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Growth Performance and Invasive Attributes of *Cassia uniflora* Mill., A Recently Introduced Plant in Central India

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ABSTRACT

Biological invasion has been unequivocally identified as one of the great threats to biodiversity. A large number of alien invasive species have been introduced in different parts of the world due to a number of anthropogenic activities including trade and transport. Indian flora constitutes 18% of alien plant species which are increasing with time on account of creation of new habitats due to developmental actions. *Cassia uniflora* is an alien invasive species reported in south India a few decades ago, is now increasing its populations gradually on road sides and other waste places in western and central India. The present paper deals with study of invasive traits of growth of *C. uniflora* in experimental plots. Besides the usual measurements of growth, relative growth rate (RGR), net assimilation rate (E), mean leaf area (F), root weight ratio (RWR) and shoot weight ratio (SWR) were calculated as growth performance traits throughout the growing period. Growth performance of *C. uniflora* was compared with soybean crop, as both are sharing the same growing season. The present study shows that *C. uniflora* is a potential invasive plant substituting native flora and could be a potential weed in soybean crop fields. Invasive traits are plastic in nature, tolerant to habitat stress conditions, competitive on account of vigorous growth, allelopathy and other morpho-physiological attributes. Path of migration is also projected from southern to northern states of India.

Keywords: *Cassia uniflora*, invasive species, growth performance, biodiversity**.**

INTRODUCTION

Biological invasion is an important component of anthropogenic global environmental changes (Vitousek et al. 1997) and leading cause of biodiversity loss (Bellard et al. 2016). Despite some controversies, the negative impacts of biological invasions on environment and biodiversity are now unambiguous at local, regional and global levels (Courchamp et al. 2017, Russel and Blackburn 2017). The biological invasions have been further aggravated by climatic change (Hellmann et al. 2008, Bellard et al. 2013) and rapid globalization of trade and transport (Hulme 2009). The number of exotic species has been increasing across continents and taxonomic groups (Seebens et al. 2017). Some of the unique traits of invasive plants are: broad native ranges, generalists in distribution, allelopathy, shorter regeneration periods, longer flowering and fruiting periods, abundant seed production and easy dispersal, ability to easily adapt and tolerance to stresses in the introduced habitats (Rejmanek and Richardson 1996, Pyšek and Richardson, 2007, 2008, Van Kleunen et al. 2010, Sol et al. 2012, Iannone et al. 2016). Alien plants that are short lived are the most successful invaders in human transformed landscapes (Golivets 2014). Reproductive and dispersal traits are essential to become naturalized. Indian flora constitutes 18% of alien species contributed from North and South America (55%), Asian (30%) and European and central Asian (15%) countries (Nayar 1977). Majority of them are herbaceous (87.3%), and shrub, climbers and trees are 8.1, 2.9 and 1.7%, respectively (Reddy 2008).

Cassia uniflora (Mill.) Irwin & Barneby (Syn. *Senna uniflora* (Mill.) I&B, is a herbaceous invasive alien species of family Caesalpiniaceae, a native of Tropical South America, was first reported from eastern Karnataka in India and subsequently reported from states of Maharashtra, Andhra Pradesh (Reddy et al. 2000), Kerala, Tamilnadu, Madhya Pradesh, Gujrat and Rajasthan (Meena and Yadav 2008). In

Madhya Pradesh, it has been observed in districts such as Guna, Sagar, Dhâr, Jhabua and other places, occupying huge areas along road sides, railway tracks and waste places. It was reported for the first time from India by Singh (1981) as *Cassia sericea* Sw., which is now accepted as *C. uniflora* (Mill.) I&B. The history of introduction of this species right from the first report indicates that it was first introduced in south India and gradually migrating towards northern states becoming dominant in central India (Madhya Pradesh) at present. It is expected to migrate further north in due course of time (Fig.1). Since it is generally growing in abundance in open area i.e. mostly on road sides, surrounding the agricultural field, it may become an aggressive crop weeds particularly of soybean crop as both share the same growing reason.

C. uniflora has the ability to persist and exhibit dominance in adverse environment conditions due to a number of physiological traits related to invasion (Ghayal et al. 2009). Further, due to non- palatability, grazing does not impact it, thereby increasing its density and population. Earlier studies on *C. uniflora*, in India are related to its occurrence at different places and morpho-physiological ones (Ghayal et al. 2009). No scientific investigations in literature are available on growth performance and invasive traits from ecological point of view. In view of the above and lack of information on the growth performance, the present study was undertaken to understand the growth performance of *C. uniflora* Mill. In this study, we focused on the aggressive nature of this species on the basis of growth parameters such as relative growth rate (RGR), net assimilation rate (E), mean leaf area (F), root weight ratio (RWR) and shoot weight ratio (SWR).

MATERIAL AND METHODS

Study was carried out in open field at Botanical garden (N23°49'48.18", E78°46'36.28) of Department of Botany, Dr. Harisingh Gour University, Sagar, Madhya Pradesh, India. The climate of the area is typically monsoonal with annual rainfall as 1234mm, mostly received during rainy season from mid-June to September and average minimum and maximum temperature were recorded 21. °C and 31.78 °C, respectively.

Seeds of *Cassia uniflora* were collected from different populations occupying in surrounding areas at the time of maturity during the month of November-December 2017. Seeds were mixed randomly and sown just before monsoon in open plot (5×5m). The density of seedling was kept 60-70 seedlings m^{-2}, as more or less the similar density was observed in fields. Seeds started germinating in the month of June with the onset of rainfall after a week of sowing. Ten complete plants were harvested at an interval of a week. Plant parts such as root, shoot, leaf and pods were separated and measurements were recorded. The dry weight of each fraction of plant was taken after 72 hours of oven drying at 50-60°C.Growth analysis is used as an analytical tool for characterizing plant growth and invasive potential. Net assimilation rate (E), relative growth rate (RGR), root weight ratio (RWR), shoot weight ratio (SWR) and mean leaf area ratio (F) of *C. uniflora* were analyzed throughout the growing season from the month of June to November 2018, at an interval of one week period. The following growth parameters were calculated following Okali (1972) and Hunt (1982):

$$\text{Relative growth rate (RGR)} = \ln\frac{(W_2 - W_1)}{(t_2 - t_1)}$$

$$\text{Mean leaf area ratio (F)} = \left(\frac{A_1}{W_1} + \frac{A_2}{W_2}\right)$$

$$\text{Net assimilation rate (E)} = \frac{(W_2 - W_1)}{(A_2 - A_1)} \cdot \frac{(\ln A_2 - \ln A_1)}{(t_2 - t_1)} \text{ g cm}^{-2} \text{ wk}^{-1}$$

Where, w_1, w_2 represents dry weight, A_1, A_2 are mean leaf area of concerned fraction of plants and t_1, t_2 are the time interval.

Morphology

C. uniflora is an annual erect herbaceous plant, up to 1.15 m tall, branches and branchlets 3-5 angled. Leaf rachis 6-12cm long (including petiole), leaflets 3-5 pairs (usually 4 pairs), hairy on lower side, leaves alternate 7-10 cm long, first leaflet pair smallest, lamina 2-3.6 × 1-1.8 cm, leaves both side pilose, pointed at top, stem pilose when young and sparely pilose at maturity, stalked glands between all pairs of leaflets except the terminal pair, stalk yellow, 1.5-2.5 mm long, Racemes axillary, 3 to 5 yellow flowers, 6-8 mm long, sepals 5 unequal boat shaped, corolla 5 unequal petals, shortly clawed, Fertile stamen 7;

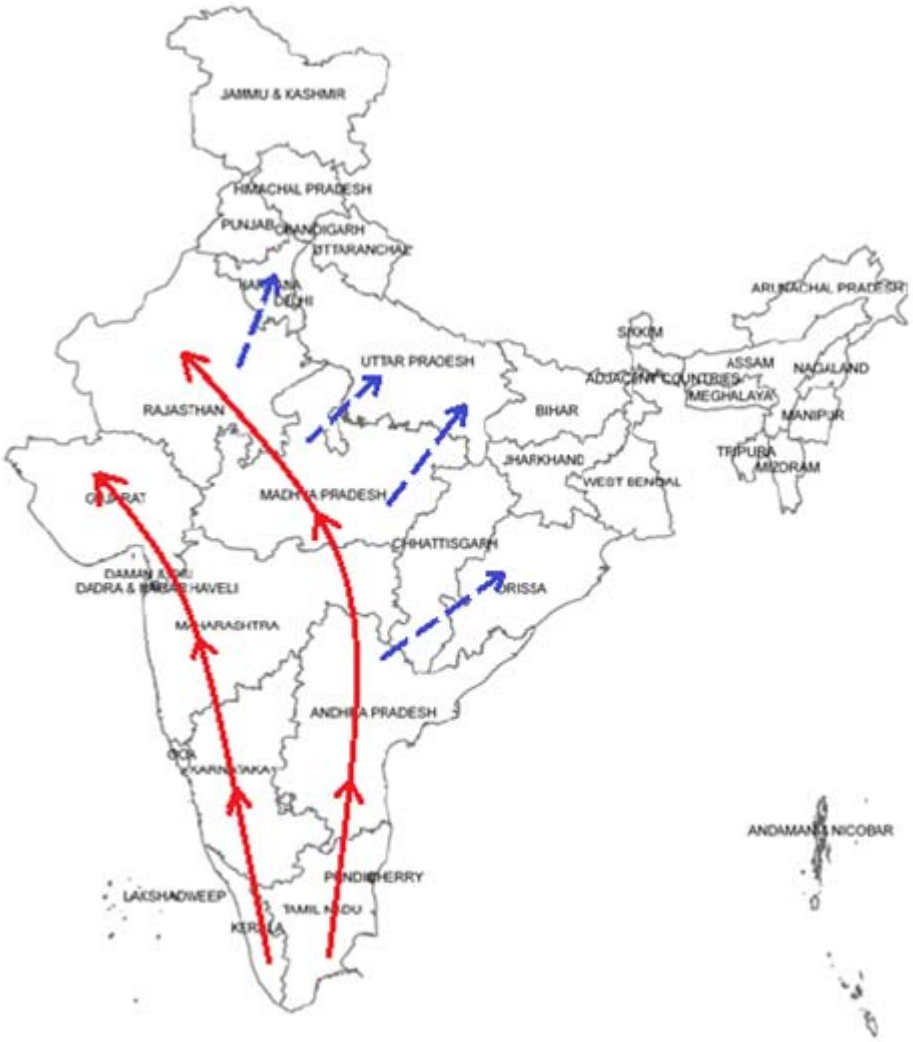

Figure 1. Present (red arrow lines) and expected future (blue arrow lines) distribution of *Cassia uniflora* in India

three large anthers narrowed at the apex, rest anthers rounded at the top, ovary densely silky containing 6-9 ovules, pod 1.8-2.9 cm (usually 2.3 cm) long, pointed at apex, seeds 3.1×2.4×2 mm quadrangular, surface wrinkled, smooth when fully ripped and healthy (Fig. 2). Germination starts during last week of June after rainfall, flowering begins in first week of September and ripening of pods in mid-November. All the phenological characters were observed during the field study. Phenological events of *Cassia uniflora* are described on the basis of field observations in the study area.

Figure 2. *Cassia uniflora* in its natural habitat

RESULTS

General growth parameters as recorded after first week showed a gradual increase in vegetative

fractions till the end of growing period, however, maximum increase was found during 4-6 weeks (Table 1). Reproductive plant fractions such as buds and flowers showed an increase till 17th week followed by a decline with the initiation of pods. The length of root nearly stabilized in the later phase (14th week) of growing season as compared to the shoot. The mean values of number of leaves and length of rachis increased upto 16th week and decreased afterwards as a result of withering of old leaves and onset of new leaves. Organic matter allocation in above and below ground part of the plants also exhibit an increase in early phases of development and a subsequent constancy was attained in dry weight of root fraction after a week (Table 2). Data envisage more biomass allocation in above ground parts as compared to below ground fractions. An important characteristic of invasive species is that they possess high SWR as compared to RWR. *Cassia uniflora* also showed that SWR, at times, was four or more times greater than the RWR. Initially, the difference in SWR and RWR was less, however, with the increasing growing period it showed a gradual increase except a few variations (Fig.3). Highest RGR was observed in early stages of development followed by decline when plants approach maturity and in terminal phases of life cycle, it was negative as the plants started dying. Net assimilation rate (E) and RGR show similar trend throughout the growing period (Fig.4). During field observations, it was

Table 1. Growth analysis of *Cassia uniflora* during growing season.

Harvesting month & date	Leaf area Cm^2 / plant	Root dry weight per plant (g)	Stem dry weight per plant (g)	Total dry weight (W) per plant (g)
Jun. 28	3.10±0.070	0.132±0.003	0.263±0.020	0.395±0.035
Jul. 05	53.96±.241	0.226±0.005	0.874±0.031	1.100±0.038
Jul. 13	99.30±0.317	0.298±0.011	1.082±0.038	1.380±0.029
Jul. 20	165.2±0.352	0.393±0.012	1.783±0.041	2.176±0.041
Jul. 26	473±1.329	0.450±0.032	2.587±0.038	3.037±0.036
Aug. 02	500±1.655	0.643±0.062	4.011±0.053	4.654±0.039
Aug. 09	819±1.673	0.927±0.081	4.190±0.057	5.117±0.043
Aug. 16	893±1.536	0.943±0.078	4.830±0.049	5.773±0.051
Aug. 21	918±1.702	0.966±0.052	5.047±0.058	6.013±0.049
Aug. 27	1173±1.721	1.487±0.096	6.214±0.063	7.701±0.052
Sep. 04	1433±2.296	1.798±0.120	6.483±0.060	8.281±0.049
Sep. 11	1588±2.371	1.831±0.110	6.642±0.071	8.473±0.056
Sep. 18	1635±2.491	1.845±0.171	7.384±0.065	9.229±0.061
Sep. 26	1711±2.608	1.853±0.168	8.437±0.083	10.290±0.053
Oct. 01	1608±2.625	1.866±0.166	9.610±0.086	11.476±0.069
Oct. 08	1498±2.611	1.872±0.170	10.288±0.091	12.160±0.071
Oct. 16	1283±1.893	1.832±0.163	11.864±0.110	13.696±0.074
Oct. 23	1195±1.529	1.894±0.167	10.312±0.121	12.206±0.058
Oct. 31	1068±1.387	1.812±0.159	8.137±0.101	9.949±0.047
Nov.07	913±1.323	1.893±0.174	7.841±0.730	9.734±0.039

Table 2. Growth characteristics of *Cassia uniflora* throughout the growing period (21-06-2018 to 31-10-2018)

Characteristics/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Plant height (cm)	6.0	7.37	14.4	20.16	27.8	42.0	52.3	60.9	75.1	81.3	87.1	100.5	105.9	107.9	113.5	117.8	127	139.8	141.8
Root length (cm)	4.2	5.87	8.5	9.6	10.8	12.6	13.2	15.3	16.5	16.6	16.8	18.6	18.6	19.8	20.1	20.6	21.0	21.8	21.9
Stem diameter (mm)	0.86	1.16	1.75	2.0	2.46	3.14	3.33	3.38	4.29	4.32	4.37	4.84	5.28	4.51	4.61	4.86	5.26	5.28	5.82
No. of leaves	-	3.00	4.66	5.6	6.0	8.4	9.6	10.2	10.5	10.5	10.6	14.0	14.3	11.8	12.6	17.0	25.6	20.2	18.25
Length of rachis (cm)	-	2.1	2.6	3.1	3.34	4.3	5.8	5.9	6.1	7.1	7.5	8.0	8.1	8.4	8.2	8.3	7.9	7.6	6.7
Shoot/root ratio	-	1.26	1.69	1.57	2.57	3.33	3.96	3.98	4.55	4.89	5.18	5.4	5.34	5.44	5.64	5.71	6.05	6.41	6.74
Buds /plant	-	-	-	-	-	-	-	-	-	IN*	IN*	18.3	16.9	16.1	18.1	21.6	26.8	12.5	18.2
Flowers/plant	-	-	-	-	-	-	-	-	-	-	-	3.0	3.9	3.0	13	17.4	32.8	23.4	16.8
Pods /plant	-	-	-	-	-	-	-	-	-	-	-	-	-	IN*	8.3	19.1	21.6	28	39

*IN: Initiation

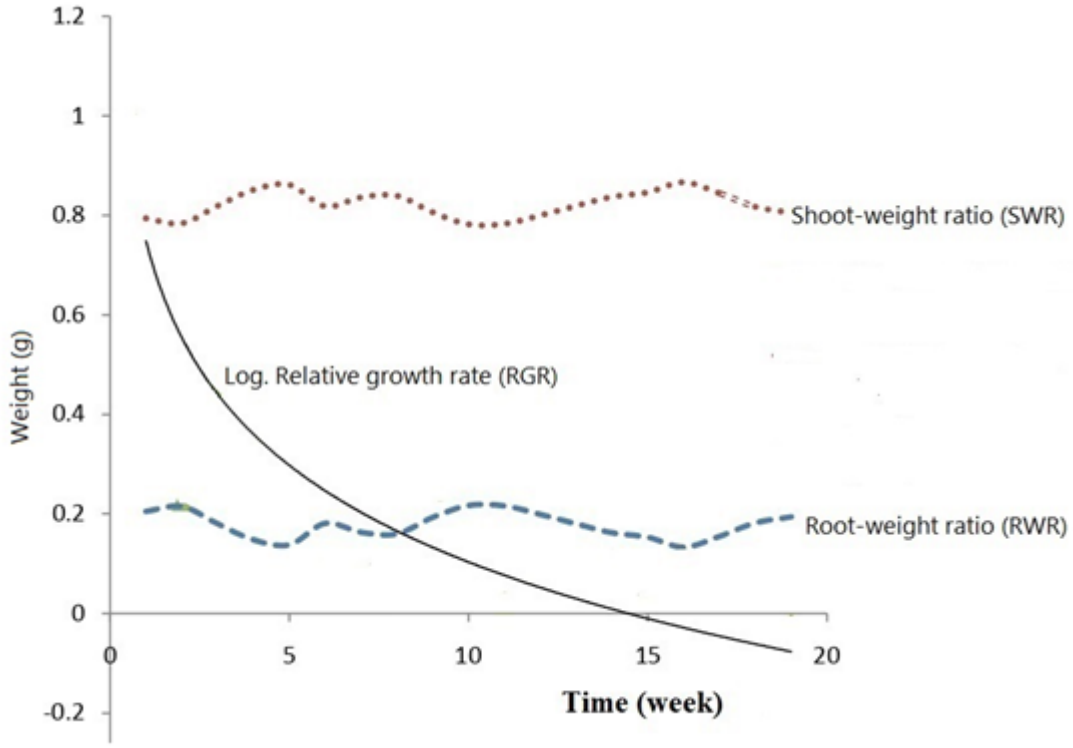

Figure 3: Shoot Weight Ratio (SWR), Root Weight Ratio (RWR) and Relative Growth Rate of *Cassia uniflora* during the growing period

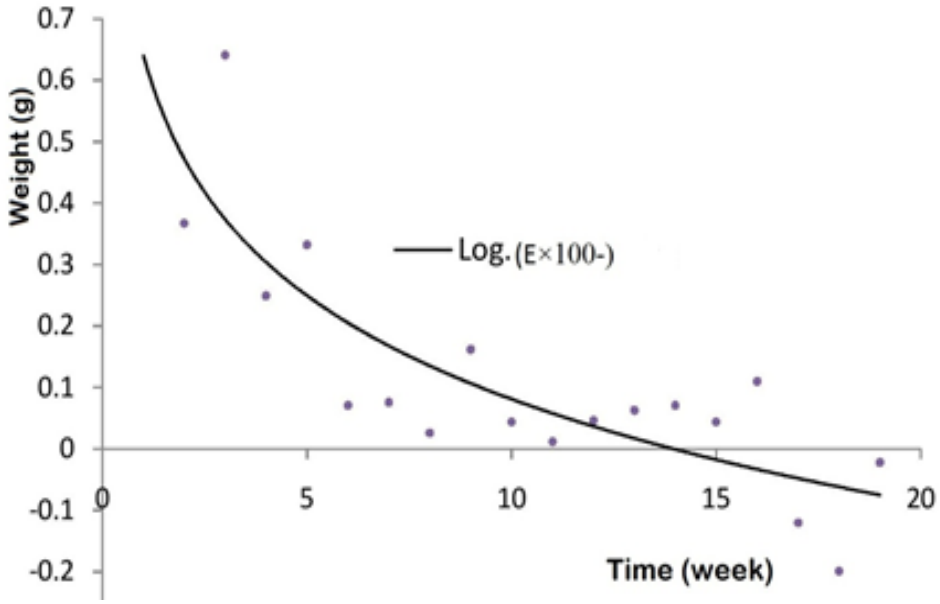

Figure 4. Net assimilation rate E (g/g/week) of *Cassia uniflora* during the growing period

noticed that seeds exhibit dual germination behavior as some of the seeds germinate afterwards when populations were already established on the sites.

DISCUSSION

The variations in growth patterns were found at different stages of development. Important complications arise when the plants enter in reproductive phase. It may be attributed to the fact that energy rich storage product started to deposit after utilization of energy. Above ground mass production is declined with initiation of reproductive phase. Leaf fall appears to be another factor for fluctuation in the growth curve.

Since the growing period of *Cassia uniflora* coincides with the *Glycine max*, an important cash crop of central India, and the former populations surround the crop fields, we tried to compare the growth performance of both. Further, the *C. uniflora*, in future, may become the competitive weed species in crop fields.

Buttery (1969) studied the growth analysis of *Glycine max* in crop fields. He analyzed RGR, CGR, NAR (E), LAI etc. of different plant fractions. RGR of various fractions was gradually declined with the passing of the developmental stage. In the present study, the leaf area of *C. uniflora* is comparatively less (1711 cm^2) than *G. max* (2000 cm^2) per plant. Optimum leaf area occupied by *G. max* was on 80^{th} day of developmental stage and maximum leaf area attained in the first week of September to last week of October (56 days).The maximum leaf area attained by both the species was approximately at the same stage of development but leaves of *C. uniflora* remain intact till the later period of the growth indicating tough competition could be possible between crop and weed. Early large canopy cover in *C. uniflora* provides the competitive ability to plant. Massive seed production, long viability, small seed size and effective dispersal mechanism envisage invasive character of this plant (Ghayal et al. 2009). Field observations indicate that all the seed of this plant do not germinate even in favorable conditions and there is fractional germination in *C. uniflora*. These characteristics of seed indicate the invasion behaviors as described by Ellsworth (2005). Initially, 54% seed germination was observed in laboratory test performed in the month of June, which is more or less the same to field germination, however, remaining seeds germinate later on. Pods of *C. uniflora* mature in different stages and some pods remain attached for longer period. Deep root system facilitates absorption of water and uptake of nutrients from the soil, besides giving better attachment to soil. These characteristics envisage the invasive behavior of plants.

Plasticity, adaptability in different condition, clumped distribution pattern, self and cross pollination of *C. uniflora* showed its high invasive potential. The massive growth and reproductive ability of *C. uniflora* may be attributed to the high amount of organic constituents like reducing total sugar, starch and protein. Further, the presence of highest phenolic contents in this species as compared to other native and invasive weeds studied (Ghayal et al. 2009) indicate its ability for protection from biotic and abiotic stresses (Forkas and Kiraaly 1962).

High content of antioxidant enzymes help in scavenging the free radicals during stress conditions (Deshmukh 2005, Joshi et al. 2006) Occurrence of high antioxidant enzymes and allelochemicals in *C. uniflora* manifest in its allopathic effects (Ghayal et al. 2009). During field studies, it was found that this species inhibit the growth and development of *Parthenium hysterophorus*, *Cassia tora* and other native population. Prevention of establishment of native communities by competing for resources such as nutrients, sunlight, space etc. establishes the aggressive invasive behavior of *C.uniflora*.

The results of the present study clearly indicate invasive traits of *C. uniflora* which may turn in to crop weed in due course of time if preventive measures are not taken. Further, it is projected that this invasive species is likely to move towards northern states of India.

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Authors' contributions: VK and PKK designed and drafted the manuscript. MLK contributed to revision of first draft.

Conflict of Interest: The authors declare that they do not have any conflict of interest.

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