



Beneficial Uptake of Soil Mineral Nutrients by Invasive Weeds towards Suppression of Phytodiversity

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ABSTRACT

The successful plant invaders have profound multitude effects on different aspects like soil properties, mineral nutrient cycling, soil organic matter dynamics, productivity and ecosystem functioning. Invaders become idiosyncratic causing effects on native plant communities as a consequence of their higher ability for acquiring soil nutrients. To test this hypothesis, *Alternanthera* (ALT) and *Euphorbia* are chosen since these species are found to be fast spreading and high density plants commonly observed in semiarid soils. The analysis of mineral nutrients from these plants indicated that the capacity for nutrient absorption is higher than a native (ACH) that leads to their luxuriant growth. Voracious uptake of minerals like K⁺ (1640.0 ppm), Ca²⁺ (910.78 ppm), PO₄³⁻ (138.4 ppm) Mg²⁺ (605.5 ppm) is observed for ALT while ACH exhibited lesser uptake (1.80 ppm, 62.66 ppm, 5.00 ppm and 312.0 ppm respectively) for these nutrients. Moreover, rhizosphere soil analysis also indicated that these plants efficiently absorb large amount of nutrients due to their better biosorption tendency. *Alternanthera* was found to be more active in mineral absorption than *Euphorbia* leading to predominant growth in various areas forming monothickets. It also showed strong positive correlation with their % frequency distribution in area exhibiting competitive advantage over natives through accelerated mineral uptake.

Keywords: *Alternanthera*, *Euphorbia*, Invasive weeds, Mineral nutrients, Rhizosphere soil.

INTRODUCTION

Many plant species grow together in nature, and interact with each other by inhibiting or stimulating the growth and yield through allelopathic interactions. In any ecosystem, the plants growing within it exhibit them in the form of monothickets or as individuals placed in specific dominance. Such dominant plant ecosystems always show the zones of inhibition around them¹. This occurs to avoid the sharing of their available natural resources with associated plants.

The alien species become invasive²⁻⁴ due to deliberate or unintentional introduction outside their natural habitats into new areas where they establish, invade and outcompete with native species by substitution of native species⁵. The threat to biodiversity due to alien species includes species extinctions and changes in ecosystem functioning and energy dynamics. Invasive species are thus a serious obstacle in conservation and sustenance of phytodiversity^{6, 7}. Majority of invaders⁸ cause threat to the ecosystem in which they have established by virtue of their aggressive qualities, superior growth, effective competition for resources, efficient dispersal, and rapid establishment due to which they overcome biological, physical, and environmental thresholds^{9, 10}. For the effective management of the invasives studies on their ecology, phenology, reproductive biology, mineral nutrition, physiology and allelochemicals / ecochemicals are essential¹¹.

The overall structure and function of a plant is governed by about 18 essential macro and microelements. The

biosynthesis of various primary and secondary metabolites, growth, development, reproduction, adaptation, tolerance to biotic and abiotic stress, defense against pathogens and pests is attributed to the status of mineral nutrients. The deficiency or toxicity of any element affects the normal metabolism of any plant. The level of accumulation of each element is a better biological indicator of soil fertility along with overall functioning of the plants¹². Comparative studies of mineral nutrition of plants in a specific community may also help to explain the nature of competition amongst them for biological resources like water, nutrients, light etc.^{13, 14}.

Pune University campus (M.S., India) is occupied by typical sub-deciduous, xerophytic vegetation, along with dominating herbaceous flora. The invasive herbaceous weed species like *Cassia uniflora* Mill. non Spreng, *Alternanthera tenella* Colla., *Synedrella nodiflora* (L) Gaertn, *Parthenium hysterophorus* L., *Bidens biternata* L., *Acalypha ciliata* Forsk, *Euphorbia geniculata* are significantly suppressing the population of native weeds like *Boerhaavia diffusa*, *Achyranthes aspera*. These native and invasive weeds interact with each other throughout their life¹⁵. It has already been established that invasive plants become more dominant over native ones through release of allelochemicals causing nutrient deficiencies to the native plants as they have very high uptake of mineral nutrients compared to native plants¹⁶⁻¹⁸. Some of these weeds like *Alternanthera*, *Euphorbia* are known to secrete allelochemicals that hamper the phytodiversity. These weeds are found in and around Pune and happen to be the part of University of Pune. In the present investigation

we have explored the uptake capacity of mineral nutrients by *Alternanthera* and *Euphorbia* so as to further strengthen the hypothesis that these weeds are indeed successful invaders even under semiarid conditions.

MATERIALS AND METHODS

Selected invasive weeds for the study

Alternanthera tenella Colla., *Euphorbia geniculata* Orteg. Native weeds selected for comparison - *Boerhaavia diffusa* L., *Achyranthes aspera* L.

Along with the phytosociological investigations through weekly visits to each site the vegetation in full growth was selected for rhizosphere soil sample collection. From the twenty randomly selected quadrats at each site, the soil samples were collected for the observed native and invasive weeds and the composite samples were prepared.

Analyses of mineral constituents in leaf and rhizosphere soil

Preparation of leaf Samples

The air shade dried powders of leaf samples were weighed (5 g) and transferred to silica dish and ignited completely to obtain individual ash. The ash samples (200 mg) were taken for mineral analysis. Respective ash was dissolved in hot concentrated Hydrochloric acid (HCl), cooled and diluted to 100ml with distilled water.

Preparation of Rhizosphere Soil Solution

Soil sample (5 g) was moistened with little distilled water and then transferred to beaker. To this 15 ml of concentrated hydrochloric acid and 5 ml of concentrated nitric acid was added. This was digested again on sand bath for 15 min. and diluted to 100 ml with distilled water.

Determination of Fe (II) and Al (III) was also supported spectrophotometrically determined using 1:10-Phenanthroline and Erichrome cyanine-R as complexing agent respectively¹⁹. λ_{max} – 500 nm and 535 nm respectively. K^+ and Ca^{2+} were also estimated by flame photometry. Phosphorus as P_2O_5 was determined titrimetrically using ammonium molybdate as precipitating agent. The yellow precipitate of ammonium molybdophosphate was dissolved in NaOH. Excess of alkali was then titrated against H_2SO_4 .

Mineral analysis by AAS

The samples of plant material and Rhizosphere soil were prepared as described above and the contents of Fe^{2+} , Ca^{2+} , Mg^{2+} , Zn^{2+} , Al^{3+} , Mn^{2+} , PO_4^{3-} , BO_3^{3-} and NO_3^{-1} were determined using Atomic Absorption Spectrophotometer (Perkin-Elmer 3100, USA).

Measurement of pH and Electrical conductivity of soil solution and leaf leachates

The pH of different concentrations of leaf leachates of *Alternanthera* and *Euphorbia* were measured (Elico LI –

610). Electrical conductivity of leachates was measured (Elico CM-180).

Statistical analyses

The data were summarized as means of three replicates with standard deviation as the measure of variability. SigmaStat 3.5 and Microsoft Excel 2007 were used for the data analyses.

RESULTS AND DISCUSSION

Mineral constituents in *Alternanthera* and *Euphorbia*

Results

The analysis of rhizosphere soil and leaves of both the alien weeds was carried out to understand the probable reason of their invasiveness. The results shown in Table 1 revealed that except for potassium, all other mineral contents were found to be highest in the rhizosphere soil of *Euphorbia* than in the leaves of the same. Similar results were obtained for soil and leaves of *Alternanthera*. In case of both these plants and respective rhizosphere soils, potassium was found to be more in leaves than in the soil. When the mineral constituents of the respective rhizosphere soils were compared, it was observed that soil of *Alternanthera* was rich in minerals like Fe^{2+} , Mg^{2+} , Mn^{2+} , BO_3^{3-} , PO_4^{3-} , NO_3^{-1} while for other minerals soil of *Euphorbia* was found to have higher contents. Similarly the comparison of the minerals from both the leaves revealed that leaves of *Alternanthera* have higher contents of Mg^{2+} , K^+ , PO_4^{3-} than leaves of *Euphorbia*. This probably indicates the rate of absorption of mineral is higher for respective weed species.

When the mineral constituents of leaves of invasive and native weeds were compared (Table 2) it was observed that all the macro and microelements were in higher amounts in invasive weeds like *Alternanthera* and *Euphorbia* than in native weeds like *Boerhaavia* and *Achyranthes*. Similarly the comparison (Table 3) of all mineral constituents from invasive and native weeds with their occurrence (frequency %) also revealed appropriate correlation between the occurrence and the amounts of mineral elements in respective invasive and native weeds.

Discussion

All the major and minor essential nutrients are involved in various catabolic and anabolic processes as well as enzymatic processes in plants. These mineral nutrients are also involved in structural materials of plant body. Hence, analysis of all these nutrients will indicate the physiological, growth and reproductive status of plants²⁰.

The impact of invasive species on biodiversity, ecosystem stability and nutrient cycling is well understood for different plant species including weeds²¹. The successful exotic weeds have profound effect on different factors of the invaded ecosystem including the soil properties and related processes such as biogeochemical cycles, soil enzyme activities²². Exotic plant invasion exerts major

influences on abundance, composition and functioning of soil microbial communities¹⁶⁻¹⁸.

The mineral nutrient status and metabolic network in plants is very well interlinked. The nutrient balance is crucial for normal growth and development of plants, as they are involved in almost all cellular reactions, synthetic processes, enzymatic activities, growth, development, flowering, fruiting and production of defense compounds (secondary metabolites). The growth, development, dominance and invasive potential of any plant species mostly depend on its metabolic and allelochemicals status²³. The ionic balance is also concerned with stress tolerance, stomatal functioning, energy metabolism, membrane functioning and structural integrity²⁰. The role of trace elements in plants is also equally important²⁴.

It has been reported that higher quantities^{25, 26} of the essential mineral constituents like N, P, K, Na, Ca, Fe, Mg, Zn are present in leaves of *Ageratum*, *Acanthospermum*, *Croton*, *Xanthium* and *Catunaregam*. The results of the present study corroborate with the work of other workers²⁷⁻²⁹. It has also been observed that exotic plant species exploit soil nutrients better than the natives indicating their beneficial ability of effective resource use strategies in the invaded range^{30, 31}. The higher concentrations of N, P, K, Ca, Mg, Zn and Cu in leaves of dominant invasive weeds like *Synedrella* and *Cassia* also has been recorded along with their luxuriant growth in the campus of Pune University (M.S.)³².

It has been observed that the sufficiency level of such mineral elements contributes to their luxuriant growth. Same may be the reason for luxuriant growth of *Alternanthera* and *Euphorbia* and other invasive weeds of the Pune University campus. The morphological and reproductive superiority in them can also be ascribed to sufficient level of mineral nutrients.

The higher contents of photosynthetic pigments, enhanced photosynthetic rate and maximum accumulation of organic constituents in both the invasive weeds may be dependent upon the higher content of different minerals as they have pivotal role in the above mentioned processes. The higher status of nitrogen might be contributing to higher contents of proteins and free amino acids in them. In addition the higher nitrogen content may also be responsible for luxuriant vegetative growth observed in these weeds. The role of potassium which is quite higher in these weeds is crucial for stress tolerance. The micronutrients like Zn²⁺, Cu²⁺ and Mn²⁺ are important cofactors for the different metabolic and enzymatic reactions in the plants.

The overall results on analyses of mineral constituents of selected invasive weeds have clearly explained the reasons of dominance, luxuriant growth, and stress tolerance in *Alternanthera* and *Euphorbia*. The macro and micronutrients existing in both the invasive weeds might be responsible for stimulated synthesis of different types of primary and secondary metabolites including allelochemicals providing inhibitory potential to both the invasive weeds, which thereby dominate the native weed species and establish themselves successfully in the university campus.

Measurement of pH and Electrical (ionic) conductivity of soil solution and leaf solutions

Results

The results recorded on pH and EC (Table 4) in rhizosphere soil and leaf solutions of both the invasive weeds *Alternanthera* and *Euphorbia* revealed that pH range was between 6.37 and 7.40, which was almost near to the neutral. While range of electrical (ionic) conductivity (EC) was between 0.12 and 4.69 ds m⁻³.

Table 1: Mineral constituents of rhizosphere soil and the leaves of *Alternanthera tenella* and *Euphorbia geniculata*

S. No.	Mineral elements	Leaves - ALT	Leaves - EUG	Soil - ALT	Soil - EUG
		Mean + SD			
1	pH	6.37 ± 0.63	6.42 ± 0.46	6.74 ± 0.47	7.40 ± 0.22
2	EC ds m ⁻³	4.38 ± 0.28	4.69 ± 0.73	0.13 ± 0.009	0.12 ± 0.004
3	Fe ²⁺ ppm	7.82 ± 0.59	35.80 ± 2.69	6231.00 ± 467.33	2476.60 ± 185.75
4	Mg ²⁺ ppm	605.5 ± 39.36	379.9 ± 24.69	1309.5 ± 85.12	901.00 ± 58.57
5	K ⁺ ppm	1640.00 ± 90.20	480.0 ± 26.40	63.75 ± 3.51	107.5 ± 5.91
6	Ca ²⁺ ppm	910.78 ± 86.52	1215.51 ± 115.47	379.36 ± 36.04	1485.92 ± 141.16
7	Al ³⁺ ppm	2.52 ± 0.25	21.1 ± 0.84	1.811 ± 0.18	1633.7 ± 163.37
8	Mn ²⁺ ppm	2.80 ± 0.22	3.15 ± 0.25	652.12 ± 52.17	74.14 ± 5.93
9	Zn ²⁺ ppm	1.64 ± 0.11	1.69 ± 0.11	9.34 ± 0.61	10.30 ± 0.67
10	BO ₃ ³⁻ ppm	0.58 ± 0.03	0.53 ± 0.03	4.68 ± 0.26	2.984 ± 0.16
11	PO ₄ ³⁻ ppm	138.43 ± 7.61	104.68 ± 5.76	447.87 ± 24.63	368.87 ± 20.29
12	NO ₃ ⁻ ppm	9.06 ± 0.82	14.84 ± 1.34	8947.36 ± 805.26	7187.5 ± 646.88

ALT: *Alternanthera tenella*; EUG: *Euphorbia geniculata*

Table 2: Mineral constituents of the leaves of invasive and native weeds

Mineral elements	ALT	EUG	BOD	ACH
Fe ²⁺ ppm	17.816 ± 0.59	35.802 ± 2.69	15.00 ± 0.87	17.00 ± 0.95
Mg ²⁺ ppm	605.5 ± 39.36	379.9 ± 24.69	126.87 ± 17.4	312.00 ± 18.00
K ⁺ ppm	1640.00 ± 90.20	480.0 ± 26.40	0.65 ± 0.04	1.80 ± 0.17
Ca ²⁺ ppm	910.78 ± 86.52	1215.51 ± 115.47	27.13 ± 0.64	62.66 ± 12.85
Al ³⁺ ppm	2.52 ± 0.25	21.1 ± 0.84	-	-
Mn ²⁺ ppm	2.80 ± 0.22	3.15 ± 0.25	1.80 ± 0.69	3.4 ± 0.83
Zn ²⁺ ppm	1.64 ± 0.11	1.69 ± 0.11	1.29 ± 0.1	1.34 ± 0.07
BO ₃ ³⁻ ppm	0.58 ± 0.03	0.53 ± 0.03	0.53 ± 0.02	0.87 ± 0.03
PO ₄ ³⁻ ppm	138.43 ± 7.61	104.68 ± 5.76	3.00 ± 0.27	5.00 ± 0.33
NO ₃ ⁻ ppm	9.06 ± 0.82	14.84 ± 1.34	0.44 ± 0.044	0.57 ± 0.045

ALT: *Alternanthera tenella* Colla.; EUG: *Euphorbia geniculata* Orteg.; BOD: *Boerhaavia diffusa* L.; ACH: *Achyranthes aspera* L.

Table 3: Comparison of minerals of invasive and native weeds with their occurrence

Weed species	Frequency %	Fe ²⁺ ppm	Mg ²⁺ ppm	K ⁺ ppm	Ca ²⁺ ppm	Al ³⁺ ppm	Mn ²⁺ ppm	Zn ²⁺ ppm	BO ₃ ³⁻ ppm	PO ₄ ³⁻ ppm	NO ₃ ⁻ ppm
ACH	60 ± 10	17.00 ± 0.95	312.0 ± 18.0	1.80 ± 0.17	62.66 ± 12.8	-	3.4 ± 0.8	1.34±0.07	0.87 ± 0.03	5.00 ± 0.33	0.57 ± 0.04
*ALT	83.33 ± 5.77	17.81 ± 0.59	605.5 ± 39.36	1640.0 ± 90.20	910.78 ± 86.52	2.52 ± 0.2	2.80 ± 0.22	1.64 ± 0.11	0.58 ± 0.03	138.43 ± 7.61	9.06 ± 0.82
BOD	43.33 ± 5.77	15.00 ± 0.87	126.8 ± 37.4	0.65 ± 0.04	27.13 ± 0.64	-	1.80 ± 0.6	1.29 ± 0.1	0.53 ± 0.02	3.00 ± 0.27	0.44 ± 0.04
*EUG	76.67 ± 15.28	35.80 ± 2.69	379.9 ± 24.6	480.0 ± 26.40	1215.5 ± 115.4	21.1 ± 0.8	3.15 ± 0.25	1.69 ± 0.11	0.53 ± 0.03	104.68 ± 5.76	14.84 ± 1.34

*Invasive weeds: ALT: *Alternanthera tenella* Colla.; EUG: *Euphorbia geniculata* Ort

Native weeds: BOD: *Boerhaavia diffusa* L.; ACH: *Achyranthes aspera* L.

Table 4: pH and conductivity leaf extracts and rhizosphere soils of *Alternanthera* and *Euphorbia*

Tests	<i>Alternanthera</i>	<i>Euphorbia</i>
p ^H	6.37 ± 0.38	7.40 ± 0.53
EC ds m ⁻³	0.12 ± 0.06	4.69 ± 0.17

Discussion

The availability of these nutrients for weeds from the rhizosphere soil was normal as the pH range was also normal. The nutrients' availability is reduced at highly acidic as well as highly alkaline pH of the soil, which is not the case of rhizosphere soil of all the weeds^{20,33}.

The pH and EC of any solution decide the dissociation of the molecules and their free movement in the cells³⁴. They may affect the membrane permeability to both cations and anions, and may bring about disruption of the ion gradient. They may further interfere with membrane impermeability, exocytosis, pinocytosis, catalysis and signaling^{35,36}. Osmotic effects of plant extracts can distort the biological responses. The acidic pH and EC of *Pouteria torta* extracts have affected the allelopathic activity³⁷. The pH and EC of solutions of *Alternanthera* and *Euphorbia* might be playing role in different biological processes of themselves and recipient plants. The work on leachates of forest plants like *Ageratina* and *Catunaregam*

supported the above findings³⁸. The direct correlation of pH and EC of plant solutions with their phytotoxicity and allelopathic activity has also been demonstrated^{39,40}.

CONCLUSION

The overall results on analyses of mineral constituents of selected invasive weeds have explained to some extent the reasons for dominance, luxuriant growth, and stress tolerance in *Alternanthera* and *Euphorbia*. The macro and micronutrients existing in both the invasive weeds might be responsible for stimulated synthesis of different types of primary and secondary metabolites including allelochemicals providing inhibitory potential to both the invasive weeds, which thereby dominate the native weed species and establish themselves successfully in the university campus.

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