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EXPLORING GERMINATING POTENTIAL OF TREE SPECIES IN DOMESTIC WASTEWATER FOR USE IN URBAN FORESTRY

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Abstract

Domestic wastewater is an important source of water and nutrients for irrigation in developing countries, particularly to arid, semi-arid and water scarce areas. The use of wastewater is widespread and represents around 10 percent of the total irrigation. It imparts both positive and negative effects on ecosystem. As wastewater reuse is currently necessary (due to water shortage), it is important to use it wisely. The best feasible management practice is to use wastewater for forest irrigation to maximize benefits and minimize damage. Species which have higher tolerance index can be used in urban forestry. In the present study, germination studies of 5 tree species were investigated, irrigated with domestic wastewater (in different concentrations). Statistical analysis revealed that germination %, seedling length/weight increase with increase in DWW concentration. But concentration beyond 50% starts imparting negative effects. Study shows that only *Millettia peguensis* Ali, *Pongamia pinnata* (L.) Pierre, *Albizia lebbeck* (L.) Benth, *Bauhinia purpurea* L. and *Dalbergia sissoo* L. can withstand toxicity of domestic wastewater and thus can be the potential candidate for urban forestry. These species show significantly high vigor index, germination index and tolerance index. Result supports the use of 50% diluted DWW for forest irrigation. This study highlights the possible solution (DWW use for urban forest irrigation) to multiple problems like, wastewater management/treatment, biodiversity loss, lack of urban green spaces and low forest cover.

Key Words: Domestic wastewater, germination, urban forestry, Fabaceae,

Introduction

In developed countries, reuse of wastewater (WW) is part of tactic to protect natural water bodies and to limit management expenses. On the other hand, in developing countries water scarcity and fertilizing properties are the main factor for its reuse (Jiménez & Garduño 2001; Anon., 2003a). Irrigation with domestic wastewater is in use of urban and peri-urban areas of arid or semiarid countries. It depends on wastewater availability, demand of fresh food, poverty and lack of alternatives. Mostly, small farmers use wastewater to fulfill their domestic need of vegetables and fodder. Very small quantities of generated products (vegetables and flowers) are sold in markets (Ensink *et al*., 2004b). Use of wastewater for irrigation has both advantages and disadvantages. Advantages include higher yields, round the year availability, round the year production, availability in arid and semi-arid areas, recycles organic matter/nutrients, reduces fertilizers amount / cost, low-cost wastewater disposal, avoids polluting surface water bodies, increases the economic efficiency, conserves freshwater sources and recharges aquifers through infiltration (Khaleel *et al*., 2013). Whereas, disadvantages/limitations include need of careful planning, storage capacity, pathogens related problems, presence of toxic materials which may contaminate ground water (Pena *et al*., 2014).

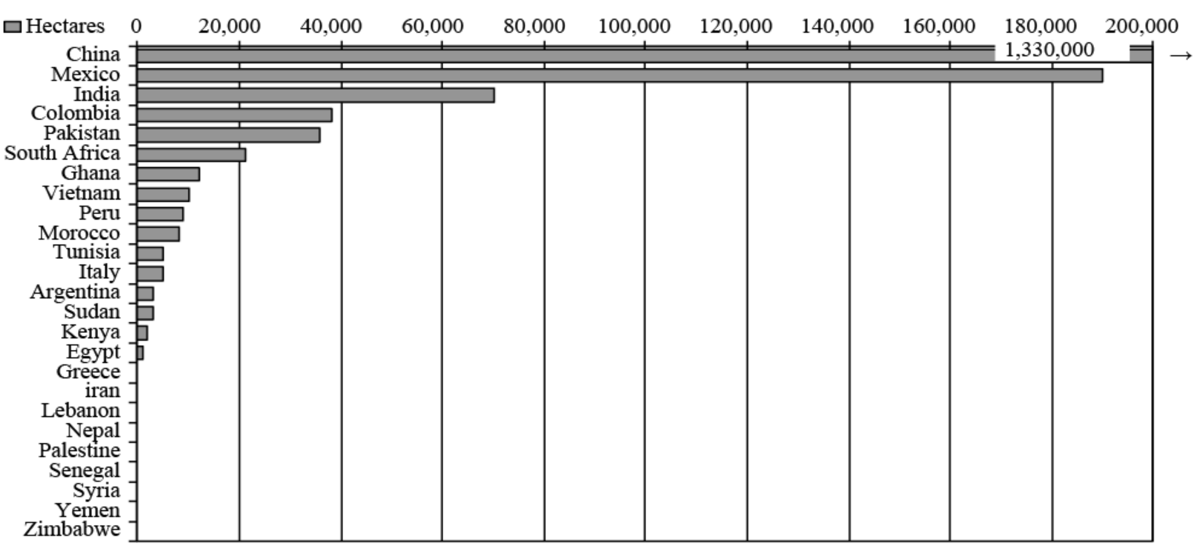

Fig. 1. Area under wastewater irrigation

There is no complete global inventory on the extent to which wastewater is used to irrigate trees (Fig. 1), however global figure commonly cited is at least 20 million hectares in 50 countries (Anon., 2003b). Estimates suggest that nearly 1/10 of world's population use WW irrigated crops (Smit & Nasr, 1992). For instance, in Hanoi (Vietnam) nearly 80% vegetables are grown using wastewater (Ensink *et al*., 2004a).

Keeping in view the benefits and limitations of wastewater irrigation, researchers have started to use it for growing forests (not edible crops). If these forests are in urban spaces then multiple benefits can be gained (Mongkhonsin *et al*., 2011). Wastewater can be used to irrigate urban forests in many forms, either treated (reclaimed water), non-treated (raw wastewater), directly or indirectly after dilution with water from rivers or reservoirs (Han *et al*., 2014). In India number of experimental sites was developed to investigate WW irrigation to trees. One example is the CSSRI (Central Soil Salinity Research Institute in Karnal, Haryana State) which evaluated the practicability of using untreated sewage to irrigate forest. *Eucalyptus tereticornis, Populus deltoides* and *Leucaena leucocephala* exhibit faster growth with no negative signs over the course of five years (Das & Kaul, 1992).

The present study deals with the investigation of germination potential of 5 tree species, under domestic wastewater and their potential use in urban forestry.

Materials and Methods

Plant and seed selection: Five tree species of family Fabaceae were used as test species; *Millettia peguensis* Ali, *Pongamia pinnata* (L.) Pierre, *Albizia lebbeck* (L.) Benth, *Bauhinia purpurea* L., *Dalbergia sissoo* L. Seeds were provided by Punjab Forest Department, Cooper Road, Lahore. Seeds were physically screened and damaged/unhealthy were excluded.

Waste water collection and analysis: Domestic waste water was collected from sewage drain near River Ravi, Lahore. The collections and physicochemical analysis of waste waters were done according to the standard protocols. Five dilutions of wastewater were prepared; named T0 (distilled water), T1 (75% diluted), T2 (50% diluted), T3 (25% diluted), T4 (0% diluted).

Germination experiment: Whatmann filter paper was put in petri dishes and seeds were placed over filter paper for 15 days. Petri dishes were arranged in complete randomized block design over laboratory table in triplicate. At the start of experiment 3ml and subsequently 2ml of respective WW dilution was added in respective petridish. Seeds were considered germinated with the emergence of radicles. Parameters recorded were: % germination, plumule length (cm), root length (cm), shoot length (cm), seedling fresh weight (g), seedling dry weight (g), seedling vigor index and tolerance indices.

Seedling vigor index = Germination (%) X seedling length

$$\text{Tolerance Indices} = \frac{\text{Wastewater treatment}}{\text{Control}} \times 100$$

$$\text{Mean time to germination (MTG)} = \frac{\sum n \times d}{N}$$

where: n = number of germinated seeds
d = incubation time
N = total number of germinated seeds

Statistical analysis: Data was analyzed for ANOVA and Duncan's Multiple Range test by Co-stat.

Results and Discussion

Number of problems is prevailing due to population explosion and lack of urban/industrial planning. These problems include water pollution, water scarcity, lack of urban green spaces and low forest cover. The single solution of these multiple problem is urban forests with wastewater irrigation.

Waste water analysis: Compared to National Environmental Quality Standards (NEQS), domestic wastewater (DWW) pH, EC, COD, BOD were found significantly above average (Table 1). N, K and P were close to the acceptable limit, where as TDS and TSS were significantly lower then the acceptable values. Due to high nutrient availability domestic wastewater can be the alternative for fertilizer. Most organic compounds of human, animal, or plant origin present in sewage are rapidly transformed in soils to stable, non-toxic organic compounds (humic and fulvic acids). Actually, soils can biodegrade a wider variety and a greater amount of organic compounds than water bodies (Han *et al*., 2014). Water application under controlled conditions (limited irrigation rate and intermittent flooding) permits the biodegradation of hundreds of kilograms of biological oxygen demand per hectare per day (kg BOD/ha/d) with no impact on the environment (Bouwer 1987). BOD levels are virtually reduced after a few meters of percolation through the soil, where total organic carbon (TOC) values of 1-5 mg/L can still be measured (Mansell *et al*., 2004; Khaleel *et al*., 2013).

The amount of nitrogen remaining in wastewater after irrigation depends on the nitrogen content and the amount of water applied to crops (Ali *et al*., 2011; Jelusic *et al*., 2013). Nitrogen removal is enhanced if flooding and drying periods are alternated, which promotes a nitrification/denitrification process on soil that can remove about 75 percent of the nitrogen in sewage (Bouwer 1987). In sewage wastewater phosphate may react with calcium, iron and aluminum oxide, all the resultant forms are insoluble. Immobilized phosphate gradually converts to mobile phosphate (Barbera *et al*., 2013).

Soaking time: Socking time is the critical factor for seed germination. It basically provides water to soften seed coat for easy rupture and release of plumule and radicle. Secondly, complex carbohydrates are broken down into monosaccharide and are able to provide energy (Mosse *et al*., 2010). Thirdly, during germination water provides aqueous media without which metabolic reactions will not proceed (Pena *et al*., 2014). Socking time varies with specie to specie. In the present study, *B. Purpurea* differed significantly from rest of the species in socking time. It needed 5 hour of socking time, whereas, *P. Pinnata* and *A. Lebbeck* showed non-significant difference (4hrs). Similarly, *D. Sissoo* and *M. Peguensis* were non-significant among each other but significantly differ from other 3 species. From practical prospective, species with low socking time duration are more preferred (Fig. 2).

Table 1. Physio-chemical characteristics of domestic wastewater.

Parameters	Values
pH	6.9
EC (µs)	88
TDS (mgL^{-1})	0.0024
TSS (mgL^{-1})	0.0018
COD (mgL^{-1})	372
BOD(mgL^{-1})	234
N (%)	1.76
K (ppm)	679
P (ppm)	422
Cl^{-1} (mgL^{-1})	340
Mg^{+2}(mgL^{-1})	71
Ca^{+2} (mgL^{-1})	156

Moisture requirement: Figure 3 depicts the relationship between germination % and water quantity requirement. All species shows hyperbolic curve, which means that seeds need optimum water quantity. Increase or decrease from optimum value will decrease the germination percentage. All 5 species respond differently at different water concentration. Optimum water requirement for *B. Purpurea, A. Lebbeck,, D. Sissoo* and *M. Peguensis* is 12-15ml, whereas *P. Pinnata* showed optimum germination at 18-20ml. Statistical analysis showed significant difference among 5 species. At low moisture, germination is effected due to the lack of water and mostly metabolic processes are dependent on water (Ali *et al.*, 2011). Whereas, at high water availability germination is reduced due to the poor aeration, reduced oxygen, leaching of essential material (enzymes, soluble food reserves, etc) from seed by exosmosis (Khaleel *et al.,* 2013).

Percentage germination: Domestic waste water is rich in nutrient and also toxic materials like pharmaceutics, detergents and surfactants etc. Theoretically, it is expected that due to more nutrients wastewater irrigation will enhance germination. The same trend is shown in the Table 2. At low domestic wastewater concentration, germination is increased as compared to the control and as the concentration of waste water is increased the germination percentage in decreased (Prabhakar *et al*., 2004). However the 5 species differ significantly in their germination response. Better response was shown by *D. Sissoo* and the least response was of *B. Purpurea.* Statistically, *M. Pegaensis* and *P. Pinnata* do not differ significantly at 25% domestic wastewater. Similarly, *D. Sissoo* and *A. lebbeck* respond same at highest concentration. This difference in germination response is due to the variable needs of difference species, some need more nutrients and other need less nutrients (Hussain *et al*., 2010). At high concentration, the toxicity of wastewater was more apparent than its effectiveness. This parameter is useful in optimizing the wastewater quantity in urban forestry (Manu *et al.,* 2012).

Mean time to germination: Domestic wastewater significantly reduces the mean time to germination (Adam & Duncan, 2002). All the 5 species differ significantly in mean time to germination (MTG). The minimum time was exhibited by *D. sissoo* and maximum was reported by *M. peguensis* (Fig. 4). The MTG values are 72, 79.2, 81.6, 88.8 and 96 (hrs) for *D. sissoo, A. lebbeck, B. purpurea, P. pinnata* and *M. peguensis,* respectively. Difference in MTG depends on seed size, seed coat thickness / permeability, degree of difference in toxin/nutrient uptake (Mekki *et al*., 2007). Studies have reported strong negative influence of salts and phenolics in delaying MTG (Mosse *et al*., 2010).

Seedling length: Seeding length is affected by wastewater but is depend on the nature and concentration of wastewater. Data for root and shoot length is presented (Fig. 5). *D. sissoo* represent most lengthy shoot and root at 75% of wastewater. Other species also exhibit better length at 75% of WW, which may be due to the more availability of nutrients (Barbera *et al*., 2013). Statistical analysis revealed that seedling length is in the following order:

D. sissoo > *A. labbeck* > *B. purpurea* > *P. pinnata* > *M. peguensis*

Seeding fresh weight: Seedling fresh weight was measure in order to know the best treatment for irrigation. Here again the trend was somewhat similar as was in germination percentage. With the increase in WW concentration the fresh weight increases up to 75% but further increase in concentration decrease the fresh weight due to the toxicity (Table 3). *B. purpurea* did not differ significantly at 50-75% of DWW. *M. peguensis* show least difference from 25-75%. It is not conform which component of DWW exhibit phyto-toxicity at higher concentration, however some evidences suggest the involvement of phosphorous, sodium, ethanol and polyphenols (Stutte *et al*., 2006). The variation in species may be due to the tolerance and differential nutrient requirements (Mosse *et al*., 2010).

Tolerance index: Tolerance index is one of the important parameter to get an idea of specie response. From the result it is clear that the *A. labbeck* is the most tolerant out of 5 species (Fig. 6). Statistical analysis also revealed that the tolerance index decrease with the increase in wastewater concentration. The maximum tolerance was shown by *A. labbeck* at 50% of DWW (133) and the least tolerance was reported by *M. peguensis* (117). All the rest differ significantly from one another. At high concentration of wastewater the salts accumulation increases which interfere with translocation and photosynthesis (Jelusic *et al*., 2013). Salts accumulation also disturbs the osmotic balance between soil and roots which creates problems in water absorption. Those species which are more tolerant are useful in agro-forestry (Pena *et al*., 2014).

Vigor index: When different dilutions of wastewater were compared for vigor index (VI) it gives very promising results. As a rule of thumb, the VI increase with the increase in WW concentration but after certain point it start decreasing (Fig. 7). Probably due to the fact that in dilute solution the toxic materials are less and as the concentration increases the amount of toxic material also increases (Ali *et al*., 2011). Statistical analysis showed that the concentrations and species differ from one another. The maximum VI was shown by *D. sissoo* in 25-75% wastewater

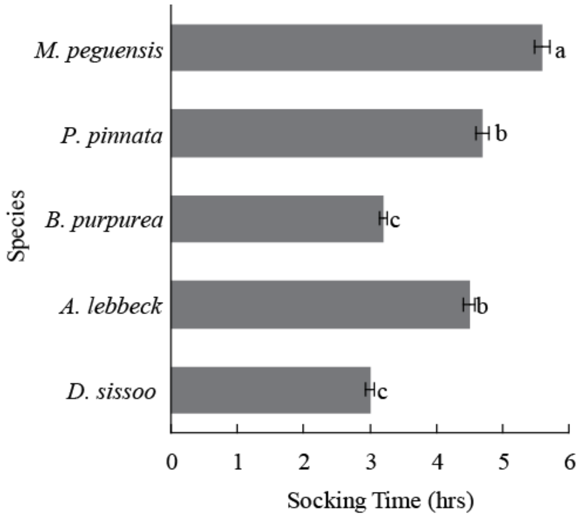

Fig. 2. Socking time requirement of different plants.

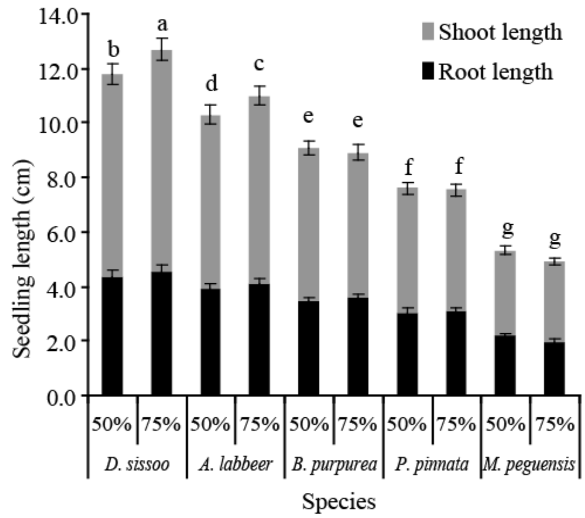

Fig. 5. Influence of domestic wastewater on root and shoot length

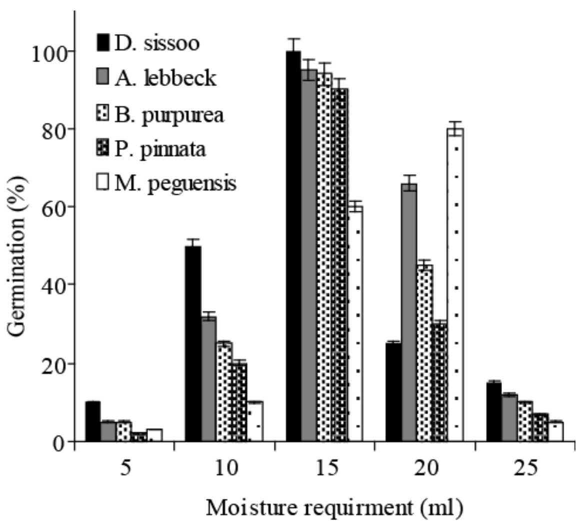

Fig. 3. Moisture requirement of different species

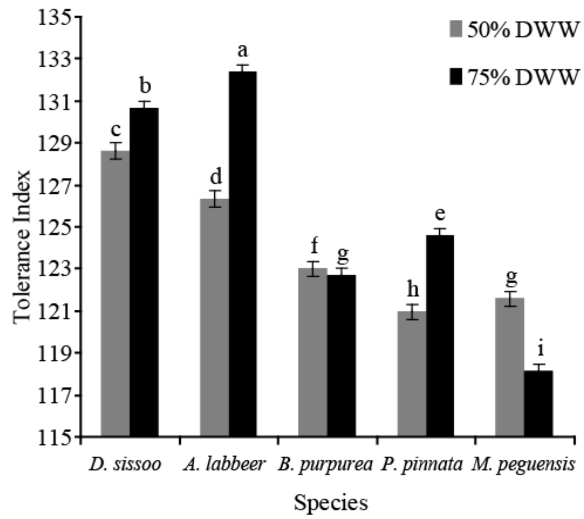

Fig. 6. Tolerance response in domestic wastewater

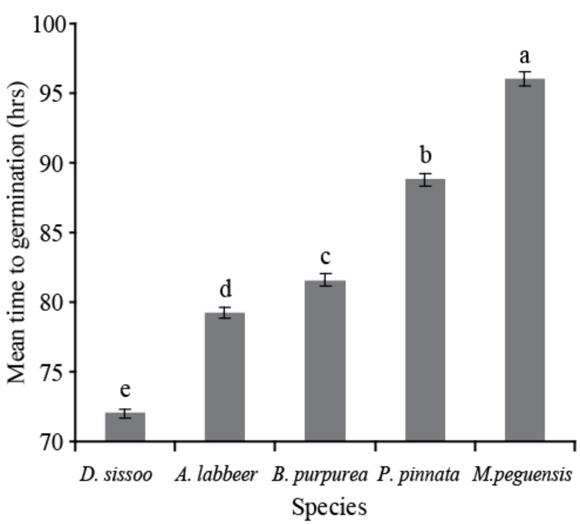

Fig. 4. Impact of domestic wastewater on germination time

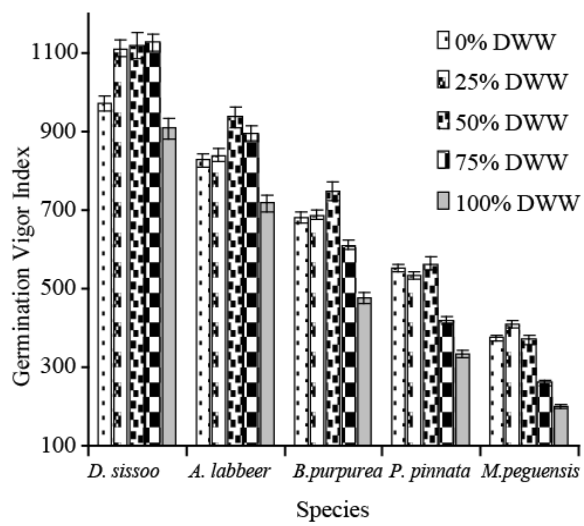

Fig. 7. Effect of domestic wastewater on vigor index

Table 2. Relationship between germination % and domestic water concentration.

	Concentration of domestic wastewater			
	25%	**50%**	**75%**	**100%**
D. sissoo	97.6±1.95 a	95.2±2.86 a	88.8 ±2.58 a	70.2±2.37 a
A. labbeck	94.9±2.85 b	90.8±2.54 b	81.3±1.63 b	69.1±2.15 a
B. purpurea	92.2±3.04 c	82.3±2.63 c	68.4±2.05 c	55.5±1.17 b
P. pinnata	84.8±3.51 d	74.2±1.34 d	55.5±1.83 d	47.7±1.05 c
M. peguensis	83.4±2.34 d	69.8±2.16 e	52.8±1.48 e	41.6±1.50 d

Treatment means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test

Table 3. Impact of DWW on seedling fresh weight (gm).

	Concentration of domestic wastewater				
	0%	**25%**	**25%**	**25%**	**25%**
D. sissoo	0.496±0.0099 a	0.55±0.0110 a	0.592±0.0184 a	0.62±0.0167 a	0.58±0.0110 a
A. labbeer	0.414±.0091 b	0.43±0.0129 b	0.49±0.0127 b	0.52±0.0156 b	0.488±0.0102 b
B. purpurea	0.241±0.0072 c	0.352±0.0123 c	0.401±0.0120 c	0.4±0.0100 c	0.35±0.0095 c
P. pinnata	0.203±0.0043 d	0.269±0.0062 d	0.323±0.0081 d	0.32±0.0058 d	0.296±0.0080 d
M. peguensis	0.173±0.0035 e	0.215±0.0039 e	0.214±0.0043 e	0.208±0.0052 e	0.2±0.0056 e

Treatment means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test.

Conclusion

This study is successful in solving local problem of wastewater pollution with indigenous and eco-system based or natural solution. Instead of artificial and man-made water purification system we must opt nature based systems as they are more reliable, eco-friendly and sustainable. It also give multiple benefits like increase in forest cover, increase in urban green spaces, reduction in air pollution, serves are heat sink.

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