RESEARCH ARTICLE

Leucaena leucocephala and *Prosopis juliflora*: A Comparative Study of their Seedlings with Better Drought Adapted Features During Rainfall Pattern Shifting

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Abstract

Leucaena leucocephala (Lam.) de wit, and *Prosopis juliflora* (Sw) DC, were introduced across the country due to their wide importance and they are posing threat to native trees and ecosystem because of their wild and invasive nature. Therefore, study of their invasive features becomes important during the current rainfall shift as India is witnessing a decrease in average rainfall and rainy events but an increase in downpour events. Our study throws light upon these plants' invasiveness and rainfall-adapted characteristics. We performed the study in the Botanical Garden, Banaras Hindu University, Uttar Pradesh, India. The study included two experiments (1) Seed germination under different treatments- 48% H^2SO^4 for 40 minutes (T1), Water at 100°C for 10 minutes (T2), one-day water-soaked seed (T3); (2) Seedlings survival percentage and growth-indices under different watering conditions i.e., 50 mL water per seedling every day (W1), 50 mL water once in four days (W2), 50 mL water once in ten days (W3). Result of this study revealed that *P. juliflora* exhibited better germination speed and percentage in all three treatments (T1, T2, T3) in comparison to the *L. leucocephala*, while under T1 treatment, both exhibited best germination. On the 60th day of experiment maximum survival percentage was recorded under W2 water condition but maximum root length was observed under W3 treatment for *L. leucocephala* and *P. juliflora* while maximum stem height was found under W1 and W2 treatments for *L. leucocephala* and *P. juliflora* respectively. These finding would conclude that *P. juliflora* is more potential invader in comparison to *L. leucocephala* as this gave the best result under the drought stress condition W2 and W3 for all the parameters and study performed. Study also highlight the need of mitigation measures to curb the unlimited growth of *P. juliflora* under the present scenario of rainfall shift favouring the invasion of drought tolerating plants.

Keywords: Invasive plants, Water conditions, Seeds gGermination, Growth indices, Survival percentage, Adaptation.

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Introduction

Invasive plant species are already known to transform the ecosystems processes and properties due to their high survival and wide range of environmental adaptability (Vitousek *et al.,* 1997; Afreen *et al*., 2018). Invaders could alter ecosystem processes by contributing to nitrogen enriched litter with higher rate in decomposition, increasing soil nutrients, along with change in soil pH (Ehrenfeld, 2010). Such modifications exhibit observable impacts on the soil's nutritional status, which in turn has an impact on plant development and community structure (Abdullahi and Elkiran, 2017). Despite international attempts to address the issue, the number of invasive alien species is increasing globally and does not appear to be slowing down. Although every country in the world have so many invasive plants species, but Indian is receiving invasion from certain countries only. Tropical America contributes maximum number of invasive species to India followed by Tropical Africa which have 74% and 11% share of total invasion to India respectively (Reddy et al., 2008). Although invasive species represent very less of the total Indian flora but invasion by *Leucaena leucocephala* (Lam.) de wit, (De wit, 1961) and *Prosopis juliflora* (Sw.) DC, due to their economic value as well as invasive property, have become a topic of discussion and a matter of concern as they have invaded over a large area in India (Witt, 2010).

L. leucocephala and *P. Juliflora* are new world plants, belonging to legume family (Fabaceae), subfamily Mimosoideae (Asfaw and Thulin, 1989; Hughes, 1998a). During period of 1970s, *L. leucocephala* was recognised as a miracle tree for its diverse uses as it provides forage, wood, organic manure, shade. It also helps in controlling the soil erosion along with soil fertility (Bogdan, 1978). Despite of being rich in nutrients and economical nature, *L. leucocephala,* now identified as weed, also contains some toxic substances such as mimosine, protocatechuic acid and gallic acid thus its utilisation becomes limited (Shelton and Brewbaker, 1994; Hughes, 1998b; Cronk and Fuller, 2014). Its character of weediness is creating problem in many agricultural sites and forest nurseries (Verma *et al.*, 2005). *P. juliflora,* having the origin from the North, South, and Central America (Pasiecznik *et al*., 2001), was introduced across the world, due to its economic value as a fuel, and fodder. It has the potential to develop deep root systems which could be as long as 20–25 m (Pasiecznik *et al*., 2001).

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These plants *are also* provided with enough biological characters such as continuous fruiting and flowering, rich in seed production, Auto-fertile, a stony seed coat, the capacity to create a seed bank, and the capacity to sprout after being burned or cut (Shiferaw *et al*., 2004). These characters help in its faster invasion to new areas and thus making it difficult to control. Considering the above characters, Space *et al.* (2000) listed *L. leucocephala* plant as an invasive tree. *L. leucocephala* and *P. juliflora*, a strong invader, can out compete the native vegetation and led to loss of native grassland and pastures as it transforms grasslands into thorny lands. (Weber, 2017).

According to a study on *P. juliflora*, this plant reduces the light intensity and moisture under its canopy (Te Beest *et al*., 2015). This reduction in light and moisture modify the plant composition and decrease the richness and native plant diversity, which leads to the eradication of selected species, most notably grasses (Davies, 2011). Allelo-chemicals released by invasive plants, such as *P. juliflora*, have an impact on soil shift caused by microorganisms, shoot and root growth, and seed germination (Coder, 1999; Getachew *et al*., 2012). Invasive plants also disturb the native animal community with the changes in the growth, survival, reproduction and behaviour of native organisms (Coder, 1999). Many native plant communities and ecosystems are being altered by invasive plant species, which is causing deterioration and biodiversity loss (Gurevitch and Padilla, 2004; Kumar and Verma, 2017). Most conservation biologists concur that alien species incursions are a major factor in the extinction and loss of recent species (Wilcove *et al.,* 1998; Fritts and Rodda, 1998).

L. leucocephala and *P. juliflora,* which were introduced as economic plants, are now disturbing the ecosystem, which would become more serious in times of rainfall shift. Rainfall pattern of the tropical country like India is changing every year (Chadwick *et al*., 2016). India is witnessing decrease in average rainfall and rainy events but increase in downpour events which is going to get more extremity in coming future because of the climate change (Malhi *et al*., 2008; Feng *et al*., 2013). Due to the fact that rainfall shift will affect soil moisture regime, soil carbon balance, soil CO_2 flux, nutrient cycling, and soil properties (Gatti *et al*., 2014; Doughty *et al*., 2015), the investigation of certain invasive characteristics of these two plants become important (Rind *et al*., 1989) to make a guess about more potential invader between these two plants for coming future under shifted rainfall regime. This would help in proper management of plants. Therefore, a thorough study of certain invasive characters like Germination rate, growth indices and germination speed of these plants under different treatments (manipulative irrigation conditions) becomes important since tropical (Indian) systems are water-limited with concentrated seasonal rainfall and extended dry periods. Two experiments were carried out to achieve the previously mentioned objectives, with the goal of comparing invasion potential of the two plants, which is crucial for comprehending how plants react physiologically to changes in rainfall. Only by understanding the invasion potential of these two plants we will be able to understand the growth strategy of an invasive plant community in a native ecosystem, which will help us to understand the native ecosystem and provide ideas for efficiently preserving, promoting, and managing native plant communities.

Materials and Methods

Seeds of *L. leucocephala* and *P. juliflora* were purchased from a local Nursery (Ganesh bagh Nursery), Varanasi, Uttar Pradesh. Seed germination was tested by putting the seeds in a beaker with water. Sunken seeds were healthy and sampled for further germination and study of invasive characters and floating seeds were discarded.

Study Site

This study was conducted in Botanical Garden of Banaras Hindu University (25°16′ N and 82°59′ E), Varanasi, Uttar Pradesh, India. Experiment was done during winter season (25 November 2020 to 5 March 2021) by transferring the soil from Botanical Garden into disposable cups.

Experimental Design

Three experiments were performed to conclude the invasive nature of *L. leucocephala* and *P. juliflora*. All the two experiments were conducted using completely randomised design (CRD) with three treatments for each experiment, three replicates for each treatment (i.e. 2 experiments x 3 treatments x 3 replicates = 18). These experiments were as follow:

- Study of seeds germination (via seed dormancy breaking) of *L. leucocephala* and *P. juliflora* under 48% H_2SO_4 treatment for 40 min. (T1), hot water treatment at 100 °C for 10 min. (T2), and 1-day water-soaked seed (T3). Seeds under the sulphuric acid treatment were gently stirred periodically. Following a 10-minute rinse under running water, the seeds were left to dry in the shade. Seeds under the hot water treatment were kept in boiling water at 100°C for 10 min after which it was allowed to cool to the temperature of room.
- Study of seedlings growth indices and survival percentage (from day 6 germinated seeds transferred into cup till day 60 stable seedlings stage) of *L. leucocephala* and *P. juliflora* under different watering conditions i.e. 50 mL watering in each cup every day (W1), 50 mL watering once in a four Days (W2) and 50 mL watering once in a 10 days (W3).

Environment Variables

A study for environmental variables was also conducted using the data provided by Indian Meteorological Department, Institute of Agricultural Science, Banaras Hindu University. All the two experiments were performed from 25 November 2020 to 14 February 2021 (approximately 80 days' experiment). To make the study of environmental variable more accurate this time period was divided into 4 slots 20 days each i.e. 25 Nov to 14 Dec (S1), 15 Dec. to 4 Jan (S2), 5 Jan to 24 Jan (S3) and 25 Jan to 15 Feb (S4). The mean 20 days' maximum temperature ranged from 21.26°C (during S3) to 26.63°C (during S4). 20 days' mean for sunshine hours' ranges from 2.11 hr (S3) to 4.54 hr (S2). Relative humidity was found maximum in morning 9AM, minimum in evening 6PM which was 93.75% (S4) and 53.6% (S4). Summary of environmental variables during the experiments is given in Table 1.

Soil Characteristics

Soil used for study was pale brown in colour and loamy in texture. BHU campus soil is defined as inceptisol (Jat *et al*.,2013; Parewa *et al*., 2014). Soil was characterised before the experiment and it was found to be slightly basic (pH = 7.2), with bulk density and Water Holding Capacity of 1.821 g/cm^3 and 41.66%, respectively.

Germination Study

A total of 500 seeds for each treatment in triplicates (after treatments i.e. T1, T2, T3) were wrapped in moistened muslin cloth and placed within the different petriplates (for each replicate of each treatment) for 24 hrs to check the further loss of water. After that, all the seeds were transferred to the different plastic trays (for each replicate of each treatment) filled with sand and kept in open environment for germination study. Then seed germination was recorded every second day for one week until germination stopped. Germination study involved the following parameters- 1) Germination Percentage (GP) = total number of germinated seeds/total seeds x 100. 2) Germination Speed (GS) = n1/d1 + n2/d2 + n3/d3 + ... n∞/d∞ (Czabator, 1962), where, n = number of germinated seeds and d = number of days.

Seedlings Survival Percentage and Growth Indices Study

For Seedlings Survival Percentage and Growth Indices study, 100 seedlings each of *L. leucocephala* and *P. juliflora* (7 days old) were transferred into the disposable cups (200mL) under three different water condition treatments (W1, W2, W3) in triplicates. These seedlings were watered according to the designed watering conditions i.e. 50mL watering in each cup every day (W1), 50 mL watering once in a four Days (W2) and 50 mL watering once in a 10 days (W3). Seedling Survival Percentage (SP) and Growth Indices for both *L. leucocephala* and *P. juliflora* were recorded on every 20th day during experiment for 2 months. Growth indices included stem height (SH) and root length (RL).

Seedling survival percentage was calculated by using the following formula:

Survival percentage = St / St-1 X 100

Where, St = number of healthy seedlings at time t and St-1 = number of healthy seedlings at time t-1

Table1: Environmental variables and their average value in respective phase S1, S2, S3 and S4 of experiment.

Environmental Parameters	*During seed Germination Study*	*During Seedling Growth Study*		
	25Nov14Dec (S1)	*15Dec-04Jan (S2)*	*5Jan-24Jan (S3)*	*25Jan-14Feb (S4)*
Max Temp (°C)	26.63 ± 0.36	21.55 ± 0.44	21.26 ± 0.81	22.56 ± 1.04
RH morning (%)	93.45 ± 0.77	91.95 ± 1.10	93.50 ± 0.79	93.75 ± 0.89
RH evening (%)	58.25 ± 1.88	55.70 ± 2.76	62.10 ± 2.09	53.60 ± 3.62
Sunshine hours	4.31 ± 0.67	4.54 ± 0.70	2.11 ± 0.59	4.52 ± 0.81

(Source: Indian Meteorological Department, I. A. Sc. Banaras Hindu University)

Statistical Analysis

Data for different parameters were subjected to Multivariate Analysis of Variance (MANOVA) to determine the effect of treatments (Germination treatments, Water condition treatments and Days treatments) on seed germination, growth indices and death rate of both the plant species. The Post Hoc (Tukey) test was used to compare the means. All these statistical analyses were performed using SPSS package (SPSS Inc., *Ver.* 16).

Results

Seed Germination Percentage and Germination Speed

Seed germination percentage varied significantly with germination treatments, days and plant species ($P < 0.05$). Maximum germination percentage was reported in H_2SO_4 treatment (T1) for both *L. leucocephala* (37.26 ± 1.84%) and *P. juliflora* (87.4 ± 1.42%) on 6th day but germination percentage of *P. juliflora* was 134.5% higher than that of *L. leucocephala* (Fig.1). Minimum germination percentage for *L. leucocephala* (14.73 ± 0.768%) and *P. juliflora* (53.4 ± 2.03%) were reported in water soaking treatment (T3) and hot water treatment (T2) respectively (Fig.1). With respect to day, T1 and T2 treatments exhibited best germination percentage till 4th day of germination (for both the plants), but under T3 treatment, best germination percentage was recorded on 6th day of germination. On the 4th day *L. leucocephala* gave 34.00 ± 2.35% and 20.07 ± 0.63% germination under H_2SO_4 treatment (T1) and hot water treatment (T2) respectively, which was 8.7% and 5.3% less in comparison to 6th day germination percentage respectively (Fig.1). On the 4th day, *P. juliflora* recorded 85.60 ± 1.56% and 51.26 ± 2.48% germination percentage under H_2SO_4 treatment (T1) and hot water treatment (T2), which was 2.05% and 3.99% less when compared to 6th day germination percentage under the same treatments i.e. T1 and T2 respectively (Fig.1).

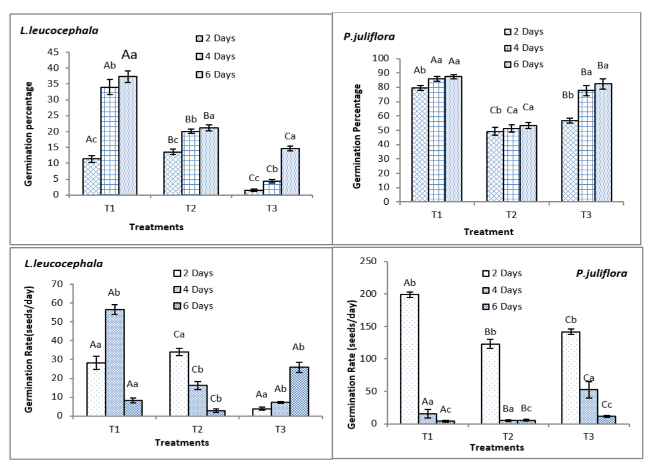

Fig.1: Germination Percentage and Germination speed for *L. leucocephala* and *P. juliflora* among different Germination treatments (T1, T2, T3) and different day treatments. Bars affixed with different combination of letters are significantly different from each other ($P < 0.05$). The uppercase letter represents Germination treatments and lowercase letter represents day treatments. Values are ± SE.

The maximum germination speed (seeds/day) for *L. leucocephala* was recorded on 4th day under H_2SO_4 treatment (T1) followed by 2nd day under hot water treatment (T2) and on 6th day for water soaking treatment (T3) which was 56.66 ± 3.40, 34.00 ± 2.02 and 25.83 ± 2.80 seeds/day respectively (Fig.1), while *P. juliflora* exhibited maximum germination speed on 2nd day of experiment for all the treatments (T1, T2 and T3) i.e. 199 ± 4.09, 123.17 ± 6.72, and 141.83 ± 3.94 seeds/day respectively (Fig.1).

Seedlings Survival Percentage

Seedlings survival percentage of both the plant species varied significantly for watering treatments ($P < 0.05$). Survival percentage increased with increase in number of days and maximum survival percentage was found on 60th day of study under all the three watering conditions (W1, W2 and W3) for both the plants (Fig.2). In the case of *L. leucocephala,* maximum survival percentage was found on 60th day under W2 watering conditions i.e. 97.51 ± 0.65% and the minimum survival percentage was found on 20th day under W3 watering condition i.e. 52.00 ± 4.35%. While in the case of *P. juliflora*, maximum survival percentage found was 98.15 ± 0.99% under W2 watering condition on 40th day of the experiment and minimum survival percentage found was 45.33 ± 4.6 under W1 watering condition on 20th day of the experiment (Fig.2).

Growth Indices

Stem height and root length varied significantly for both plant species under different watering conditions ($P < 0.05$). On the 60th day, *L. leucocephala* plants attained maximum stem height (24.42 ± 1.18 cm) and maximum root length (7.74 ± 0.8 cm) under W1 watering condition and W3 watering condition respectively, while in case of *P. juliflora,* both maximum stem height (8.6 ± 0.67 cm) and maximum root length (6.76 ± 0.40 cm) were recorded under W3 watering condition (Table 2). Minimum stem height for *L. leucocephala* (13.64 ± 1.33 cm) and *P. juliflora* (5.92 ± 0.33 cm) were recorded under W3 and W1 watering conditions respectively. Minimum root length for *L. leucocephala* (6.08 ± 0.52 cm) and *P. juliflora* (3.3 ± 0.20 cm) was recorded under W2 and W1 watering conditions respectively (Table 2).

Discussion

Invasive Alien Plants Species (IAPS) are non-native plants that occur outside their adapted natural ranges and dispersal potential along with outcompeting the native species. Invasive aliens plant species have several strategies to tackle the environmental changes i.e. seed dormancy, higher germination speed, drought resistance nature etc. (Shiferaw *et al*., 2004). An experiment on the seed of *L. leucocephala* was performed by Rusdy (2016) in Indonesia in order to explain the germination speed and germination percentage of *L. leucocephala*. Experiment was performed in laboratory under controlled environmental conditions and he found that H_2SO_4 has stimulatory effect on seed germination. Also, he recorded that lowest germination took place in water soaking treatment. Similarly, in our experiment we found that maximum germination percentage was found in the H_2SO_4 treatment (T1) for both the plants, and minimum germination percentage was found in Water soaking treatment/Control(T3) for *L. leucocephala* and in hot water treatment (T2) for *P. juliflora* (Fig.1). The highest stimulatory effect of H_2SO_4 on scarification of the seeds during germination was also reported in many other plants i.e. *Atriplex canescens* (Nosrati *et al*., 2008), *Tamarindus indica* L. (Muhammad and Amusa, 2003). Treating seeds with acid removes waxy layer by chemical decomposition of the components of seed coat (Dachung and Verinumbe, 2006). H_2SO_4 disrupts the seed coat and thus lumens of the macro-sclereids get exposed and allows the imbibition of water which triggers protein synthesis and encourages the germination (Jackson, 1994). Slow germination of *P. juliflora* under hot water treatment (T2) in comparison to water soaking treatment/control (T3) yet needs to be studied.

Leucaena leucocephala achieved its maximum germination percentage on 4th day under H_2SO_4 treatment (T1) but under water soaking treatment (T3) it took 6 days to achieve maximum germination percentage (Fig.1). Germination speed depends on the efficiency of germination treatment given to the seeds.

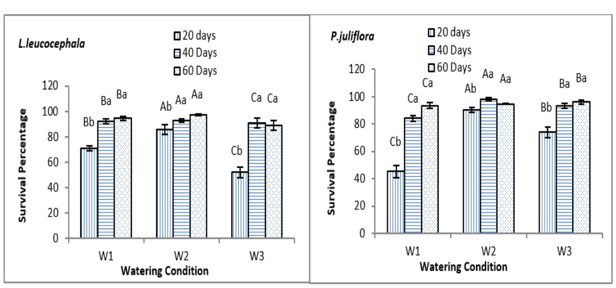

Fig.2: Survival Percentage for *L. leucocephala* and *P. juliflora* among different watering condition treatments (W1, W2, W3) and different day treatments. Bars affixed with different combination of letters are significantly different from each other ($P < 0.05$). The uppercase letter represents watering condition treatments and lowercase letter represents day treatments. Values are ± SE

Table. 2: Effect of different watering conditions on Growth indices (Stem Height SH; Root length RL) of *L. leucocephala* and *P. juliflora* seedlings. Units of both SH and RL is cm.

Watering Conditions	*Plant species*	*Parameters*	*Days*		
			20th day	*40th day*	*60th day*
50 mL water every-day in each plant (W1)	*L. leucocephala*	SH	5.42 ± 0.27	10.04 ± 0.73	24.42 ± 1.18
		RL	3.24 ± 0.20	3.80 ± 0.09	6.16 ± 0.19
	P. juliflora	SH	2.68 ± 1.56	3.84 ± 0.33	5.92 ± 0.33
		RL	1.16 ± 0.09	2.60 ± 0.18	3.30 ± 0.20
50 mL water every 4th day in each plant (W2)	*L. leucocephala*	SH	5.06 ± 0.21	6.98 ± 0.56	15.04 ± 1.43
		RL	3.30 ± 0.11	4.18 ± 0.23	6.08 ± 0.52
	P. juliflora	SH	2.68 ± 0.12	4.24 ± 0.13	7.42 ± 0.43
		RL	1.84 ± 0.06	2.46 ± 0.12	4.08 ± 0.12
50 mL water every 10th day in each plant (W3)	*L. leucocephala*	SH	5.14 ± 0.31	6.20 ± 0.37	13.64 ± 1.33
		RL	3.52 ± 0.26	4.84 ± 0.26	7.74 ± 0.80
	P. juliflora	SH	3.18 ± 0.22	4.94 ± 0.25	8.60 ± 0.67
		RL	1.96 ± 0.24	3.92 ± 0.13	6.76 ± 0.41

Faster rate of germination under T1 was because of higher potential of H_2SO_4 for seed scarification in comparison to water under T3 (control, water soaking) which gave the slowest germination speed (Rusdy, 2016). The hot water technique to break the dormancy is simplest to perform, but the expected results for most legumes are mixed (Nascimento & Oliveira, 1999)

Prosopis juliflora exhibited maximum germination speed on the 2nd day of experiment under all the treatments (Fig.1). The possible reason may be thinner seed coat which allows easy permeability of water, therefore, for *Prosopis juliflora* seeds scarification agent is not needed. Nascimento and Oliveira (1999) have reported that water soaking treatment for 24 hours is the cheapest techniques for seed germination and to break the seed dormancy but it is effective only when water enters into the integument quickly (Nascimento and Oliveira, 1999).This result is consistent to the findings of Duguma *et al*.(1988) i.e. acid scarification (by H_2SO_4) is the most efficient way to improve the coat permeability followed by other scarification methods i.e. hot water treatment and acetone treatment. Plant growth depends on the speed of seed germination (Valente *et al*., 2016) so this may be one reason for increased invasiveness of *P. juliflora* which significantly ($P < 0.05$) exhibited higher and better germination percentage and speed in our experiment (Fig.1).

Survival percentage of *L. leucocephala* and *P. juliflora* exhibited the similar trend. Survival percentage on the 60th day of experiment was significantly higher in comparison to the 20th day of experiment for both the two plants under all the three water conditions (W1, W2, W3) respectively (Fig.2). In comparison to 20th day, higher survival percentage on the 60th day of experiment was observed on account of favourable environmental condition during this time period (Table 1), as Paiva *et al*. (2008) have reported that emergence of seedlings, their survival and plant growth depends on the weather conditions too. The other reason behind the increased survival percentage of plants would be the shift in Water Use Efficiency (WUE). Spreer *et al*. (2009) reported that WUE of *L. leucocephala* changes with change of different water application levels and main effect was significant with change in water levels in respect to WUE. On 20th day, both the plant exhibited maximum survival percentage in W2 water condition followed by W1 and W3 in *L. leucocephala* and by W3 and W1 in *P. juliflora* (Fig.2). One reason for lowest survival percentage of *L. leucocephala* under W3 and *P. juliflora* under W1 water condition (Fig.2) may be due to difference in WUE of different plant types under different water conditions as change in WUE depends on plant species (Kireger and Blake, 1994). Kireger and Blake (1994) also reported that WUE and plant water status does not respond in the same way for all crops, rather it changes with the methods of irrigation and soil characteristics.

In terms of growth indices, *L. leucocephala* exhibited maximum stem height under W1 water condition followed by W2 and W3 but root length under W3 condition was slightly larger than W1 and W2 (Table 2). Reason for this kind of growth indices is the different pattern of biomass distribution under different water conditions. Plants tend to distribute more biomass in stem during favourable (rainy) condition but in roots during drought condition (van Wijk, 2011). Same pattern was observed in case of *P. juliflora* root length, but exhibited a different pattern for stem height. Stem height of *P. juliflora* was found maximum under W3 water condition followed by W2 and W1 water conditions (Table 2). Riaz *et al.* (2013) have already reported that drought pose significant effect on the plant height, root length and leaves number. Many studies have reported significant interaction of different plant types with water treatments (Ashraf and Khan, 1993; Dhanda *et al*., 2004; Asghari *et al*., 2009).

Several other studies have reported that productivity of ecosystem is nonlinearly and asymmetrically related to different precipitation treatments (Luo *et al.,* 2017; Zhang *et al*., 2017; Felton *et al*., 2019). Therefore, experiments with changing precipitation amounts would also show the variation in net primary productivity (NPP) (McCarthy, 2007; Bardgett and Wardle 2010). One general theory to explain the change in allocation pattern of plant biomass under variation in water condition is optimal partitioning theory (Bloom *et al*., 1985; Hui and Jackson, 2006; van Wijk, 2011). According to the optimal partitioning theory, plants would allocate more carbohydrate to the roots experiencing the drought conditions to maximize water uptake, but when extensive supply of water is available to the plants, plants would allocate more carbohydrate to stem or aboveground portion so that it can maximize its growth and water use efficiency for better access to the light resources (Hui and Jackson, 2006; Mokany *et al*., 2006; van Wijk, 2011).This result certainly draws attention towards the need of less amount of water dose for growth due to increase in WUE. Shifera (2021) also performed an experiment on *P. juliflora* to study the seasonal need of water and he found that during winter season *P. juliflora* exhibited decreased uptake of water in comparison to summer season. His result is consistent with our study where we observed a shift in WUE of *P. juliflora* across the seasons.

Conclusion

The study explained about the water adapted and advantageous characters of *Prosopis juliflora* over *Leucaena leucocephala,* as former species envisages the better germination potential in all the three circumstances, there is no need for seed scarification for *P. juliflora*; although the plant gave the similar germination percentage under H_2SO_4 treatment. The study of survival percentage (under different watering conditions) envisages that *P. juliflora* plant is more adapted to manipulative water doses. Certainly, these characters make *P. juliflora* a better adapted plant in the coming time due to expected shift in rainfall patterns. *P. juliflora* along with *L. leucocephala* exhibited maximum root length under W3 treatment (50mL watering once in a 10 days) that makes an increase in the invasiveness character under drought condition. In future these invasive traits of both the plants could cause serious damage to the native plant community. Overall, our work will be valuable in giving a clear understanding of several characteristics that make P. juliflora a potential invader under rainfall fluctuation. Our study also emphasises the urgent need for various alternative management techniques used by individuals in addition to government efforts. Mechanical and chemical control as well as biological control of P. juliflora employing seed-feeding beetles (Algarobius bottimeri and Algarobius prosopis) have been tried, but have shown to be expensive and ineffectual. To further enhance management, it may be possible to investigate additional control mechanisms like the control by utilisation method. Adopting effective management techniques, such as charcoal production, would help to advance not only the rural economy but also the native plant community's protection and promotion.

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Authors' Contributions

Ashish Mishra conceived the experiment. Both Ashish Mishra and Swati Mishra drafted the manuscript. Prakash Rajak performed the statistical analysis. Hema Singh reviewed the manuscript and made the needful corrections as well. All authors have read and approved the manuscript.

Conflict of Interests

None.

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