UNIVERSITI PUTRA MALAYSIA

EFFECTS OF DIFFERENT CONCENTRATIONS OF MUNICIPAL WASTEWATER ON SEED GERMINATION AND SEEDLING PERFORMANCE OF THREE RICE (ORYZA SATIVA L.) VARIETIES

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By

UMARU MOHAMED GASSAMA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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DEDICATION

This Work Is Dedicated To Allah and My Family

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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January 2015

Chairman: Adam bin Puteh, Ph.D.

Faculty: Agriculture

Agriculture is the largest user of fresh water for irrigation. As the demand of fresh water is increasing, there is a need to recycle municipal wastewater for agricultural activities. The objective of the study was to determine the effect of different concentrations (0, 2.5, 5, 10, 25, 50, and 100%) of untreated and treated municipal wastewater on seed germination and seedling performance of fresh and aged rice seeds, seedling nutrient uptake and seedling chlorophyll content. Laboratory experiments were conducted using three Malaysian rice varieties, MR219, MR220 and MR253.

This study revealed varying responses of rice for germination percentage, germination rate index, seedling length, seedling fresh weight, seedling dry weight, root volume, root surface area, seedling vigour index, root:shoot ratio and percentage phytotoxicity when the seeds were irrigated with different concentrations of municipal wastewaters. The seeds imbibed in untreated wastewater gave higher values of seed germination and seedling growth and development than treated wastewater. Lower municipal wastewater concentrations (2.5-25%) showed promoting effect on rice seed germination while higher wastewater concentrations (50-100%) retarded seed germination and crop growth and development. Significant difference ($p<0.05$) was observed between untreated and treated wastewaters for germination rate index, seedling length, seedling fresh weight, root volume and root surface area. All the varieties tested showed varying responses to germination percentage, seedling length, seedling fresh weight, seedling dry weight, root volume and root surface area when imbibed with municipal wastewater for aged and fresh rice seeds. However, no significant difference was observed among the three rice varieties for germination rate index and seedling length for aged seed. Municipal wastewater contains essential nutrients for plant growth and development. Nitrogen, phosphorous, potassium, calcium, magnesium, zinc, iron, copper and manganese were high in the untreated municipal wastewater compared to treated municipal wastewater. Rice seed imbibed with untreated municipal wastewater had more nutrients uptake than treated municipal wastewater as detected in the seedlings in this study. Furthermore, higher concentration of municipal wastewater >50% inhibit nutrients uptake while lower concentration of municipal wastewater <25% stimulate nutrients uptake. The study shows that P, K, Mg, Mn and Zn were sufficient for the rice seedling while N and Ca were far from optimum level for rice but Cu and Fe were excess and toxic to the rice seedlings. The municipal wastewaters showed inhibitory effect on chlorophyll content. The inhibition effect was observed at >50% concentration of both untreated and treated municipal wastewater while

promoting effects were observed at lower <25% concentration. Positive and significant correlation was indicated between parameters of rice seed germination; seedlings performance and chlorophyll content while all the nutrients elements were negatively and highly correlated with quantity of municipal wastewater.

Therefore, municipal wastewater can be used to raise quality seedlings without affecting seedling growth. The results indicated that untreated wastewater is better for rice seed germination and seedling performance than treated wastewater. This can be due to the high amount of nutrient in the untreated municipal wastewater which triggers the physiological process of the seeds that leads to increase in seedling growth and development. This study indicates that municipal wastewater of < 25% concentration is safe enough to be used in irrigation for rice production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN PERBEZAAN KEPEKATAN AIR KUMBAHAN PERBANDARAN TERHADAP PERCAMBAHAN BIJI BENIH DAN PRESTASI ANAK BENIH TIGA JENIS BERAS (ORYZA SATIVA L.)

Oleh

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Pertanian adalah pengguna terbesar air tawar untuk pengairan. Oleh kerana permintaan air bersih semakin meningkat, terdapat keperluan untuk mengitar semula air kumbahan perbandaran untuk aktiviti pertanian. Objektif kajian ini adalah untuk menentukan kesan kepekatan (0, 2.5, 5, 10, 25, 50, dan 100%) daripada yang tidak dirawat dan dirawat air kumbahan perbandaran pada percambahan benih dan anak benih, prestasi benih padi dan pengambilan nutrien oleh anak benih dan kandungan klorofil anak benih. Ujian makmal telah dijalankan dengan menggunakan tiga jenis varieti padi iaitu MR219, MR220 dan MR253.

Kajian ini mendedahkan pelbagai respons padi ke atas peratusan percambahan, indeks kadar percambahan, panjang anak benih, berat segar anak benih, berat kering anak benih, bilangan akar, kawasan permukaan akar, indeks kecergasan, nisbah akar: pucuk dan peratusan fitotoksisiti apabila biji benih bercamban pada kepekatan air kumbahan perbandaran yang berbeza. Benih padi yang menyerap air kumbahan yang tidak dirawat memberi nilai peratus percambahan benih dan pertumbuhan anak benih lebih tinggi berbanding air kumbahan dirawat. Kepekatan air kumbahan perbandaran yang rendah (2.5%-25%) pertumbuhan anak benih padi, manakala kepekatan air kumbahan yang tinggi (50%-100%) mempengamhi percambahan dan pertumbuhan anak benih. Terdapat perbezaan signifikan ($p<0.05$) antara air kumbahan yang tidak dirawat ke atas indeks kadar percambahan, panjang anak benih, anak benih berat segar, jumlah akar dan luas permukaan akar. Semua jenis diuji menunjukkan tindak balas yang berbeza-beza untuk peratusan percambahan, panjang anak benih, anak berat sagar benih, anak berat kering benih, jumlah akar dan luas akar permukaan di antara air kumbahan perbandaran untuk benih padi segar dan dalam. Walau bagaimanapun, tiada perbezaan yang ketara antara ketiga-tiga jenis padi untuk indeks kadar percambahan dan panjang anak benih untuk berumur. Air kumbahan perbandaran mengandungi nutrien penting untuk pertumbuhan dan anak benih. Kepekatan Nitrogen, fosforus, kalium, kalsium, magnesium, zink, besi, tembaga dan mangan adalah tinggi dalam air kumbahan perbandaran yang tidak dirawat berbanding dengan air kumbahan yang dirawat. Biji benih padi yang menyerap air kumbahan perbandaran yang tidak dirawat menyerap lebih banyak nutrien ke dalam anak benih. Kepekatan air kumbahan perbandaran >50% yang mempunyai kepekatan yang tinggi telah menghalang pengambilan nutrien manakala air

kumbahan perbandaran <25% merangsang pengambilan nutrient oleh anak benih. Kajian menunjukkan bahawa P, K, Mg, Mn dan Zn adalah mencukupi untuk pembenihan padi manakala N dan Ca adalah rendah dari tahap optimum untuk padi tetapi Cu dan Fe adalah berlebihan dan bertosik untuk pembenihan padi. Air kumbahan bandaran merendahkan kandungan klorofil di dalam daun anak benih padi. Kesan kekurangan kandungan klorofil berlaku pada >50% kepekatan, manakala air kumbahan berkepekatan rendah <25% menunjukkan kesan yang baik ke atas kandungan klorofil pada anak benih. Korelasi positif dan signifikan telah ditunjukkan antara parameter percambahan benih padi, prestasi anak benih dan kandungan klorofil manakala semua nutrien unsur-unsur negatif dan telah berkait rapat dengan kuantiti air kumbahan perbandaran.

Oleh itu, air kumbahan perbandaran boleh digunakan untuk meningkatkan benih berkualiti tanpa menjejaskan pertumbuhan anak benih. Keputusan menunjukkan bahawa air kumbahan yang tidak dirawat adalah lebih baik bagi percambahan benih padi dan prestasi anak benih daripada air kumbahan dirawat. Ini disebabkan oleh jumlah nutrien yang tinggi dalam air kumbahan yang tidak dirawat merangsang proses fisiologi benih yang membawa kepada peningkatan dalam pertumbuhan. Kajian ini menunjukkan konsentrasi <25% air kumbahan perbandaran adalah selamat untuk digunakan sebagai pengairan dalam pengeluaran padi.

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APPROVAL

I certify that a Thesis Examination Committee has met on 7th January 2015 to conduct the final examination of Umaru Mohamed Gassama on his thesis entitled "Effect of Different Concentrations of Municipal Wastewater on Seed Germination and Seedling Performance of Three Rice (Oryza sativa L.) Varieties" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision,
- supervision responsibilities as slated in Rule 41 in Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABREVIATIONS

APHA	American Public Health Association
ANOVA	Analysis of Variance
ASOA	Association of Official Seed Analysts
FGP	Final Germination Percentage
GRI	Germination Rate Index
G	Gram
LSD	Least Significant Different
MG/L	Milli gram per liter
TW	Treated Wastewater
UTW	Untreated Wastewater
CM	Centimeter
MR	Malaysian Rice
VAR	Variety
CONC	Concentration
WTR	Water

CHAPTER 1

INTRODUCTION

Water is a major factor on earth and top priority for the existence of human life and crop production. The major challenge faced by developing countries is the inability to produce adequate food for the growing human population and their domestic animals due to the shortage of fresh water for irrigating agricultural fields. This is evident as the demand of the fresh water is increasing with an increase in human population. Rice (*Oryza sativa*) is grown in more than hundred countries and as a cereal grain crop. It is an important staple food in Asia, Africa and the West Indies.

Metropolitan centers discharge the wastewater into the water bodies which are eventually used for irrigation in agriculture fields. The major sources of organic pollution in fresh water bodies are sewage derived from discharge of wastewater. This sewage includes domestic, hospital and small scale industrial waste operating under municipal areas (Dash, 2012). Effluent pollution most often affects water resources and this might be attributed to non-existing effluent treatment facilities and accurate dumping system of the wastewater (Kumar, 2011). In general, crops cultivated on wastewater irrigated soils show high level of heavy metals as compared to those grown on tube well water-irrigated soils. Meeting the trials of feeding the ever rising human populace, proficient uses of water and land resources is extremely vital in crop production. Modern agriculture is also responsible for development of large number of industries especially the agro-based industries in addition to meeting the food requirement. These agro-based industries have toxic effect on the air, water and soil depending on the nature of raw materials used. However, industrialization and pollution are complementary to each other and therefore, steps are to be taken for proper disposal of pollutant (Manunatha, 2008). The use of domestic wastewater for agricultural production is increasing, especially as domestic wastewaters are rich in plant nutrients and organic matter which are essential for plant growth and development. This practice may help reduce the pressure of using fresh water for watering or irrigation (Dash, 2012).

Looking into the context of wastewater, it can be a measurement of both positive and negative resources. The positive aspect of using wastewater in agriculture activities is that it has nutrients which can be used for irrigation, thus benefits the farming community, societies and municipalities. The negative aspect of wastewater reuse is the damaging effect on humans, plants, animals and ecological system that needs to be recognized and considered (Hussain *et al.*, 2002). Potential means to guarantee rice seed productivity is to ensure that the quality of the seeds for sowing is good. Good and quality seeds are free of weed seeds, seed-borne diseases, pathogens, insects, or other matters and they possess high germination, vigor, viability and seedling performance (Chhetri, 2009).

Generally, wastewater (treated and untreated) is extensively utilized in farming because it is a rich basis of nutrients and provides all the moisture vital for crop growth. At the same time, a number of hazard factors have been recognized in wastewater reuse. Some are notably short term and vary in severity (e.g., microbial pathogens), whereas others have longer-term problems that rise alongside the endured use of reprocessed water (e.g., impact of salinity on soil) (Hussain *et al.,* 2002; Papadopoulos *et al.,* 2009). In countless arid and semi-arid states, water is becoming an increasingly scarce resource and planners are compelled to ponder any sources of water that could be utilized frugally and efficiently to promote development. At the same time, with increasing population at an elevated rate, the demand for increased food production is apparent.

The potential for irrigation to raise both agricultural productivity and the living standards of the rural poor has long been recognized. There are several reports indicating beneficial effect of wastewater on seed growth and development but not many studies have evaluated the use of municipal wastewater on agricultural productivity. Agriculture is the largest user of water with about 75% of fresh water being used for irrigation. As the demand of fresh water is increasing with increase in human population, there is a need to recycle wastewater to be used for agricultural activities. In both developed and developing countries, the most prevalent practice is the application of municipal wastewater (both treated and untreated) to land. In developed countries where environmental standards are applied, much of the wastewater is treated prior to use for irrigation of fodder, fiber, and seed crops. In developing countries, though standards are set, these are not always strictly adhered to. Wastewater, in its untreated form, is extensively used for agriculture and aquaculture and has been the practice in many countries.

Seed germination and crop growth are important phase that determines plant population and crop productivity. As the demand of wastewater is increasing, it is therefore essential to determine the effect on quality of seeds. The studies were conducted by using municipal wastewater to find out the seed quality attribute of rice with the following objectives:

1. To determine the influence of different concentrations of municipal wastewaters on fresh and aged seed germination and seedling performance of MR219, MR220 and MR253 rice varieties.

2. To determine the effect of municipal wastewaters on nutrients uptake by the rice seedlings.

3. To determine the effect of municipal wastewaters on the chlorophyll contents of the rice seedlings.

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