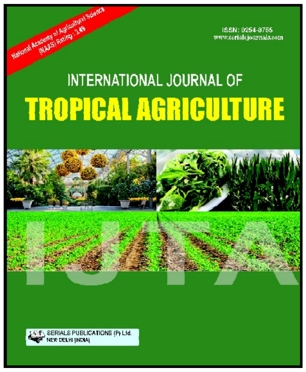

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Comparative Analysis of Plant Functional Traits between Invasive (*Prosopis juliflora*) and Native (*Acacia nilotica*) Species

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Abstract: The interaction of invasive species with native species are often been discussed but sparse data has been available on comparative studies of invasive species with native dominant species. In this study, we compare different plant functional traits of invasive tree *Prosopis juliflora* (Sw.) DC. and dominant native tree *Acacia nilotica* (L.) Willd. ex Delile, because better plant functional traits mean better adaptability and invasiveness of a particular alien species. Both *P. juliflora* and *A. nilotica* are from the same family 'Fabaceae' and occupy the similar habitat. Most of the leaf traits including leaf chlorophyll content and leaf span are significantly higher for *P. juliflora* than *A. nilotica*. *Prosopis juliflora* also performs much better as compared to *A. nilotica* in terms of growth rate parameters such as root length and shoot length. Leaf nutrient content is also better in *P. juliflora*, which means better nutrient uptake capacity as compared to *A. nilotica*. The present study clearly inflicts that *P. juliflora* possesses better functional traits than *A. nilotica*.

Keywords: leaf traits, stem traits, root traits, *Prosopis juliflora*, *Acacia nilotica*

INTRODUCTION

Invasion is a global phenomenon which has accelerated of late, largely because of human interference. Conservation biologists have globally ranked invasive alien/exotic species as the second most important and serious threat to species diversity after habitat loss, whereas Clavero and García-Berthou [1] are of the view that invasive alien species plays a major role in species extinction. Biological invasion occurs when species move from one geographical region to another, establish and proliferate there, and in fact negatively influence the native ecosystems [2]. The invasion of exotic species has profound effects on native ecosystems [3] and along with climate change these invasive species have been found to reduce biodiversity [4], alter nutrient cycling processes [5,6], affect ecosystem functioning [7] and even have evolutionary consequences [8].

In an attempt to identify a set of traits that confer invasive ability to an exotic plant, a variety of plant functional traits (PFTs) has been screened [9,10]. It has now become quite evident that 'successful' plant functional traits (PFT's) are context-, scale- and species-dependent [11,12]. The case study of different invasive species shows an important role of PFT's in imparting invasive potential. Plasticity in growth habitat helps *Ageratum conyzoides* to invade diverse geographical regions [13,14]. Saldana *et al.* [15] discussed how *Blechnum chilense* shows plasticity in ecophysiological traits depending upon environmental conditions that help it to adapt to wide range of habitats. *Acacia dealbata* is another invasive species in Europe and American continents that has been introduced as an ornamental and resource plant, but has now invaded denuded and fire prone areas because of its ability of rapid growth, high tolerance to varying soil qualities, high phenotypic plasticity, and quick vegetative and reproductive growth [16]. Invasive species are often characterized by rapid growth, so they can crowd out native species [17,18]. Other growth related features associated with their competitive success include high photosynthetic rates, low tissue construction costs (CC) and high total leaf area [19], high specific leaf area (SLA) [20].

Prosopis juliflora is an exotic species native to Mexico, and is now found invasive in almost all parts of Indian subcontinent. *Prosopis juliflora* is a thorny tree that attains a height of nearly 20 m, but is known for its highly developed root structure. Roots are found even at the depth of about 50 m [21]. Initially it has been introduced deliberately in semi-arid and salt affected areas with the intention that it is tolerant to extreme conditions of water scarcity [22] and high salinity [23]. However, later on it is found to be an opportunistic plant that can flourish luxuriantly when given the favourable conditions and have the tendency to grow faster. Its ability to form root nodules with different bacterial species ensures constant nutrient supply to the plant [24]. *Prosopis juliflora* is mainly found in arid regions [25]. In addition to that, the plant is highly allelopathic [26-30]. Much is already known about invasiveness of *P. juliflora*, but very fewer studies are available analysing the role of plant functional traits in its invasion.

On the other hand, *A. nilotica* is a native to Indian subcontinent and highly dominant species of arid region and possesses very alike properties as that of *P. juliflora*. The ultimate goal of this study is to compare functional traits between native and exotic con-familial plant genera so as to find out which invasive characteristics enabled *P. juliflora* to displace *A. nilotica* and other native species.

MATERIALS AND METHODS

Leaves of *P. juliflora* and *A. nilotica* were collected from the plantations established in experimental dome conditions of Department of Botany, Panjab University, Chandigarh, India. Leaf chlorophyll content was determined on weekly basis [31,32] beginning from the time of new leaf formation until leaf fall. Average Leaflet blade length and breadth of 20 leaflets per plant was measured using graph paper. Leaf area of one to six mature leaves per plant has been measured using graph method. Specific leaf area (SLA) was calculated by dividing leaf area by dry leaf mass (obtained by drying at 75^{0}C for 24 h). Leaf tissue density was calculated as dry leaf mass divided by fresh leaf mass and leaf thickness was determined as leaf fresh mass (roughly equal to leaf volume) divided by leaf area. Construction cost was determined as per Huang *et al.* [33] and calculated as per McDowell *et al.* [19]. Leaf life span of ten leaves per plant was calculated by tagging newly formed leaves till final leaf fall.

Shoot length, shoot fresh weight, shoot dry weight, wood density, bud distance, number of leaves per vegetative bud, number of branched shoots and branch length of both plants were calculated after a year. The growth rate was calculated as difference in shoot length, shoot fresh weight and shoot dry weight between first harvest (3 months after plantation) and second harvest (1 year after plantation) for both *P. juliflora* and *A. nilotica*.

Root length, root fresh weight and root dry weight of both plants were calculated after 1 year growth period. The growth rate was calculated as difference in shoot length, shoot fresh weight and shoot dry weight between first harvest (3 months after plantation) and second harvest (1 year after plantation) for both *P. juliflora* and *A. nilotica*.

Leaf nutrient analysis likes of macro and micro nutrients K, Ca, S, P, Cl, Na, Mg, Fe, Mn, Zn and Cu has been done through WD-XRF spectrophotometer (Bruker, Germany).

Statistical analysis was done through SPSS software ver.16.0, by applying independent t-test. The data significance has been checked using variance significant value $p \leq 0.01$ and $p \leq 0.05$.

RESULTS

Leaf traits

Fresh weight of leaves of *P. juliflora* tends to be higher than *A. nilotica* (Table 1), but the difference was not significant. Hence, both the species did not show much difference in growth rate on fresh weight basis. Dry weight of leaves of *P. juliflora* was much lower as compared to *A. nilotica* with significant difference ($p \leq 0.01$). Hence, difference in growth rate on the basis of dry weight showed better growth trends in case *P. juliflora*. Specific leaf area was marginally higher for *A. nilotica* than *P. juliflora*, but the difference was not significant. Hence growth rate did not significantly differ on the basis of specific leaf area. In case of leaf tissue density, *A. nilotica* has shown significant higher values as compared to *P. juliflora* ($p \leq 0.01$). Leaf thickness was much higher for *P. juliflora* (≈45%) compared to *A. nilotica* with a significant value ($p \leq 0.01$)

Chlorophyll content in fully mature, i.e., 4 weeks old leaves, was lower for *A. nilotica* (nearly 17% lower) when compared with *P. juliflora* (Table 1) at $p \leq 0.01$; whereas, if we consider effective chlorophyll content (Fig. 1) throughout the life of leaf it comes out to be nearly 30% lower for *A. nilotica* than *P. juliflora*. Hence, relative growth rate with respect to chlorophyll content was higher in *P. juliflora* compared to *A. nilotica*. Leaf biomass per plant for *P. juliflora* was much higher as compared to *A. nilotica,* i.e., more than 77% higher ($p \leq 0.01$). The relative growth rate with respect to total leaf biomass was higher for *P. juliflora* compared to *A. nilotica*. The higher level of stem branching, larger stem mean length and lesser bud distance in case of *P. juliflora* were the main reasons for possessing higher leaf biomass. Leaf life

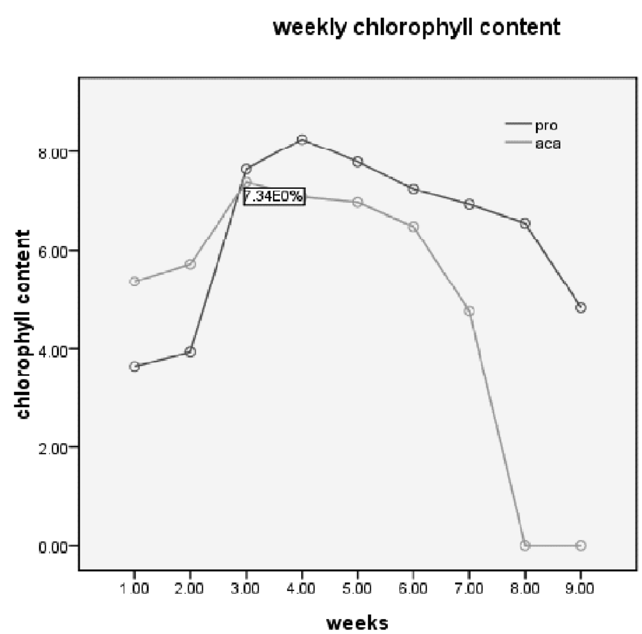

Figure 1: Weekly changes in chlorophyll content with leaf life span in invasive *P. juliflora* and native *A. nilotica*.

Table 1
Leaf functional traits of *P. juliflora* and *A. nilotica* under dome conditions after 6 months of germination

Leaf Functional Traits	*P. juliflora*	*A. nilotica*
Single leaflet blade width (cm)	0.226±0.007	0.124±0.01*
Single leaflet blade length (cm)	1.02±0.058	0.62±0.04*
Leaf fresh weight (mg)	134.2±2.13	132.6±4.39
Leaf dry weight (mg)	44.6±1.21	63.94±1.74*
Leaf area (cm^2)	8.30±0.08	12.0±0.12*
Leaf Tissue density	0.33±0.001	0.48±0.01*
Specific leaf area (cm^2 g^{-1})	186.54±3.37	196.94±2.66
Leaf thickness (g cm^{-2})	0.016±0.001	0.011±0.001*
Construction cost (g glucose g^{-1} dry weight)	1.18±0.02	1.27±0.02*
Chlorophyll content (µg g^{-1} dry weight)	8.24±0.01	7.0±0.05*
Bud distance (cm)	1.41±0.04	2.04±0.05*
Number of leaves/ bud	2.6±0.24	1.6±0.24*
Number of branches	5.6±0.51	3.2±0.37*
Mean length of branches (cm)	38.2±2.46	16.4±0.92*
Leaf biomass per plant (g)	10.3±0.40	5.8±0.23*
Total biomass per plant (g)	38.12±1.25	23.48±0.86*
Leaf life span (weeks)	9-10	7-8

± represents standard error, * represents significant difference between *P. juliflora* and *A. nilotica* at $p \leq 0.05$

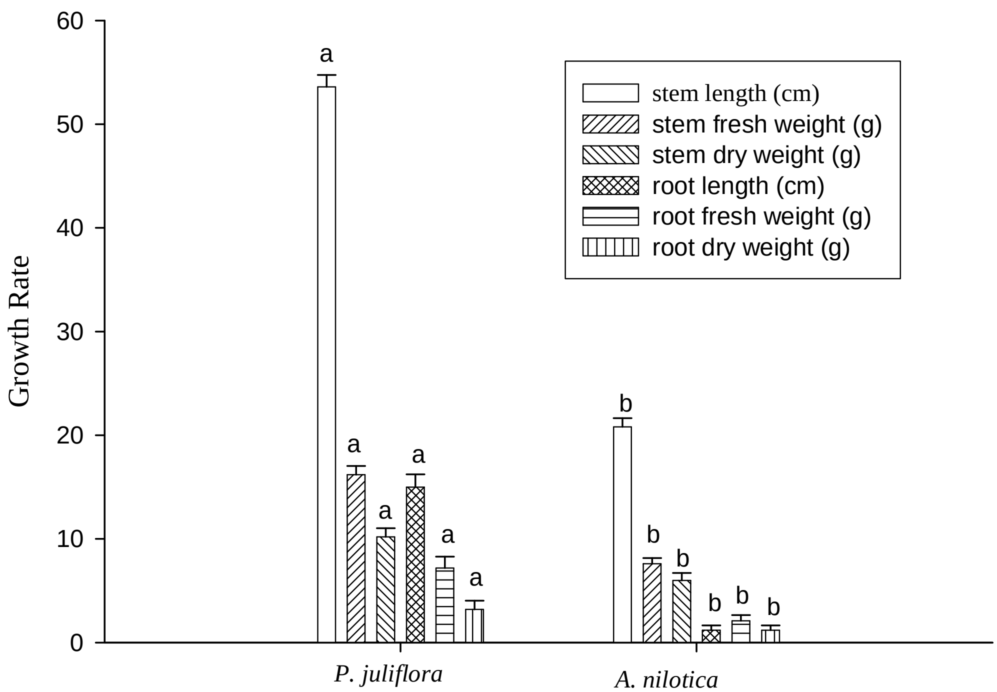

Figure 2: Relative growth rate of root and stem functional traits of *P. juliflora* and *A. nilotica* from 1st to 2nd harvest

Data presented as mean and standard error. * represents significant differences between values, applying independent t-test at $p \leq 0.05$

span for *P. juliflora* was significantly higher as compared to *A. nilotica*. This shows that the relative growth rate with respect to leaf life span was higher for *P. juliflora* compared to *A. nilotica*.

Macro-and Micro-nutrients

Most of the macro and micro nutrients were significantly higher in *P. juliflora* compared to *A. nilotica*, i.e., Ca (≈52% higher), K (≈43% higher), S (≈125% higher), Mg (≈142% higher), Fe (≈28% higher), Mn (≈22% higher), Zn (≈33% higher) and Cu (≈87% higher); whereas P, Cl, and Na were slightly higher in *A. nilotica* (Table 2). Hence, nutrient transfer rate was higher in *P. juliflora* compared to *A. nilotica*. This showed that the relative growth rate with respect to nutrient content is higher for *P. juliflora* compared to *A. nilotica*.

Table 2
Macro and Micro nutrient content in leaves of *Prosopis julilora* and *Acacia nilotica*

Sr. no.	*Nutrients*	*P. juliflora*	*A. nilotica*
1	Ca (mg g^{-1})	37.1±0.32	24.4±0.39*
2	K (mg g^{-1})	17.5±0.31	12.2±0.28*
3	P (mg g^{-1})	1.8±0.11	2.1±0.09
4	S (mg g^{-1})	7.2±0.18	3.2±0.15*
5	Cl (mg g^{-1})	5.2±0.14	7.0±0.16*
6	Na (mg g^{-1})	0.14±0.01	0.22±0.01
7	Mg (mg g^{-1})	4.6±0.09	1.9±0.10*
8	Fe (mg g^{-1})	0.5±0.01	0.39±0.01
9	Mn (mg g^{-1})	0.11±0.01	0.09±0.01
10	Zn (μg g^{-1})	32.0±1.01	24.0±0.89*
11	Cu (μg g^{-1})	15.0±0.89	8.0±0.71*

± represents standard error, * represents significant difference between *P. juliflora* and *A. nilotica* at $p \leq 0.05$

Stem traits

Although there were no significant differences seen between root and stem parameters of both plants until first harvest after 3 months, but these differences had increased significantly afterwards.

Parameters like shoot length, dry weight and fresh weight were increased significantly ($p \leq 0.01$) for both plants *P. juliflora* and *A. nilotica* from 1st harvest to 2nd harvest. However after 2nd harvest stem length was more for *P. juliflora* the difference was insignificant. However shoot dry weight and fresh weight were significantly ($p \leq 0.01$) higher for *P. juliflora* than *A. nilotica*. In case of wood density difference was not significant after 1st harvest. However after 2nd harvest it has been found out to be significantly higher for *P. juliflora*. Relative growth rate for three parameters (i.e. length, fresh and dry weight) comes out to be two times for *P. juliflora* than *A. nilotica* from the period of 1st harvest to 2nd harvest.

Table 3
Stem and Root functional traits of *P. juliflora* and *A. nilotica* grown in pots under dome conditions after one year

Stem functional traits	*P. juliflora*	*A. nilotica*
Length of the stem (cm)	105.48±1.505	101.54±0.923
Fresh weight (g)	20.86±1.189	14.4±0.432*
Dry weight (g)	12.68±0.676	9.64±0.246*
Wood density (kg m^{-3})	730±25.3	584±11.5*
Root functional traits	*P. juliflora*	*A. nilotica*
Length of the root (cm)	37.98±1.589	22.76±0.778*
Fresh weight (g)	8.194±0.477	3.592±0.143*
Dry weight (g)	3.854±0.176	1.956±0.582*

± represents standard error, * represents significant difference between *P. juliflora* and *A. nilotica* at $p \leq 0.01$

Root traits

Root dry weight and fresh weight were increased significantly ($p \leq 0.01$) in case of both *P. juliflora* and *A. nilotica* from 1st harvest to 2nd harvest. However in case of root length the difference was significant only in *P. juliflora*. After one year of growth period all the three parameters, i.e., root length, root dry weight and root fresh weight were significantly higher ($p \leq 0.01$) for *P. juliflora* than *A.* nilotica. Relative growth rate in terms of root fresh weight and root dry weight was two times greater for *P. juliflora* than *A. nilotica* from the period of 1st harvest to 2nd harvest, however in case of root length the relative growth rate was almost 8 times for *P. juliflora* than *A. nilotica*.

DISCUSSION

The invasive character of a plant species does not depends merely upon a single particular trait, but depends upon various physiological characters [34], particularly leaf, roots and shoot traits [35,36]. Invasive species possess higher SLA as compared to native species [20,37,38]. However in the present study the data reveals that SLA of *P. juliflora* does not show any significant difference as compared to *A. nilotica*. This could be possible due to the fact that difference in SLA is rather less prominent under pot conditions compared to field natural conditions [38]. On the other hand, *P. juliflora* has performed better for other parameters like fresh leaf weight to dry leaf weight ratio, chlorophyll content and leaf life span. Hence, it possesses lower leaf construction cost, a common character possessed by invasive species [37,39]. It has been defended in various studies that invasive alien species invests less on leaf construction cost as compared to other species [20,39]. Higher nutrient content in leaves of *P. juliflora* as compared to *A. nilotica* indicates better ability of the former towards resource use efficiency because of better fluid transfer rate to the leaves. It has been proved in some previous studies that plant with better nutrient supply rate possess better growth rate [40]. Leaf tissue density was the only parameter that comes out to be higher for *A. nilotica* as compared to *P. juliflora* which indicates lower nutrient transfer rate for *A. nilotica*. Lower tissue density means higher leaf life span, another invasive attribute found to be greater for *P. juliflora*. It has also been discussed earlier that species with lower tissue density are accompanied with higher leaf and root mass at early stages, but the condition reverses at later stages [41]. This has also been observed in the current study that at the time of 1st harvest *A. nilotica* performed little better than *P. juliflora*, but during 2nd harvest *P. juliflora* dominated in terms of root length, shoot length, total biomass and secondary branching. Further it was emulated that invasive species have higher relative growth rate as compared to native species [20], and our data showed that *A. nilotica* lags much behind *P. juliflora* in this case. Several studies have proved that high wood density [40] is the most important factor that adds to the invasive characteristics, especially in case of woody species [41] and the above results shows that *P. juliflora* possessed higher wood density as compared to *A. nilotica*. Root traits for *P. juliflora* are also the determining factors as these were better when compared to *A. nilotica*, thus improving resource capturing and water use efficiency in *P. juliflora* and creating stressful environment for the competitor species [21].

CONCLUSIONS

In conclusion, *P. juliflora* performed much better than *A. nilotica* under experimental conditions. Although at the time of first harvest, the results were not much pronounced, however in the following harvest growth rate in the form of stem and root traits described a significant increase in case of *P. juliflora* as compared to *A. nilotica*. Leaf traits play a significant role in the invasiveness of *P. juliflora*. All of the leaf traits, i.e., leaf construction cost, leaf life, chlorophyll content and leaf tissue density and total biomass explained why *P. juliflora* is now a dominant plant in the regions earlier occupied by *A. nilotica*.

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CONFLICTS OF INTEREST

The author declare no conflict of interest

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