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Role of juvenile traits for identification of some crop field dicotyledonous weeds in relation to their taxonomy and management

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Abstract

Seedling morphological traits of 74 dicotyledonous weeds of 64 genera under 30 families of angiosperms are studied in the crop fields of two subdivisions i.e. Barrackpur and Barasat in the district of North 24-Parganas of West Bengal. Conservative juvenile traits are considered for artificial key formation which is helpful for identification of weeds before flowering and fruiting. It is crucial for weed management program. All 74 seedling species are categorized into six seedling types based on nature, phyllotaxy and stipule of first two leaves. The families are arranged according to Takhtajan's system of classification (1997). This study also promotes importance of seedling features in determining inter-relationships among the taxa studied through PCA analysis. The seedling taxonomy is correlated with other botanical disciplines partly.

Keywords: Seedling morphology, artificial key, interdisciplinary approach, PCA analysis, Weed management.

Introduction

Weeds are one of the major significant threats to crop production with losses in crop yield and quality. Therefore, it brings a great economic impact for many farmers all over the world. Weeds compete with crops for nutrients, soil moisture, soil radiation and space; and reduce the yield and quality of produce[1]. It is reported that weeds cause yields loss overall 34% in the major crop fields like rice, maize, potatoes, soybean and cotton[2]. Most weeds germinate and established rapidly under favourable conditions. They also produce large no. of viable seeds even under environmental and soil conditions that are not favourable for the crop plants. Rapid and accurate weed identification at the seedling stage may be the first step towards a successful weed management program[3] because most of the weeds are effectively controlled at a very young stage, so it is important to identify them as early as possible[4].

Investigation of proper phenotypic traits of weed seedlings is the primary key for prominent weed identification leading towards suitable integrated weed management (IWM) program. In, Eastern India, it is the traditional method of farmers to kill mature existing weeds while already abundant mature viable seeds have been added to the soil[5]. These seeds may contain a hard seed coat and be resistant to different herbicides germinating in the next season. Therefore, before flowering and fruiting, the juvenile stage is the proper phase to prevent the manifestation of weeds. Hence, identification of weeds must be done at the seedling stage through appropriate keys constructed based on their constant conservative juvenile characters followed by some pioneer workers[3,5,6].

Survey of literatures reveals that there are some floristic works[7-11] on weeds in West Bengal as well as in the district North 24-Pargas. Even weed seedlings are studied by several workers [5,13,15]. But there is no work on seedlings in the crop field weeds in the district of North 24 Parganas, although this district possesses 2,39,000 hectares of vegetable crop fields from which major portion of vegetable crops Kolkata - a metropolitan city, gets. The two sub-divisions, Barrackpur and Barasat which are nearer to Kolkata, supply a vast amount of vegetables every day to Kolkata. Considering the weed manifestation problem, a strategy for the identification of weeds at the seedling stage to enforce the weed management programme of the above two blocks has been considered.

Materials and methods

74 crop field weed seedlings (Table-1) have been collected from different crop fields of Barrackpur-II (GPS coordinates of 22°46'2.7372" N and 88°23'18.0384" E) and Barasat-I (GPS coordinates 22°43'34.1616" N and 88°28'29.8560" E) of North 24 Parganas (latitude 22°11'6" N to 23°15'2" N and longitude from 88°20' E to 89° E with an aerial extent of 4094 sq. km.) district in southern West Bengal, India, throughout the year of 2020. Soil type varies from alluvial to clay loam as it falls within the Gangetic delta.

Collections have been made through repeated field visits and field photographs have been taken for documentation. All recorded specimens were examined and identified using standard literatures[14-29]. The mature seeds were also collected from the same crop fields and grown in the experimental garden of Bejoy Narayan Mahavidyalaya for identity confirmation.

Seedlings collected from crop fields as well as from experimental gardens have been documented in the form of herbarium sheets which are deposited in the herbarium section of the Department of Botany of the college. Mature weed plants were identified by various literatures[30-36]. At least 10 specimens were studied for each species of seedling from different crop fields. A list of taxa studied with the author's citation and photoplate figures have also been given (Table-1). The studied taxa are arranged according to Takhtajan's system[37] of classification-1997 (Table-1). An artificial key has been constructed for the identification of taxa at the juvenile stage, where 74 species are initially grouped under six types (Type-I to Type-VI) [38]. During the preparation of key for family and genera having a single species are kept in the parenthesis. Under each type, keys are made up of species-level identification.

For statistical analysis, all morphological characters are used where qualitative characters are being converted to numerical form. All the statistical tests are performed using Minitab 19 and SPSS ver. 20.0. The morphometric analysis is run through Principal Component Analysis (PCA) using the Varimax method to visualize the relationship among studied taxa and to select interrelated variables[13,39].

Results and discussion

All the studied taxa showed phenerocotylar type of seedlings. The distinctiveness of the juvenile traits helps to distinguish them on the natural habitats. These are taxonomically delimited at different ranks through an artificial key.

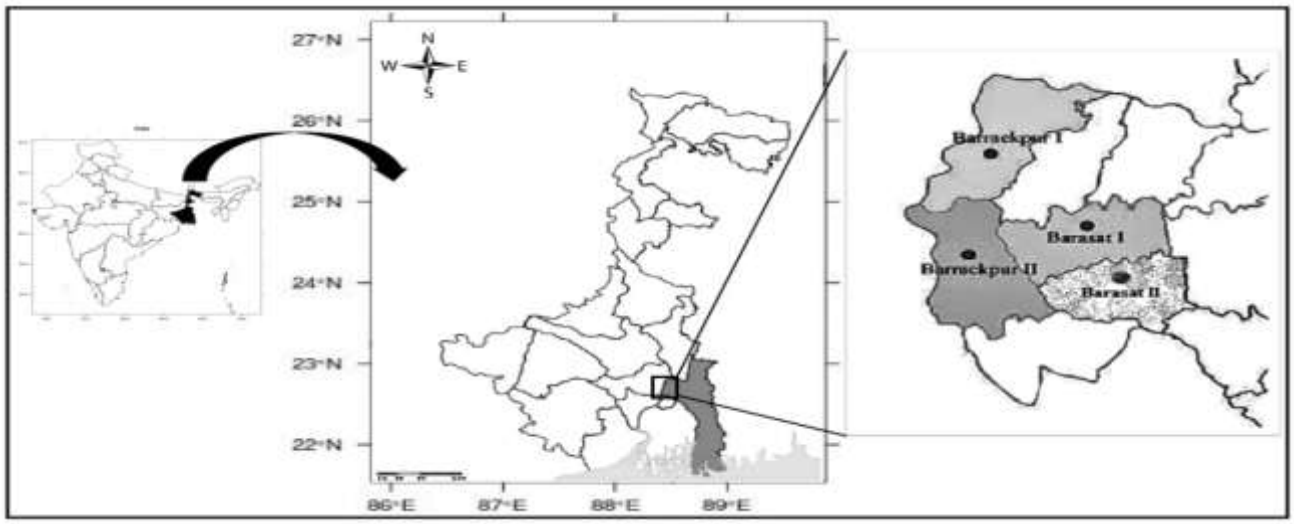

Figure-1: Study area.

Table-1: List of taxa studied with author's citation and photo plate figures.

Family	Sl. No.	Species	Plt. No.
Piperaceae	1	*Peperomia pellucida* (L.) Kunth	[Figure-4, fig.-A]
Ranunculaceae	2	*Ranunculus sceleratus* L.	[Figure-4, fig.-B]
Fumaraceae	3	*Fumaria indica* (Hausskn.) Pugsley	[Figure-4, fig.-C]
Nyctaginaceae	4	*Boerhavia diffusa* L.	[Figure-4, fig.-D]
Aizoaceae	5	*Trianthema portulacastrum* L.	[Figure-4, fig.-E]
Portulacaceae	6	*Portulacca oleracea* L.	[Figure-4, fig.-F]
Molluginaceae	7	*Glinus oppositifolius* (L.) Aug.DC.	[Figure-4, fig.-G]
Caryophylaceae	8	*Stellaria media* (L.) Vill.	[Figure-4, fig.-H]
	9	*Amaranthus viridis* L.	[Figure-4, fig.-I]

Amaranthaceae	10	*Amaranthus tenuifolius* Willd.	[Figure-4, fig.-J]
	11	*Alternanthera sessilis* (L.) R.Br. ex DC.	[Figure-4, fig.-K]
	12	*Achyranthes aspera* L.	[Figure-4, fig.-L]
Chenopodiaceae	13	*Chenopodium album* L.	[Figure-4, fig.-M]
	14	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	[Figure-4, fig.-N]
Polygonaceae	15	*Rumex dentatus* L.	[Figure-4, fig.-O]
	16	*Persiceria hydropiper* (L.) Delarbre	[Figure-4, fig.-P]
	17	*Polygonum plebeium* R.Br.	[Figure-4, fig.-Q]
Primulaceae	18	*Anagallis arvensis* L.	[Figure-4, fig.-R]
Cucurbitaceae	19	*Mukia scabrella* (L. f.) Arn.	[Figure-4, fig.-S]
	20	*Trichoxanthes cucumarina* L.	[Figure-5, fig.-A]
	21	*Coccinia grandis* (L.) Voigt	[Figure-5, fig.-B]
Capparaceae	22	*Cleome rutidosperma* DC.	[Figure-5, fig.-C]
	23	*Cleome viscosa* L.	[Figure-5, fig.-D]
Brassicaceae	24	*Cardamine flexuosa* With.	[Figure-5, fig.-E]
	25	*Rorippa palustris* (L.) Besser	[Figure-5, fig.-F]
Malvaceae	26	*Malvastrum coromandelianum* (L.) Garcke	[Figure-5, fig.-G]
	27	*Malachra capitata* (L.) L.	[Figure-5, fig.-H]
	28	*Urena lobata* L.	[Figure-5, fig.-I]
	29	*Sida cordata* (Burm.f.) Borss.Waalk.	[Figure-5, fig.-J]
	30	*Sida rhombifolia* L.	[Figure-5, fig.-K]
	31	*Corchorus aestuans* L.	[Figure-5, fig.-L]
Cannabaceae	32	*Cannabis sativa* L.	[Figure-5, fig.-M]
Urticaceae	33	*Pilea microphylla* (L.) Liebm.	[Figure-5, fig.-N]
	34	*Pouzolzia zeylanica* (L.) Benn.	[Figure-5, fig.-O]
Euphorbiaceae	35	*Euphorbia hirta* L.	[Figure-5, fig.-P]
	36	*Euphorbia serpens* Kunth	[Figure-5, fig.-Q]
	37	*Phyllanthus urinaria* L.	[Figure-5, fig.-R]
	38	*Phyllanthus fraternus* G.L.Webster	[Figure-5, fig.-S]

	39	*Croton bonplandianus* Baill.	[Figure-6, fig.-A]
	40	*Micrococca mercurialis* (L.) Benth.	[Figure-6, fig.-B]
	41	*Chrozophora plicata* (Vahl) A. Juss. ex Spreng.	[Figure-6, fig.-C]
	42	*Acalypha indica* L.	[Figure-6, fig.-D]
Fabaceae	43	*Senna tora* (L.) Roxb.	[Figure-6, fig.-E]
	44	*Senna sophera* (L.) Roxb.	[Figure-6, fig.-F]
	45	*Senna occidentalis* (L.) Link	[Figure-6, fig.-G]
	46	*Desmodium triflorum* (L.) DC.	[Figure-6, fig.-H]
	47	*Desmodium scorpiurus* (Sw.) Desv.	[Figure-6, fig.-I]
Oxalidaceae	48	*Oxalis corniculata* L.	[Figure-6, fig.-J]
Zygophyllaceae	49	*Kallstroemia pubescens* (G.Don) Dandy	[Figure-6, fig.-K]
Asteraceae	50	*Parthenium hysterophorus* L.	[Figure-6, fig.-L]
	51	*Eclipta prostrata* (L.) L.	[Figure-6, fig.-M]
	52	*Xanthium strumarium* L.	[Figure-6, fig.-N]
	53	*Ageratum conyzoides* (L.) L.	[Figure-6, fig.-O]
	54	*Tridax* procumbens (L.) L.	[Figure-6, fig.-P]
	55	*Synedrella nodiflora* (L.) Gaertn.	[Figure-6, fig.-Q]
	56	*Blumea lacera* (Burm.f.) DC.	[Figure-6, fig.-R]
Rubiaceae	57	*Spermacoce hispida* L.	[Figure-7, fig.-A]
	58	*Oldenlandia corymbosa* L.	[Figure-7, fig.-B]
Solanaceae	59	*Solanum americanum* Mill.	[Figure-7, fig.-C]
	60	*Nicotiana plumbaginifolia* Viv.	[Figure-7, fig.-D]
	61	*Physalis minima* L.	[Figure-7, fig.-E]
	62	*Solanum sisymbriifolium* Lam.	[Figure-7, fig.-F]
Convolvulaceae	63	*Evolvulus nummularius* (L.) L.	[Figure-7, fig.-G]
	64	*Ipomoea eriocarpa* R. Br.	[Figure-7, fig.-H]
Boraginaceae	65	*Heliotropium indicum* L.	[Figure-7, fig.-I]
Scorphulaceae	66	*Scoparia dulcis* L.	[Figure-7, fig.-J]
	67	*Mazus pumilus* (Burm.f.) Steenis	[Figure-7, fig.-K]

	68	*Mecardonia procumbens* (Mill.) Small	[Figure-7, fig.-L]
	69	*Lindenbergia indica* Vatke	[Figure-7, fig.-M]
	70	*Lindernia viscosa* (Hornem.) Merr.	[Figure-7, fig.-N]
Acanthaceae	71	*Ruellia tuberosa* L.	[Figure-7, fig.-O]
	72	*Ruellia prostrata* Poir.	[Figure-7, fig.-P]
Lamiaceae	73	*Leucas aspera* (Willd.) Link	[Figure-7, fig.-Q]
	74	*Hyptis suaveolens* (L.) Poit.	[Figure-7, fig.-R]

Systematic enumeration:
Artificial Key (Key is valid for the taxa studied only)

Key to the seedling types

1a. First two leaves simple……2
1b. First two leaves compound……5
2a. First two leaves sub-opposite to alternate……3
2b. First two leaves opposite……4
3a. First two leaves stipulate……Type-I
3b. First two leaves exstipulate……..Type-II
4a. First two leaves stipulate……Type-III
4b. First two leaves exstipulate……..Type-IV
5a. First two leaves sub-opposite to alternate……Type-V
5b. First two leaves opposite……Type-VI

Type-I
Key to the families

1a. Primary vein of paracotyledons one, venation hyphodromous; margin of first two leaves entire, primary vein one, venation camtodromous or hyphodromous……2
1b. Primary vein of paracotyledons three, venation actinodromous; margin of first two leaves serrate, dentate or crenulate, primary veins 3-7, venation actinodromous or acrodromous……Malvaceae
2a. Hypocotyl oblate; paracotyledons thick; paracotyledons and subsequent leaves with prominent purple border……Aizoiaceae (*Trianthema portulacastrum*)
2b. Hypocotyl terete; paracotyledons thin; paracotyledons and subsequent leaves with normal green border…....3
3a. Seedling with watery latex; stipule free lateral……Euphorbiaceae
3b. Seedling without watery latex; stipule ochreate……Polygonaceae

Key to the genus/ species
Malvaceae

1a. Paracotyledons ovate to widely ovate……2
1b. Paracotyledons elliptic to widely elliptic……4
2a. First two leaves with dentate margin……*Sida*
2b. First two leaves with serrate to crenate margin……3
3a. Venation of paracotyledons acrodromous; first two leaves orbicular, margin crenate, base reniform, apex mucronulate…..**.....***Malvastrum* (*M.coromandelianum*)
3b. Venation of paracotyledon actinodromous; first two leaves elliptic to shallowly trilobed, margin irregularly serrate, base cordate, apex obtuse…*Urena* (*U. lobata*)
4a. Base of paracotyledons obtuse, venation acrodromous; first two leaves ovate, base reniform, apex acute to obtuse, primary veins three….*Corchorus* (*C.aestuans*)
4b. Base of paracotyledons subtruncate to truncate, venation actinodromous; first two leaves orbicular, base cordate, apex subrounded to rounded, primary veins 5-7…….. *Malachra* (*M. capitata*)

Key to the species
Genus: *Sida*

1a. Base of paracotyledons subrounded, venation actinodromous; first two leaves with pilose hairs, blade broadly ovate, base cordate, apex acute, primary veins 5-7……..…..……..*S. cordata*
1b. Base of paracotyledons shallowly cordate, venation acrodromous; first two leaves with stellate hairs, blade rhombic to obovate, base cuneate, apex obtuse, primary veins three…….....*S. rhombifolia*

Euphorbiaceae
Key to the species
Genus: *Phyllanthus*

1a**.** Hypocotyl purple to purplish green, sparsely pubescent; paracotyledons sessile; eophylls papery, apex mucronulate; internode suppressed (0.5-1.5 mm), branching appeared after 6-12 leaf stages ……*P. urinaria*
1b. Hypocotyl green, glabrous; paracotyledons petiolate; eophylls herbaceous, apex rounded; internode 5-12 mm; branching appeared after 5th leaf stage……*P. fraternus*

Polygonaceae
Key to the species

1a. Paracotyledons sessile, oblance-falcate; first two leaves linear-oblanceolate…….....*Polygonum* (*P. plebeium*)
1b. Paracotyledons petiolate, ovate to ovate-elliptic; first two leaves ovate to elliptic- oblong…….....2
2a. First two leaves ovate, base sub-truncate, apex obtuse; subsequent leaves with toothed base and undulate margin…….*Rumex dentatus*
2b. First two leaves lanceolate, base alternate, apex acute; subsequent leaves entire margin……*Parsicaria hydropiper*

Type II
Key to the families
1a. First two leaves glabrous……..2
1b. First two leaves hairy……7
2a. First two leaves with single primary vein…….3
2b. First two leaves with 2-5 primary veins ……5
3a. Apex of first two leaves obtuse to rounded; venation hyphodromous; internode rounded.....4
3b. Apex of first two leaves emarginate, venation camptodromous; internode angular……Amaranthaceae
4a. Paracotyledons lanceolate, base cuneate, apex obtuse; first two leaves obovate, base cuneate; internode glabrous……Portulacaceae (*Portulaca oleracea*)
4b. Paracotyledons ovate, base sub-truncate, apex acute; first two leaves elliptic, base obtuse; internode puberulous…….Molluginaceae (*Glinus oppositifolius*)
5a. Hypocotyl light green to green, terete; paracotyledons thin, herbaceous; eophylls radical…….……6
5b. Hypocotyl translucent, angular; paracotyledons thick, fleshy; eophylls cauline……..Piperaceae (*Peperomia pellucida*)
6a. Paracotyledons widely elliptic to elliptic, apex retuse to emarginate; subsequent leaves lyrate……Brassicaceae
6b. Paracotyledons lanceolate, apex acute; subsequent leaves deeply trilobed…….Ranunculaceae (*Ranunculus sceleratus*)
7a. Seedling with latex……..Euphorbiaceae
7b. Seedling without latex……..8
8a. Hypocotyl hollow (exception *Evolvulus nummularius*)…….……9
8b. Hypocotyl solid…….10
9a. Paracotyledons thin, herbaceous…....Convolvulaceae
9b. Paracotyledons thick, fleshy……Cucurbitaceae
10a. Paracotyledons sessile, leaf base sheathing; first two leaves with base subsessile, sheathing; subsequent leaves compound……Fumariaceae (*Fumaria indica*)
10b. Paracotyledons petiolate, leaf base simple; first two leaves petiolate, not sheathing; subsequent leaves simple…….11
11a. Subsequent leaves with base asymmetrical or oblique (exceptions *Nicotiana plumbaginifolia*)……Solanaceae
11b. Subsequent leaves with base symmetrical……12
12a. Texture of first two leaves coriaceous…….……....Chenopodiaceae
12b. Texture of first two leaves herbaceous……13
13a. First internode angular……..……....Boraginaceae (*Heliotropium indicum*)
13b. First internode terete ……..Asteraceae

Key to the genus/ species
Amaranthaceae
Key to the species
Genus: *Amaranthus*
1a. Paracotyledons linear; first two leaves oblance-lanceolate, base attenuate; internode quadrangular……*Amaranthus tenuifolius*
1b. Paracotyledons lanceolate; first two leaves ovate, base obtuse; internode penta to hexangular…..*Amaranthus viridis*

Brassicaceae
Key to the species
1a. Base of paracotyledons obtuse, apex retuse; first two leaves shallowly trilobed, base minutely reniform; venation actinodromous .....*Cardamine flexuosa*
1b. Base of paracotyledons cuneate, apex emargnate; first two leaves elliptic to rectangular; venation camptodromous……*Rorripa palustris*

Euphorbiaceae
Key to the species
1a. Hypocotyl reddish-orange; paracotyledons coriaceous, blade elliptic-oblong, apex rounded, primary vein one, venation hyphodromous; apex of first two leaves acute……*Croton bonplandianus*
1b. Hypocotyl purplish; paracotyledons herbaceous, blade narrowly oblong, apex obtuse, primary veins three, venation acrodromous; apex of first two leaves obtuse……..…..*Crozophora plicata*

Convolvulaceae
Key to the species
1a. Hypocotyl fistulose; paracotyledons bilobed, each lobe apex obtuse, base cordate, primary veins five, venation actinodromous; first two leaves cordate, base cordate, primary veins five, venation campylodromous; first internode glabrous……..*Ipomea eriocarpa*
1b. Hypocotyl terete; paracotyledons oblong, apex retuse, base obtuse, primary vein one, venation camptodromous; first two leaves elliptic, base subrounded, primary vein one, venation camptodromous; first internode hairy ……..……..*Evolvulus nummularius*

Cucurbitaceae
Key to the species
1a. Paracotyledons sessile, venation hyphodromous; first two leaves palinactinodromous……*Trichosanthes cucumerina*
1b. Paracotyledons petiolate, venation brochiododromous, first two leaves actinodromous……...2

2a. Hypocotyl glabrous; apex of first two leaves retuse, margin regularly dentate; internode pubescent ……*Coccinia grandis*
2b. Hypocotyl hairy; apex first two leaves obtuse, margin irregularly dentate; internode hispid …*Mukia scabrella*

Solanaceae
Key to the genera
1a. Hypocotyl highly suppressed; eophylls rossulate; base of first two leaves cuneate.....*Nicotiana plumbaginifolia*
1b. Hypocotyl prominent; eophylls cauline; base of first two leaves oblique…….……2
2a. Paracotyledons lanceolate to lance-ovate, apex acute……*Solanum*
2b. Paracotyledons ovate, apex obtuse…*Physallis minima*

Key to the species
Genus: *Solanum*
1a. Paracotyledons lance-ovate, base obtuse; first two leaves ovate to pinnatisect, apex acute, margin pinnately lobed, surface densely hairy with prickles…….……*S. sisymbriiflolium*
1b. Paracotyledons lanceolate, base cuneate, first two leaves typically ovate, apex obtuse, margin entire, surface sparsely pubescent……*S. americanum*

Chenopodiaceae
Key to the species
1a. First two leaves lanceolate to lance-ovate, apex acute to narrowly acute, margin entire, surface with farinaceous hair; venation hyphodromous; first internode rounded with densely farinaceous hair……..*Chenopodium album*
1b. First two leaves ovate-oblong, apex sub-rounded, margin weavy, surface with pubescent; venation camptodromous; first internode angular with minutely hispid hair…….…..*Dysphania ambrosioides*

Asteraceae
Key to the species
1a. Hypocotyl reddish-brown; paracotyledons thick, apex acute, primary veins three, venation acrodromous; base of first two leaves sub-cordate, venatoion actinodromous……*Xanthium strumarium*
1b. Hypocotyl light green; paracotyledons herbaceous, apex obtuse, primary vein one, venation hyphodromous; base of first two leaves cuneate, venatoion camtodromous……2
2a. Paracotyledons subsessile, widely elliptic to sub-orbicular, base obtuse; first two leaves widely elliptic, apex obtuse; subsequent leaves elliptic-lacerate……...…….…..…*Blumea lacera*
2b. Paracotyledons petiolate, lanceolate, base cuneate; first two leaves bi or trilobed, apex acute; subsequent leaves pinnatisect…….*Parthenium hysterophorus*

Type-III
Key to the families
1a. Paracotyledons pubescent, base oblique; first two leaves with stipule free lateral, blade obcordate, apex retuse; internode oval ……Fabaceae (*Desmodium trifloram*).
1b. Paracotyledons glabrous, base cuneate to obtuse; first two leaves with stipule interpeotiolar, blade lanceolate, apex acute; internode angular……..Rubiaceae.

Rubiaceae
Key to the species
1a. Hypocotyl papillate; paracotyledons ovate-oblong, base cuneate, apex sub-rounded; first two leaves scabrous; blade obtuse, venation camptodromous; internode hirsute…….*Spermacoce hispida.*
1b. Hypocotyl glabrous; paracotyledons ovate, base obtuse, apex obtuse; first two leaves glabrous, base narrowly cuneate, venation hyphodromous; internode glabrous …….*Oldenlandia corymbosa.*

Type- IV
Key to the families
1a. First two leaves and subsequent leaves sessile……Primulaceae (*Anagalis arvensis*)
1b. First two leaves and subsequent leaves petiolate……2
2a. Seedling with latex……Euphorbiaceae
2b. Seedling without latex……3
3a. First two leaves with margin entire……4
3b. First two leaves with margin serrate or dentate or toothed…….……8
4a. Paracotyledons with primary veins 3-5, venation acrodromous…….……..Acanthaceae
4b. Paracotyledons with primary vein one, venation hyphodromous…….…...……5
5a. Paracotyledons with obtuse to sub-rounded base ….6
5b. Paracotyledons with cuneate base ……..7
6a. First two leaves with base truncate, apex subrounded to rounded…….....Nyctaginaceae (*Boerrhavia diffusa*)
6b. First two leaves with base obtuse, apex acute to obtuse…….……Urticaceae
7a. First two leaves glabrous; internode rounded, glabrous……Caryophyllaceae (*Stellaria media*)
7b. First two leaves hairy; internode angular, hairy…….Amaranthaceae
8a. Venation of first two leaves craspedodromous; subsequent leaves compound……....Cannabinaceae (*Cannabis sativa*)
8b. First two leaves with venation acrodromous to camptodromous; subsequent leaves simple……..9
9a. First internode angular (exception-*Mazus pumilus*)…10
9b. First internode rounded to oval……Asteraceae
10a. Seedling aromatic with densely hispid to hirsutose hair…….…….……Lamiaceae
10b. Seedling non-aromatic with glabrous or pubescent hair……Scrophulariaceae

Key to the genus/species

Euphorbiaceae

1a. Paracotyledons narrowly oblong to elliptic-oblong, glabrous, apex rounded……..……2

1b. Paracotyledons widely elliptic, pubescent, apex retuse…….……*Acalypha* (*A. indica*)

2a. Hypocotyl terete; no. of primary vein one of paracotyledons one, hyphodromous; first two leaves elliptic, hairy, first internode oval to oblate……*Euphorbia*

2b. Hypocotyl rounded; no. of primary veins of paracotyledons three, acrodromous; first two leaves ovate, glabrous; first internode quadrangular……*Micrococca* (*M. mercurialis*)

Key to the species

Genus: *Euphorbia*

1a. Hypocotyl hairy, green; paracotyledons elliptic, margin crenulated; first two eaves with base cuneate, apex sub-acute; venation hyphodromous……..…*E. hirta*

1b. Hypocotyl glabrous, purplish; paracotyledons narrowly oblong, margin entire; first two eaves with base rounded, apex minutely emarginate; venation eucamptodromous.....*E. serpens*

Acanthaceae

Genus: *Ruellia*

Key to the species

1a. Hypocotyl rounded with pilose and glandular hair; base of paracotyledons obtuse, apex retuse, first two leaves with base cuneate, apex subrounded, venation eucamptodromous; first internode with pilose hair……..……*R. tuberosa*

1b. Hypocotyl quadrangular with sparsely pubescent hair; base of paracotyledons rounded to sub-truncate, apex obtuse, first two leaves with base obtuse, apex acute, venation brochiododromous; first internode with densely hispid hair ……*R. prostrata*

Urticaceae

Key to species

1a. Hypocotyl glabrous, translucent green; paracotyledons widely elliptic, primary vein one, venation camtodromous; first internode translucent green, glabrous……*Pilea microphylla*

1b. Hypocotyl strigulose, light green; paracotyledons ovate to sub-orbicular, primary veins three, venation actinodromous; first internode green, strigulose……..*Pouzolzia zeylanica*

Amaranthaceae

Key to species

1a. Hypocotyl soft; paracotyledons ovate, apex obtuse to sub-rounded; first two leaves fleshy, sparsely villous, blade elliptic, base attenuate……*Alternanthera sessilis*

1b. Hypocotyl semihard; paracotyledons narrowly elliptic, apex acute; first two leaves herbaceous, tomentose, blade obovate, base obtuse……*Achyranthes aspera*

Asteraceae

Key to the species

1a. First two leaves with primary veins three, venation acrodromous; first internode purplish-green…….2

1b. First two leaves with primary vein one, venation camptodromous; first internode green……3

2a. Paracotyledons elliptic-oblong, base cuneate, apex rounded; first two leaves lance-ovate with strigulose hairs; first internode with densely strigose hairs……*Eclipta prostrata*

2b. Paracotyledons widely elliptic, base obtuse, apex obtuse; first two leaves widely elliptic with lanate hairs; first internode with villous hairs……..…*Ageratum conyzoides*

3a. Hypocotyl hirsute hairy, green; paracotyledons with apex retuse; first two leaves with base attenuate, margin entire……*Tridax procumbens*

3b. Hypocotyl papillate hairy, purple; paracotyledons with apex rounded; first two leaves with base cuneate to obtuse, margin serrate ……*Synedrella nodiflora*

Lamiaceae

Key to the species

1a. Hypocotyl light-green; paracotyledons elliptic-oblong, venation hypodromus; first two leaves with base cuneate, apex obtuse, tomentose hair…*Leucas aspera*

1b. Hypocotyl purplish-green; paracotyledons widely ovate, venation camptodromus; first two leaves with base subrounded, apex acute, hirsute hair…….……....*Hyptis suaveolens*

Scrophulariaceae

Key to the species

1a. Base of paracotyledons cuneate; first two leaves spathulate, margin minutely toothed……....*Mazus pumilus*

1b. Base of paracotyledons obtuse to sub-truncate; first two leaves rhombic-ovate to ovate, margin serrate or dentate……2

2a. Paracotyledons glabrous, first two leaves glabrous, apex acute; internode glabrous ……..3

2b. Paracotyledons hairy, first two leaves hairy, apex obtuse to subrounded; internode hairy……4

3a. Hypocotyl light-green; apex of paracotyledons acute; base of first two leaves cuneate, margin dentate from middle to apex; subsequent leaves petiolate; internode prominent green……..…..*Scoparia dulcis*

3b. Hypocotyl purple-green; apex of paracotyledons obtuse; base of first two leaves obtuse, margin minutely serrate; subsequent leaves sessile; internode purplish green……*Mecardonia procunbens*

4a. Hypocotyl hairy; base of paracotyledons obtuse, apex rounded; first two leaves base truncate or cordate, surface hispid; subsequent leaves base cuneate, apex acute ……..……*Lindenbergia indica*

4b. Hypocotyl glabrous; base of paracotyledons truncate, apex obtuse; first two leaves with base cuneate, surface strigulose; base of subsequent leaves subtruncate, apex obtuse.....*Lindernia viscosa*

Type-V

Key to the families

1a. First two leaves and subsequent leaves with leaflets 2-10 pairs……..……2

1b. First two leaves and subsequent leaves with leaflets always trifoliolate…….Oxalidaceae (*Oxalis corniculata*)

2a. Hypocotyl semihard; paracotyledons sub-sessile, fleshy thick, glabrous, venation actinodromous…..Fabaceae

2b. Hypocotyl soft; paracotyledons petiolate, herbaceous, pubescent, venation acrodromous…..…Zygophyllaceae (*Kallstroemia pubescens*)

Key to the genera/species

Fabaceae

Key to the species

Genus: *Senna*

1a. Paracotyledons base sub-cordate, apex narrowly retuse; leaflet apex emarginate; subsequent leaves contain an ovoid brown gland near the base……....*Senna occidentalis*

1b. Paracotyledons base auriculate, apex rouded; leaflet apex obtuse, gland absent at the base of the subsequent leaves……2

2a. Leaflets ovate; subsequent leaflets with 3 pairs of leaflets……*Senna tora*

2b. Leaflets oblance-ovate; subsequent leaves with 4-10 pairs of leaflets….....*Senna sophera*

Type-VI

Key to the families

1a. Paracotyledons petiolate, apex obtuse; first two leaves trifoliate, exstipulate…….....Capparaceae

1b. Paracotyledons subsessile, apex rounded or retuse; first two leaves unifoliate, stipulate……...Fabaceae (*Desmodium scorpiurus*)

Key to the genera/species

Capparaceae

Key to the species

1a. Hypocotyl purple; paracotyledons with base cuneate; subsequent leaves trifoliolate.....*Cleome rutidospermum*

1b. Hypocotyl green; paracotyledons with base obtuse; subsequent leaves 3-5 foliolate…….....*Cleome viscosa*

Using morphological parameters of seedlings, 74 species of dicotyledonous weeds belonging to 64 genera under 30 families have been studied in crop fields throughout the year 2020. Under the artificial key, the studied taxa are categorized into six seedling types based on nature, phyllotaxy and stipule of the first two leaves of seedlings. Since we have studied a limited number of taxa in the fields under the families using only juvenile characters, so some of the families have shown their placement of more than one seedling types i.e., Euphorbiaceae in type I, type II and type IV; Amaranthaceae in type II and type IV; Asteraceae in type II and type IV; and Fabaceae in type III, type V and type VI. For many families, only one species have been studied i.e. Aizoiaceae (*Trianthema portulacastrum*), Portulacaceae (*Portulaca oleracea*), Molluginaceae (*Glinus oppositifolius*), Piperaceae (*Peperomia pellucida*), Ranunculaceae (*Ranunculus sceleratus*), Boraginaceae (*Heliotropium indicum),*Primulaceae (*Anagallis arvensis*), Cannabinaceae (*Cannabis sativa*), Oxalidaceae (*Oxalis corniculata*), Zygophyllaceae (*Kallstroemia pubescens*) and Fumariaceae (*Fumaria indica*).

The classification of seedling is totally based on conservative juvenile traits and shows some homology with Takhtajan's classification (1997) system. Polygonaceae has been isolated and placed in type I while other families like Amaranthaceae, Portulacaceae, Molluginaceae, Chenopodiaceae and Nyctaginaceae of Takhtajan's Caryophyllidae are placed in seedling types II and IV, except Aizoaceae which is placed within the seedling type I where Polygonaceae present. Thus the majority of studied families of Caryophyllidae are placed in type II and IV separating Polygonaceae. This partially supports the concept of Takhtajan. Taxa having compound leaves are placed in seedling types V and VI on the phyllotaxy of the first two leaves. Here type V possesses Oxalidaceae, Fabaceae and Zygophyllaceae and type VI contains Capparaceae and Fabaceae. Thus, Fabaceae is an exception. Fabaceae, Zygophyllaceae and Oxalidaceae are placed in subclass Rosidae and Capparaceae is in subclass Dilleniidae of Takhtajan. Seedling characters separate Capparaceae into seedling type V where only the *Desmodium gangeticum* of Fabaceae also belongs. Therefore, partial evidence homology is evident to Takhtajan (1997).

Juvenile characters have also supported a few other botanical disciplines such as pollen morphology, molecular biology, anatomy etc. The phylogeny of six taxa of Amaranthaceae using RAPD and showed that *Achyranthes* and *Alternanthera* tend to stay together while *Amaranthus* is separated out from them[40]. In seedling traits, the former two taxa belong to type IV while later taxon has been accommodated in type II supporting the molecular phylogeny. A study on the pollen grains of a few *Chenopodium* spp. showed that *C. album* and *C. ambrosioides* (*Dysphania ambrosioides* at present) share similar radial symmetrical, isopolar, pantopolyporate spheroidal pollen grains with scabrate ornamentations[41]. In seedling characters, although they are placed in the same type II, but are separated from each

other by the characters of paracotyledons and first two internodes. Thus, partial disfavouring of pollen characters is evident here. In the seedling characters, *Xanthium strumarium* and *Ageratum conyzoides* are placed in type II and IV respectively. Anatomically *Xanthium* displays anisocytic stomata and non-glandular unicellular trichomes separating the *Ageratum conyzoides* by its anomocytic stomata and non-glandular unicellular hairs[42]. This is an evidence of a positive correlation.

Among 74 investigated taxa, 20 showed heteroblastic development (Table -2). There are 29 seedling taxa which are of invasive alien species. Some of them are *Ageratum conyzoides* (Trop. America), *Cleome rutidosperma* (Trop. America), *Ipomoea eriocarpa* (Trop. Africa), *Oxalis corniculata* (Europe), *Peperomia pellucida* (Trop. South America), *Synedrella nodiflora* (West Indies), *Malvastrum coromandelianum* (Trop. America) etc.

PCA analysis: The score plot of PCA distributed the 30 families with their quantitative and qualitative seedlings traits where most of the families are distributed lower part and upper right-hand plots of four sections indicating their partial affinities (Figure-2).

Seedling phenotypic traits are consistently distributed in among PCA 1 and PCA 2. Two major groups indicated as two circles have emerged from PCA analysis. The smaller group at right above side contains only qualitative traits indicating their interdependency; whereas the larger group has both qualitative and quantitative traits indicating their dependency. It also depicts major numbers of both traits with significant inter-relationship. Only two quantitative traits i.e., paracotyledon size and paracotyledon petiole length, remain outside from these groups. These traits show less importance for taxonomic correlation and might not be used for artificial key construction.

Table-2: Heteroblastic development of eophylls (phyllotaxy, nature, margin, shape and leaflets pair).

Sl. No.	Name of the taxa	Family	Heteroblastic development
1	*Acalypha indica*	Euphorbiaceae	Phyllotaxy opposite to alternate
2	*Cannabis sativa*	Cannabinaceae	Leaves simple to compound
3	*Cardamine flexuosa*	Brassicaceae	Leaves simple to compound
4	*Chenopodium album*	Chenopodiaceae	Leaf margin entire to notch
5	*Desmodium triflorum*	Fabaceae	Leaves unifoliate to trifoliate
6	*Desmodium scorpions*	Fabaceae	Leaves unifoliate to trifoliate
7	*Dysphania ambrosioides*	Chenopodiaceae	Leaf margin entire to irregularly serrulate
8	*Fumaria indica*	Fumaraceae	Leaves linear to pinnatisect
9	*Kallstroemia pubescens*	Zygophyllaceae	Leaflets two pairs to three-eight pairs
10	*Malvastrum coromandelianum*	Malvaceae	Leaf blade orbicular to ovate
11	*Parthenium hysterophorus*	Asteraceae	Leaves simple to pinnatily lobed
12	*Phyllanthus urinaria*	Euphorbiaceae	Phyllotaxy whorled to alternate
13	*Ranunculus sceleratus*	Ranunculaceae	Trilobed to multinotched trilobed
14	*Rorippa palustris*	Brassicaceae	Leaf margin entire to double serrate
15	*Rumex dentatus*	Polygonaceae	Leaf margin entire to weavy
16	*Senna occidentalis*	Fabaceae	Leaflets two pairs to three-five pairs
17	*Senna sophera*	Fabaceae	Leaflets two pairs to four-ten pairs
18	*Senna tora*	Fabaceae	Leaflets two pairs to three pairs
19	*Solanum sisymbriifolium*	Solanaceae	Leaf blade simple to pinnatisect
20	*Tridax procumbens*	Asteraceae	Leaf margin entire to serrate

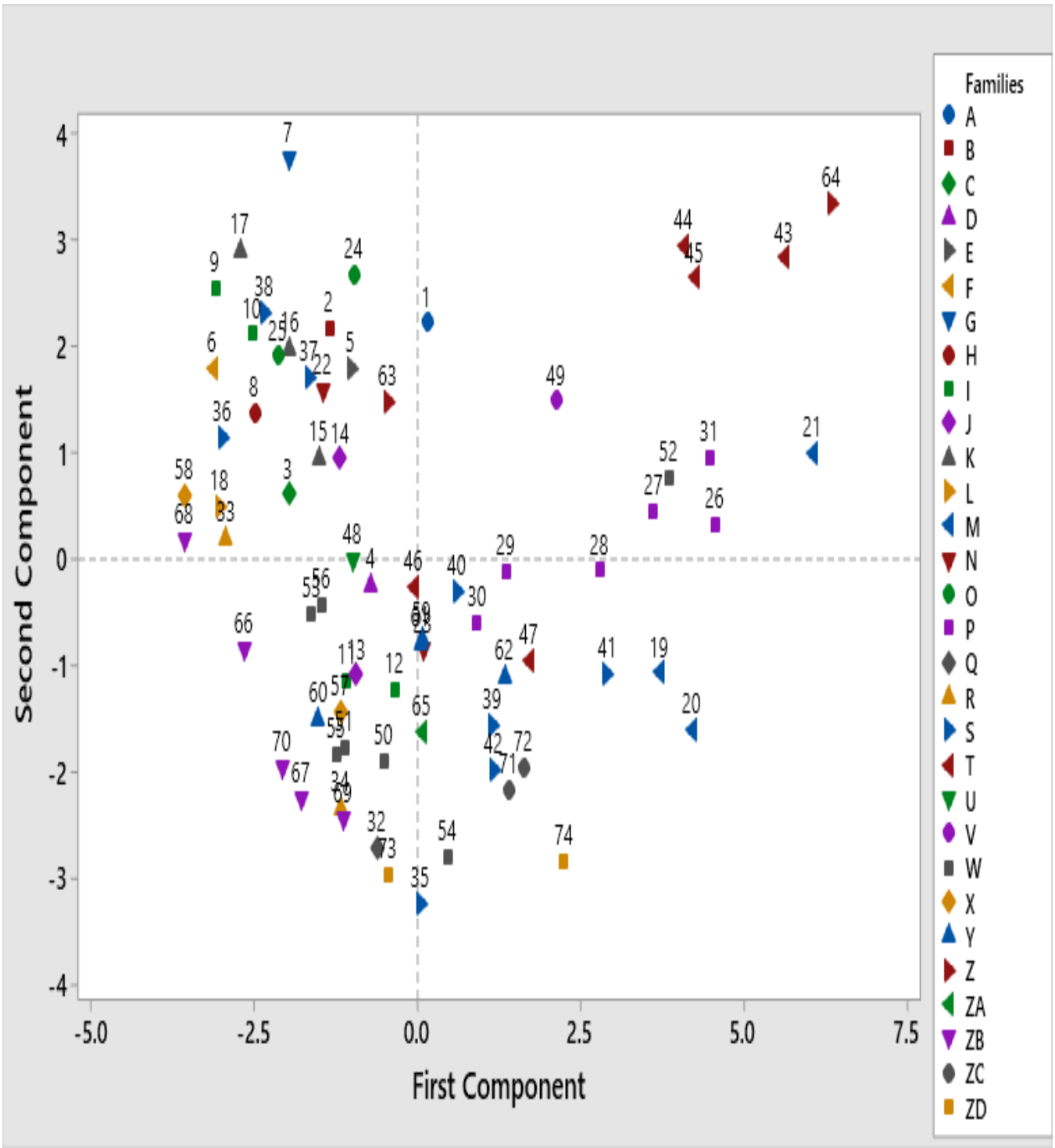

Figure-2: Score plot of Principal Component Analysis based on 30 quantitative and qualitative seedling morphological traits showing a relationship among 74 weed species from 30 families. Species are denoted with numbers (same as the table-I) and grouped by colored symbols. Each alphabet denote different families like - A=Piperaceae, B= Ranunculaceae, C= Fumaraceae, D= Nyctaginaceae, E= Aizoaceae, F= Portulacaceae, G= Molluginaceae, H= Caryophyllaceae, I= Amaranthaceae, J= Chenopodiaceae, K= Polygonaceae, L= Primulaceae, M= Cucurbitaceae, N= Capparaceae, O= Brassicaceae, P= Malvaceae, Q= Cannabaceae, R= Urticaceae, S= Euphorbiaceae, T= Fabaceae, U= Oxalidaceae, V= Zygophyllaceae, W= Asteraceae, X= Rubiaceae, Y= Solanaceae, Z= Convolvulaceae, ZA= Boraginaceae, ZB= Scorphulaceae, ZC= Acanthaceae, ZD= Lamiaceae.

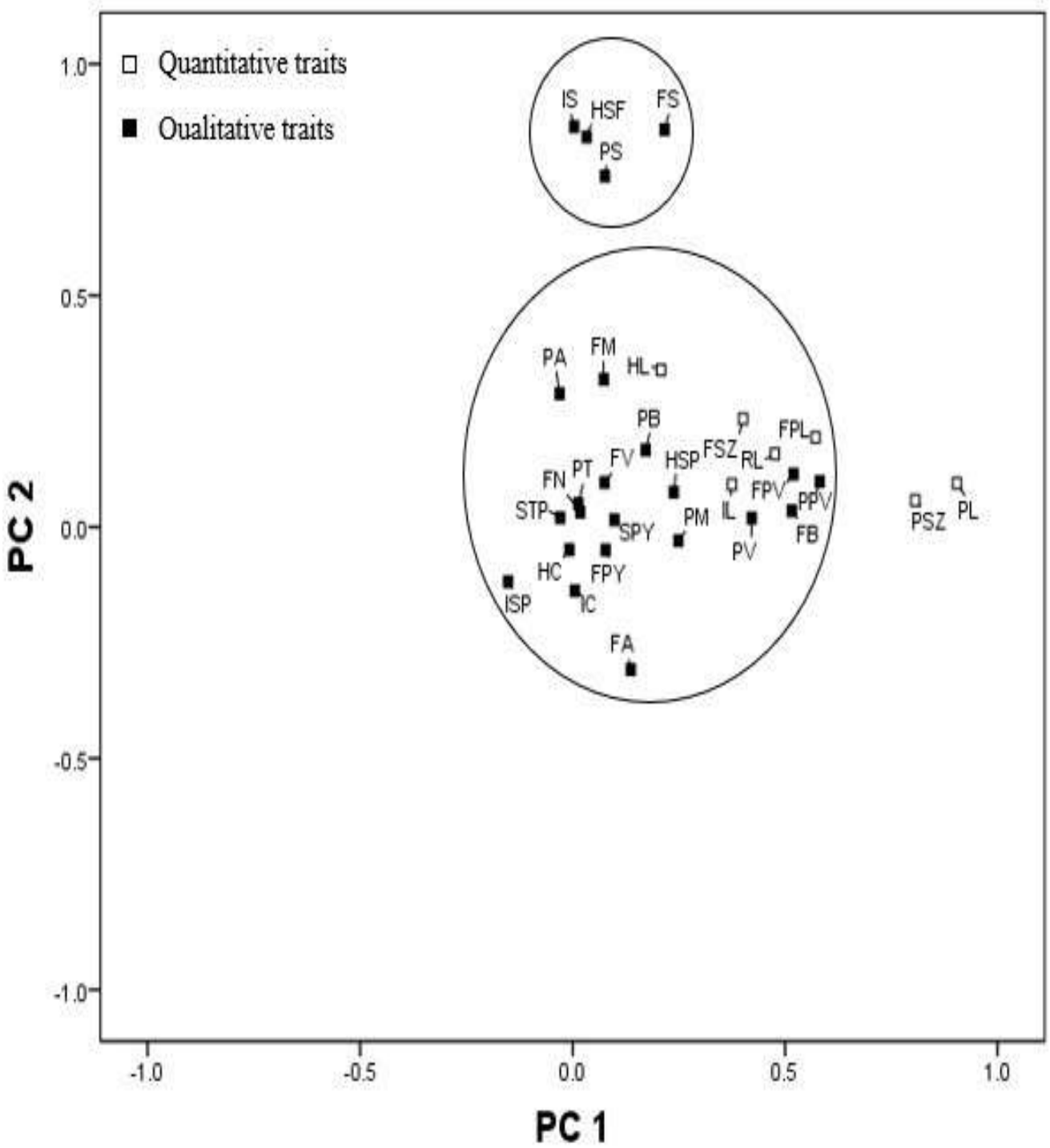

Figure-3: Loading plot of Principal Component Analysis for seedling of 74 weed species ordinated on the basis of qualitative and quantitative traits. Both the traits on the PC 1 and PC 2 axis. White (open) and black (closed) square symbols denote quantitative and qualitative traits respectively. Parameters are denoted by abbreviations as follows: FPY=First two leaves phyllotaxy, STP= stipule, SPY= Subsequent leaves phyllotaxy, RL= Root length, HL=Hypocotyl length, HSF= Hypocotyl surface, HSP= Hypocotyl shape, HC= Hypocotyl colour, PT= Paracotyledon texture, PL= Petiole length, PS= Petiole surface, PB= Paracotyledon base, PA= Paracotyledon apex, PSZ=Paracotyledon size, PM= Paracotyledon margin, PPV= Paracotyledon primary vein, PV= Paracotyledon venation, FN= First two leaves nature, FPL= First two leaves petiole, FSZ= First two leaves size, FB= First two leaves base, FA= First two leaves apex, FM= First two leaves margin, FS= First two leaves surface, FPV= First two leaves primary vein, FV= First two leaves venation, IL= Internode length, ISP= Internode shape, IS= Internode surface, IC= Internode colour.

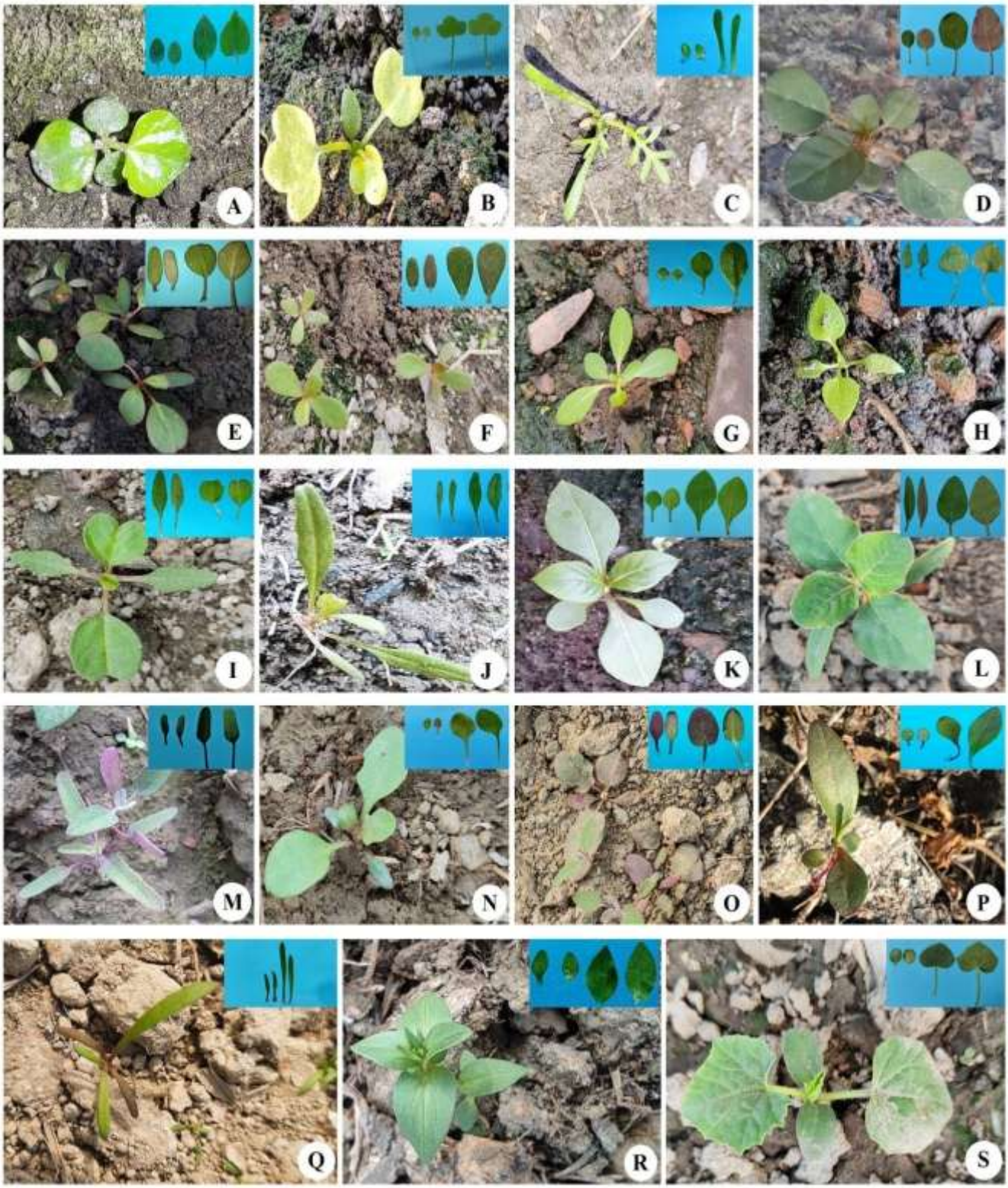

Figure-4: Figs. A. *Peperomia pellucida*; B. *Ranunculus sceleratus*; C. *Fumaria indica*; D. *Boerhavia diffusa*; E. *Trianthema portulacastrum*, E. *Portulacca oleracea*; G. *Glinus oppositifolius*, H. *Stellarla media*, I. *Amaranthus viridis*; J. *Amaranthus tenuifolius*; K. *Alternanthera sessilis*; L. *Achyranthes aspera*; M. *Chenopodium album*; N. *Dysphania ambrosioides*; O. *Rumex dentatus*; P. *Persicaria hydropiper*, Q. *Polygonum plebeium*; R. *Anagallis arvensis*, S. *Mukia scabrella*.

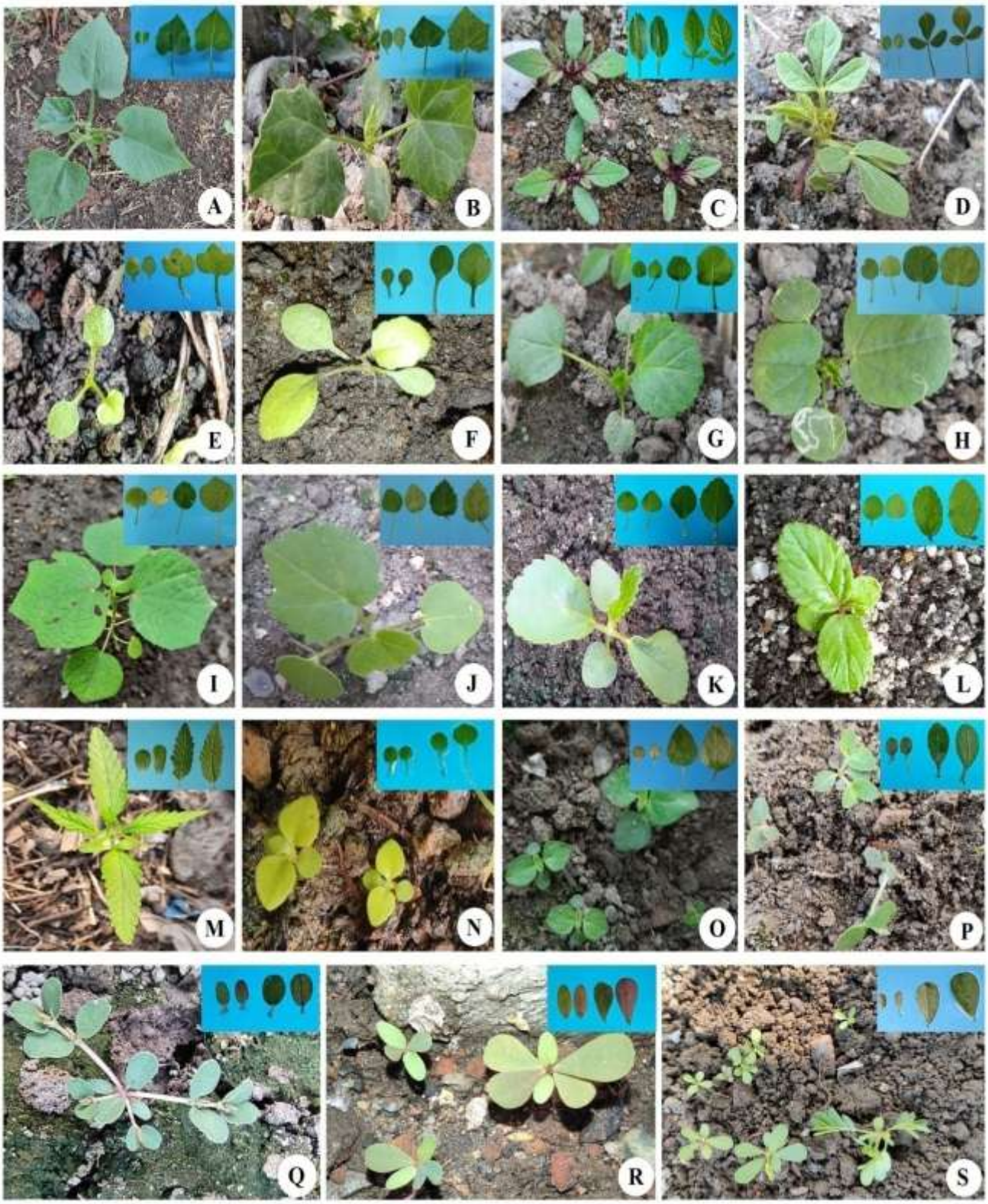

Figure-5: Figs. A. *Trichosanthes cucumerina*; B. *Coccinia grandis*; C. *Cleome rutidosperma*; D. *Cleome viscosa*; E. *Cardamine flexuosa*; F. *Rorippa palustris*; G. *Malvastrum coromandelianum*; H. *Malachra capitata*; I. *Urena lobata*; J. *Sida cordata*; K. *S. rhombifolia*; L. *Corchorus aestuans*; M. *Cannabis sativa*; N. *Pilea microphylla*; O. *Pouzolzia zeylanica*: P. *Euphorbia hirta*; Q. *E. serpens*; R. *Phyllanthus urinaria*; S. *P. fraternus*

Figure-6: Figs. A. *Croton bonplandianus*; B. *Micrococca mercurialis*; C. *Chrozophora plicata*; D. *Acalypha indica*; E. *Senna tora*; F. *S. sophera*; G. *S. occidentalis*; H. *Desmodium triflorum*; I. *D. scorpiurus*; J. *Oxalis corniculata*; K. *Kallstroemia pubescens*; L. *Parthenium hysterophorus*; M. *Eclipta prostrata*; N. *Xanthium strumarium*; O. *Ageratum conyzoides*; P. *Tridax procumbens*; Q. *Synedrella nodiflora*; R. *Blumea lacera*.

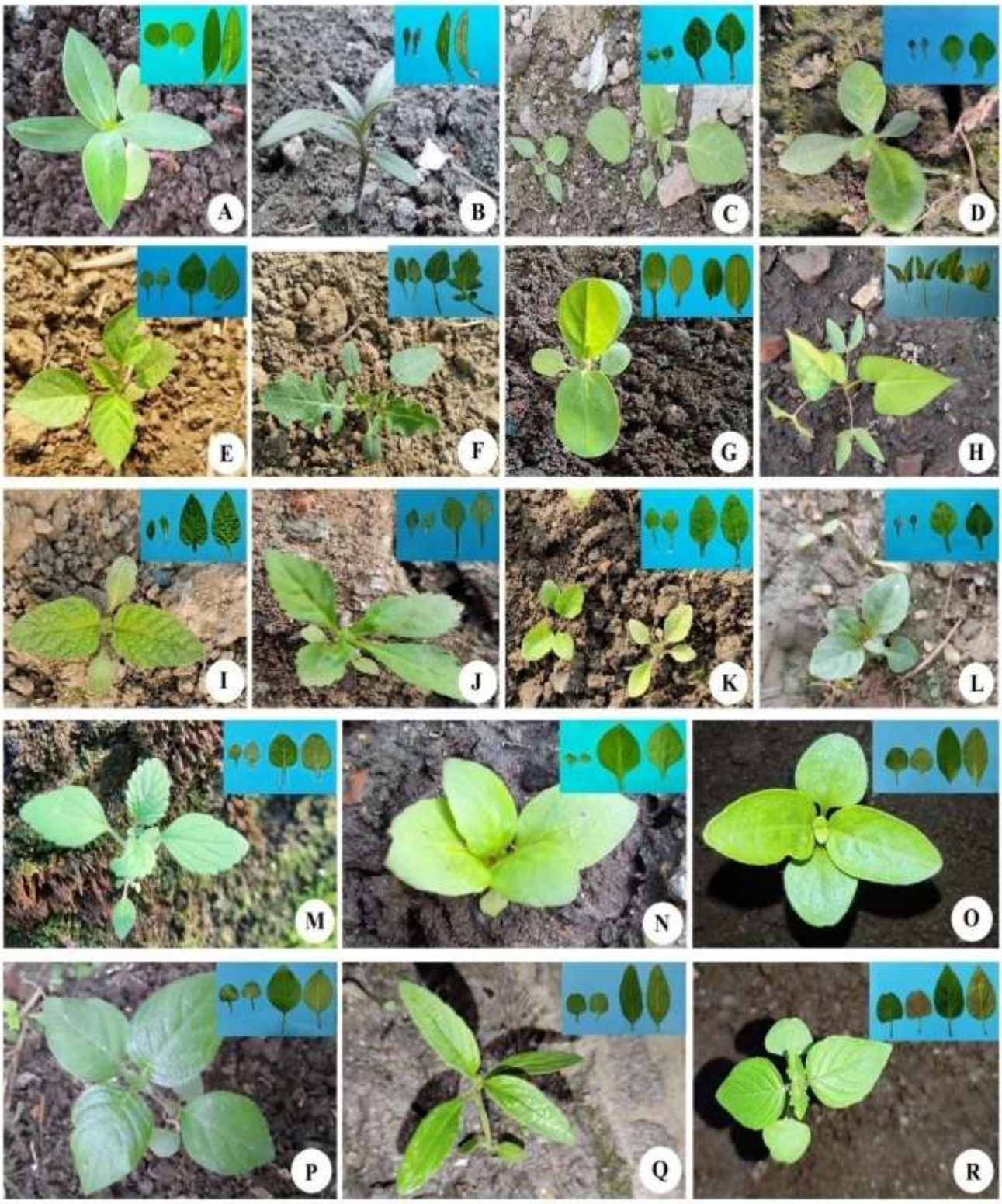

Figure-7: Figs. A. *Spermacoce hispida*; B. *Oldenlandia corymbosa*; C. *Solanum americanum*; D. *Nicotiana plumbaginifolia*; E. *Physalis mínima*; F. *Solanum sisymbriifolium*; G. *Evolvulus nummularius*; H. *Ipomoea erlocarpa*; L. *Heliotropium indicum*; J. *Scoparia dulcis*; K. *Mazus pumilus*; L. *Mecardonia procumbens*; M. *Lindenbergia indica*; N. *Lindernia viscosa*; O. *Ruellia tuberosa*; P. *R. prostrata*; Q. *Leucas aspera*; R. *Hyptis suaveolens*

Conclusion

In taxonomic studies seedling characters have been neglected earlier possibly due to lack of abundant literatures and voucher specimens. But an array of seedling features contributes much to knowledge of seedling taxonomy which enables to identify the plants at juvenile stage i.e. much before flowering and fruiting[44]. Thus, the artificial key is helpful for early identification of weed s at seedling stage that may minimize the cost of weed manifestation in crop fields. Besides, in this limited scope of studies, taxonomic correlation of taxa may be done partially. PCA analysis depicts the interdependence of some quantitative and qualitative traits of seedlings to distinguish the taxa at different taxonomic levels. This may fulfil our knowledge on the life cycle of angiosperms taxa where we may enlist some peculiar juvenile features. Heteroblastic development is the example of peculiar juvenile behaviour that gradually differentiates seedlings up to adult stage. These distinctiveness are useful for identification at juvenile stage and manifest an initial step for weed management.

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