Poll Res. 40 (1) : 71-78 (2021)

ISSN 0257–8050

EFFECTS OF MEAT PRODUCT WASTEWATER ON SEED GERMINATION OF RD 41 RICE (*ORYZA SATIVA* L.) FOR REUSE PURPOSE

R. PATSINGHASANEE[1], P. DHANMANONDA[1], S. BUALERT[1], O. PHEWNIL[1,3] AND D. ONWIMOL[2]

[1]*Departmnet of Environmental Science, Kasetsart University, 10900, Bangkok, Thailand*
[2]*Department of Agronomy, Kasetsart University, 10900, Bangkok, Thailand*
[3]*The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, 7610, Phetchaburi, Thailand*

(Received 17 August, 2020; accepted 24 September, 2020)

ABSTRACT

Meat product wastewater was investigated for the effects on seed germination of RD 41 rice seeds (*Oryza sativa* L.) due to its high quantity and possibility to reuse and mitigate water shortage situation. The wastewater with pH 7.66, EC 722 mS/cm, COD 960 mg/L diluted by deionized water to 0, 12.5, 25, 50, and 100 %, and 10, 20, 30, 40, 50, and 60 % concentrations by volume were applied to germinate 50 rice seeds by a between paper method for 5 days at 5 replicated. The germination percentage, total length, seed vigor index, wet weight/seedling, dry weight/seedling, and the mean germination time (MGT) of radical emergence were investigated. The significantly different of shorter MGT of radical emergence results for 10, 20, and 30 % concentration illustrated the better germination environment, therefore, 30% concentration was suitable to seed germination due to the highest quantity of wastewater to be reused.

KEY WORD: Meat product, Wastewater reuse, Agriculture, Seed germination

INTRODUCTION

Extreme weather event, raising population, expanding agriculture land, and increasing industries caused water shortage situation in many areas. Therefore, reclaiming industrial wastewater for irrigating cereal such as rice (*Oryza sativa* L.) the stable foods, were implemented worldwide. Then there were the researches on applying wastewater such as a pulp industry (Panichsukpatana *et al*., 2002), the pig manure tea (U-sanggenon *et al*., 2012), a swine and an aqua culture farm (Hay and Iwai, 2018), an ink industry (Zayne *et al*., 2015), sugar mill (Rath *et al*., 2013, Saini and Pant, 2014; Nagda *et al*., 2006, tannery (Faiz *et al*., 2010) and seafood processing (Mendez and Joseph, 2014) on rice, barley, wheat, and quinoa germination.

At the germination stage, exogenous and endogenous factors regulated seed germination were water, temperature, light, andphytohormones (He and Yang, 2013). Previous researches stated that factors affected seed germination were salinity, micro nutrients such as Ca, Cu, Zn, Fe, Na, non-nutrients such as Hg, Pb, Cd, and Cl. NaCl and other salts produced salt stress, interrupted osmotic relations of water and seeds, enhanced conductivity of solutes that seed adsorbed for germination, inhibited water uptake, cell expansion and lateral bud development in root medium, and reduced % seed germination, protein, starch content, and biomass production (Yeo and Flower, 1986; Glenn and Brown, 1999; Munns and Tester, 2008; Rajakumar *et al*., 2013; Mendez and Joseph, 2014). Moreover, Na+ accumulation in cells caused decreasing cellular metabolism activity including photosynthesis, necrosis, leaf mortality, and chlorosis. However, some salt solution showed beneficial result on seed germination, Theerakulpisul *et al*. (2016)

found that among NaCl, KCl, CaCl, and KNO3 seed priming agents under salt stress 150 mM NaCl, the 0.75 % KNO_3 reduced proline content, the symptom of salt stress, by functioning as an osmoregulatory and essentialelements for metabolic process, and prevented salinity building up in plant tissue (Shabala and Cuin, 2008, Szczerba *et al*., 2009). Dutta and Boishya (2000) investigated that higher concentration negative effects occurred from the surplus of TN, PO_4, K, SO_4, Cl that injured plant growth from decrease water absorption and obstruct the metabolic processes, moreover high Ca and Mg could cause injury to plant and had negative results on seedling growth (Rajannan and Oblisami, 1979). High amount of Na, Cl, SO_4 could obstruct the uptake of other nutrient such as K, Ca, P and Mg and caused shoot length reduction. High sodium content could reduce water intake rate and increase alkalinity. There were many researches applied industrial wastewater on seed germination. The treated effluent from ink industry with pH 7.25, COD at 388 mg/L, Na at 127 mg/L, Cu at 0 mg/L was applied on barley seed germination (Zayne*et al*., 2015) and yield 99 % germination. Swine effluent at 100 % concentration with high EC at 3.801 ms/cm, high COD at 7,200 mg/L gave 0% germination (Hay and Iwai, 2018). The swine manure tea was also applied as seed priming for rice seed germination, 5% concentration by volume increased seed vigor in term of increase seed quality enhancement (U-sanggenon *et al*., 2020). Sugar factory distillery spent wash andsugar mill effluent with concentration less than 25% concentration gave 80-99.6 % germination for wheat and rice while 50-100% concentration yielded 25-58% germination (Rath *et al.*, 2013, and Samuel and Muthukkaruppan, 2011). Saini and Pant (2014) applied paper mill effluent with pH at 8.4, EC 4.27 mS/cm, COD 590 mg/L on rice germination in soil and found that at 10-30 % concentration gave 91-99 % germination.

The purpose of this study is to reveal characterization of meat product wastewater and its effect on the germination and seedling growth results and to investigate the suitable concentration on RD 41 rice seed germination.

MATERIALS AND METHODS

Collection of wastewaters

Meat product wastewater was collected from a Sausage and beacon factory in Muel Sap Land Factory Land, Khok Krabue, Mueang Samut Sakhon District, Samut Sakhon Province, Thailand and stored in plastic containers and keep in refrigerator below 5 °C until application.

Collection of seed

RD 41 seeds were supported by the Pathum thani Rice Research Center, Thailand.

Analytical Procedure

Wastewater was analyzed as following; pH, Temperature, Electrical Conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solid (TDS), Alkalinity, Fats, Oil and Grease (FOG), Total Kjeldahl Nitrogen (TKN), Ammonia Nitrogen (NH4), Nitrate (NO3), Phosphate (PO4), Potassium (K), Sulphate (SO4), Calcium (Ca), Magnesium (Mg), Iron (Fe), Boron (B), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd), Chromium (Cr), Lead (Pb), Mercury (Hg) according to AWWA (2017). Sodium Adsorption Ratio (SAR) was calculated by the following equation:

$$SAR = \frac{Na^+}{\left[\frac{Ca^{2+} + Mg^{2+}}{2}\right]^{1/2}}$$

Where,
SAR = Sodium Adsorption Ratio
Na^+= sodium, concentrations (meq/L)
Ca^{2+} = calcium concentrations (meq/L)
Mg^{2+}= magnesium concentrations (meq/L)

Experimental Design

Seed germination experiments were conducted for 5 days at a Laboratory, The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Phetchaburi Province, Thailand. The experiment conducted by a Completely Randomized design (CRD) with five replications. RD 41 rice seeds were randomly selected for 50 seeds and germinated by between paper method using 25 cm. x 30 cm. germination paper in 9 in x 14 in plastic bags, covering loosely with rubber bands, moistening with 30 mL of 0, 12.5, 25, 50, 100 % concentration respectively, keeping at room temperature approximately 35 °C and provide light with fluorescent bulb 24 hrs. After 5 days % germination, root length, shoot length, seedling vigor index, fresh weight, and dry weight were investigated. Then the results of 100% concentration showed significant difference ($P \leq 0.05$) compared to

0, 12.5, 25, 50 % for seed vigor index, and dry weight. The 0 - 60% concentration with 10% interval were applied to germinate the seed and the mean germination time (MGT) of radical emergence was additionally examined.

Germination Percentage (GP)

Germination percentage calculated from number of seeds germinated per total number of seeds by the following equation:

$$GP = \left(\frac{N}{N1}\right) 100$$

Where,
GP = Germination Percentage
N =The number of germinated seeds
N1=Number of seeds used

Seedling Length

The seedling length was the total length of the root length and shoot length. The root length was measured by the primary seed radical and the shoot length was measured from the primary seed plumule in centimeter.

Fresh Weight and Dry Weight

The electronic balance was used to determine fresh weight seedling after the germination and dry weight seedling after drying in the hot air oven at 70^{o}C for 72 hrs.

Vigor Index (VI)

Root length and shoot length of seedling and percent germination were calculated for Seed Vigor Index by the following equation:

SVI = (RL+SL)xGP
Where,
SVI = Seed Vigor Index (cm.)
RL = Mean Root length (cm.)
SL = Mean Shoot length (cm.)
GP=Germination Percentage

Mean germination time (MGT) of radical emergence (day)

The Radical emergence mean germination time was calculated by the following equation:

$$MGT=\frac{\Sigma(nT)}{\Sigma n}$$

Where,
n = number of seeds newly germinated (2 mm, radicle emergence) at time T
T = hours from the beginning of the germination test
Σ_n = final germination

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) Version 10 was applied to analyze the data including the analysis of variance (One Way ANOVA). The results meanwas compared with the least significance difference (LSD) at $P \leq 0.05$.

RESULTS AND DISCUSION

Meat product wastewater contained *E. coli* at 2x10^5 MPN/100 mL while FAO's agricultural reuse in crops that are consumed and not processed commercially identify the criterion after secondary disinfection at <200 MPN/100mL. Total Coliform Bacteria and the Fecal Coliform Bacteria were observed and found at 2,400x10^3 MPN/100mL and 1,300x10^3 MPN/100 mL respectively. The bacteria were found due to the pipe leakage from the restroom to the wastewater collection tank before transferring to the central wastewater treatment of the factory land. The challenges on pathogens to reuse wastewater for agriculture reuse also found in the developing countries (Jaramillo and Restrepo, 2017), however in this case the pipe fixation will solve the contamination.

The physical and chemical characteristics of meat product wastewater were illustrated and compared to the guideline for agriculture reuse (FAO, 1985), and Standards and Meteorology Corporation Jordan (WHO, 2005) were compared in Table 1. The value of potential irrigation problem parameters such as electrical conductivity (EC), TDS, SAR, Na, Cl, B, NO_3, pH were 0.722 dS/m, 484 mg/L, 14.08, including 388.66, 479.64, 0.0419, <0.5, mg/L and 7.66 respectively, observing that salinity in term of EC and TDS were identified as slight-moderate degree of restriction on use, however SAR, Na, and Cl value was identified as sever degree of restriction on use. The value for parameters respected to the wastewater guideline for agricultural reuse such as As, Cd, Cr, Cu, Fe, Mn, Pb, Zn, BOD, TSS were <0.002, <0.0005, 0.0031, 0.0075, 0.3290, 0.0121, 0.001, 0.2228, 276 and 81 mg/L consecutively, noticing that only BOD that exceeding the guideline value due to the wastewater was raw water before treatment. The value of parameters the maximum permissible value for field crops and forestry by the Jordanian Standard such as COD, PO_4, SO_4, HCO_3, Mg,Ca, FOG were 960, 5.38, 259.30, 225.01, 13.87, 34.91, 34.06 mg/L consecutively, perceiving that COD was exceeding the recommended value. K was additionally investigated with the value of 53.98

mg/L. Some physical and chemical wastewater quality were exceeding the recommended value according the collection before the wastewater treatment plant, however this situation was also observed by Adesuyi *et al.*,(2016).

The germination %, seedling length, seed vigor index, wet weight/seedling, and dry weight/seeding results from 0, 12.5, 25, 50, 100 % wastewater concentration were shown in the Table 2. The germination %, seedling length were highest at 12.5% with the value of 97.20±2.28 % and 15.6 ± 1.3 cm while the germination % and seedling length were lowest at 100% wastewater concentration with the value of 94.80±3.03 % and 13.4±1.6 cm. From 25 % wastewater concentration and other higher wastewater concentration the germination % and

Table 1. Wastewater physical and chemical quality

Parameters		Meat Product Wastewater	Degree of restriction on use[1]			Max. permissible value[2]
			None	Slight-moderate	Severe	
Potential Irrigation Problems						
Salinity						
	EC (dS/m)	0.722	<0.7	0.7-3.0	>3.0	-
	TDS (mg/L)	484	<450	450-2,000	>2,000	1500
Infiltration						
SAR	0-3	EC	>0.7	0.7-0.2	<0.2	9.0
	3-6		>1.2	1.2-0.3	<0.3	
	6-12		>1.9	1.9-0.5	<0.5	
	12-20	(SAR 14.08, EC 0.722)	>2.9	2.9-1.35	<1.3	
	20-40		>5.0	5.0-2.9	<2.9	
Specific Ion Toxicity (affects sensitive crops)						
SAR	Na (mg/L)	388.66	<3.0	3.0-9.0	>9.0	230
	Surface Irrigation		<69	>69	-	
	Cl (mg/L)	479.64	<142	142.0-355.0	>355	400
	B (mg/L)	0.0419	<0.7	0.7-3	>3.0	1.0
	NO_3(mg/L)	<0.5	<5.0	5.0-30	>30	45
	pH	7.66		6.5-8.4		6-9
Others						
	As (mg/L)	<0.002		0.1	0.1	
	Cd (mg/L)	<0.0005		0.1	0.01	
	Cr (mg/L)	0.0031		0.1	0.1	
	Cu (mg/L)	0.0075		0.2	0.2	
	Fe (mg/L)	0.3290		5.0	5.0	
	Mn (mg/L)	0.0121		0.20	0.2	
	Pb (mg/L)	0.0010		5.0	5.0	
	Zn (mg/L)	0.2228		2.0	5.0	
	BOD (mg/L)	276		30**	300	
	TSS (mg/L)	81		260**	150	
	COD (mg/L)	960		-	500	
	PO_4 (mg/L)	5.38		-	30	
	SO_4 (mg/L)	259.30		-	500	
	HCO_3 (mg/L)	225.01		-	400	
	Mg (mg/L)	13.87		-	100	
	Ca (mg/L)	34.91		-	230	
	FOG	34.06		-	8.0	
	K*(mg/L)	53.98		-	-	

[1]FAO's water quality for irrigation (FAO,1985)

[2]Jordanian Standard (JS: 893/2002) for effluent reuse guideline of maximum permissible value for field crops and forestry (WHO, 2005) *K was additional observed due to its function as macronutrient for plants, Al, Be, Co, F, Li, Mo, Ni, Se, V were specified[2] but were not investigated due to the low possibility to found from the factory processes and laboratory limitation ** FaO's agricultural reuse in crops that are consumed and not processed commercially

seedlings length were gradually declined. However, the wet weight/seedling and the dry weight/ seedling were not significantly different from 0% wastewater concentration or control concentration. Moreover, the seed vigor index was highest at 12.5% wastewater concentration at the value of 1513.5±155.5 and not significantly different with the seed vigor index results from 25% and 50% wastewater concentration as shown in Fig 1. The observation that the higher concentration caused lower % germination, which conformity with the study of Rani and Alikhan (2007). However, to identify the most suitable wastewater concentration, germination the seed with the 0 - 60 % wastewater concentration with 10% interval were investigated with additional radical emergence mean germination time (MGT) parameter.

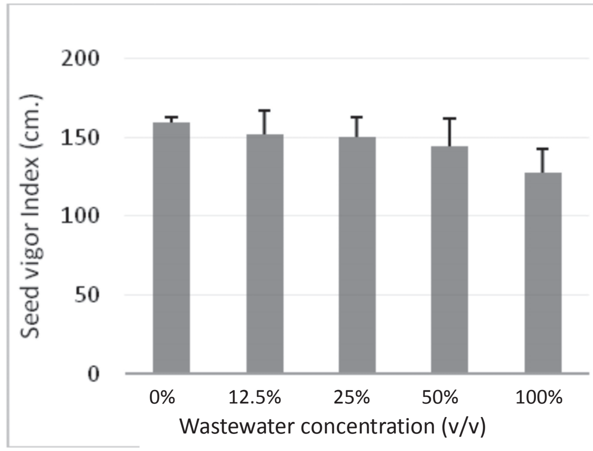

Fig. 1. Seed Vigor Index for 0, 12.5, 25, 50 % wastewater concentration

The germination %, seedling length, seed vigor index, wet weight/seedling, dry weight/seedling, and radical emergence (MGT) results from 0, 10, 20, 30, 40, 50, 60 % wastewater concentration were shown in the Table 3. The germination %, seed vigor index, wet weight/seedling, and dry weight/ seeding results were not significantly different. However, the seedling length result for 60 % wastewater concentration were significantly different from 0, 10, 20, 30, 40, and 50 % wastewater concentration with the value of 1218.2±350.1 cm radical emergence (MGT) results were not significantly different among 0, 10, 20, and 30% wastewater concentration with the value of 1.22±0.07, 1.21±0.17, 1.27±0.11 and 1.34±0.07 day respectively, but significantly different with 40, 50 and 60% wastewater concentration with the value of 1.68±0.07, 1.63±0.09, and 1.84±0.02 day respectively as shown in Fig 2.

The higher concentration or higher dissolved solid, which contributed to salinity, inhibited germination and seedling growth due to it disturbed

Table 2. Effect of 0 - 100 % concentration(v/v) wastewater on RD 41 seed germination

Wastewater Concentration v/v (%)	Germination Percent (%)	Seedling length (cm)	Seed Vigor Index	Wet weight/ seedling (mg.)	Dry weight/ seedling (mg)
0	97.20±1.10[a]	16.3±0.4[a]	1,588.5±37.6[a]	60.85±3.44[a]	16.73±0.43[a]
12.5	97.20±2.28[a]	15.6±1.3[a]	1,513.5±155.5[a]	57.43±4.48[a]	17.59±0.60[a]
25	95.20±3.03[a]	15.5±1.9[a]	1,500.6±129.2[a]	59.75±5.75[a]	17.70±0.65[a]
50	96.40±2.61[a]	14.9±1.7[a]	1,438.4±180.8[ab]	63.03±4.31[a]	17.58±0.59[a]
100	94.80±3.03[a]	13.4±1.6[a]	1,276.1±146.6[b]	58.39±4.28[a]	17.69±0.24[a]

Table 3. Effect of 0 - 60 % concentration (v/v) wastewater on RD 41 seed germination

Wastewater Concentration v/v (%)	Germination Percent(%)	Seedling length (cm)	Seed Vigor Test		Wet weight/ seedling (mg)	Dry weight/ seedling (mg)
			Seed Vigor Index (cm)	Radical emergence MGT (day)		
0	98.00 ± 2.83 [a]	14.10 ± 2.39 [a]	1,401.2±216.9[a]	1.22 ± 0.07 [a]	57.20 ± 4.65 [a]	19.30 ± 0.50 [a]
10	98.80 ± 1.79 [a]	14.17 ± 2.66 [a]	1,399.8±263.2[a]	1.21 ± 0.17 [a]	55.20 ± 1.26 [a]	18.40 ± 0.55 [a]
20	96.50 ± 2.52 [a]	14.92 ± 3.07 [a]	1,393.6±249.3[a]	1.27 ± 0.11 [a]	56.30 ± 1.26 [a]	18.00 ± 0.12 [a]
30	96.80 ± 2.28 [a]	14.29 ± 2.06 [a]	1,335.8±134.9[a]	1.34 ± 0.07 [a]	55.80 ± 1.92 [a]	17.00 ± 2.83 [a]
40	96.80 ± 1.79 [a]	14.39 ± 2.45 [a]	1,332.6±168.8[a]	1.68 ± 0.07 [b]	54.40 ± 2.97 [a]	18.60 ± 0.55 [a]
50	98.40 ± 0.89 [a]	14.86 ± 2.21[a]	1,336.3±215.4[a]	1.63 ± 0.09 [b]	57.20 ± 1.79 [a]	16.40 ± 4.72 [a]
60	97.00 ± 2.00 [a]	12.56 ± 3.61[b]	1,218.2 ±350.1[b]	1.84 ± 0.02 [c]	54.00 ± 2.71 [a]	19.30 ± 0.50 [a]

osmotic relationship of the seed and water, caused less water absorption, reduced amount of oxygen, restricted the energy supply, slowed the growth and

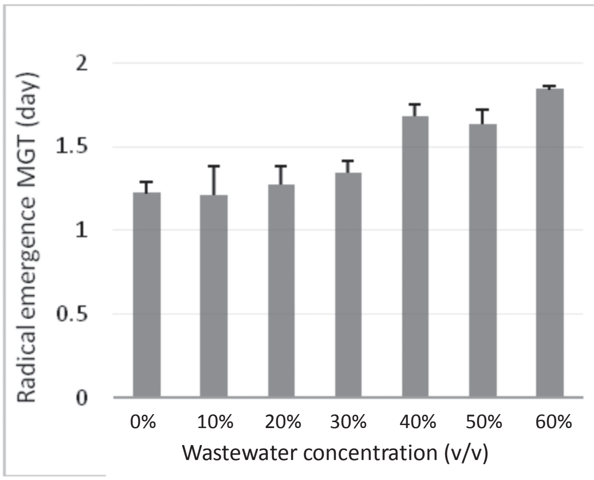

Fig. 2. Radical emergence MGT for 0, 12.5, 25, 50% wastewater concentration

seedling development, and obstructed the metabolic processes (Dutta and Boishya, 2000, Hussain *et al*., 2013). Higher FOG content was suspected to reduced seed germination, but Hay and Iwai, (2017) study results revealed that FOG from aquaculture wastewater with the value of 1,500 mg/L also yield 95% germination. Higher Ca and Mg content could cause injury to plant and had negative results on seedling growth (Rajannan and Oblisami, 1979). Higher Na, Cl, SO_4 content could obstruct the uptake of other nutrient such as K, Ca, P and Mg and caused shoot length reduction. Higher sodium content could reduce water intake rate.

At lower concentrations P, and K, were in the optimize for metabolic enzyme to catalyze germination process and enhance seedling growth (Bam *et al*., 2006). Moreover, at lower concentrations, the negative effect from excess nutrients such as Fe on cell membranes, DNA, and protein damage from free radical (Arora *et al*., 2002, Rasafi *et al*., 2016), Pb on morphology, growth and photosynthetic process (Bot *et al*., 2008, Asati *et al*., 2016), Cu on osmotic potential and water flow to the seed (Quartacci *et al*.,2001), Cr on cell membrane damage (Asati *et al*., 2016), Zn on reduce root length and shoot length (Peralta *et al*., 2001, Rasafi *et al*., 2016) were lower. Additionally, K, PO_4, Ca Clin the wastewater could form KH_2PO_4, KCl, $CaCl_2$ and function as seed priming agent that 1) mitigated salt stress, decreased the electrolyte leakage, suppressed Nauptake and stimulating K uptake in shoot (Iqbal *et al*., 2006, Theerakulpisut *et al*., 2017), 2) ameliorated a-amylase activity, which enhanced the level of soluble sugars in the primed Kernels (Farooq *et al*., 2006) 3) shortened the seed germination time, increased dehydrogenase activity and accelerate catabolic chemical in anaerobic respiration during germination (Oaikhena *et at*., 2013)

The radical emergence MGT results was the key to justify the suitable wastewater concentration for seed germination and rice vigor test (Onwimol *et at*., 2015; U-sanggenon *et at*., 2020) due to the radical emergence MGT reflected deterioration of seed quality the among the non-significantly different result of radical emergence MGT from 10, 20, 30% wastewater concentration, 30% concentration is suitable for seed germination practice.

CONCLUSION

The study results revealed that meat product wastewater that contained numerous nutrients at higher concentration showed some negative effect on seed germination however at lower concentration fewer negative effects were found and suitable dilution could be practically apply to germinate rice.

ACKNOWLEDGEMENTS

The author thanks the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Petchaburi, Thailand for technical and financial supports, the Faculty of Environment, and Department of Agronomy, Kasetsart University, Bangkok, Thailand for technical guidance and equipment supports, the S.T.C. Foods Co., Ltd., Khok Krabue, Mueang Samut Sakhon, Samut Sakhon for the wastewater support, and the Pathum thani Rice Research Center for the RD 41 rice seed support.

REFERENCES

Adesuyi, A. A., Nnodu, V. C., Njoku, K. and Jolaoso, A. O. 2016. Evaluation of Industrial Discharge Point Source Pollution in Ikeja Industrial Estate, Ikeja, Lagos, Nigeria. *UNILAG Journal of Medicine, Science and Technology*. 4 (2) : 26-46.

Aquila, A. 1987. Mean germination time as a monitor of seed aging. *Plant Phys. Biochem.* 25 : 761-768.

Arora A, Sairam R.K. and Srivastava, G.C. 2002. Oxidative stress and antioxidative system in plants. *Cur Sci.* 82 : 1227-1338.

Asati, A., Pichhode, M. and Nikhil, K. 2016. Effect of

Heavy Metals on Plants: An Overview. *International Journal of Application or Innovation in Engineering & Management*.

Bam, R.K., Kumaga, F.K., Ofori, K. and Asiedu, E.A. 2006. Germination, Vigour and Dehydrogenase Activity of Naturally Aged Rice (*Oryza sativa* L.) Seeds Soaked in Potassium and Phosphorus Salts. *Asian Journal of Plant Sciences*. 5 : 948-955.

Bot, P.,Kabir, M.,Iqbal, M., Shafiq, M. and Farooqi, Z. 2008. Reduction in germination and seedling growth of *Thespesia populnea* L., caused by lead and cadmium treatments. *Pakistan Journal of Botany*. 40 : 2419-2426.

Peralta, J.R., Panichsakpatana, S., Suwannarat, C. and Phuangraya, N. 2002. Utilization of pulping waste water as source of potassium for paddy, Final report on research fund 1997-2000, project id 2 B1.1.40, Kasatsart University, 123 p.

Dutta, S. K. and Boissya, C.L. 2000. Effect of paper mill effluent on the yield component of rice (*Oryza sativa* L. Var Masuri). *Eco. Env. Conserv*. 6 (4) : 453-457.

Faiz, H. and Malik, S. A., Athar, M., Bashir, N., Younis, U., UL HASSAN, M. and Mahmood, S. 2010. Effect of tannery effluents on seed germination and growth of two sunflower cultivars. *African Journal of Biotechnology*. 9 : 5113-5120.

Food and Agriculture Organization (FAO). 1985. Water quality for agriculture Irrigation and Drainage Paper 29 Rev. 1, Rome, Italy.

Farooq, M., Barsa, S.M.A. and Wahid, A. 2006. Priming of field-sown rice seed enhances germination, seedling establishment, allometry and yield. *Plant Growth Regul*. 49 : 285-294.

Glenn, E.P. and Brown, J.J. 1999. Salt tolerance and crop potential of halophytes. *Critical Reviews in Plant Sciences*. 18 : 227-255.

He, D. and Yang, P. 2013. Proteomics of rice seed germination. *Frontiers in Plant Science*. 2013.

Hussain, F., Malik, S., Athar, M., Bashir, N., Younis, U. and Hussan, M. 2013. Effect of tannery effluent on seedgermination and growth of two sunflower cultivars. *African J Biotechnology*. 9(32) : 5113 - 51120

Hay, V. and Iwai, C. B. 2018, Utilization of wastewater on seed germination and physiological parameters of rice (*Oryza sativa* L.), *Conference Series: Materials Science and Engineering*. 334 : 12-36

Iqbal, M., Ashraf M, Jamil A. and Rehman U.S. 2006. Does seed priming induce changes in the levels of some endogenous plant hormones in hexaploid wheat plants under salt stress?. *J Integr Plant Biol*. 48 : 181-189.

Jaramillo, M. and Restrepo T. I. 2017. Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits. *Sustainability MDPI, Open Access Journal*. 9 (10) : 1-19.

Munns, R., and Tester, M. 2008. Mechanisms of salinity tolerance. *Annual Review of Plant Biology*. 59 : 651-681.

Mendez, R.M. and Joseph, G. 2014. Impact of seafoodprocessing factory effluent on seed germination and early seedling growth of *Vigna sinensis* L. and *Oryza sativa* L.*Nature Environment and Pollution Technology*. 13 : 165-168.

Nagda, G.K., Diwan, A. M. and Ghole, V. S. 2006. Seed germination bioassay to assess toxicity of molasses fermentation based bulk drug industry effluent. *Environ Agri Food Chem*. 5 (6) : 1598-1603.

Oaikhena, E. E., Ajibade, G. A., Appah, J. and Bello, M. 2013. Dehydrogenase Enzyme Activities in Germinating Cowpea (*Bigna unguiculata* (L) Walp). *Journal of Biology, Agriculture and Healthcare*. 3(20) : 32-36

Onwimol, D., Changsee, P. and Chanprasert, W. 2015. Seed vigour Evaluation by Single Counts of Radicle Emergence in Rice *(Oryza sativa* L.). *Proceedings of the 12th national seed conference*. pp275-281. Bangkok, Thailand: the Seed Association of Thailand Rajamangala University, Lampang

Panuccio, M. R. , Jacobsen, S. E. , Akhtar, S. S. and Muscolo, A. 2014. Effect of Saline Water on Seed Germination and Early Seedling Growth of The Halophyte Quinoa. *AoB Plants*. 6: plu047. doi: 10.1093/aobpla/plu047."

Peralta, J.R., Gardea-Torresdey, J.L. and Tiemann, K.J. 2001. Uptake and effects of five heavy metals on seed germination and plant growth in alfalfa (*Medicago sativa* L.). *Bull Environ Contam Toxicol*. 66 (6) : 727-734.

Quartacci, M. F., Cosi, E. and Navari, F. I. 2001. Lipids and NADPH-dependent superoxide production in plasma membrane vesicles from roots of wheat grown under copper deficiency or excess. *Journal of Experimental Botany*. 52 (354) : 77-84.

Rajakumar, R. 2013. A study on effect of salt stress in the sed germination and biochemical parameters of rice (*Oryza sativa* L.) under *in vitro* condition. *Asian Journal of Plant Science and Research*. 3 (6) : 20-25

Rajannan, G. and Oblisami, G. 1979. Effect of paper factory effluent on soil and crop palnts. *Indian Journal of Environmental Health*. 21 : 120-130.

Rani, R. and Alikhan, M. A. 2007. Utilization of distillery effluent and its effect on growth and physiciology of *Oryza sativa* L. *Proceeding of the Natinal Conference on Ecofriendly Utilization of Recyclable Organic Resources from Sugar and Distillery Industries for Sustainable Agriculture, March 6-7 Trichy*. p 1-9.

Rasafi, T. E., Nouri, M., Bouda, S. and Abdelmajid, H. 2016. The Effect of Cd, Zn and Fe on Seed Germination and Early Seedling Growth of Wheat and Bean. *Ekológia (Bratislava)*. 35 (3) : 213-223.

Rath, P., Biswal, K. and Misra, M.K. 2013. Effects of sugar factory distillery spentwash on germination and seedling growth of rice (*Oryza sativa L.*). *Int J Sci Innov Disc*. 3 : 191-201.

Saini, S. and Pant, S. 2014. Physico-chemical analysis of Sugar mill Effluent and their Impact on Changes of Growth of Wheat (*Triticum aestivum*) and Maize (*Zea mays L.*). *IOSR Journal of Environmental Science, Toxicology and Food Technology*. 8 : 57-61.

Samuel, S. and Muthukkaruppan, S.M. 2011. Physico-Chemical Analysis of Sugar Mill Effluent, Contaminated Soil and its Effect on Seed Germination of Paddy (*Oryza sativa* L.). *International Journal of Pharmaceutical & Biological Archives*. 2(5) : 1469-1472

Shabala, S. and Cuin, T.A. 2008. Potassium transport and plant salt tolerance. *Physiol Plant.* 133 : 651-669

Szczerba, M.W., Britto, D.T. and Kronzucke, H.J. 2009. K^+ transport in plants: physiology and molecular biology. *J Plant Physiol*. 166 : 447-466.

The International Seed Testing Association (ISTA). 2007. International Rules for Seed Testing, Bassersdorf, Switzerland

Theerakulpisut, P., Kanawapee, N. and Panwong, B. 2017. Seed priming alleviated salt stress effects on rice seedlings by improving Na^+/K^+ and maintaining membrane integrity. *International Journal of Plant Biology*. 7 (1) : 53-58.

U-sanggenon, P., Aroonrungsikul , C. and Juttupornpong, S. 2012. Effect of pig manure tea to seed germination and seed quality enhancement of emergence stage in rice (*Oryza sativa* L.) varieties RD 31. *Proceedings of 50th Kasetsart University Annual Conference: Agricultural Extension and Home Economics, Plants*. 420 p., The Thailand Research Fund, Bangkok (Thailand).

World Health Organization (WHO). 2005. A compendium of standards for wastewater reuse in the Eastern Mediterranean Region. Regional Office for the Eastern Mediterranean. Regional Centre for Environmental Health Activities.

Yeo, A.R., Flowers, T.J., Turner, N.C. and Passioura, J.B. 1986. Salinity resistance in rice (*Oryza sativa* L.) and a pyramiding approach to breeding varieties for saline soils, Effect of drought on plant growth. Salts in soils, Melbourne, Australia CSIRO. 161-173

Zayne, C., L., Khanous, Olfa, E., Naima, J., Grubb, C.D., Bassem, K., Hafedh, M. and Amine, E. 2015. Morphological, Physiological and Biochemical Impact of Ink Industry Effluent on Germination of Maize (*Zea mays*), Barley (*Hordium vulgare*) and Sorghum (*Sorghum biocolor*). *Bull Environ Contam Toxicol*. 95 : 687-693.