Original Research Article

Determining the growing potential of *Jatropha curcas* and *Pongamia pinnata* under various water regimes

ABSTRACT

Pakistan is the among the most populated countries of the world with predominantly arid climate facing different challenges like food insecurity, energy crises, poor health system, poverty, small forest area cover, and significant effects of global warming and climate change. However, there is still a large areawith scanty vegetation. Research on devising cultivation techniques for growing more economically profitable plants in these areas will not only improve the ecological environment but also the people's living standards.*Jatropha curcas* (JC) and *Pongamiapinnata*(PP) are two economically important species (bioenergy plants) with potential to grow on dry tropical arid land.Therefore, this study was carried out to check the hypothesis "JC and PP are the suitable species to grow in the dry tropical arid land of Pakistan due to their drought tolerance ability".The experiment was carried out at the nursery of Bahauddin Zakariya University, Multan.One year old seedlings of both plants were used in the experiment.The design involves two plants of the same species in each row, four treatments, and three replications. The levels of drought were T_1 (100% water), T_2 (75% water), T_3 (50% water), and T_4 (25% water).A generalized linear model was applied to check the variation among species and within the treatments of the same species. There is a significant difference ($p \geq 0.05$) in growth among species and within the treatments of the same species. JC showed better growth as compared to PP in water stress conditions but PP grow as well. The growth parameters of JC showed a positive response in T_2 (75% water) and T_3 (50% water)drought levels while the growth parameters of PP showed a positive response in treatments T_1 (100% water) and T_2 (75% water)as compared to other drought levels. In the case of the fresh and dry weight of JC and PP significant difference ($p \geq 0.05$) was also found among species and within the treatments. Both JC and PP are recommended to grow in the dry tropical regions of Pakistan but JC is declared as the prime specie as compared to PP.

Keywords: Dry tropical arid region, Suitable specie, water stress, *Jatropha curcas*, *Pongamiapinnata*, Pakistan

1. INTRODUCTION

A world population over 1.6 billion rely directly on forests for subsistence and livelihood including 13 million individuals working in the official sector of forest operations [1]. The interdependence of social and economic functions is acknowledged, and the 2030 agenda objectives and SDGs rely on forest policies for equitable and sustainable growth (FAO 2018). Forested watersheds provide 75% of the world's available freshwater [2]. As the population reaches 9 billion people by 2050, forests can support and fulfill the expanding demands for food, fiber, biofuel, shelter, and other non-wood forest products (NWFP's), and they are one of the most poorly managed resources in many countries [3]. Increasing the number of trees planted in unused areas and improving natural resources might provide economic security as well as other environmental and social advantages. The development of green value chains and ecosystem services offered by forests may aid in the realization of circular economies, which are often referred to as green economies.

According to the FAO [4] to meet global demand and reach the objective of "zero hunger" by 2030, about 50% more food, animal feed, and biofuel must be produced by 2050 than they were in 2012. The burden on forests will rise due to this anticipated increase.Climate change caused by deforestation has a larger positive carbon feedback than fossil fuel emissions, which adds to a loss in tropical forest carbon storage [5].

Forest restoration can assist in the recovery of the ecosystem services offered by these ecosystems in the form of services like water filtration, replenishing the groundwater table, improving pollination, reducing soil erosion, etc., which are important in promoting health and lowering social inequalities. The rehabilitation initiatives may contribute to the development of green jobs, which would boost the economy. It should improve ecological integrity to restore the site's biological and ecological features to their native condition. However, it must be ensured that it is sustainable and scalable. A successful forest restoration program should prioritize many advantages, as well as their quality and quantity. This requires considering the proper approach, which includes the proper location, species, and stakeholders [6].

Pakistan has a population of about 220 million people and is growing at a pace of 2.67% per year. According to Pakistan's 2010 economic study, it would be the fourth most populated country in 2050 [7]. The country is facing different challenges such as food insecurity, energy demand, poor health system, poverty, fewer jobs availability, small forest area cover, and significant effects of global warming and climate change. However, there is still a large amount of land in the dry tropical regions of the country that is not being used. Research on economic plants in these areas will greatly improve the ecological environment and people's living standards in the entire tropical arid region of Pakistan especially Balochistan, Punjab and Sindh provinces. Although the tropical dry area of Pakistan may appear to have a disadvantage due to its high temperatures and intense sunlight these conditions are beneficial for the growth of certain tree species that provide various NWFPs.The cultivation of suitable tree species could be a solution to food insecurity, fulfill the energy demand, improvethe health sector, poverty reduction,and income for the residents of the tropical arid region in Pakistan also be helpful in the mitigation of global warming and climate change.

Jatropha curcas (L) (Physic nut) (JC) is a small tree or tall shrub up to 5-7 m tall with an average life span of 50 years and belongs to the Euphorbiaceae family [8, 9, 10, 11]. It may be found across the tropics and subtropics [12, 13, 14, 15], and it has adapted to a wide variety of precipitation and soil conditions [16]. Aside from biofuel, several plant components offer medicinal properties.After the oil is extracted from its seeds, a variety of significant byproducts are created that are suitable for commercial use [17.18.19.20]. Jatropha cultivation is essential since mature plants absorb 18 lbs of carbon dioxide (CO2) annually [21]. Twenty tonnes of CO2 are produced annually through the growth of plants and trees on one hectare of land [22]. JC plant needs fewer nutrients and management without interfering with an existing food crop [23, 24, 25]. The JC plant typically matures after 6 years, and seed production continues for the next 30–40 years [26]. JC is a hardy tree with excellent protein-rich oil and low water requirements [27]. It may be grown to restore arid and disturbed soils [28].

Pongamiapinnata (L) Pierre (Pongamia) (PP) is a tree that has traditionally been utilized as a source of several NWFPs such as traditional remedies, green manure, animal feed, biofuel, bio-pesticide, and fish poison in India and adjacent countries [29]. Pongamia has lately sparked interest due to its potential as a biofuel source, as its seeds contain around 40% oil. It can also withstand a wide range of climatic and edaphic conditions, allowing it to be grown in dry tropical locations [30] .Its symbiotic capacity to fix nitrogen is a key benefit [31]. This significantly improves Pongamia attractiveness as a biofuel source since it may lessen the demand for synthetic nitrogen fertilizer [32].

JCand PP have been reported to have various desired characteristics such as heat tolerance, fastgrowth, easy cultivation, and drought tolerance, and can be grown on dry tropical arid land.In dry tropical arid conditions drought tolerance is the main characteristic which should be present in the suitable species. Therefore this study was carried with the objective to explore suitability of JCand PPas suitable species to grow under different moisture regimes under arid conditions.

2. MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the nursery of Bahauddin Zakariya University, Multan. Multan is in a dry tropical environment. During the summer, the temperature in this location remains between 35-45 °C and the average temperature is 25.6 °C while the average precipitation is 175mm recorded annually.

Plant material

One year old seedlings of JCandPPplants with uniform similarity in height with in species were transplanted in earthen pots.

Soil analysis

The soil wasanalysed in lab before filling the earthen pots. The result of soil analysis showed electrical conductivity (EC) of 3.10dSm^{-1}, pH of 7.5, an organic matter of 0.36%, available phosphorus of 4.21 Ppm, available potassium of 111 Ppm, a saturation of 23 percent. The soil sample has a loamy texture.

Design and treatment plan

Randomized Complete Block Design (RCBD) was used as an experimental design. The design involves multi factors (drought and species). The levels of drought were T_1 (100% water), T_2 (75% water), T_3 (50% water), and T_4 (25% water). 12 replications were made for each treatment.

Measuring soil field capacity

The quantity of water content that may be held in the soil after surplus water has been drained away and the pace of downward movement has been significantly slowed is referred to as field capacity. In previous soils with a homogeneous structure and texture, this normally happens within two to three days of rain or irrigation. The field capacity was determined in the laboratory through the volumetric method [33].

Experimental procedure

We have taken a 35g soilsample by weighing on a weighing balance.We placed a small piece of cotton at the beginning of the neck of the funnel and placed the soil sample intothe funnel. We saturate the soil with the prescribed amount of distilled water (20ml). Then set it aside for 48 hours. The amount of water drained from the measuring cylinder's bottom was calculated to be 2.5ml. We have noted the amount of soil water particles in the measuring cylinder. Weigh the sample after 48 hours before placing it in the oven. Then place it in the oven to dry. Weigh the soil sample again after it has dried. The field capacity was calculated by subtracting the measured amount of water (20ml) from the amount of drained water at the bottom of the measuring cylinder (2.5ml). The value of field capacity was found 17.5ml. The required amount of water was calculated by using the formula (Veihmeyer, 1949). The required amount of water for T1, T2, T3 and T4 were calculated at 3.21L, 2.4L, 1.6L and 0.80L respectively.

Measurement variables

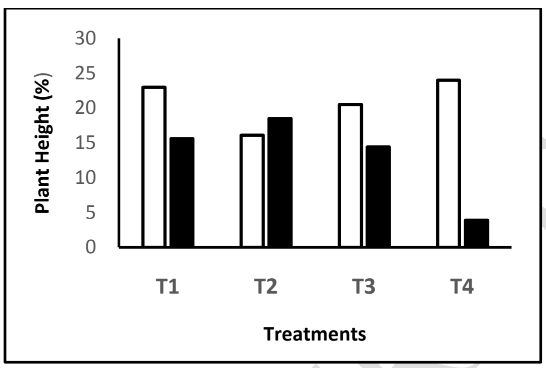
Through the use of a measuring tape, the height of JC and PP sample plants was determined from collar to tip. At the collar region, the diameter was measured using a Vernier caliper. Through a leaf area meter, the leaf area was measured (Kaur, 2014). A chlorophyll meter was used to measure the amount of chlorophyll (Liu et al., 2020). Manual counting was done to determine the number of branches and leaves.Data were collected at the end of each monthfrom all plants of both species. Plants were uprootedat the end of the experiment. The roots and branches of each plant were separated and weighed. Each plant's roots and branches were dried in an oven for 48 hours.

Statistical Analysis

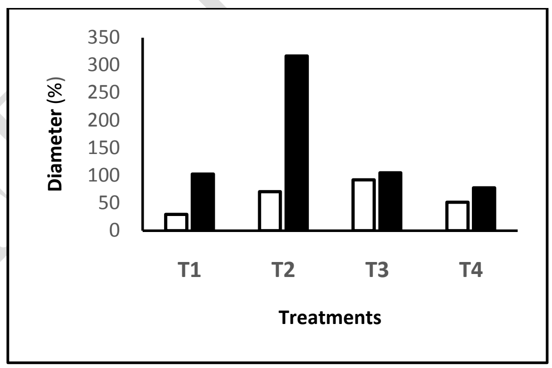
Statistical design in RCBD was applied. Further, descriptive statistical analysis was also used to organize and explain the collected data. A generalized linear model (GLM): univariate analysis of variance was applied followed by [34] Moreno et al. (2022) to check the variation among species and within the treatments using IBM Statistical Package (SPSS 20).

3. RESULTS

As shown in Figure1a-f, results revealed that, concerning plant height, maximum percent increase in JC was observed in T1 (23%) followed by T3 (20.5%) whereas in PP T2 showed increased plant height percent of 18.5 folowed by T1 (15.6%). T3 resulted in higher percent increase in diameter as 92.3% in JC and plant height as 18.5%whereaasin PP T2 attained highest percent increase in diameter aas 317%. SimialrlyRegaring chlorophyll contents T3 remained instrumental in increased percentage from T3 treatment both in JC and PP. Percent increase in leaf area was observed higher in T2 both in JC (107%) and PP (89.6%). Number of leaves percentage found higher in JC in T2 (103%) and T1 (288). in PP whereas *Jatropha curcas*, plants grown in treatment T4 attained the maximum height percentage increment i.e. 24 followed by plants grown in treatment T1 attained height percentage increment i.e. 23% in comparison with treatments T2 and T3, where percentage increment of height remained 16.1% and 20.5% while in *Pongamia pinnata*, after 60 days, plants grown in treatment T2 attained the highest height percentage increment i.e.18.5% followed by plants grown in treatment T1 attains height percentage increment i.e. 15.6% in comparison with treatment T3 where the percentage increment remained i.e. 14.4%. There occurred a reduction in percentage increment of height i.e. 3.9% when treatment T4 was applied.



a)



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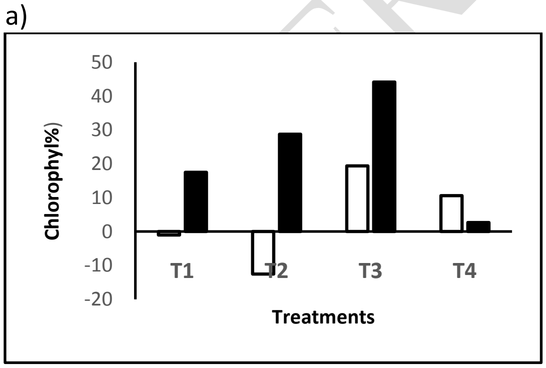

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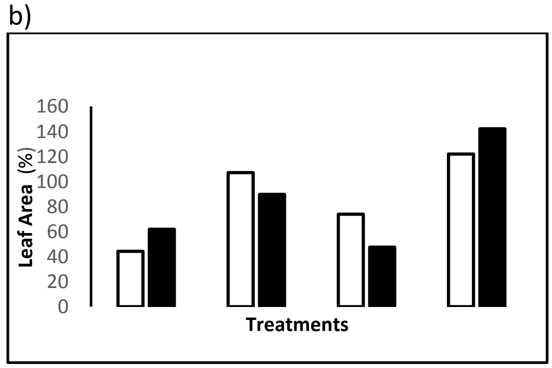

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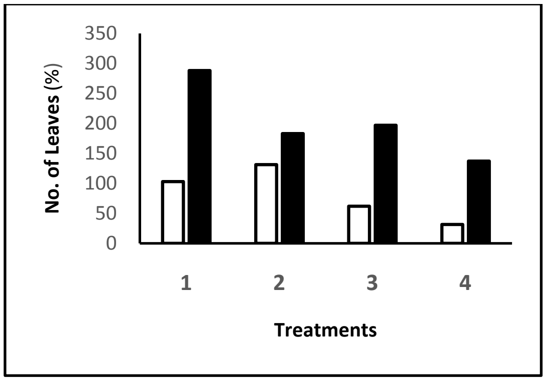

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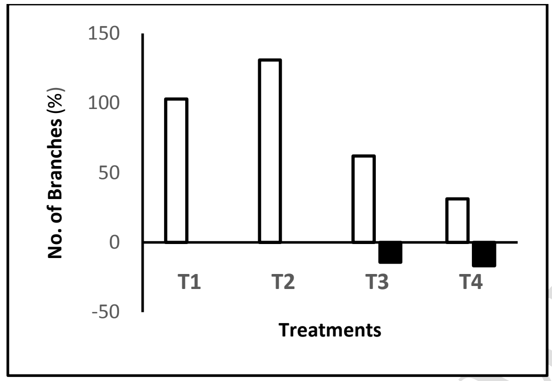

f)

Figure 1. Different parameters (a-f) of Jatropha curcuss (JC) and Pongamia pinnata (PP) as affeceted by different water regimes treatment

3.3.Factual data of generalized linear model

As shown in Table 1, there is a significant difference ($p \geq 0.05$) in growth parameters among species and within the treatments. JC showed better growth as compared to PP in water stress conditions but PP grow as well. The growth parameters of JC showed a positive response in Treatments T_2 (75% water) and T_3 (50% water) drought levels while the growth parameters of PP showed a positive response in treatments T_1 (100% water) and T_2 (75% water) as compared to other drought levels.

Table 1. Relationship of different growth parameters among species and within treatments

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Fresh weight	89365.958a	7	12766.57	5.422774	0.002	0.703
	Dry weight	11545.167b	7	1649.31	5.589301	0.002	0.709
Plant species	Fresh weight	12834.38	1	12834.38	5.451577	0.03	0.254
	Dry weight	1734	1	1734	5.876306	0.03	0.269
treatments	Fresh weight	65285.46	3	21761.82	9.243631	0.0008	0.63
	Dry weight	7763.5	3	2587.833	8.769839	0.001	0.621
Error	Fresh weight	37668	16	2354.25			
	Dry weight	4721.333	16	295.0833			

a. R Squared = .703 (Adjusted R Squared = .574)

b. R Squared = .710 (Adjusted R Squared = .583)

Fresh weight of JC and PP

In case of fresh weight of JC and PP, it is observed that there is a significant difference ($p \geq 0.05$) between both species and also among the treatments within specie as shown in d Table 2. JC showed higher fresh weight as compared to PP in all four treatments. The treatments T_1 and T_4 plants of JC showed a higher value of fresh weight as compared to T_2 and T_3 while the treatments T_1, T_2 and T_3 showed a higher value as compared to T4 in the case of PP.

The dry weight of JC and PP

In the case of the dry weight of JC and PP, it is observed that there is also a significant difference ($p \geq 0.05$) between both species and also among the treatments within specie as shown in Table 2. PP showed higher dry weight as compared to JC in all four treatments. The treatments T_1, T_2 and T_3 plants of PP showed a higher value of dry weight as compared to T_4 plants while the treatments T_1, T_2, and T_4 showed a higher value as compared to T_3 in the case of JC.

Table 2. Relationship between species (PP and JC) and among the treatments of the same species

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Among Plant species	Fresh weight	12834.38	1	12834.38	5.45	0.03	0.254134
	Dry weight	1734	1	1734	5.88	0.02	0.268615
Among treatments	Fresh weight	65285.46	3	21761.82	9.24	0.00	0.634126
	Dry weight	7763.5	3	2587.83	8.77	0.00	0.621834
Error	Fresh weight	37668	16	2354.25			
	Dry weight	4721.333	16	295.08			
a. R Squared = .703							
b. R Squared = .710							

4. DISCUSSION

Pakistan is facing different challenges such as food insecurity, energy demand, poor health system, poverty, fewer jobs availability, small forest area cover, and severe impacts of global warming and climate change. However, there is still a large amount of land in the dry tropical regions of the country that is not being used. Research on economic plants in these areas will greatly improve the ecological environment and people's living standards in the entire tropical arid region of Pakistan especially Balochistan, Punjab, and Sindh provinces. The cultivation of suitable tree species could be a solution to food insecurity, fulfill the energy demand, improvethehealth sector, poverty reduction and income for the residents of the tropical arid region in Pakistan,and also help in the mitigation of global warming and climate change.

JC and PP are the two important tree species grown throughout the world especially in dry tropical arid regions [12,13, 14, 15] to obtain NWFP's in the form of Biofuel, medicinal products, and commercial cosmetic products.Bothcanadaptto a wide range of precipitation and soil conditions (Francis et al., 2005). Both are hardy tree species with great oil that contains protein and little water demand [27]. It can be planted to recover degraded and desert soils [28]. Therefore this study was carried out to check the hypothesis "JC and PP are the suitable species to grow in the dry tropical arid land of Pakistan due to their drought tolerance ability".

It is concluded that both species can grow in water stress conditions and are suitable for growing in the dry tropical arid land. A similar finding is also found in other research studies [35,36,37]. JC has grown quickly, thrives on poor-quality soils, and requires less water [38, 39].It is also noted that there is a significant difference ($p \geq 0.05$) in growth parameters among species and within the treatments. Water scarcity is a multifaceted pressure that affects plants at several levels of association [40]. JC showed better growth as compared to PP in water stress conditions but PP grow as well. The growth parameters of JC showed a positive response in Treatments T_2 (75% water) and T_3(50% water) drought levels while the growthparameters of PP showed a positive response in treatments T_1(100% water) and T_2(75% water) as compared to other drought levels. Water stress reduces growth and leaf formation; however, JC plants continue to grow even when watered with 30% water stress [41]. PP seedlings are resistant to drought stress without urea treatment and perform better when 50% water is available [42]. Water stress did not affect the chlorophyll contents of JC [43].

In the case of the fresh and dry weight of JC and PP significant difference ($p \geq 0.05$) was also found among species and within the treatments. The fresh weight of JC is significantly higher than the fresh weight of JC while the dry weight of PP is higher as compared to the dry weight of JC. The fresh and dry weight of JC showed a higher value in Treatments T_1, T_2, and T_4 drought levels while the fresh and dry weight of PP showed a higher value in treatments T_1, $T_2$and T_3as compared to other drought levels.[43] Sapeta et al. (2013) identified two JC successions under water stress conditions and determined that plants in both successions retain total biomass when limited water is available.

5. CONCLUSIONS

This study was carried out to check the hypothesis "JC and PP are the suitable species to grow in the dry tropical arid land of Pakistan due to their drought tolerance ability". Different growth parameters were determined and analyzed by using a generalized linear model. There is a significant difference ($p \geq 0.05$) in growth parameters among species and within the treatments of the same species. JC showed better growth as compared to PP in water stress conditions but PP grow as well. The growth parameters of JC showed positive relation in Treatments T_2 (75% water) and T_3(50% water) drought levels while the growth parameters of PP showed a positive response in treatments T_1 (100% water) and T_2 (75% water) as compared to other drought levels. In the case of the fresh and dry weight of JC and PP significant difference ($p \geq 0.05$) was also found among species and within the treatments. Both JC and PP are recommended to grow in the dry tropical regions of Pakistan but JC is declared as the prime specie as compared to PP. It is also recommended that research studies should be conducted on other different important aspects of both JC and PP varieties found in Pakistan.

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