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RESEARCH ARTICLE

Occurrence and distribution of *Alternanthera bettzickiana* (Regel) Voss., an invasive weed in the uplands of Kerala

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ABSTRACT

A survey was conducted in the uplands (or garden lands) along roadsides, uncultivated areas and in wastelands in seven agro-ecological units (AEUs) representing the central zone of Kerala during 2020 and 2021 to assess the occurrence and invasiveness of *Alternanthera bettzickiana* (Regel) Voss. The weed exhibited highest summed dominance ratio and importance value index in all but one of the AEUs. Diversity indices like Shannon-Wiener index, Simpson's diversity index and Evenness index were lower for a particular region (AEU 9), showing the dominance of this weed species there. The density of *A. bettzickiana* was positively correlated with nitrogen content, and dry matter production was influenced by both organic carbon and nitrogen content of the soil. The study concluded that *A. bettzickiana* is gaining the status of problematic weed in the central parts of Kerala, dominating mostly in uncultivated areas with occational occurrence observed in cropped lands also. Hence, efforts to prevent its spread need to be taken up by concerned authorities.

Keywords: *Alternanthera bettzickiana*, Distribution, Dominance, Invasive weed, Survey

INTRODUCTION

Biological invasion by plants, insects and mammals is a global concern due to the environmental, ecological and economic issues caused by them and is considered as the second worst threat to biological diversity after habitat fragmentation. Among these, invasive plants are a major threat to global agricultural production. An invasive plant species is deliberately or unintentionally introduced into an area outside its natural habitat, which alters the native biological diversity. Such plants expand into the native plant communities and quickly broaden their spatial distribution (Richardson *et al.* 2000). They possess various biological and physiological characteristics that favor their invasiveness, including the capability to produce large number of minute light weight seeds which aid in rapid dispersal, higher competitive ability, lack of seed dormancy, absence of natural enemies, release of allelopathic chemicals and greater physiological adaptability to new environments (Shah *et al.* 2020).

Alternanthera bettzickiana (Regel) Voss. is a spreading perennial herb, which is acquiring the status of an invasive weed in many parts of the world. It belongs to the family Amaranthaceae and is commonly known as calico plant. It has its origin in tropical America and now successfully inhabited various parts of Asia. In India, it is found throughout the plains, degraded deciduous forests and wastelands in the southern and north-eastern states, especially in Kerala, Karnataka, Tamil Nadu and Assam (Rao *et al.* 2019). Rapid spreading behavior of this weed often causes alteration of species structure of plant communities in the invaded areas (Thangamani *et al.* 2019). *A. bettzickiana* is now appearing as a major weed in vegetable, fruits and tuber growing areas, and also in unutilized lands in Kerala. Since it has started gaining attention only recently, systematic studies on the extent of its wide occurrence in Kerala have not been attempted. Hence a survey was conducted to study the occurrence and the extent of distribution of *A. bettzickiana* in the central zone of Kerala.

MATERIALS AND METHODS

A survey was conducted in the central zone of Kerala which includes Agro- Ecological Units (AEUs) 5, 6, 9, 10, 11, 15 and 22 covering Malappuram, Palakkad, Thrissur and Ernakulam districts (**Figure 1**). The survey was conducted from October to December in 2020 and 2021 in the uplands or garden lands where water stagnation did not occur. The wetlands, where rice is cultivated, were not included in the survey. Quadrats of size 0.5 x 0.5 m were placed randomly in uncultivated lands

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including road sides and wastelands of each location of the surveyed areas. Cropped lands were observed for the incidence of the weed but no data regarding density and dominance of weed were recorded. Locations for survey within AEUs were randomly selected and a total of 20 quadrats were sampled at each AEU. Within each quadrat, the number of *A. bettzickiana* and other weed species were recorded separately and various measures indicating weed abundance like density, relative density, frequency, relative frequency, relative abundance, summed dominance ratio and importance value index were worked out for each species as per the standard methods proposed by Misra (1968), Odum (1971) and Raju (1977). Weed survey data of both the years was pooled for each locality. Plants of *A. bettzickiana* and soil samples were collected from each location. The data presented here pertains to uncultivated areas of surveyed AEUs. General climatic parameters like mean annual temperature, annual rainfall and soil type are depicted in **Table 1** and surveyed locations are depicted in **Figure 1.**

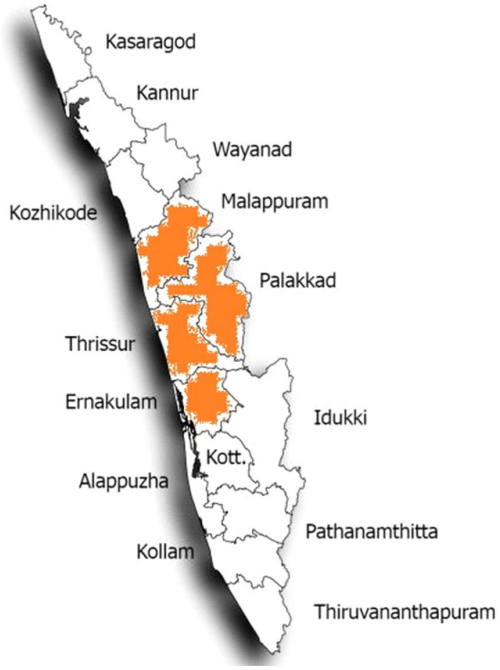

Figure1. Representation of surveyed locations

Table 1. Climatic parameters and soil types of surveyed AEUs

Agro-ecological unit	Mean annual temperature (°C)	Rainfall (mm)	Soil type
AEU 5	27.6	3,049	Sandy loam
AEU 6	27.8	2,902	Gravelly clay
AEU 9	26.5	2,827	Laterite soil
AEU 10	27.6	2,795	Gravelly clay
AEU 11	27.9	3,006	Gravelly clay
AEU 15	26.2	3,460	Acidic clay soil
AEU 22	27.6	1,196	Non gravelly loams

(KAU 2020)

Community diversity indices of the surveyed areas like species richness (R: total number of species in a given area), Shannon-Wiener diversity index (H'), Simpson's diversity index (C), Simpson's dominance index (C') and Evenness index (J) were worked out using following equations

$$\text{Shannon's diversity index } H' = -\sum_{i=1}^{K} Pi\ lnPi$$

$$\text{Simpson's diversity index } (C) = \sum_{i=1}^{K} Pi^{2}$$

$$\text{Simpson's dominance index } (C') = 1 - \sum_{i=1}^{K} Pi^{2}$$

$$\text{Evenness index} = \mathrm{H'} / \log \mathrm{R}$$

Where, Pi is the proportion of number of individuals of species 'i' to the total number of individuals of all species in the quadrat (K)

Chemical characteristics of the soil samples (pH, EC, available nitrogen, phosphorus and potassium) collected from surveyed locations were analyzed using standard procedures. A correlation analysis between densities of *A. bettzickiana* and soil characters was performed.

RESULTS AND DISCUSSION

Phytosociological indices indicated that *A. bettzickiana* was a dominant weed in all the surveyed areas except in AEU 5 which is a part of Ernakulam district. A total of 15 weed species were observed in uncultivated lands of AEU 5 and 9, 21 in AEU 6 and 10, 23 in AEU 11 and 17 each in AEU 15 and 22. In majority of these areas *A. bettzickiana* recorded highest density, frequency, relative density, relative frequency, importance value index and summed dominance ratio. Broad-leaved weeds *Synedrella nodiflora*, *Ageratum conyzoides*, *Cleome burmanii* and *Mitracarpus hirtus*, grasses like *Cynodon dactylon* and *Dactyloctenium aegyptium*, and the sedge *Cyperus rotundus* were also found to be dominant.

Lowest density of *A. bettzickiana* was recorded in AEU 5 (2.6 plants/ m^2) which covered parts of Ernakulam district and highest (5.1 plants/ m^2) was recorded in AEU 9 and 10 (**Table 2**) in the districts of Ernakulam and Palakkad. Various factors like season of the year, climate, soil texture and structure, soil chemical characters *etc*. influence the density of a weed species in an area (Bukun and Guler 2005). Difference in density of *A. bettzickiana* at various locations observed in this survey may be due to the variation of soil in organic carbon content and soil nutrient status (**Table 7**).

Table 2. Density and frequency of weed species observed in surveyed locations

Weed species	Density (no./m^2)							Frequency (%)						
	AEU							AEU						
	5	6	9	10	11	15	22	5	6	9	10	11	15	22
Aerva lanata	-	-	0.2	-	0.4	-	0.5	-	-	10.0	-	15.0	-	15.0
Ageratum conyzoides	1.3	-	1.2	1.6	-	2.2	1.3	47.5	-	47.5	45.0	-	57.5	37.5
Alternanthera bettzickiana	2.6	4.4	5.1	5.1	4.5	5.0	4.5	62.5	82.5	82.5	75.0	80.0	80.0	80.0
Alternanthera brasiliana	-	0.5	-	-	-	-	-	-	15.0	-	-	-	-	-
Axonopus compressus	-	-	-	0.4	0.8	-	-	-	-	-	15.0	30.0	-	-
Bidens pilosa	-	-	0.7	-	-	1.6	-	-	-	25.0	-	-	50.0	-
Biophytum sensitivum	1.3	0.7	-	-	0.7	-	0.9	35.0	20.0	-	-	20.0	-	27.5
Borreria hispida	-	-	-	-	-	2.1	-	-	-	-	-	-	40	-
Brachiaria distachya	-	-	0.9	-	-	-	-	-	-	30.0	-	-	-	-
Cardiospermum helicacabum	-	2.0	-	-	0.7	-	-	-	65.0	-	-	20.0	-	-
Centrosema pubescens	-	0.4	-	0.4	0.3	-	0.5	-	15.0	-	15.0	10.0	-	30.0
Chromolaena odorata	-	-	-	-	0.2	0.3	0.7	-	-	-	-	10.0	20.0	25.0
Cleome burmannii	-	0.8	0.5	1.3	1.2	0.8	-	-	32.5	22.5	45.0	37.5	35.0	-
Colocasia esculenta	0.7	-	-	-	-	-	-	40.0	-	-	-	-	-	-
Commelina sp.	-	-	-	0.5	0.8	0.6	1.2	-	-	-	15	25.0	22.5	40.0
Cyclea peltata	-	-	-	0.2	-	-	-	-	-	-	-	15.0	-	-
Cynodon dactylon	2.4	2.2	1.3	2.6	1.9	3.8	1.6	52.5	47.5	42.5	50.0	50.0	75.0	42.5
Cyperus iria	-	1.4	-	-	-	-	-	-	35.0	-	-	-	-	-
Cyperus rotundas	1.9	1.5	1.1	1.4	1.7	2.1	1.3	55.0	42.5	37.5	50.0	42.5	62.5	40.0
Dactyloctenium aegyptium	2.6	-	2.0	1.9	0.8	1.1	1.5	55.0	-	50.0	47.5	17.5	40.0	42.5
Digitaria sanguinalis	1.4	1.0	-	1.2	-	-	1.0	42.5	25	-	30.0	-	-	30.0
Eragrostis tenella	-	-	-	-	1.1	-	-	-	-	-	-	20.0	-	-
Euphorbia hirta	-	-	-	-	0.3	0.5	-	-	-	-	-	15.0	20.0	-
Hemidesmus indicus	0.8	-	-	0.8	-	-	-	52.5	-	-	25.0	-	-	-
Ischaemum indicum	-	0.5	-	1.3	0.7	-	0.9	-	15	-	30.0	15.0	-	27.5
Leucas aspera	-	0.5	-	-	-	-	-	-	15	-	-	-	-	-
Ludwigia parviflora	-	1.9	0.4	-	-	-	-	-	35.0	10.0	-	-	-	-
Melochia corchorifolia	-	-	-	0.5	-	-	-	-	-	-	25.0	-	-	-
Merremia vitifolia	-	-	-	-	-	-	0.3	-	-	-	-	-	-	15.0
Mikania micrantha	1.4	-	-	-	0.6	0.7	-	55.0	-	-	-	20.0	37.5	-
Mimosa invisa	-	0.6	-	-	-	0.5	-	-	20.0	-	-	-	25.0	-
Mimosa pudica	1.3	0.8	-	-	-	0.7	0.3	55.0	32.5	-	-	-	35.0	15.0
Mitracarpus hirtus	-	2.1	0.9	1.0	-	2.5	-	-	35.0	17.5	40.0	-	40.0	-
Mollugo verticillata	-	-	-	1.0	-	-	-	-	-	-	30.0	-	-	-
Paspalum distichum	-	0.5	-	-	0.7	-	-	-	15.0	-	-	20.0	-	-
Phyllanthus niruri	-	0.7	1.0	-	-	-	-	-	20.0	30.0	-	-	-	-
Pouzolzia zeylanica	-	-	-	-	2.2	-	-	-	-	-	-	50.0	-	-
Scoparia dulcis	1.0	-	-	0.9	0.8	-	-	45.0	-	-	32.5	15.0	-	-
Sida acuta	-	-	-	-	0.5	-	-	-	-	-	-	30.0	-	-
Sida rhombifolia	0.8	0.4	-	0.3	-	0.2	-	50.0	20.0	-	-	-	-	15.0
Sphagneticola trilobata	-	1.8	1.3	-	1.0	1.9	-	-	40.0	30.0	20.0	22.5	50.0	-
Synedrella nodiflora	3.4	3.7	2.9	3.2	3.1	3.4	2.3	67.5	70.0	72.5	62.5	65.0	67.5	60.0
Vernonia cineria	1.1	-	0.3	-	0.4	-	0.6	45.0	-	12.5	-	20.0	-	22.5

The frequency of *A. bettzickiana* ranged from 62.5% to 82.5% which indicated the wide distribution of the weed in the surveyed areas. *A. bettzickiana* was observed at a frequency of 50% in the pineapple plantations of Kerala spreading over the central districts of the state (Girija and Menon 2019). The highest frequency of 82.5% was found in AEU 6 which includes parts of Malappuram and Thrissur districts and AEU 9 in the district of Ernakulam and lowest value was in AEU 5 where *Synedrella nodiflora* was found to be the most frequently distributed species (67.5%) (**Table 2**).

The numerical strength of a species in a given community is indicated by relative density. Relative frequency points out the ecological importance of various species in a plant community and it is regarded as the degree of dispersion of a given species in relation to all the individuals occurring in an area (Travlos *et al*. 2018). Relative density and relative frequency of *A. bettzickiana* in surveyed areas ranged from 12.3% to 29.3% and 9.6% to 17.7% respectively, which was higher than other weed species of the observed communities. Girija and Menon (2019) reported 27% relative frequency for *A. bettzickiana* in the pineapple cultivating tracts of Kerala. Relative abundance was also found to be highest for *A. bettzickiana* in all the surveyed agro-ecological units except in AEU 5 where *Synedrella nodiflora* and *Cynodon dactylon* exhibited greater values (**Table 3**).

Importance value index (IVI) judges the overall significance of a species in a community since it is calculated using the relative abundance, relative frequency and relative density of an individual. The

Table 3. Relative density, Relative frequency and relative abundance of weed species observed in surveyed locations

Weed species	Relative density (%) AEU							Relative frequency (%) AEU							Relative abundance (%) AEU						
	5	6	9	10	11	15	22	5	6	9	10	11	15	22	5	6	9	10	11	15	22
Aerva lanata			1.3		1.6		2.5			2.1		2.4		2.7			5.0		3.1		6.3
Ageratum conyzoides	5.9	-	6.9	5.9	-	8.4	6.7	7.3	-	10.2	7.0	-	8.6	6.8	6.7	-	5.9	6.0	-	7.8	6.9
Alternanthera bettzickiana	12.3	17.7	29.3	19.5	17.8	19.1	23.4	9.6	13.0	17.7	11.8	12.5	12.1	14.5	10.6	9.1	14.5	11.1	7.2	12.3	11.2
Alternanthera brasiliana	-	1.8	-	-	-	-	-	-	2.3	-	-	-	-	-	-	4.2	-	-	-	-	-
Axonopus compressus	-	-	-	1.6	3.0	-	-	-	-	-	2.1	4.6	-	-	-	-	-	4.0	2.9	-	-
Bidens pilosa	-	-	3.8	-	-	7.1	-	-	-	-	-	-	8.1	-	-	-	-	-	-	7.0	-
Biophytum sensitivum	7.1	2.4	-	-	2.9	-	4.5	5.6	3.1	5.5	-	3.1	-	5.0	9.5	4.1	6.3	-	4.7	-	6.2
Borreria hispida	-	-	-	-	-	7.1	-	-	-	-	-	-	5.6	-	-	-	-	-	-	9.5	-
Brachiaria distachya	-	-	5.7	-	-	-	-	-	6.3	-	-	-	-	-	-	-	7.5	-	-	-	-
Cardiospermum helicacabum	-	7.1	-	-	2.6	-	-	-	9.9	-	-	3.1	-	-	-	3.8	-	-	4.2	-	-
Centrosema pubescens	-	1.5	-	1.4	1.0	-	2.8	-	2.3	-	2.1	1.5	-	5.5	-	3.4	-	3.5	3.2	-	3.6
Chromolaena odorata	-	-	-	-	0.8	1.3	-	-	-	-	-	1.5	3.3	-	-	-	-	-	2.6	3.3	-
Cleome burmannii	-	-	2.9	4.8	4.9	3.2	3.5	-	-	4.8	7.4	5.9	5.4	4.6	-	-	5.6	4.6	4.3	4.6	5.1
Colocasia esculenta	4.0	-	-	-	-	-	-	6.4	-	-	-	-	-	-	4.7	-	-	-	-	-	-
Commelina sp.	-	-	-	1.8	3.1	2.4	6.1	-	-	-	2.1	3.9	3.4	7.3	-	-	-	4.5	4.1	5.1	6.2
Cyclea peltata	-	-	-	0.8	-	-	-	-	-	-	2.1	-	-	-	-	-	-	2.0	-	-	-
Cynodon dactylon	11.8	9.3	7.2	10.3	7.6	14.7	8.0	8.0	7.6	9.2	7.1	7.8	11.3	7.7	12.0	7.7	6.9	7.6	4.9	10.1	7.6
Cyperus iria	-	4.9	-	-	6.9	-	-	-	5.3	-	-	6.6	-	-	-	4.9	-	-	5.3	-	-
Cyperus rotundas	-	6.2	6.6	5.5	3.1	8.1	6.9	-	6.8	8.1	7.1	2.8	9.4	7.3	-	6.1	7.0	4.0	5.8	6.8	6.6
Dactyloctenium aegyptium	12.2	-	12.7	7.2	-	3.7	8.0	8.4	-	10.4	7.3	-	5.6	7.7	11.9	-	10.0	6.2	-	5.0	7.4
Digitaria sanguinalis	6.7	3.6	-	4.5	-	-	5.0	6.5	3.8	-	4.7	-	-	5.5	8.3	5.0	-	6.4	-	-	6.4
Eragrostis tenella	-	-	-	-	4.2	-	-	-	-	-	-	3.0	-	-	-	-	-	-	6.7	-	-
Euphorbia hirta	-	-	-	-	1.2	2.1	-	-	-	-	-	2.3	3.1	-	-	-	-	-	2.6	6.0	-
Hemidesmus indicus	3.7	-	-	3.0	-	-	-	8.2	-	-	3.8	-	-	-	3.8	-	-	5.0	-	-	-
Ischaemum indicum	-	1.8	-	5.1	2.8	-	4.7	-	2.3	-	4.3	2.3	-	5.0	-	4.2	-	6.2	6.2	-	6.7
Leucas aspera	-	1.6	-	-	-	-	-	-	2.3	-	-	-	-	-	-	3.8	-	-	-	-	-
Ludwigia parviflora	-	6.7	1.8	-	-	-	-	-	5.3	2.2	-	-	-	-	-	6.7	7.6	-	-	-	-
Melochia corchorifolia	-	-	-	1.8	-	-	-	-	-	-	3.6	-	-	-	-	-	-	2.7	-	-	-
Merremia vitifolia	-	-	-	-	-	-	1.4	-	-	-	-	-	-	2.8	-	-	-	-	-	-	3.2
Mikania micrantha	6.6	-	-	-	2.2	2.6	-	8.4	-	-	-	3.2	5.7	-	6.8	-	-	-	3.5	3.6	-
Mimosa invisa	-	2.2	-	-	-	1.9	-	-	3.2	-	-	-	3.7	-	-	4.5	-	-	-	4.0	-
Mimosa pudica	6.2	3.4	-	3.9	-	2.9	1.7	8.5	5.2		5.7		5.4	2.7	6.0	4.4		3.5		4.1	4.4
Mitracarpus hirtus	-	7.7	5.0	6.4	-	8.5	-	-	5.3	3.8	5.3	-	5.6	-	-	7.6	11.7	8.5	-	11.3	-
Mollugo verticillata	-	-	-	3.9	-	-	-	-	-	-	4.7	-	-	-	-	-	-	5.7	-	-	-
Paspalum distichum	-	1.8	-	-	2.8	-	-	-	2.3	-	-	3.1	-	-	-	4.2	-	-	4.5	-	-
Phyllanthus niruri	-	2.6	5.4	3.5	-		-	-	3.1	6.5	5.0	-	-	-	-	4.4	7.3	4.4	-	-	-
Pouzolzia zeylanica	-	-	-	-	8.6	-	-	-	-	-	-	7.8	-	-	-	-	-	-	5.6	-	-
Scoparia dulcis	4.2	-	-	2.7	3.0	-	-	6.7	-	-	4.3	2.3	-	-	5.5	-	-	4.1	6.4	-	-
Sida acuta	-	-	-	-	1.8	-	-	-	-	-	-	4.5	-	-		-	-	-	1.9	-	-
Sida rhombifolia	3.8	1.5	-	1.2	-	-	1.0	7.7	3.1	-	2.9		-	2.7	4.0	2.5	-	2.2		-	2.8
Sphagneticola trilobata	-	7.2	6.5	-	3.9	7.2	-	-	6.3	6.7	-	3.5	7.5	-	-	7.4	9.1	-	5.5	7.5	-
Synedrella nodiflora	16.1	14.9	16.6	12.3	12.4	13.3	11.8	10.3	11.0	15.6	9.7	10.2	10.2	10.9	12.7	9.2	9.3	8.3	6.2	10.1	7.6
Vernonia cinerea	6.3	-	1.4	-	1.6	-	-	7.2	-	2.7	-	3.0	-	-	6.5	-	4.4	-	2.6	-	-

contribution of a weed species to the weed population of an area is represented by summed dominance ratio (SDR) (Bhager *et al*. 1999). Higher IVI (32.5 - 61.5) and SDR (10.8% - 20.5%) of *A. bettzickiana* (**Table 4**) in the surveyed areas indicated its dominance over other species. No prominent variation in the density, dominance and occurrence of *A. bettzickiana* and weed flora composition was observed across the years of survey.

Higher values of Shannon-Wiener diversity index (H'), Evenness index (J) and Simpson's diversity index (C) and lower value of Simpson's dominance index (C') indicates more diverse community with even distribution of various species. Dominance of a single species in a community causes reduction in the value of H', C and J and escalation of C' (Nkoa *et al*. 2015). Lower values of H' (2.01), C (0.85) and J (0.81) and higher value of C' (0.14) recorded in AEU 9 including portions of Ernakulam district indicated the domination of a single weed species, primarily *A. bettzickiana*, when compared to other surveyed areas. AEU 5, which had lowest density and frequency of *A. bettzickiana*, recorded highest evenness index (0.95), indicating more uniform distribution of various species in the observed community (**Table 5**). AEU 11 comprising parts of the Malappuram district, which possessed highest species richness of 23, recorded highest Simpson's diversity index and lowest dominance index.

Spatial variation in the infestation of a weed species depends upon the physical, chemical and biological properties of soil, along with climate and topography. Edaphic factors are more influential in explaining the dominance, relative abundance and growth of a weed species in an area (Lousada *et al*.

Table 4. Summed dominance ratio (SDR) and importance value index (IVI) of weed species observed in surveyed locations

Weed species	IVI AEU							SDR (%) AEU						
	5	6	9	10	11	15	22	5	6	9	10	11	15	22
Aerva lanata	-	-	8.4	-	9.6	-	11.6	-	-	2.8	-	2.4	-	3.9
Ageratum conyzoides	19.9	-	23.1	18.8	-	23.7	20.5	6.6	-	7.7	6.3	-	8.3	6.8
Alternanthera bettzickiana	32.5	39.8	61.5	42.4	29.9	36.8	49.1	10.8	13.3	20.5	14.1	12.5	14.5	16.4
Alternanthera brasiliana	-	8.3	-	-	-	-	-	-	2.8	-	-	-	-	-
Axonopus compressus	-	-	-	7.7	-	-	-	-	-	-	2.6	-	-	-
Bidens pilosa	-	-	15.6	-	-	14.6	-	-	-	5.2	-	-	4.7	-
Biophytum sensitivum	22.2	9.5	-	-	8.0	-	15.7	7.4	3.2	-	-	3.5	-	5.2
Borreria hispida	-	-	-	-	-	15.2	-	-	-	-	-	-	5.1	-
Brachiaria distachya	-	-	19.5	-	-	-	-	-	-	6.5	-	-	-	-
Cardiospermum helicacabum	-	20.8	-	-	12.4	-	-	-	6.9	-	-	3.6	-	-
Centrosema pubescens	-	7.1	-	7.0	4.7	-	11.8	-	2.4	-	2.3	1.9	-	3.9
Chromolaena odorata	-	-	-	-	4.1	6.6	-	-	-	-	-	1.6	2.6	-
Cleome burmannii		12.5	19.5	16.7	-	14.1	-	-	4.2	6.5	5.6	-	4.4	-
Colocasia esculenta	15.0	-	-	-	-	-	-	5.0	-	-	-	-	-	-
Commelina sp.	-	-	-	-	14.8	14.5	19.5	-	-	-	-	5.0	3.6	6.5
Cyclea peltata	-	-	-	8.4	-	-	-	-	-	-	2.8	-	-	-
Cynodon dactylon	31.8	24.6	23.3	4.9	11.1	30.9	23.3	10.6	8.2	7.8	1.6	3.7	12.0	7.8
Cyperus iria	-	15.1	-	-	-	-	-	-	5.0	-	-	-	-	-
Cyperus rotundas	24.6	19.1	21.6	16.6	20.5	21.6	20.8	8.2	6.4	7.2	5.5	6.8	8.1	6.9
Dactyloctenium aegyptium	32.5	-	33.2	20.7	18.2	10.6	23.1	10.8	-	11.1	6.9	6.3	4.8	7.7
Digitaria sanguinalis	21.5	12.5	-	15.6	-	-	16.9	7.2	4.2	-	5.2	-	-	5.6
Eragrostis tenella	-	-	-	-	13.3	-	-	-	-	-	-	3.9	-	-
Euphorbia hirta	-	-	-	-	9.7	16.6	-	-	-	-	-	4.6	3.8	-
Hemidesmus indicus	15.7	-	-	11.9	-	-	-	5.2	-	-	4.0	-	-	-
Ischaemum indicum	-	8.3	-	15.6	4.8	-	16.4	-	2.8	-	5.2	2.0	-	5.5
Leucas aspera	-	7.7	-	-	-	-	-	-	2.6	-	-	-	-	-
Ludwigia parviflora	-	18.8	11.7	-	-	-	-	-	6.3	3.9	-	-	-	-
Melochia corchorifolia	-	-	-	8.1	-	-	-	-	-	-	2.7	-	-	-
Merremia vitifolia	-	-	-	-	-	-	7.4	-	-	-	-	-	-	2.5
Mikania micrantha	21.7	-	-	-	11.0	11.9	-	7.2	-	-	-	2.9	4.0	-
Mimosa invisa	-	9.9	-	-	-	11.8	-	-	3.3	-	-	-	3.2	-
Mimosa pudica	20.7	12.9		13.1		13.1	8.8	6.9	4.3	-	4.4	-	4.1	2.9
Mitracarpus hirtus	-	20.6	20.5	20.2	-	17.0	-	-	6.9	6.8	6.7	-	8.5	-
Mollugo verticillata	-	-	-	14.3	-	-	-	-	-	-	4.8	-	-	-
Paspalum distichum	-	8.3	-	-	12	-	-	-	2.8	-	-	4	-	-
Phyllanthus niruri	-	10.0	19.2	12.9	-	-	-	-	3.3	6.4	4.3	-	-	-
Pouzolzia zeylanica	-	-	-	-	21.3	-	-	-	-	-	-	7.3	-	-
Scoparia dulcis	16.3	-	-	11.2	8.6	-	-	5.4	-	-	3.7	3.9	-	-
Sida acuta	-	-	-	-	6.4	-	-	-	-	-	-	2.7	-	-
Sida rhombifolia	15.6	7.0		6.3	-	-	6.5	5.2	2.3	-	2.1	-	-	2.2
Sphagneticola trilobata	-	20.9	22.3	-	12.9	22.4	-	-	7.0	7.4	-	4.3	7.4	-
Synedrella nodiflora	39.0	35.0	41.5	30.3	27.4	30.4	30.4	13.0	11.7	13.8	10.1	9.6	11.2	10.1
Vernonia cinerea	20.0	-	8.5	-	5.6	-	12.0	6.7	-	2.8	-	2.4	-	4.0

Table 5. Diversity indices of surveyed locations

Diversity indices	Agro ecological units (AEU)						
	5	6	9	10	11	15	22
Shannon-Wiener diversity index (H')	2.24	2.62	2.05	2.71	2.61	2.39	2.56
Simpson's diversity index (C)	0.91	0.92	0.85	0.92	0.92	0.90	0.87
Simpson's dominance index (C')	0.09	0.08	0.15	0.08	0.08	0.10	0.13
Evenness index (J)	0.95	0.86	0.81	0.90	0.86	0.89	0.90

Table 6. Characteristics of *A. bettzickiana* in the surveyed Agro ecological units (AEU)

AEUs	Shoot length (cm)	Leaf length (cm)	Leaf width (cm)	No. of flowers	No. of seeds/plant	Biomass (g/plant)
AEU 5	79.0	6.4	1.8	98.4	590.0	22.8
AEU 6	93.7	5.5	2.3	83.5	555.0	26.5
AEU 9	111.1	7.2	3.2	104	624.0	41.3
AEU 10	102.2	6.3	3.3	110	606.0	38.0
AEU 11	62.8	4.0	1.8	66.3	442.8	27.6
AEU 15	94.5	5.2	2.1	92.0	552.0	35.0
AEU 22	88.2	5.1	1.9	86.3	541.5	29.4

Table 7. Soil chemical properties in the surveyed AEUs

AEUs	pH	EC (dS/m)	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
AEU 5	5.68	0.11	0.60	135.0	48.2	115.2
AEU 6	5.81	0.21	0.89	170.5	54.1	178.6
AEU 9	5.64	0.24	1.29	313.2	89.5	167.0
AEU 10	5.75	0.18	1.60	326.5	39.1	225.5
AEU 11	6.01	0.16	0.76	203.4	30.3	262.0
AEU 15	5.86	0.25	0.98	273.0	76.7	194.0
AEU 22	5.77	0.17	0.68	195.0	26.0	158.5

2013). Morphological features of the weed showed slight variation with respect to locations surveyed (**Table 6**), indicating that there was only a single ecotype of the weed. Density of *A. bettzickiana* was correlated positively with all the studied soil properties, while only nitrogen content of the soil exhibited significant correlation (**Table 8**). Sandy loam soil type and relatively low organic C, available N and K contents could be related to the lowest density and frequency of *A. bettzickiana* in AEU 5 (**Table 7**). Weed biomass had significant positive correlation with organic carbon and nitrogen content of the soil. Plants belonging to Amaranthaceae family are efficient accumulators of nitrogen. Leaf nitrogen content of *A. bettzickiana* ranged from 1.6 to 2% while it was reported to be 2.4% in *Alternanthera philoxeroides* (Boyd 1968) and 2.8% in *Alternanthera tenella* (Patil and Kore 2015). This could be one of the possible reason for dense and dominant growth of the weed in nitrogen rich soils.

Table 8. Spearman's correlation coefficient for chemical properties of the soil in relation to density and biomass of *A. bettzickiana*

Soil parameters	Density of *A. bettzickiana*	Biomass g/plant
pH	0.198	-0.285
EC	0.753	0.579
Organic carbon	0.684	0.854*
Available nitrogen	0.818*	0.974*
Available phosphorus	0.276	0.551
Available potassium	0.608	0.271

Phytosociological and density indices obtained from the survey clearly indicated that *A. bettzickiana* had become a problematic dominating weed in the non-cultivated areas and waste lands in the central zone of Kerala with its abundant growth in soils with high organic carbon and nitrogen content. Its incidence has been noticed in various cropped areas also during the survey, pointing to its chance of becoming a major weed in crops, particularly vegetable, tuber and fruit crops, in future. *A. bettzickiana* thus becomes a serious weed threat in the upland cultivated areas of the state and warrants for the development and implementation of a comprehensive management strategy.

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