experimental findings clearly indicate that the higher age groups (yearlings) of IMC are able to resist artificial infection with *A. invadans* (whereas the same age groups of snakehead were susceptible).

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Weed floristic composition in palm gardens in Plains of Eastern Himalayan region of West Bengal

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Weeds are unwanted plants in the crop land that compete for nutrients, water and space. Proper knowledge about weed flora is important for their management. Weather conditions in sub-Himalayan West Bengal favour weed growth. Therefore, a study was conducted to find out the weed floristic composition of different palm gardens in this region. The results showed that dicots were predominant in the palm gardens. Maximum number of weeds was found in the oil palm gardens and the least in the fruiting arecanut gardens. A total of 20 angiosperm families were found in the study area. Among them, 17 belonged to dicots and three to monocots. A total of five pteridophytes were found. Members of Poaceae, Asteraceae, Oxalidaceae and Urticaceae were found in all the plots studied. Three species, viz. *Ageratum conyzoides*, *Oxalis corniculata* and *Vandelia* were found to be more widely distributed in all four palms as well as in fallow land, showing Shannon's index value >0.75. Prevalence of some weeds in all the study areas revealed that they can grow under any conditions.

Keywords: Control, plains, Eastern Himalayas, palm gardens, weeds.

WEEDS compete with other crops for water, nutrients and space. Weeds also act as alternate hosts for pests and diseases. The abundance or distribution of weed species in a cropped field varies due to the nature of the crop, cultural practices and cropping pattern/system, soil type, moisture availability, location and season. Knowledge of weed flora enables one to use the required herbicide and formulate other suitable management strategies. It is also useful in exploiting abundant weeds as a cover crop or pasture and for other economic uses. Extensive literature is available on weed flora dynamics in field crops[1–3], as well as on weed flora in palms grown as plantations[4,5], date palm[6,7], arecanut[8] and peach palm[9,10]. Control of weeds by hand-weeding or application of herbicides is essential for better crop yield. However, one should have a clear idea about the existence of different weed flora under the shade of different plantation crops like arecanut, coconut and oil palm. According to Derksen *et al.*[1], the study of weed dynamics is essential to formulate a management strategy for

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the cropping system in the Northern Great plains of Canada. The present investigation was carried out to find out weed floristic composition in palm gardens in the plains of the eastern Himalayan region, West Bengal.

The study was conducted at the CPCRI Research Centre, Mohitnagar located at 26°N lat., 88°E long., with a mean altitude of 91.3 m asl. Agro-ecologically, it is called the sub-Himalayan Terai region. It receives an annual rainfall of more than 4000 mm and maximum rainfall occurs between April (995 mm) and September (996.5 mm). The intensity of rainfall then gradually decreases up to October and there is only occasional rainfall during the rest of the year. The maximum and minimum temperature varies between 5.5 and 37°C. The soil is predominantly sandy loam of Teesta alluvial with a pH of 5.5–6.5. The area under study is cropped with arecanut, coconut and oil palms.

Five different areas, viz. those with coconut (*Cocos nucifera* L), oil palm (*Elaeis guineensis*, Jacq.), adult arecanut (*Areca catechu* L.) (more than 30-yr-old), prebearing arecanut garden (three-yr-old), and fallow land were selected for weed study. Oil palm, coconut and arecanut were planted at a spacing of 10 m × 10 m, 6 m × 6 m and 2.7 m × 2.7 m respectively. Adult oil palm was maintained at 20–25 leaf/palm. The study was conducted during September 2004, just after the rainy season. Quadrates of 10 sq. m area were laid down in different locations in a random manner. For each type of field, ten quadrates were included for weed study. Various species and the total number of individuals of each species were noted. Average data of ten replications/quadrate were considered for statistical analysis. Frequency, abundance, density (per sq. m) of the species noted were calculated using the formula by Sharma[11].

On the basis of per cent frequency values for each type of field, the various species were distributed into five frequency classes. Representation of each of the five frequency classes in the total number of species was calculated using the formula by Sharma[11].

The proportion (P_i) of occurrence of each species or each plot was used in each trait (i) and the Shannon–Weaver estimates[12] were worked out using the formula:

$$H' = -\sum_{i=1}^{n} P_i \log_2 P_i,$$

where n is the total number of species/plot, P_i is the proportion of individuals in the ith species/plot. The index value calculated is divided by $\log_2 n$ to get equivalence.

A similarity index has been worked out using the formula SI = $2C/(A + B)$[13], where C is the number of similar weed species occurring in palm garden/fallow land compared, A is the number of weed species occurring in the first plot and B is the number of weed species occurring in the second plot being compared.

Frequency, abundance and density of different weed species in different cropped areas as well as fallow land are given in Table 1. Forty-four weed species were found in different cropped areas as well as fallow land. The number and type of weed varied in different locations of the area under study. Maximum number of weeds was present in the fallow land (24), followed by oil palm (23), young arecanut – 3-yr-old (21), coconut field (15), and adult arecanut – fruiting stage (14). The number of weed species studied in this experiment revealed that the growth of different weed species depends on the canopy spread of plantation.

Among the 24 weed species in fallow land, maximum frequency of weed population (100%) was recorded for *Andropogon aciculate*, *Boreria alata*, *Brachiaria* sp., *Centella asiatica*, *Clerodendron infortunetum*, *Cyperus* spp., *Leucus aspera*, *Melastoma* sp. and *Oxalis corniculata*. About 90% frequency was recorded for *Cynodon dactylon*, *Desmodium trifoliatum*, *Ageratum conyzoides*, *Boraria* sp., *Cynodon dactylon* and *Imperata cylindrica.* In coconut field, *A. conyzoides*, *Borreria* sp., *Centella asiatica*, *Gnaphalium* sp., *O. corniculata*, *Solanum nigrum* and *Vandelia* sp. occurred with 100% frequency. Ninety per cent frequency was observed for *C. infortunetum*, *Dryopteris* sp., *I. cylindrica* and *Melastoma* sp. Weed cover of the adult arecanut garden was different from that of the other fields. Weeds like *Colocasia* sp., *Drymeria* sp. and *Stelaria media* were present only in the adult arecanut field. In the case of the oil palm field, maximum frequency (100%) of weeds like *A. conyzoides*, *Brachiaria* sp., *C. dactylon*, *D. trifoliatum*, *D. sanginalis*, *Rungia* sp. and *Spermacocci latifolia* was recorded. *I. cylindrica* and *Melastoma* sp. were found to have 90% frequency. Among oil palms, rubber and coconut plantations, pasture establishment and livestock establishment seem to be the best in coconut gardens due to the lack of competition for light between pasture grass/legume and coconut[14]. *A. conyzoides* and *O. corniculata* occurred in all the fields with different frequencies, revealing that they can grow in any situation irrespective of shade. The wild *Colocasia* sp. was found only in the arecanut field. *Drosera* sp., *Mimosa pudica*, *Pteridium* sp. and *Pteris* sp. were found only in fallow land, which indicates that they require full sunlight for their growth and development.

Figure 1 shows that about 37.93, 80 and 64.28% weeds were recorded at 81–100% frequency range in fallow, co

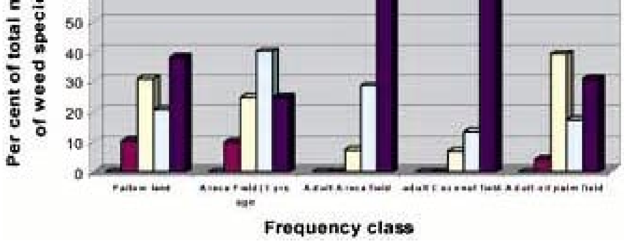

Figure 1. Per cent of total number of weed species in different fields.

Table 1. Different weed species and their frequency, abundance, density and diversity

Weed species	Fallow land			Juvenile arecanut field (3-yr-old)			Adult arecanut field			Adult coconut field			Oil palm field			Shannon's index
	F	A	D	F	A	D	F	A	D	F	A	D	F	A	D	
Ageratum conyzoides (A)	70	63.0	4.41	100	165.2	16.52	70	13.6	0.95	100	135.6	13.56	100	74.8	7.48	0.820
Andropogon aciculate (P)	100	351.5	35.15		–	–	–	–	–	–	–	–	70	44.9	3.14	0.176
Borreria alata (R)	100	50.1	5.01	100	25.0	2.50	–	–	–	100	29.9	2.99	60	5.16	0.31	0.716
Brachiaria sp. (C)	100	591.3	5.913	50	23.5	1.17	100	70.9	7.09	–	–	–	100	119.9	11.99	0.486
Centella asiatica (Ap)	100	60.3	60.3	60	35.83	2.15	–	–	–	100	16.9	1.69	80	13.0	1.04	0.721
Clerodendron infortunetum (V)	100	23.9	23.9	–	–	–	–	–	–	90	10.1	.91	70	6.9	0.48	0.556
Colocasia sp. (Ar)	–	–	–	–	–-	–	60	1.8	0.11	–	–	–	–	–	–	0.000
Cymbopogon citrates (P)	50	12.0	6.0	–	–	–	–	–	–	–	–-	–	–	–	–	0.000
Cynodon dactylon (P)	90	438.2	394.4	100	710.9	71.09	–	–	–	–	–	–	100	143.0	14.30	0.580
Cyperus spp. (C)	100	197.6	197.6	–	–	–	90	39.7	3.57	–	–	–	–	–	–	0.266
Desmodium trifoliatum (F)	90	113.5	102.2	70	103.3	7.23	–	–	–	–	–	–	100	101.2	10.12	0.675
Digitaria sanguilalis (P)	–	–	–	80	25.4	2.03	80	13.4	1.07	–	–	–	100	797.3	79.73	0.114
Drosera sp. (D)	60	59.5	35.7	–	–	–	–	–	–	–	–	–-	–	–	–	0.000
Drymeria sp. (Ca)	–	–	–	–	–	–	100	194.0	19.40	–	–	–	–	–	–	0.000
Dryopteris sp. (Pter)	60	23.66	14.2	–	–	–	–	–	–	90	38.1	3.43	50	27.0	1.35	0.444
Echinocloa colonum (P)	–	–	–	50	5.8	0.29	–	–	–	–	–	–	40	51.0	2.01	0.235
Elucine indica (P)	–	–	–	80	19.4	1.55	–	–	–	–	–	–	–	–	–	0.000
Emelia sonchifolia (A)	–	–	–	–	–	–	100	24.1	2.41	–	–	–	–	–	–	0.000
Euphorbia hirta (E)	80	27.87	22.3	80	29.8	2.38	–	–	–	–	–	–	–	–-	–	0.430
Gnaphalium sp. (A)	–	–	–	–	–	–	100	74.5	7.45	100	32.3	3.23	–	–	–	0.381
Hyptis sp. (L)	60	2.83	1.7	–	–	–	–	–	–	–	–	–	–	–	–	0.000
Imperata cylindrica (P)	60	166.5	99.9	100	393.6	39.36	–	–	–	90	36.7	3.30	90	79.3	7.14	0.614
Leucus aspera (L)	100	71.4	71.4	30	3.3	0.10	–	–	–	–	–	–	80	10.5	0.84	0.248
Lindenbergia sp. (S)	–	–	–	60	21.33	1.28	–	–	–	–	–	–	–	–	–	0.000
Lygodium sp. (Pter)	70	6.71	4.7	–	–	–	–	–	–	–	–	–	50	2.6	0.13	0.325
Melastoma sp. (M)	100	28.6	28.6	40	2.3	0.09	–	–	–	90	7.9	0.71	90	8.0	0.72	0.590
Micania micrantha (A)	30	6.0	1.8	50	2.6	0.13	–	–	–	–	–	–	50	3.0	0.15	0.677
Mimosa pudica (F)	60	10.33	6.2	–	–	–	–	–	–	–	–	–	–	–	–	0.000
Oxalis corniculata (O)	100	104.9	104.9	100	93.4	9.34	100	292.6	29.26	100	46.3	4.63	60	113.3	6.80	0.757
Pauzolgia sp. (U)	–	–	–	70	51.0	3.57	70	7.8	0.51	80	16.6	1.33	60	9.8	0.59	0.671
Polygonum aurantale (Po)	60	10.33	6.2	–	–	–	–	–	–	–	–	–	–	–	–	0.000
Pteridium sp. (Pter)	40	6.25	2.5	–	–	–	–	–	–	–	–	–	–	–	–	0.000
Pteris sp. (Pter)	30	1.33	0.4	–	–	–	–	–	–	–	–	–	–	–	–	0.000
Rungia sp. (Ac)	–	–	–	–	–	–	–	–	–	100	74.1	7.41	100	25.6	2.56	0.354
Saccharum spontaneum (P)	–	–	–	80	14.6	1.17	–	–	–	80	21.8	1.74	–	–	–	0.419
Scoparia dulsis (S)	80	10.75	8.6	60	3.5	0.21	–	–	–	–	–	–	–	–	–	0.308
Selaginella sp. (pter)	–	–	–	–	–	–	–	–	–	60	234.3	14.06	–	–	–	0.000
Solanum nigrum (So)	–	–	–	70	3.9	.27	70	7.3	0.51	100	11.6	1.16	–	–	–	0.580
Spermacocci latifolia (R)	70	13.85	9.7	–	–	–	100	15.4	1.54	–	–	–	100	19.7	1.97	0.658
Spilanthes sp. (*A*)	–	–	–	–	–	–	–	–	–	–	–	–	60	4.2	0.25	0.000
Stelaria media (*Ca*)	–	–	–	–	–	–	100	159.2	15.92	–	–	–	–	–	–	0.000
Triumfetta rhomboidea (*T*)	50	4.4	2.2	–	–	–	–	–	–	–	–	–	50	1.8	0.09	0.374
Vandelia sp. (*S*)	60	39.0	23.4	80	69.3	5.54	100	25.5	2.59	100	71.3	7.13	–	–	–	0.795
Vernonia cinera (A)	70	15.28	10.7	–	–	–	–	–	–	–	–	–	60	6.5	0.39	0.361
Shannon's index			0.645			0.488			0.515			0.618			0.468	

Abbreviation within bracket indicates the family of the weeds species (see Table 3).

Table 2. Weed species in different crop lands

	Fallow land	Juvenile arecanut garden	Adult arecanut garden	Adult coconut garden	Adult oil palm garden
Ageratum conyzoides	√	√	√	√	√
Andropogon aciculate	√	–	–	–	√
Borreria alata	√	√	–	√	√
Brachiaria sp.	√	√	√	–	√
Centella asiatica	√	√	–	√	√
Clerodendron infortunetum	√	–	–	√	√
Colocasia sp.	–	–-	√	–	–
Cymbopogon citrates	√	–	–	–	–
Cynodon dactylon	√	√	–	–	√
Cyperus spp.	√	–	√	–	–
Desmodium trifoliatum	√	√	–	–	√
Digitaria sanguilalis	–	√	√	–	√
Drosera sp.	√	–	–	–	–
Drymeria sp.	–	–	√	–	–
Dryopteris sp.	√	–	–	√	√
Echinocloa colonum	–	√	–	–	√
Elucine indica	–	√	–	–	–
Emelia sonchifolia	–	–	√	–	–
Euphorbia hirta	√	√	–	–	–
Gnaphalium sp.	–	–	√	√	–
Hyptis sp.	√	–	–	–	–
Imperata cylindrica	√	√	–	√	√
Leucus aspera	√	√	–	–	√
Lindenbergia sp.	–	√	–	–	–
Lygodium sp.	√	–	–	–	√
Melastoma sp.	√	√	–	√	√
Micania micrantha	√	√	–	–	√
Mimosa pudica	√	–	–	–	–
Oxalis corniculata	√	√	√	√	√
Pauzolgia sp.	–	√	√	√	√
Polygonum aurantale	√	–	–	–	–
Pteridium sp.	√	–	–	–	–
Pteris sp.	√	–	–	–	–
Rungia sp.	–	–	–	√	√
Saccharum spontaneum	–	√	–	√	–
Scoparia dulsis	√	√	–	–	–
Selaginella sp.	–	–	–	√	–
Solanum nigrum	–	√	√	√	–
Spermacocci latifolia	√	–	√	–	√
Spilanthes sp.	–	–	–	–	√
Stelaria media	–	–	√	–	–
Triumfetta rhomboidea	√	–	–	–	√
Vandelia sp.	√	√	√	√	–
Vernonia cinera	√	–	–	–	√

'√' Presence and '–' absence of weed species in respective fields.

conut and adult arecanut fields respectively, whereas in young arecanut gardens 40% weeds were in the 61–80% frequency range.

The density of the weed species varied considerably in the different fields. Maximum density of weed in fallow land was recorded for *Bracharia* (59.13) and minimum for *Pteris* sp. (0.4). In the arecanut field (3-yr-old), maximum density was recorded for *C. dactylon* (71.09) and minimum for *Melastoma* sp. (0.09), whereas in the adult arecanut field, maximum weed density was recorded for *O. corniculata* (29.26) and minimum for *Colocasia* sp. (0.11). In the coconut field, maximum density was recorded for *Selaginella* sp. (14.06) and minimum for *Melastoma* (0.71). In oil palm gardens, maximum weed density was recorded for *Digitaria sanguinalis* (79.73) and the minimum for *Triumfetta rhomboidea* (0.09).

Maximum abundance of different weed species in fallow land, young arecanut garden, adult arecanut, coconut and oil palm gardens was recorded as *C. dactylon* (438.2), *C. dactylon* (710.9), *O. corniculata* (292.6), *Selaginella* sp. (234.3) and *C. dactylon* (143.0) respectively, whereas minimum abundance was recorded as *Pteris* (1.33), *Melastoma* sp. (2.3), *Colocasia* sp. (1.8), *Melastoma* sp. (7.9) and *Triumfetta rhomboidea* (1.8), respectively.

Among the 44 weed species, only two (*A. conyzoides* and *Oxalis* sp.) were present in all the fields irrespective of the crops whereas, seven weeds (*Cymbopogon citrate*, *Drosera* sp., *Hyptis* sp., *M. pudica*, *Polygonum aurantale*, *Pteridium* sp. and *Pteris* sp.) were present in fallow land only (Table 2). This reveals the fact that full sunlight is an essential requirement for the growth of these seven weeds. *Pauzolgia* sp. was present in all the palm gardens but not in fallow land. Two weeds (*Elicine indica* and *Linderbergia* sp.) are specific to young arecanut gardens, whereas *Colocasia* sp., *Drymeria* sp., *Emelia sonchifolia* and *Stelaria medica* were present only in adult arecanut plantations. *Selaginella* sp. was present only in the coconut field and *Euphorbia hirta* and *Scoparia dulsis* were found only in young arecanut gardens and fallow land. *Cyprus* spp. was present only in the adult arecanut plantations and fallow land. *Spilantes* sp. was present in oil palm garden, but *Vandelia* sp. was absent in this garden. Weed species like *A. aciculate*, *Lygodium* sp., *T. rhomboidea* and *Vernonia cinera* were present only in adult arecanut plantations. Such weeds need to be observed in many palm gardens and their specific association needs to be understood by detailed investigations. It was observed that when weed species are grown under shade conditions, the plant part is soft when compared to those in open fields where the plant parts are relatively hardy.

Shannon's index of weed flora diversity was observed for oil palm (0.468) and young arecanut garden (0.488), whereas it was high in fallow land (0.645). In this study, coconut gardens have recorded high weed flora diversity (0.618) next only to fallow land (0.465). Of the 44 weed species in the study, 15 are limited in distribution among the systems investigated. They are shown in Table 1, with a Shannon's index value of 0. Only three species were found to be distributed at greater frequency in all four palms, except oil palm where *Vandelia* sp. was not found, as well as in fallow land which shows Shannon's index value >0.75. They are *A. conyzoides*, *O. corniculata* and *Vandelia* sp. These need special attention as general weeds in humid tropics in the palm gardens. *A. conyzoides* prevailed as the dominant weed species in glyphosate-treated peach palm gardens[9].

There are many reports on light penetration in canopies of different palm species. About 47.8% of light penetrates the canopy of adult arecanut palm, which is more than 50% of light penetration in young arecanut palm[15]. It is 43% in young coconut palm[16], and as low as 47–50% in oil palm gardens[17].

Reports on light penetration in palm canopies support our results. Oil palm gardens show a high similarity index (0.72) of weed flora (Table 3) with fallow land. As the oil palm canopy is able to use only 47–50% of light[17] the weeds are able to grow luxuriantly as in fallow land utilizing excess light. Weed flora in adult arecanut gardens was dissimilar (0.29) to that in fallow land as well as in oil palm gardens. This could be due to the low light availability in adult arecanut gardens[16]. The similarity index of weed flora in adult and juvenile arecanut regions was 0.42. This further supports the difference in light availability[16] in juvenile and adult arecanut palms which is as high as 50%.

Weed species distributed in different taxonomic groups are given in Table 4. As many as 17 families of dicots, three families of monocots and four members of pteridophytes were noticed during the study. Members of the families Droseraceae and Polygonaceae were present only in fallow land, while members of Araceae and Caryophyllaceae were found only in adult arecanut gardens. Members of Poaceae, Asteraceae, Oxalidaceae and Urticaceae were found in all the plots studied. Pteridophytes were present in fallow land, coconut and oil palm gardens. Dicots were dominant in all the plots studied. Among monocots, only Poaceae, Cyperaceae and Araceae were noticed in the study. Dicots dominated over monocots in all the study areas. High annual rainfall, fertile loamy soil of the

Table 3. Similarity index of weed species in palm gardens

Fallow land	Juvenile arecanut	Adult arecanut	Coconut	Oil palm
Fallow land	0.58	0.29	0.38	0.72
Juvenile arecanut		0.42	0.59	0.67
Adult arecanut			0.44	0.29
Coconut				0.56
Oil palm				

Table 4. Weed species of different botanical families in palm gardens under study

Family	Fallow land	Juvenile arecanut	Adult arecanut	Coconut	Oil palm
Monocotyledons	5	6	5	1	5
Araceae (Ar)	0	0	1	0	0
Cyperaceae (C)	2	1	2	0	1
Poaceae (P)	3	5	1	1	4
Dicotyledons	19	14	10	12	15
Acanthaceae (Ac)	0	0	0	1	1
Apiaceae (Ap)	1	1	0	1	1
Asteraceae (A)	3	2	3	2	4
Caryophyllaceae (Ca)	0	0	2	0	0
Droseraceae (D)	1	0	0	0	0
Euphorbiaceae (E)	1	1	0	0	0
Fabaceae (F)	2	1	0	1	1
Labiatae (L)	2	1	0	0	1
Melastomaceae (M)	1	1	0	1	1
Oxalidaceae (O)	1	1	1	1	1
Polygonaceae (Po)	1	0	0	0	0
Rubiaceae (R)	2	1	0	1	2
Scrophulariaceae (S)	2	3	1	1	0
Solanaceae (So)	0	1	1	1	0
Tiliaceae (T)	1	0	0	0	1
Urticaceae (U)	0	1	1	1	1
Verbenaceae (V)	1	0	0	1	1
Pteridophytes (Pter)	4	0	0	1	2
Total	28	20	13	14	22

Teesta valley, and the wide range of summer and winter temperatures favoured luxuriant dicot vegetation in the area. Monocots were found to be few in number in cropped area. The density of the monocots was almost universally low in the palm gardens than in fallow land, which indicates that the adaptability of monocots is more in fallow land than in cropped land.

Gopinathan Nair and Chami[4] found dicotyledons to be dominant in coconut gardens. Cyperaceae, Poaceae and Commmelinaceae are the major monocot families, and Asteraceae, Fabaceae and Rubiaceae are the predominant dicot families seen in coconut gardens. They also concluded that the weeds of the families Cyperaceae and Poaceae are the most troublesome. Souza *et al.*[10] found the plants of Poaceae, Euphorbiaceae, Fabaceae, Cyperaceae and Verbenaceae to be predominant weeds in Cupuacu and peach palm gardens.

The present investigation reveals that the different weed species can grow in different shade conditions and that their growth depends on the availability of sunlight along with other growth conditions. Prevalence of dicot weed species was higher in all conditions under study than that of the monocots. Restriction of some weed species to particular areas supports the fact that they require special conditions for growth, whereas the presence of some weeds in all the study areas shows that they can grow under varied light conditions.

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