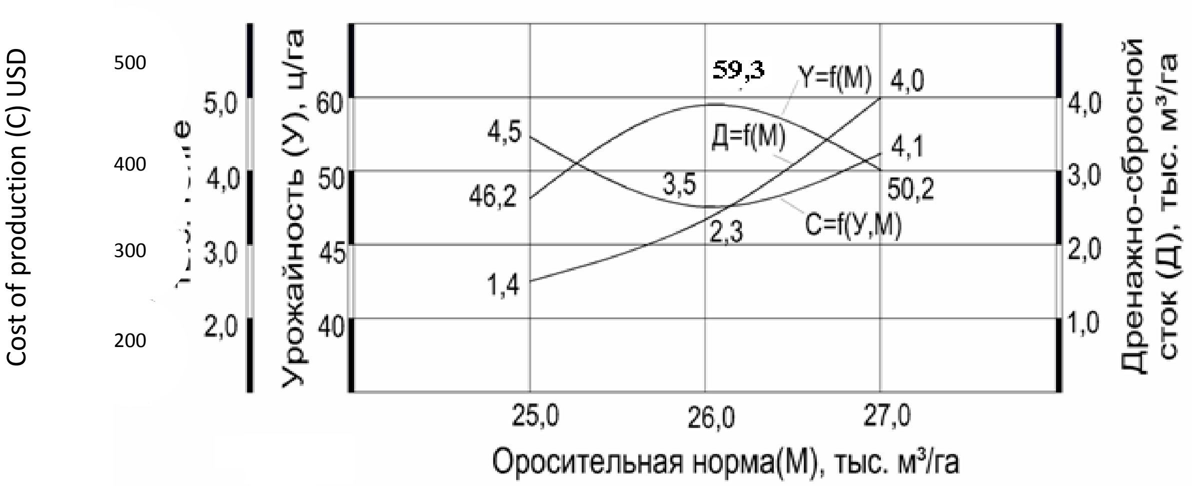

Figure 1 *- Effect of irrigation rate (M), drainage flow volume of (D) on rice yield (Y) and cost of production (C)*

Such rice irrigation technology allows to save irrigation water and provides high economic and environmental efficiency of land use in the cultivation of this crop

3. Conclusion

An important role in determining the economic efficiency of irrigated agriculture plays the volume of investment in creation of irrigation systems, as well as labor supply on farms over the periods of the year covering the periods of cultivation of crops and livestock. Consideration of the economic efficiency of agricultural crops cultivation on the basis of these criteria will allow a better assessment of the cultivation feasibility of a crop in the area, identify measures to enhance the effectiveness of cultivation and efficient use of irrigated lands.

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IDENTIFICATION OF SOIL ACIDIFICATION AND FERTILITY STATUS IN SELECTED FARM FROM TWO DIFFERENT POLISH REGIONS IN THE ASPECT OF SHAPING SUSTAINABLE CROP PRODUCTION

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Abstract: *A study was conducted to evaluate the acidification of soils and abundance of phosphorus , potassium and magnesium in 50 selected farms located in two different regions in Poland. It has been found that in many cases, soils were characterized by improper - in the aspect of formation of a sustainable crop production- reaction and the content of P, K and Mg. Based on the results, recommendations were formulated to improve the current situation.*

Keywords: SUSTAINABLE CROP PRODUCTION, REACTION AND ABUNDANCE OF SOIL, FARMS IN POLAND

1. Introduction

The soil reaction and its abundance of macroelements as phosphorus, potassium and magnesium are the primary determinants of the sustainable crop production. The soil reaction affects on the content and assimilation of nutrients in plants, both macro- and microelements. Phosphorus, potassium and magnesium are essential plant nutrients, which are necessary for its proper growth and development. In crop production it is very important that the soil is rich in all these components at the appropriate level. However excessive and insufficient levels of soil fertility are both unfavorable. If in soil is a deficiency of some components, and others are sufficient or even excess, their effect is limited by those which are not enough (according to the Liebig's law of the minimum states that the yield of a crop depend on the nutrient occurring in the soil in the smallest amount). In turn, if in the soil is too much of the component, it increases risk of its losses, which has negative economic consequences and may pose a risk to the environment. Thus, for economic and environmental reasons, especially related with water protection, it is important that soil reaction and its fertility were maintained at an optimum level. For this purpose, it is necessary to determinate soil acidity and content of the phosphorus, potassium and magnesium in soil.

2. Problem discussion

Baltic Sea waters, due to delivering excessive amounts of nutrients has become a basin strongly eutrophicated. Eutrophication causes many adverse changes in marine flora and fauna (it is considered the most important environmental problem of the Baltic Sea) and generates a large social and economic losses. The largest anthropogenic source of nutrients delivered to the Baltic Sea are compounds of nitrogen and phosphorus from agricultural sources. Therefore, in the Baltic Sea region, also in Poland, it is necessary to undertake various activities aimed at reducing discharges of these components to the waters. In Poland, where 99,7 % of territory is in the area of the watershed Baltic Sea, to the activities that would contribute to reducing agricultural pressure on water, may include regulation of soil reaction and rationalization of fertilization on the basis of determination soil acidity and its richness in phosphorus, potassium and magnesium.
This issue have been analyzed - as a case study, based on the results of research conducted in farms situated in two Polish regions, with regard to pH and the content of P, K, Mg in the soils of agricultural land belonging to these farms. In this study was considered the following research problem: What are the real needs to improve soil reaction and fertility in farms covered by the studies in terms of shaping their sustainable crop production?

3. Objective and research methodologies

The aim of the study was to assess the state of acidity and soil fertility in the example of selected farms situated in two Polish regions and on the basis of results, elaborate the recommendations to optimize fertilizer management in these farms, and indirectly, represented by these farms area.
Soil samples was collected in 2013 in 50 farms. These farms after half (i.e. 25) were located in the Pomorskie Voivodeship (in 16 counties) and Mazowieckie voivodship (in 4 counties - typically agricultural). Average area of farms in Pomorskie was 26.9 ha (from 7.3 to 52.8 ha) and Mazowieckie 38.6 ha (12.0 to 100.0 ha). 858 soil samples from the farm fields from both of these voivodships (429 of each) was analyzed. Soil samples for laboratory tests were taken by sampling stick from the top layer 0-20 cm.
Determination of soil samples:

- granulometric composition using laser diffraction method (in mineral soils);
- pH - potentiometrically in 1 mol KCl;
- content of available phosphorus, potassium and magnesium, methods: P and K in mineral soils the Egner-Riehm method, Mg – the Schachtschabel method; P, K and Mg in organic soil in extract 0,5 mol $HCl \cdot dm^{-3}$.

Based on the results of determinations granulometric composition, analyzed mineral soils are classified by agronomic category on: very light (to 10% of floatable particles with a diameter <0.02 mm), light (11-20% of floatable particles), medium (21-35% of floatable particles) and severe (> 35% of floatable particles).

Assessment of soil reaction was performed according to classification used for this purpose in Poland - Table 1. For the assessment soil abundance in digestible macronutrients: P, K and Mg used criteria specified in the standards: PN-R-04023, PN-R-04022, PN-R-04020, PN-R-04024

Table 1. *Assessment of soil reaction*

The pH range in KCl	Reaction
≤4,5	very acid
(4,5-5,5>	acid
(5,5-6,5>	light acid
(6,5-7,2>	neutral
> 7,2	alkaline

4. Results

Executed research showed that soil of agricultural land in farms from Pomorskie and Mazowieckie voivodeships were significantly different in terms of agronomic categories, reaction (and needs for liming) and abundance of P, K and Mg – Figure 1-6.

Soils from the farms in Pomorskie voivodeship characterized :

– highly unfavorable pH (about 65% of tested soil samples has very acidic or acid reaction);
– large deficiency of available phosphorus (more than 53% of tested samples graded into classes with very low and low abundance);
– very large deficiency available forms of potassium, especially in peat soils) (about 71% of the samples were classified as "low" or "very low" rich in K);
– considerable deficit of magnesium (magnesium content in more than 42% of the analyzed soil samples was very low, or low).

Soils from the farms in Mazowieckie voivodeship stand out:

– unsatisfactory, but in a large part correct pH (around 29% of samples tested soils had neutral reaction) or tolerable (ie. slightly acidic - approx. 35% of the samples);
– fairly good abundant in phosphorus (soil with a more than 60% of the samples were classified into classes of high and very high abundance of phosphorus, and only less than 19% for classes with very low and low abundance);
– average abundance of potassium (more than 68% of the samples soils was characterized by at least an average level abundance potassium);
– good state accumulation of magnesium (only in soil with 3.3% of the sample population found to "low" or "very low" state of the accumulation of magnesium).

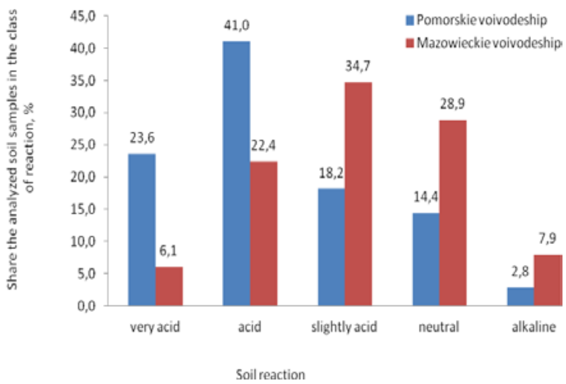

__Fig. 1__ Distribution of of soil reaction in the farms from Pomorskie and Mazowieckie

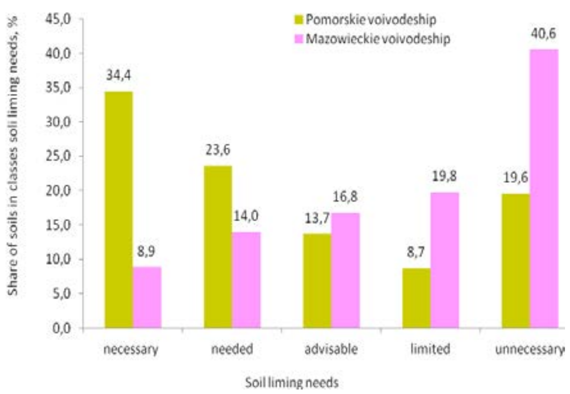

__Fig. 2__ Distribution of soil liming needs in the farms from Pomorskie and Mazowieckie

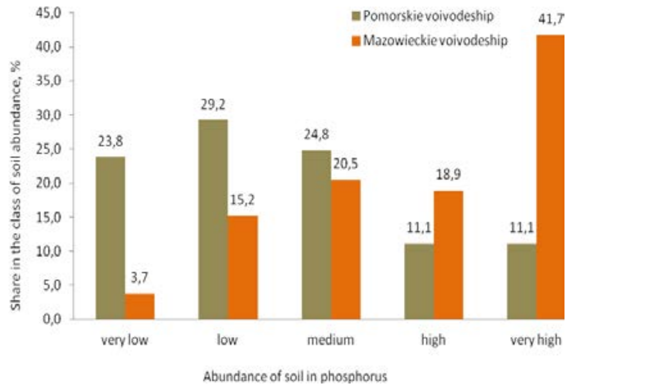

__Fig. 3__ Distribution of soil abundance in phosphorus in farms from Pomorskie and Mazowieckie

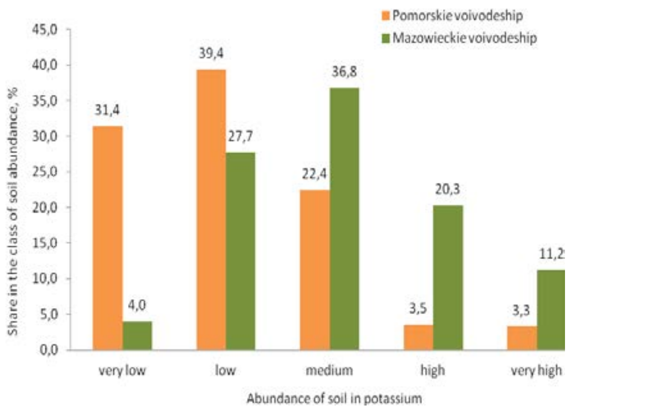

__Fig. 4__ Distribution of soil abundance in potassium in the farms from Pomorskie and Mazowieckie

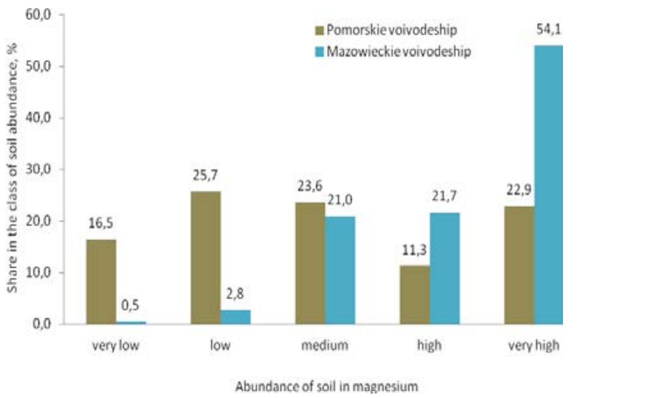

__Fig. 5__ Distribution of soil abundance in magnesium in the farms from Pomorskie and Mazowieckie

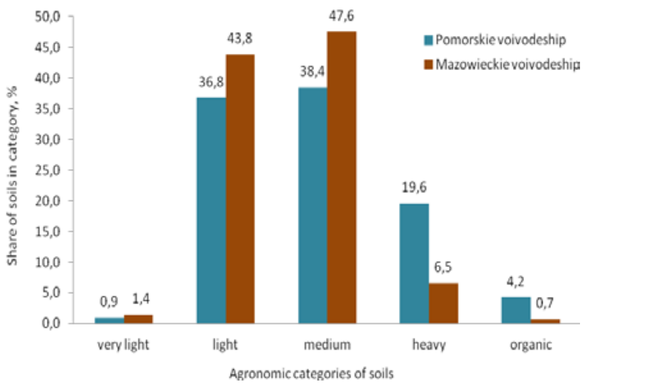

__Fig. 6__ Share of soils in farms from Pomorskie and Mazowieckie in various categories agronomic

5. Conclusion

Obtained results showed that on a very large area of agricultural land in evaluated farms from the province Pomeranian, exist a needs to regulate soil pH (by conducting liming) and rationalize fertilization, in adjusting to the needs of cultivated plants.

In the farms of the Mazowieckie voivodeship (and it can be assumed that also in all 4 counties where farms are located) soils have a much more favourable reaction and are much more abundant in P, K and Mg in soils than evaluated farms from the Pomorskie voivodeship. It seems that in these farms management practices for maintaining proper soil reaction and the abundance of major nutrients do not require radical remedial action, but rather nature perfecting (i.e. correction). These should to improve soil reaction on the plots with defective pH and to increase content of P, K and Mg in soils which are poor in mineral compounds. At the same time, they should eliminate unjustifiable using of excessively high doses of fertilizers, especially in situations where soils are very rich in nutrients. This applies especially to supply soil with phosphorus. In both groups of farms in each of the voivodeships occur the farms, where reaction and abundance of soil are on an appropriate level. It would be helpful to use experience of the owners of these farms, associated with conducting sustainable crop production in the agricultural advisors work.

6. Literature

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PN-R-04022:1996 Agrochemical soil analyse. Determination of assimilated potassium content.

PN-R-04023:1996 Agrochemical soil analyse. Determination of assimilated phosphorus contents.

PN-R-04024:1997. Agrochemical soil analyse. Determination of available phosphorus, potassium, magnesium and manganese contents in organic soils.

The research was realized within the project: „Self-evaluation and risk analysis by farmers concerning losses of nutrients and low cost remedial measures” financed by the Foundation Baltic Sea

EVALUATION OF WATER PRODUCTIVITY FOR LOWLAND RICE UNDER SENSOR BASED DEFICIT IRRIGATION SYSTEM

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Abstract: *Rice, as the main food produced in Asia, requires more water than the other cereals. Flooded irrigation, the most common method of irrigation in rice, results high water losses and emits more greenhouse gases. Changes in climate, decrease in water resources and arable lands, necessitates the water productivity increasing strategies for rice. Soil matric potential based irrigation is such a strategy to irrigate rice under these conditions. This paper presents an experiment carried out inside a climate chamber to assess the water productivity of Bg300 rice variety using above approach. Three irrigation treatments; flooded treatment with a ponding water depth of 3cm and treatments with soil matric potentials at -150mbar and -300mbar were imposed in three large containers. Soil matric potentials were maintained using tensiometers installed at a depth of 20cm. Treatment at -150mbar showed best performance in terms of yield, water productivity and water savings. This strategy is transferable to a wide range of locations under different climates and reduces time for many field experiments.*

Keywords*: SOIL MATRIC POTENTIAL, IRRIGATION, RICE, WATER PRODUCTIVITY, YIELD, BG300*

1. Introduction

Food security to sustain growing world population is one of the key challenges in 21st century with the existing water scarcity and degradation in arable land. Agriculture as a major component of the economy of Sri Lanka, and rice as a major food crop cultivated, faces many challenges due to increasing population demand.

Irrigated land in Sri Lanka is mainly developed for paddy cultivation and accounts for 80% of rice production. Rice being a semi-aquatic crop requires 2–3 times more water than other cereals (Bouman et al. 2007). Besides, the looming water demand for domestic and industrial sectors, conflicts between these sectors, climate change and low economic viability of agriculture are restricting the expansion of irrigated agriculture.

Therefore, increasing crop water productivity or the amount of agricultural output produced per unit amount of water used, is a viable solution to overcome the above mentioned challenges.

About 90% of the world's rice production is harvested from irrigated or rain-fed lowland rice fields. Lowland rice is raised in a nursery bed and transplanted into a main field which is kept mostly under continuous or intermittent ponded water conditions to help weed and pests (GRiSP (Global Science Partnership) 2013). Water for lowland rice is required for land preparation, to fulfill the crop water demand and to match seepage and percolation losses (Allen et al. 1998). The water required to produce 1 kg of rice varies from 1-3 tons of water (FAO 2000). Usually one third of it is used in the land preparation prior to cultivation.

Although the rice plant is unique in its ability to grow and yield in a wide range of agro ecological conditions such as flooded lowlands, drought-prone uplands, humid tropics and cool temperate climates, yield declines when soil dries below saturation.

However, lowland rice fields have large amounts of water losses and less fertilizer use efficiency apart from heavy emissions of methane, ammonia and nitrous oxide gases. Water saving irrigation strategies such as aerobic rice cultivation could save significant amount of water.

Therefore, improved irrigation management techniques for aerobic and flooded rice systems concerning uncertainties in soil, climate and management practices are important in near future.

Deficit irrigation, defined as the application of water below full crop-water requirements is an important tool to achieve the goal of reducing irrigation water use (Fereres & Soriano 2007).

The objective of this study was to evaluate water productivity of a lowland Sri Lankan rice variety (Bg300) under deficit irrigation conditions with a view of reducing water input and ensuring minimum yield losses.

2. Materials and Methodology

Experiment was conducted in a constructed climate chamber (2m x 2m x 4m), within the laboratory premises of Dresden University of Technology, from 08th of May till 19th of September, 2015. Three irrigation treatments, T1, T2 and T3 were imposed, based on soil matric potential levels. Each treatment was imposed in a separate large PVC container (1m x 0.6m x 0.8m) as shown in Figure 1. Treatment T1 was maintained with a 3cm of ponding water level throughout the treatment period. Other two treatments were maintained with soil matric potential levels at -150mbar (T2) and -300mbar (T3) respectively throughout the treatment period. Irrigation treatments duration was from two weeks after seed establishment up to two weeks before physiological maturity.

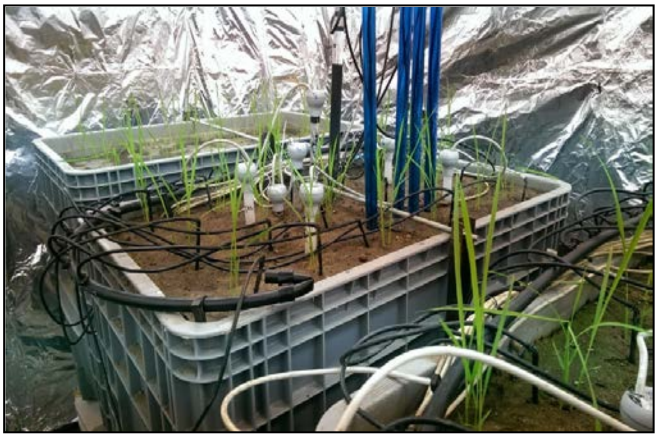

Figure 1: *Experimental set up*

Containers of treatments T2 and T3 were placed on fabricated weighing balances. They were connected to a data logger (DT80) for frequent water balance measurements. However, treatment T1 was not placed on a weighing balance but placed at the same vertical position with other containers.

Tropical climate conditions were simulated by installing two growing lamps (Osram power star HQI-BT 400 W/D PRO) above each container. They were connected to a timer to automatically switch on lamps to create 12 hours of day and 12 hours of night cycles. Additionally, climate chamber inner walls and roof were covered with aluminium foils to provide homogeneous lighting conditions.

In order to maintain required soil matric potentials in T2 and T3, tensiometers (T4 and Bambach digital tensiometers) were installed at 10cm interval up to 40cm depth. Twelve tensiometers were installed in each container. Control tensiometer was installed at 20cm depth to maintain soil matric potential at threshold level and to trigger the irrigation system.

Soil moisture content was measured using time domain reflectometry (Campbell Scientific, TDR100) probes installed at same depths. Both tensiometers and TDR probes were connected separately to two data loggers.

Sub-surface drip irrigation system (Netafim NMC-pro) was installed to irrigate treatments T2 and T3 (see Figure 2). Irrigation system was triggered upon reaching relevant soil matric potential thresholds at 20cm depth.

Each drip emits 1.2 l/hr of water to plants. Single irrigation event was set to 5 minutes and allowed to distribute water for 2 hours. After 2 hours, if required threshold level is not achieved then it re-irrigates to bring down the soil tensions.

Figure 2: *dripper installed next to a planting hill*

Rice seeds were soaked in water for 24 hours and incubated in a cloth bag for 48 hours to germinate. Germinated seeds were established in soil at a planting space of 20cm x 15cm in all containers. This allowed each container to grow 18 planting hills.

After seed establishment, basal fertilizer (N P K) was applied at a rate of 5 kg/ha, 50 kg/ha and 20 kg/ha respectively to all three containers. All fertilizer applications were carried out according to the fertilizer recommendations issued in 2001 by the Department of Agriculture, Sri Lanka.

Soil in all containers were kept at saturation for two weeks in order to establish homogeneous plant density. At two weeks additional plants were removed by leaving 3 plants per planting hill.

Air temperature, soil surface temperature, temperature at weighing balance (to account for changes in resistance in load bearing cells) were logged using temperature sensors. Other climate data such as radiation, relative humidity were measured periodically.

Plant growth measurements, leaf area, leaf nitrogen content, stomatal conductance, leaf rolling and phenology were measured weekly. At physiological maturity, grain yield, total above ground and below ground biomass and root growth were measured.

3. Results and Discussion

Under Sri Lankan climate and irrigation conditions, rice requires 900-1200 mm of water per season.

According to the experimental results, highest grain yield was observed in treatment T1 in comparison to the average yield observed under flooded field conditions in Sri Lanka, where ponding water depth is usually 5-10cm.

Amount of yield gained in three irrigation treatments were linearly related to the soil moisture stress. Lowest yield was obtained in most dry treatment. For this particular rice variety yield reduction in T1 is non-significant as shown in Table 1. Considering the water productivity, highest water productivity was obtained in drier treatment, T3.

Even though highest water saving is achieved in Treatment T3 yield reduction is significant compared to the reference yield. However, comparing yield, water productivity and water savings of each treatment, treatment T2 shows the best performance.

Table 1: *Summary of the experimental results*

Treatment	Yield [t/ha]	Water productivity [kg/m^3]	Yield reduction [%]	Water Savings [%]
T1	4.93	1.08	5.7	56.8
T2	4.33	1.49	17.2	72.4
T3	3.15	1.78	39.7	83.1
Reference	5.23	0.58	-	-

4. Conclusions

According to the above results, T1 and T2 had no significant difference in yield compared to the reference yield, which is a long term average value for Bg 300 rice variety under Sri Lankan tropical climate and flooded conditions.

However, all three irrigation treatments resulted comparatively higher water productivities. Water productivity is expressed in terms of total irrigation amount. If this is expressed in terms of crop evapotranspiration, much higher water productivities could be expected.

Considering overall results; yield, water productivity and irrigation water savings are high in T2. Sensor based automatic irrigation provides reliable results and feasible in irrigation scheduling for rice under field conditions. This strategy can be applied to a wide range of locations under different climates, is transferable and reduces time for many field experiments.

Main disadvantage of this kind of experiments is the high expenses for electricity to operate growing lamps for a long time period. As a solution white colour LED lamps could be used at a low cost.

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EFFET OF USING HUMIC, FOLIAR APPLICATION OF COMPOST TEA AND WERMIWASH ON YIELD AND YIELD COMPONENT OF SAFFLOWER CARTHAMUS TINCTORIUS L.

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Abstract

The objective of the present study was to determine of effect of humic acid application and different foliar application of vermicompost extract and vermiwash on yield and yield components of safflower under using different levels of humic acid application in soil. A field experiment was conducted at the Vali-e-Asr University of Rafsanjan, Rafsanjan, Iran. The experiment was conducted as factorial based on randomized complete block design. Treatments were included soil application of humic fertilizer (0, 500, 1000 and 1500 kg.ha-1) and foliar spraying of vermiwash 1:10, vermiwash 1:20, compost tea and distilled a water as control. Seeds were hand-sewn with density of 40 plants m^{-2} *and a depth of 5 cm with row spacing of 50 cm. The plots were irrigated after 70 mm cumulative evaporation from standard evaporation pan class A and irrigation amount was based on soil moisture depletion. Seed yield and number of heads were determined by harvesting 10 plant at random from the four central rows at physiological maturity stage. Seed yield in each plot measured with 14% humidity. Number of seeds per heads was determined by measuring 30 heads at random from 10 randomized harvested plants. Analyses were performed with a personal computer using the MSTATC software. A factorial analysis of variance (ANOVA) was performed for all parameters. Results showed that humic fertilizer significantly affected head number, seed number, 1000 seed weight and seed yield of safflower, however there was no effect on branch number. The highest grain yield (5822.1 kg.ha*$^{-1}$*) obtained in 1500 kg humic. Foliar spraying significantly effect on branch number and the highest yield (4858 kg.ha*$^{-1}$*) was obtained by spraying of compost tea.*

Keywords*: FOLIAR APPLICATION; HUMIC; SAFFLOWER; YIELD; YIELD COMPONENT*

I. INTRODUCTION

Safflower (*Carthamustinctorius* L.) is an annual oilseed crop which is belongs to Asteraceae (Compositae) family. It is commercially cultivated for its dye, which is extracted from the flowers, and for high quality vegetative oil of that is extracted from the seeds [3]. The direct yield components of safflower are number of plants per plot, number of heads per plant, number of seeds per head and weight of seeds [7]. The relative importance of each yield component is affected by many factors, including genotype, environmental conditions and cultural practices. Nutrient management is one of the critical inputs in achieving high productivity of safflower [4]. Vermicompost and nitrogen availability are important parameters affecting yield and yield components in safflower. The availability of nutrient can be manipulated by adopting suitable package of fertilizer management. Under fairly good nutrient availability conditions, the appropriate fertilizer dose and their time of application may act as major driving force in pushing up the crop yields and increase the fertilizer use efficiency [2]. humic acid have consistently improved seed germination, enhanced seedling growth and development, and increased plant productivity much more than would be possible from the mere conversion of mineral nutrients into more plant-available forms [6]. The objective of the present study was to determine of effect of humic acid application and different foliar application of vermicompost extract and vermiwash on Yield and Components of Safflower (*Carthamustinctorius* L.) under using different levels of humic acid application in soil.

II. MATERIALS AND METHODS

A field experiment was conducted at the Vali-e-Asr University of Rafsanjan, Rafsanjan (latitude 30.23 °N, longitude 56 °E and 1469m asl), Iran. The experiment was conducted as factorial based on randomized complete block design with three replications at one place. Treatments were included soil application of humic fertilizer (0, 500, 1000 and 1500 kg.ha-1) and foliar spraying of vermiwash 1:10, vermiwash 1:20, compost tea and distilled a water as control. Seeds were sowing by hand with density of 40 plants m^{-2} and a depth of 5 cm with row spacing of 50 cm. The plots were irrigated after 70 mm cumulative evaporation from standard evaporation pan class A and irrigation amount was based on soil moisture depletion. There was no effect of flooding or water deficit stress. Determination of agronomic traits of each experimental plot, 10 plants were randomly selected and their morphological characteristics were measured. Seed yield and number of heads were determined by harvesting 10 plant at random from the four central rows at physiological maturity stage. Seed yield in each plot measured with 14% humidity. Number of seeds per heads was determined by measuring 30 heads at random from 10 randomized harvested plants. Analyses were performed with a personal computer using the MSTATC software. A factorial analysis of variance (ANOVA) was performed for all parameters. In addition the Duncan's Multiple Range Test (DMRT) (P = 0.05) was used to conduct mean comparison of treatments and find significant differences among means. And for charts was drawn with Excel software.

III. RESULTS AND DISCUSSION

Number of Heads per Plant (NH/P)

There was a significant difference between foliar spraying on head no. of safflower (Fig. 1). All spraying treatments significantly increased the head no. of safflowers compared with distilled water. N and other elements in Vermicompost play an important role in different metabolic processes in plant. And this may be attributed to improving water absorption and plant nourishing due to nitrogen andelements in Vermicompost. This result was agreement by (Naseri; 2010) who indicated that application of Nfertilizer increased number of heads on plant. On the other hand, head no. significantly increased with increasing humic acid application (Fig 2.). This result indicated that using humic acid could improve soil nutrition availability to absorption of nutrition.

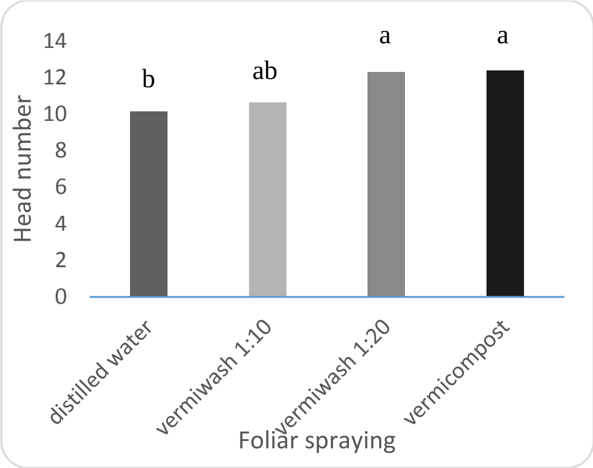

Fig 1.Effect of foliar spraying on head number of safflower

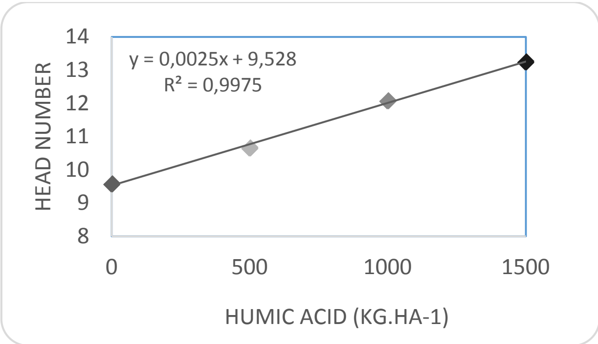

Fig 2. Effect of humic on head number of safflower

Seed number and 100 seed weight.

Seed number and 100 seed weight influenced by using humic acid (fig 3, 4). Similarly to head no. Seed number and 100 seed weight increased with application of humic acid which is probably due to more availability of nutrition element and better soil conditions. As the humic acid has positive effect on heads per plant therefore the Seed number increased. In other word, using humic acid appropriate levels provide better nutrient and water uptake and plant photosynthesis through improving roots expansion.

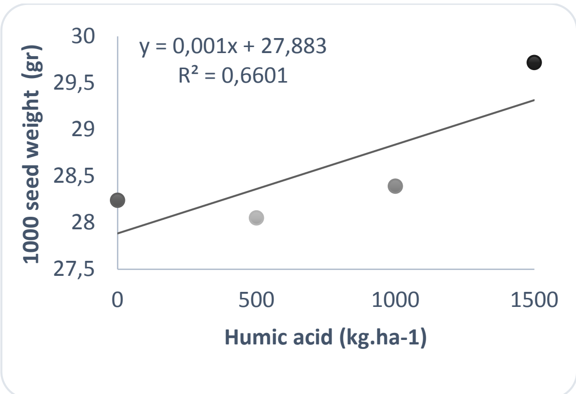

Fig 3. Effect of humic on 1000 seed weight of safflower

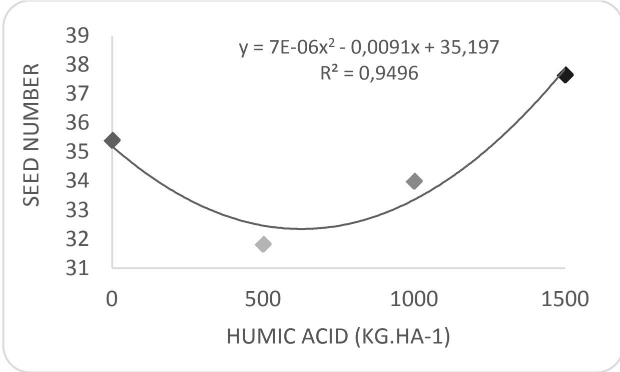

Fig 4. Effect of humic on seed number of safflower

Seed Yield

Analysing seed yield variance showed that there was a significant different between foliar treatments and humic acid application. Seed yield increased with application of vermiwash and vermicompost extraction (Fig. 5, 6). The highest amount of seed yield observed in vermicompostextraction (4856 kg/ha-1) which have no significant difference with vermiwash. It is reported that Vermicompost tended tobe higher in nitrates, which is the more plant-available form of nitrogen [9]. Hammermeister et al. (2004)indicated that Vermicomposted manure has higher N availability than conventionally composted manure on aweightbasis [1]. The latter study also showed that the supply rate of several humic acids could significantly increase the seed yield of safflower compared with control (Fig 6). Many researchers have found that Vermicompost stimulates further plant growth even when the plants are already receivingoptimal nutrition [5, 10]. Vermicompost have consistently improved seed germination, enhanced seedlinggrowth and development, and increased plant productivity much more than would be possible from the moreconversion of mineral nutrients into more plant-available forms.

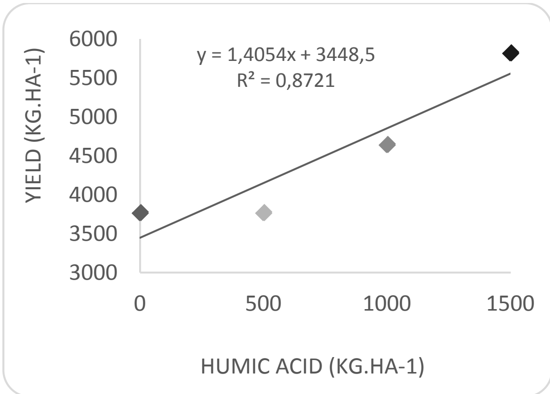

Fig 5. Effect of humic on seed yield of safflower

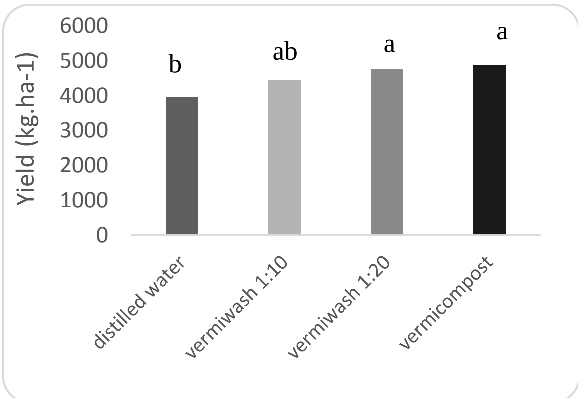

Fig 6. Effect of foliar spraying on seed yield of safflower

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