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# Describing morphological characters of seedlings of some dicotyledonous weeds for their identification and management

**Ayan Das[1] and Parasuram Kamilya***

*[1]University of Calcutta,35, Ballygaunge Circular Road, Kolkata, West Bengal 700019, India*

**Department of Botany, Balurghat College, Balurghat, Dakshindinajpur, West Bengal 733101, India*

**Email: pkamilya.in@gmail.com*

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**ABSTRACT**

Seedling traits of 60 weeds under 24 families of Magnoliopsida have been studied in some crop fields of Dakshin Dinajpur district of West Bengal. Conservative seedling characters emphasize that the studied taxa may be enlisted in four artificial groups *i.e*, Type I to IV, each having some families and/ or genera. Artificial keys have been made for identification under field observations. The bearing of this study has also been addressed by camping seedling data with other botanical disciplines. Peculiar juvenile behaviors like heteroblastic developments have also been observed. Seedling study is very much significant for eradication of weeds at juvenile stage before display of variable weeds in crop fields.

## INTRODUCTION

Weeds are undesired plant species that grow with cultivated crops and intervene or compete with the crops for growth and nutrients and in this way affect the productivity leading to economic loss (Marwart *et al.* 2013). Most of the weeds are annual and complete their life cycle within a short period of time producing a large number of viable seeds that germinates immediately in almost every season to interact with crops. Therefore, rapid and accurate identification of weeds in seedling stage might be helpful for a successful weed management that can save both time and cost of production as well as lower chemical herbicide usage (Parkinson *et al.* 2013).

Importance of studying phenotypic traits of weed seedlings for their correct identification has a major role in suggesting suitable post-emergence herbicides for effective weed management. It is a common practice for the farmers in most parts of Eastern India that they use herbicides on mature weeds during pre or post harvesting period while abundant seeds have already been added by the weeds in the soil. Seeds protected by hard seed coats are not affected by the herbicides and they germinate into the next generation of weeds demanding proportional use of herbicides over the years. Hence, a strategy of weed management using herbicide or manual labor may be administered at the seedling stage *i.e.*, before flowering and fruiting to stop the next generation before it germinates. For this, weeds must be identified at the seedling stage through proper keys constructed based of their juvenile traits of cotyledons or other parts, which are conservative and viable for weeds growing in any geological or ecological conditions and this process has already advocated by some workers (Parkinson *et al.* 2013, Chomas *et al.* 2001, Chancellor 1966).

## MATERIALS AND METHODS

Thorough survey for collection of seeds and/or seedlings has been done from March, 2017 to February, 2018 in the crop fields located in different mouzas (administrative unit) of Balurghat block. The list of seedlings studied is given in **Table 1**. The taxa are arranged family wise after Takhtajan, 1997 and alphabetically with author's name(s), and photograph number within each family. The seedlings are collected in pre- and post-harvesting periods as well as growth stages of crops. The seeds are air-dried and sown in prepared seedbeds separately from time to time with proper tagging to raise seedlings in the experimental garden of Balurghat College. So-raised seedlings were compared to natural ones for proper identification. Few seedlings were also identified following literatures of Chancellor (1966), Chomas *et al.* (2001) and Parkinson *et al.* (2013). The seedlings were described with following Duke (1965), Burger (1972), de Vogel (1980), Paria *et al.* (1990, 2006), and Das and Kamilya (2014). Field photographs taken with Nikon digital camera of all the seedlings with highlighted paracotyledons and first two leaves have

**Table 1. List of species studied with author's names and photograph numbers arranged under each families following Takhtajan (1997)**

| | |
|---|---|
| Ranunculaceae | Oxalidaceae |
| *Ranunculus sceleratus* L. [Figure A1] | *Oxalis corniculata* L. [Figure B15] |
| Papaveraceae | Apiaceae |
| *Argemone mexicana* L. [Figure A2] | *Centella asiatica* Urban [Figure C1] |
| *Fumaria indica* (Hasskn.) Pugsley [Figure A3] | *Hydrocotyle sibthorpioides* Lam. [Figure C2] |
| Molluginaceae | *Oenanthe benghalensis* (Roxb.) Benth. & Hook. *f.* [Figure C3] |
| *Glinus lotoides* L. [Figure A4] | Asteraceae |
| *Glinus oppositifolius* (L.) Aug. DC. [Figure A5] | *Ageratum conyzoides* L. [Figure C4] |
| Caryophyllaceae | *Ageratum haustonianum* Mill. [Figure C5] |
| *Drymaria cordata* (L.) Willd. *ex*Schult. [Figure A6] | *Centipeda minima* (L.) A.Br. & Asch. [Figure C6] |
| *Polycaarpon prostratum* (Forssk.) Asch. & Schweinf. [Figure A7] | *Eclipta prostrata* (L.) L. [Figure C7] |
| Portulacaceae | *Gnaphalium polycaulon* Pers. [Figure C8] |
| *Portulaca oleracea* L. [Figure A8] | *Grangea maderaspatana* (L.) Poir. [Figure C9] |
| Amaranthaceae | *Xanthium strumarium* L. [Figure C10] |
| *Achyranthus aspera* L. [Figure A9] | Rubiaceae |
| *Alternanthera paronychoides* A.St. Hil. [Figure A10] | *Dentella repens* L. [Figure C11] |
| *Alternanthera sessilis* (L.) R.Br. *ex* DC. [Figure A11] | *Oldenlandia corymbosa* L. [Figure C12] |
| *Amaranthus gangeticus* L. [Figure A12] | Convolvulaceae |
| *Amaranthus viridis* L. [Figure A13] | *Evolvulus nummularius* (L.) L. [Figure C13] |
| Chenopodiaceae | Solanaceae |
| *Chenopodium album* L. [Figure A14] | *Physalis minima* L. [Figure C14] |
| *Chenopodium ambrosioides* L. [Figure A15] | *Physalis peruviana* L. [Figure C15] |
| Polygonaceae | *Solanum nigrum* L. [Figure D1] |
| *Persicaria hydropiper* (L.) Delabre [Figure B1] | *Nicotiana plumbaginifolia* Viv. [Figure D2] |
| *Persicaria orientalis* (L.) Spach [Figure B2] | Boraginaceae |
| *Polygonum plebeium* L. [Figure B3] | *Coldenia procumbens* L. [Figure D3] |
| *Rumex dentatus* L. [Figure B4] | *Heliotropium indicum* L. [Figure D4] |
| Malvaceae | Scrophulariaceae |
| *Sida rhomboidea* Roxb. *ex*Flaming [Figure B5] | *Lindernia ciliata* (Colsm.) Pennell [Figure D5] |
| Sterculiaceae | *Lindernia crustacea* (L.) F. Muell. [Figure D6] |
| *Melochia corchorifolia* L. [Figure B6] | *Lindernia nummulariifolia* (D. Don) Wettst. [Figure D7] |
| Urticaceae | *Lindernia parviflora* (Roxb.) Haines [Figure D8] |
| *Pouzolzia zeylanica* (L.) Benn. & R.Br. [Figure B7] | *Lindernia procumbens* (Krock.) Philcox [Figure D9] |
| Euphorbiaceae | *Mazus pumilus* (Burm. *f.*) Steinis [Figure D10] |
| *Acalypha indica* L. [Figure B8] | *Mecardonia procumbens* (Mill.) Small. [Figure D11] |
| *Chrozophora rottleri* (Geiseler) A. Juss. *ex*Spreng. [Figure B9] | *Scoparia dulcis* L. [Figure D12] |
| *Croton bonplandianus* Baill. [Figure B10] | Acanthaceae |
| *Euphorbia hirta* L. [Figure B11] | *Hygrophilla difformis* Blume [Figure D13] |
| Onagraceae | Lamiaceae |
| *Ludwigia perennis* L. [Figure B12] | *Leucas aspera* (Willd.) Link. [Figure D14] |
| Fabaceae | *Salvia plebeia* R.Br. [Figure D15] |
| *Desmodium triflorum* (L.) DC. [Figure B13] | |
| *Senna tora* (L.) Roxb. [Figure B14] | |

been displayed in **Plate A** to **D**. A table (**Table 2**) has been prepared with the major qualitative traits (given in abbreviated form) used for the diagnosis of the seedlings. Artificial keys have been constructed using both qualitative and quantitative traits to identify the seedlings of the weeds. In the key to the families, single species in a family has been mentioned in the parenthesis.

**Artificial key** (applicable for the studied taxa only)

### Key to the seedling types

1. First two leaves subopposite to alternate…2
1a. First two leaves opposite……..……...3
2. First two leaves exstipulate……..……Type I
2a. First two leaves stipulate……..……Type II
3. First two leaves exstipulate……..…Type III
3a. First two leaves stipulate……..…...Type IV

### Key to the families of Type I

1. Seedlings with latex; venation of paracotyledons parallelodromous……..……....…Papaveraceae
1a. Seedlings without latex; venation of paracotyledons hyphodromous or actinodromous…….……..…….2
2. First two leaves with three or more primary veins…… …….....3
2a. First two leaves with single primary vein .....……4
3. Margin of second leaf entire…..... ……...…Ranunculaceae [*Ranunculus sceleratus*]
3a. Margin of second leaf crenate…..... ……..…Apiaceae
4. Pracotyledons narrowly oblong, apex obtuse; first internode angular.....…….....5
4a. Paracotyledons otherwise, apex acute or rounded; first internode round…….....……..6

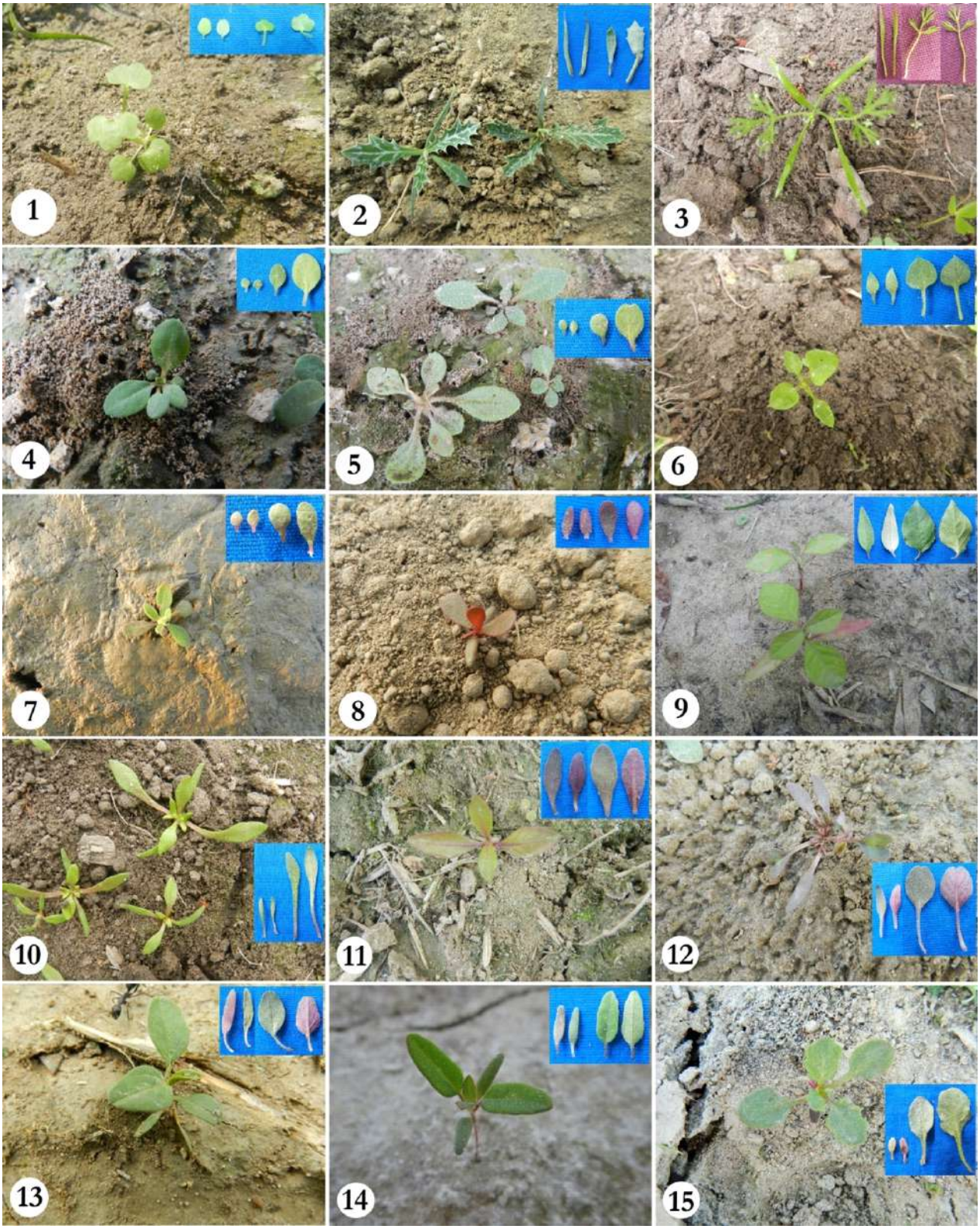


**Plate A: 1. *Ranunculus sceleratus*; 2. *Argemone mexicana*; 3. *Fumaria indica*; 4. *Glinus lotoides*; 5. *Glinus oppositifolius*; 6. *Drymaria cordata*; 7. *Polycarpon prostratum*; 8. *Portulaca oleracea*; 9. *Achyranthus aspera*; 10. *Alternanthera paronychioides*; 11. *Alternanthera sessilis*; 12. *Amaranthus gangeticus*; 13. *Amaranthus viridis*; 14. *Chenopodium album*; 15. *Chenopodium ambrosioides.***

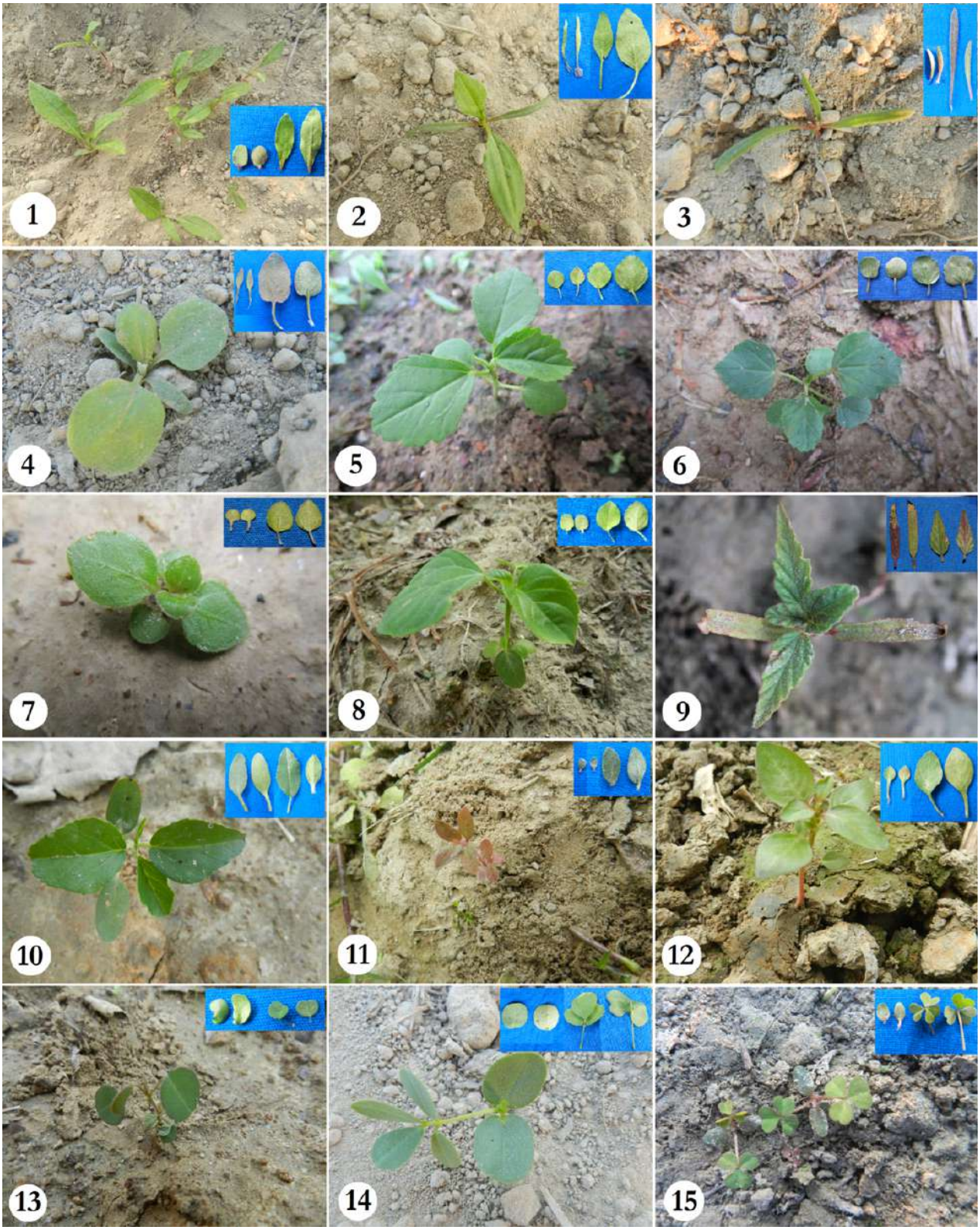


**Plate B: 1. *Persicaria hydropiper*; 2. *Persicaria orientalis*; 3. *Polygonum plebeium*; 4. *Rumex dentatus*; 5. *Sida rhomboidea*; 6. *Melochia corchorifolia*; 7. *Pouzolzia zeylanica*; 8. *Acalypha indica*; 9. *Chrozophora rottleri*; 10. *Croton bonplandianus*; 11. *Euphorbia hirta*; 12. *Ludwigia perennis*; 13. *Desmodium triflorum*; 14. *Senna tora*; 15. *Oxalis corniculata.***

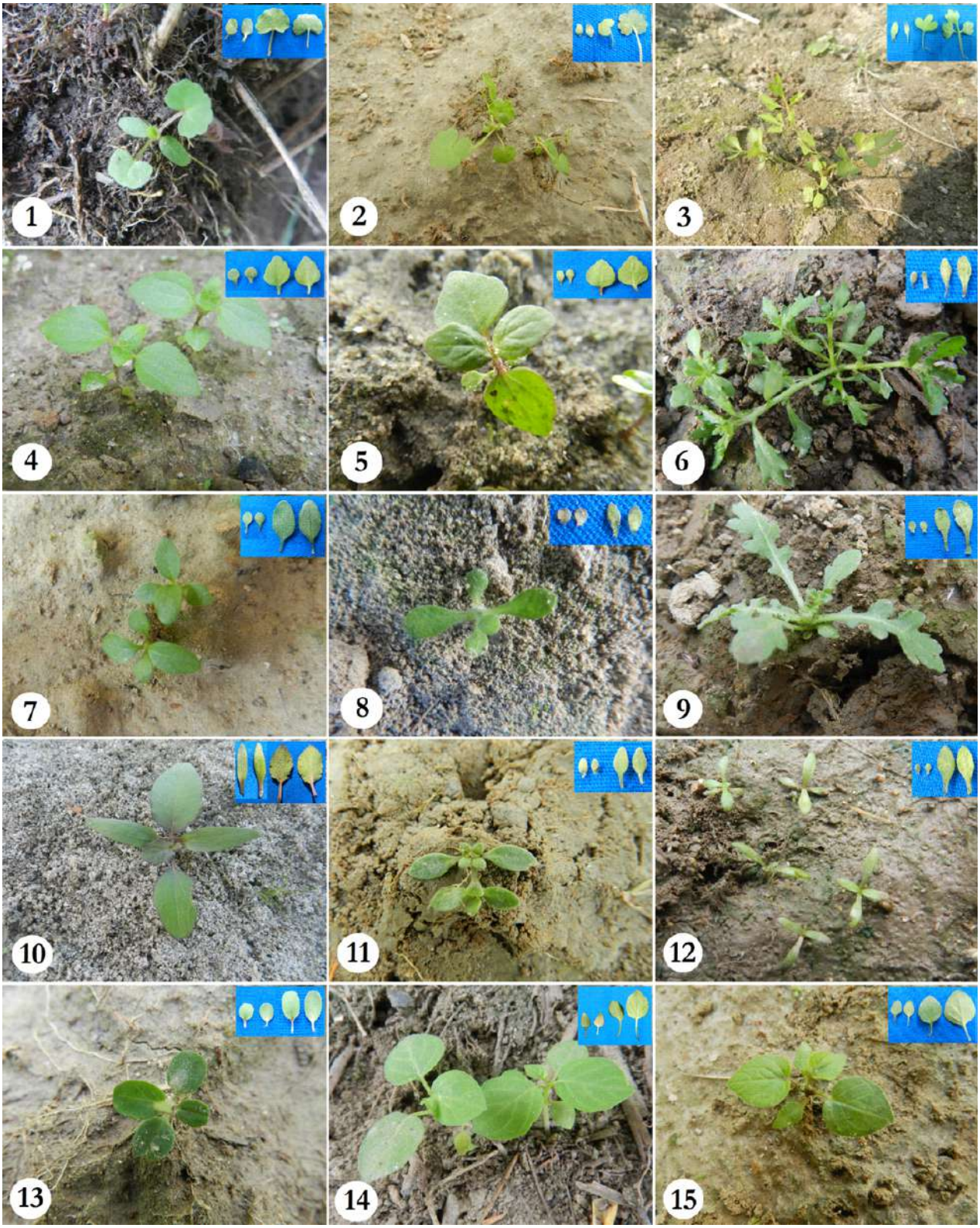


**Plate C: 1. *Centella asiatica*; 2. *Hydrocotyle sibthorpioides*; 3. *Oenanthe benghalensis*; 4. *Ageratum conyzoides*; 5. *Ageratum haustonianum*; 6. *Centipeda minima*; 7. *Eclipta prostrate*; 8. *Gnaphalium polycaulon*; 9. *Grangea maderaspatana*; 10. *Xanthium strumarium*; 11. *Dentella repens*; 12. *Oldenlandia corymbosa*; 13. *Evolvulus nummularius*; 14. *Physalis minima*; 15. *Physalis peruviana.***

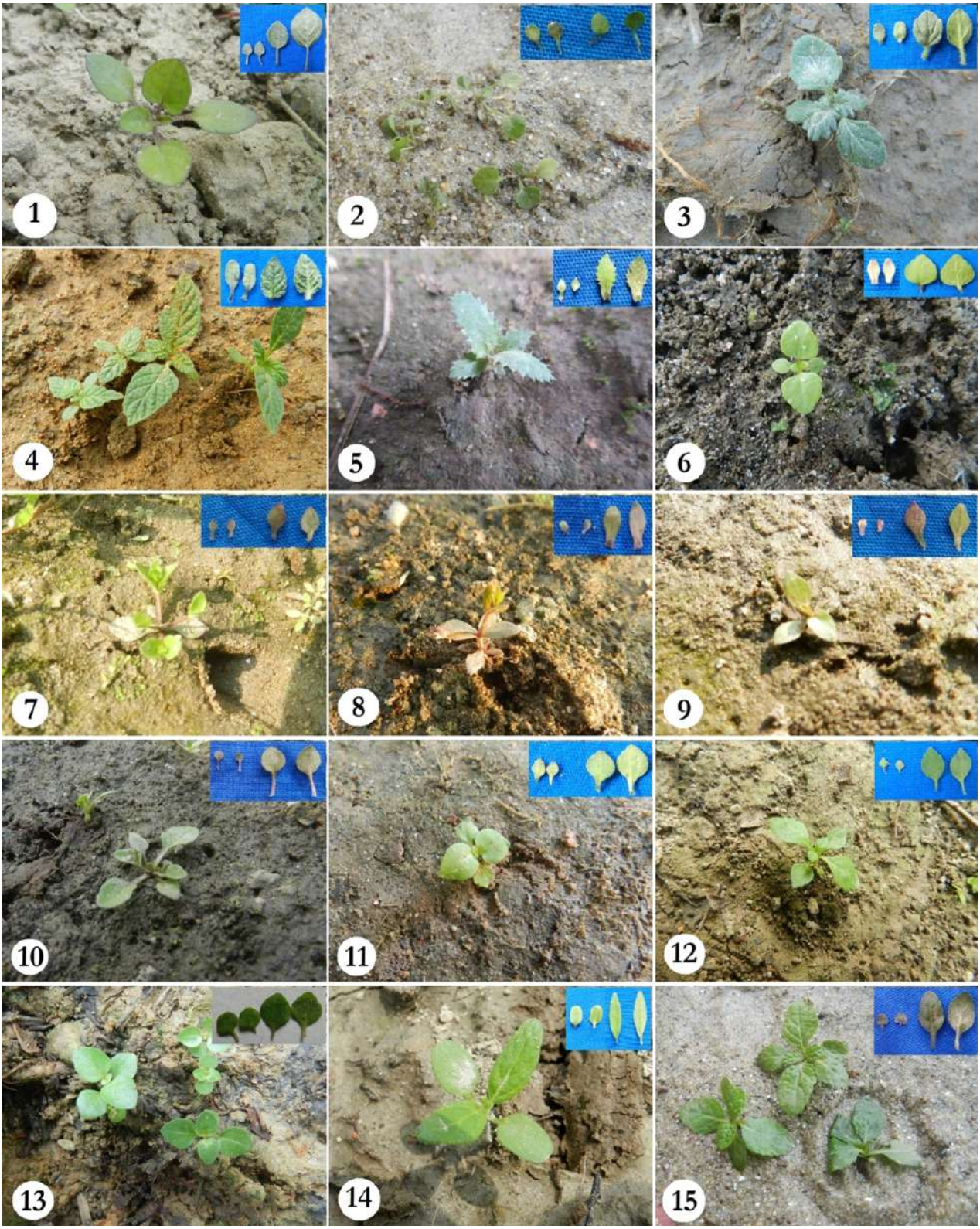


**Plate D: 1. *Solanum nigrum*; 2. *Nicotiana plumbaginifolia*; 3. *Coldenia procumbens;* 4. *Heliotropium indicum*; 5. *Lindernia ciliata*; 6. *Linternia crustacea*; 7. *Lindernia nummulariifolia*; 8. *Lindernia parviflora*; 9. *Lindernia procumbens*; 10. *Mazus pumilus*; 11. *Mecardonia procumbens*; 12. *Scoparia dulcis*; 13. *Hygrophilla difformis*; 14. *Leucas aspera*; 15. *Salvia plebeian.***

| Name of the species | Hypocotyl | | Paracotyledons | | | | | | | | | | First two leaves | | | | | | | | | | | First internode | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shape | Surface | Texture | Surface | Petiole | Shape | Base | Apex | Margin | Pri. veins | Venation | Phyllotaxy | Nature | Texture | Surface | Petiole | Stipule | Shape | Base | Apex | Margin | Pri.veins | Venation | Shape | Surface |
| *Ranunculus sceleratus* | r | glb | her | glb | 1 | obl | s.rnd | rnd | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | 3lb | s.crd | rnd | ent | 3 | act | r | glb |
| *Argemone mexicana* | r | glb | thk | glb | 0 | lin | cnt | acu | ent | 4 | prl | alt | smp | her | glb | 0 | 0 | spt | atn | acu | spn-dnt | 1 | cam | r | glb |
| *Fumaria indica* | r | glb | her | glb | 1 | lin | atn | obt | ent | 3 4 | prl | alt | smp | her | glb | 1 | 0 | pinn | cnt | acu | ent | 1 | cam | r | glb |
| *Glinus lotoides* | r | glb | her | glb | 1 | ov-s.orb | cnt | obt | ent | 1 | hyp | alt | smp | her | glb | 1 | 1 | ov-elp | cnt | rnd | ent | 1 | hyp | an | glb |
| *Glinus oppositifolius* | r | glb | her | glb | 1 | obvs.orb | cnt | rnd | ent | 1 | hyp | alt | smp | her | glb | 1 | 1 | obv-elp | atn | rnd | ent | 1 | hyp | an | glb |
| *Drymaria cordata* | 4-an | glb | her | glb | 1 | ov-lnc | cnt | acu | ent | 1 | hyp | opp | smp | her | m.pub | 1 | 0 | b.ov | s.trn | acu | ent | 1 | cam | 4-an | pub |
| *Polycaarpon prostratum* | 4-an | glb | her | glb | 1 | ov-elp | s.rnd | s.rnd | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | obv | cnt | s.rnd | ent | 1 | hyp | 4-an | tom |
| *Portulaca oleracea* | r | glb | fls | glb | 1 | obl | s.rnd | obt | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | obv | cnt | s.rnd | ent | 1 | hyp | r | glb |
| *Achyranthus aspera* | r | glb | her | glb | 1 | lnc | cnt | acu | ent | 1 | cam | opp | smp | her | pub | 1 | 0 | elp-rhm | cnt | acu | ent | 1 | cam | 4-an | pub |
| *Alternanthera paronychioides* | r | scb | fls | glb | 1 | n.lnc | atn | obt | ent | 1 | hyp | opp | smp | her | sp.pub | 1 | 0 | oblnc | atn | s.acu | ent | 1 | cam | r | pub |
| *Alternanthera sessilis* | r | glb | fls | glb | 1 | elp-obl | atn | rnd | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | obv | atn | obt | ent | 1 | cam | 4-an | pub |
| *Amaranthus gangeticus* | r | glb | her | glb | 1 | n.obl | cnt | obt | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | obv | cnt | emr | ent | 1 | cam | 4-an | glb |
| *Amaranthus viridis* | r | glb | her | glb | 1 | n.obl | cnt | obt | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | ov-elp | cnt | rts | ent | 1 | cam | 4-an | glb |
| *Chenopodium album* | r | glb | fls | glb | 1 | n.obl | cnt | obt | ent | 1 | hyp | alt | smp | crs | scb | 1 | 0 | obl-lnc | cnt | obt | ent | 1 | cam | 4-an | pub |
| *Chenopodium ambrosioides* | r | glb | her | glb | 1 | n.obl | cnt | obt | ent | 1 | hyp | alt | smp | crs | glb | 1 | 0 | ov-obl | cnt | s.rnd | s.ent | 1 | cam | 4-an | m.hsp |
| *Persicaria hydropiper* | r | glb | her | glb | 1 | obt-recs.orb | s.cnt | rnd | ent | 1 | cam | alt | smp | cor | glb | 1 | 1 | elp-obl | atn | obt | ent | 1 | cam | r | sp.pub |
| *Persicaria orientalis* | r | glb | her | glb | 1 | lin | atn | acu | ent | 1 | hyp | alt | smp | her | pub | 1 | 1 | elp-lnc | atn | acu | ent | 1 | cam | r | hrs |
| *Polygonum plebeium* | r | scb | her | glb | 0 | lin-flc | atn | obt | ent | 1 | hyp | alt | smp | her | glb | 1 | 1 | lin | atn | acu | ent | 1 | hyp | r | scb |
| *Rumex dentatus* | r | glb | her | glb | 1 | n.obl | cnt | obt | ent | 1 | hyp | alt | smp | her | glb | 1 | 1 | ov | s.trn | obt | ent | 1 | cam | r | glb |
| *Sida rhomboidea* | r | hrs | her | hrs | 1 | s.orb | s.rnd | s.rts | ent | 3 | acr | alt | smp | her | pub | 1 | f.l | ov.rhm | cnt | obt | srt | 3 | act | r | hrs |
| *Melochia corchorifolia* | r | pub | her | glb | 1 | s.orb | rnd | rnd | ent | 5 | act | alt | smp | her | pub | 1 | 1 | s.orb.b.ov | s.rnd | obt | crn-srt | 3 | act | r | pub |
| *Pouzolzia zeylanica* | r | scb | her | d.pub | 1 | orb.ov | s.rnd | rts | ent | 1 | cam | opp | smp | her | hrs | 1 | 1 | ov | s.trn | obt | ent | 3 | act | 4-an | m.hrs |
| *Acalypha indica* | r | scb | her | sp.pub | 1 | elp-s.orb | rnd | s.trn | ent | 3 | acr | opp | smp | her | scb | 1 | 1 | ov | rnd | acu | srt | 3 | act | r | scb |
| *Chrozophora rottleri* | r | scb | her | sp.pub | 1 | b.elp.s.orb | rnd | s.trn | ent | 3 | acr | opp | smp | her | scb | 1 | 1 | ov | rnd | acu | d.srt | 3 | act | r | scb |
| *Croton bonplandianus* | r | stl | crs | stl | 1 | obl | cnt | s.rnd | ent | 3 | acr | alt | smp | her | stl | 1 | 1 | ov-elp | s.rnd | acu | srt | 3 | act | r | stl |
| *Euphorbia hirta* | r | glb | her | glb | 1 | obl | s.rnd | s.rnd | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | obv | cnt | s.rnd | ent | 1 | cam | r | d.pub |
| *Ludwigia perennis* | r | glb | her | glb | 1 | ov | b.cnt | acu | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | ov | b.cnt | acu | ent | 1 | cam | r | glb |
| *Desmodium triflorum* | r | pub | thk | scb | 0 | flc-obl | obq | rnd | ent | 3 | act | opp | smp | her | glb | 1 | f.l | b.obv | b.cnt | sh.emr | ent | 1 | cam | 6-an | hrs |
| *Senna tora* | r | sp.pub | thk | glb | 0 | obv-obl | aur | rnd | ent | 3 | act | alt | cmp | her | pub | 1 | f.l | obv | obq.trn | rts | ent | 1 | cam | 4-an | pub |
| *Oxalis corneculata* | r | sp.pub | her | glb | 1 | ov.elp | cnt | rnd | ent | 1 | hyp | alt | cmp | her | glb | 1 | 1 | obcrd | cnt | dp.emr | ent | 3 | act | r | hrs |
| *Centella asiatica* | r | glb | her | glb | 1 | obl-rec | s.rnd | rnd | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | s.ren | crd | rnd | crn | 5 | act | r | glb |
| *Hydrocotyle sibthorpioides* | r | glb | her | glb | 1 | ov | s.rnd | rnd | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | ren | s.crd | rnd | und | 7 8 | act | r | glb |
| *Oenanthe benghalensis* | r | glb | her | glb | 1 | elp | cnt | obt | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | 3-lb | s.trn | rnd | | 3 | act | r | glb |
| *Ageratum conyzoides* | r | scb | her | glb | 1 | ov | cnt | rts | ent | 1 | hyp | opp | smp | her | m.pub | 1 | 0 | ov | s.trn | acu | d.srt | 3 | acr | r | pub |
| *Ageratum haustonianum* | r | scb | her | scb | 1 | ov | cnt | rts | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | ov | b.cnt | obt | d.srt | 3 | acr | r | hrs |
| *Centipeda minima* | r | glb | her | glb | 1 | elp | cnt | s.rnd | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | elp-obv | atn | obt | ent | 1 | hyp | r | glb |
| *Eclipta prostrata* | r | glb | her | glb | 0 | obvs.orb | cnt | rnd | ent | 1 | cam | opp | smp | her | pub | 1 | 0 | ov-elp | cnt | s.acu-obt | d.srt | 3 | acr | r | pub |
| *Gnaphalium polycaulon* | r | glb | her | glb | 1 | s.orb | s.rnd | rnd | ent | 1 | hyp | alt | smp | her | d.pub | 1 | 0 | elp | atn | obt | ent | 1 | hyp | r | tom |
| *Grangea maderaspatana* | r | glb | her | glb | 0 | obv-elp | atn | s.rnd | ent | 1 | hyp | alt | smp | her | pub | 1 | 0 | obv-obl | atn | obt | ent | 1 | hyp | r | hrs |
| *Xanthium strumarium* | r | glb | cor | glb | 1 | elp-lnc | atn | s.acu | ent | 3 | acr | opp | smp | cor | d.pub | 1 | 0 | ov | s.rnd | acu | srt | 3 | acr | r | hrs |
| *Dentella repens* | 4-an | glb | her | glb | 1 | b.ov | rnd | obt | ent | 1 | hyp | opp | smp | her | glb | 1 | int | n.elp | cnt | acu | ent | 1 | hyp | 4-an | glb |
| *Oldenlandia corymbosa* | r | glb | her | glb | 1 | ov-s.orb | s.trn | rnd | ent | 3 | act | opp | smp | her | scb | 1 | 1 | n.elp | cnt | obt | ent | 1 | cam | 4-an | glb |
| *Evolvulus nummularius* | r | glb | her | glb | 1 | rec-s.orb | b.cnt | rnd | ent | 3 | act | alt | smp | her | glb | 1 | 0 | obv | b.cnt | rts | ent | 1 | cam | r | hrs |
| *Physalis minima* | r | m.pub | her | scb | 1 | ov | rnd | acu | ent | 1 | hyp | alt | smp | her | s.glb | 1 | 0 | ov | obq.s.rnd | acu | ent | 1 | cam | r | pub |
| *Physalis peruviana* | r | pub | her | sp.pub | 1 | ov | b.cnt | acu | ent | 1 | hyp | alt | smp | her | pub | 1 | 0 | ov | obq.s.rnd | obt | irr.und | 1 | cam | r | tom |
| *Solanum nigrum* | r | pub | her | glb | 1 | ov-lnc | cnt | acu | ent | 1 | hyp | alt | smp | her | m.pub | 1 | 0 | b.ov | s.rnd | acu | wvy | 1 | cam | r | hrs |
| *Nicotiana plumbaginifolia* | r | glb | her | glb | 1 | s.orb | s.rnd | rnd | ent | 1 | hyp | alt | smp | her | glb | 1 | 0 | b.ov | s.trn | acu | ent | 1 | cam | r | glb |
| *Coldenia procumbens* | r | d.pub | cor | hrs | 1 | ov.rec | b.cnt | rnd | ent | 1 | hyp | opp | smp | her | vil | 1 | 0 | ov | b.cnt | acu | ent | 1 | cam | r | glb |
| *Heliotropium indicum* | r | pub | her | pub | 1 | ov-obl | cnt | rnd | ent | 1 | hyp | opp | smp | her | d.pub | 1 | 0 | ov | rnd | acu | ent | 1 | cam | r | hrs |
| *Lindernia ciliata* | r | glb | her | scb | 0 | ov | cnt | obt | ent | 1 | hyp | opp | smp | her | hrs | 0 | 0 | obl-spat | atn | acu | dnt | 1 | hyp | 4-an | m.pub |
| *Lindernia crustacea* | r | scb | ±thk | glb | 1 | ov | s.trn | obt | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | ov | s.trn | obt | crn | 1 | hyp | 4-an | glb |
| *Lindernia nummulariifolia* | r | glb | her | glb | 1 | elp | cnt | acu | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | ov-elp | cnt | acu | ent | 1 | hyp | 4-an | glb |
| *Lindernia parviflora* | r | glb | her | glb | 1 | elp | cnt | s.rnd | ent | 1 | hyp | opp | smp | her | glb | 0 | 0 | elp | atn | acu | ent | 1 | hyp | 4-an | glb |
| *Lindernia procumbens* | r | glb | her | glb | 1 | elp-s.orb | cnt | s.rnd | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | elp-ov | cnt | acu | ent | 3 | acr | 4-an | glb |
| *Mazus pumilus* | r | glb | her | glb | 1 | b.ov | s.rnd | acu | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | ov | atn | obt | ent | 1 | cam | 4-an | glb |
| *Mecardonia procumbens* | r | glb | her | glb | 1 | ov | cnt | obt | ent | 1 | hyp | opp | smp | her | glb | 1 | 0 | b.ov | b.cnt | obt | ent | 1 | hyp | 4-an | glb |
| *Scoparia dulcis* | r | scb | her | glb | 1 | ov | cnt | acu | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | ov | cnt | acu | ent | 1 | cam | 4-an | scb |
| *Hygrophilla difformis* | r | glb | her | glb | 1 | s.orb | s.rnd | s.rts | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | b.ov | cnt | obt | ent | 1 | cam | 4-an | pub |
| *Leucas aspera* | r | hrs | her | scb | 1 | obl-rec | b.cnt | rnd | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | n.elp | atn | acu | srt | 1 | cam | 4-an | pub |
| *Salvia plebeia* | r | glb | her | glb | 1 | s.orb | trn | rnd | ent | 1 | hyp | opp | smp | her | pub | 1 | 0 | ov | atn | obt | srt | 1 | cam | 4-an | d.pub |

Abbreviations: act: actinodromous; acm: acuminate; acu: acute; alt: alternate; ang: angular; atn: attenuate; aur: auriculate; b: broadly; bip: bipinnate; cam: camptodromous; cmp: compound; cnt: cuneate; crs: coriaceous; crd: cordate; cre: crenate; dnt: dentate; elp: elliptic; emg: emarginate; ent: antire; ep: epigeal; flb: flabellate; flc: falcate; glb: glabrous; her: herbaceous; hsp: hispid; hrs: hirsute; hyp: hyphodromous; irr: irregularly; lnc: lanceolate; lin: linear; min: minutely; muc: mucronate; n: narrowly; obl: oblong; obt: obtuse; obv: obovate; obq: oblique; opp: opposite; orb: orbicular; ov: ovate; plt: peltate; pm: palmately; prl: parallel; pub: pubescent; r: round; ren: reniform; rhm: rhomboidal; rnd: rounded; rtn: rectangular; rts: retuse; s: sub; scb: scabrous; sh: shallowly; sint: sinuately; smp: simple; sp: sparsely; spn: spiny; srt: serrate; str: strigose; tk: thick; tmn: tomentose; trn: truncate; wvy: wavy; 0: absent; 1: present; 3an: triangular; 4an: 4-angular; (species are arranged according to table 1)

5. First two leaves with apex emarginate or retuse; margin of subsequent leaves entire, first internode glabrous……...Amaranthaceae

5a. First two leaves with apex subrounded or obtuse; margin of subsequent leaves toothed, first internode hairy……Chenopodiaceae

6. Venation of paracotyledons actinodromous; apex of first two leaves retuse…… …Convolvulaceae [*Evolvulus nummularius*]

6a. Venation of paracotyledons hyphodromous; apex of first two leaves acute or obtuse……7

7. First two leaves elliptic or obovate oblong, base attenuate; length of first internode comparatively short (±1mm)…… ...Asteraceae

7a. First two leaves ovate, base oblique or subrounded; length of first internode comparatively long (5-12mm)…… Solanaceae

## Key to the families of Type II

1. Subsequent leaves simple…… ……...2
1a. Subsequent leaves compound……....6
2. Stipule ochreate…….…….Polygonaceae
2a. Stipule linear…… ……..…… .3
3. Venation of paracotyledons hyphodromous; first two leaves glabrous, venation hyphodromous; first internode angular, glabrous, comparatively short (±1mm).....…….. Molluginaceae
3a. Venation of paracotyledons acrodromous or actinodromous; first two leaves hairy, venation actinodromous; first internode hairy, round, comparatively long (3.5-10mm).....….....…. .4
4. Paracotyledons oblong; apex of first two leaves acute; seedlings aromatic; latex and stellate hair present……..…Euphorbiaceae [*Croton bonplandianus*]
4a. Paracotyledons suborbicular; apex of first two leaves obtuse; seedlings not aromatic; latex and stellate hair absent…….…….....……..5
5. Paracotyledons hirsute, primary veins 3; first two leaves ovate-rhomboid, base cuneate; first internode hirsute……Malvaceae [*Sida rhomboidea*]
5a. Paracotyledons glabrous, primary veins 5; first two leaves suborbicular to broadly ovate, base subrounded; first internode pubescent ….....Sterculiaceae [*Melochia corchorifolia*]
6. Paracotyledons with venation actinodromous; venation of first two leaves camptodromous; first internode angular; apex of subsequent leaves not emarginate.....… ……....…Fabaceae
6a. Paracotyledons with venation hyphodromous; venation of first two leaves actinodromous; first internode round; apex of subsequent leaves emarginate…….....…….Oxalidaceae [*Oxalis corneculata*]

## Key to the families of Type III

1. Hypocotyl angular…….....….Caryophyllaceae
1a. Hypocotyl round…….....…2
2. Seedlings with milky latex…….…… ……..…Euphorbiaceae [*Euphorbia hirta*]
2a. Seedlings without milky latex…….....……3
3. Margin of subsequent leaves entire…....……4
3a. Margin of subsequent leaves serrate or toothed… … …….....……6
4. Venation of first two leaves hyphodromous….. .....Portulacaceae [*Portulaca oleracea*]
4a. Venation of first two leaves camptodromous……5
5. First two leaves ovate…….....…… .....Onagraceae [*Ludwigia perennis*]
5a. First two leaves otherwise…….....…… ……...……Amaranthaceae
6. Venation of first two leaves acrodromous; first internode round…….....Asteraceae [exception *Centipeda minima*]
6a. Venation of first two leaves camptodromous or hyphodromous; first internode angular…….....7 [exception *Lindernia procumbens*]
7. Paracotyledons hairy…….....Boraginaceae
7a. Paracotyledons glabrous…… …….....…8
8. Hypocotyl reduced (±1mm); paracotyledons elliptic or ovate, comparatively smaller (1.5-2mm × 1-1.5 mm)…….....Scrophulariaceae
8a. Hypocotyl elongating; paracotyledons suborbicular or rectangular-oblong, comparatively larger (2.5-6mm ×2-4mm)….....9
9. Apex of paracotyledons subretuse, margin of first two leaves entire…… Acanthaceae [*Hygrophila difformis*]
9a. Apex of paracotyledons rounded, margin of first two leaves serrate……Lamiaceae

## Key to the families of Type IV

1. Paracotyledons hairy, venation camptodromous or acrodromous; first two leaves ovate, base subtruncate or rounded, venation actinodromous, comparatively larger (3-7mm × 2-7 mm)…….....……2
1a. Paracotyledons glabrous, venation hyphodromous; first two leaves narrowly elliptic, base cuneate, venation hyphodromous, comparatively smaller (1-2mm × 1-2mm)…….....……Rubiaceae
2. Apex of paracotyledons retuse, venation camptodromous; first two leaves hirsute, base subtruncate, margin entire; subsequent leaves opposite decussate; first internode angular…… Urticaceae [*Pouzolzia zeylanica*]
2a. Apex of paracotyledons subtruncate, venation acrodromous; first two leaves scabrous, base rounded, margin serrate; subsequent leaves alternate; first internode round…….....…… …….....……Euphorbiaceae

## Key to the genus/species of Type I

**Papaveraceae**

1. Paracotyledons sessile, apex acute; first two leaves sessile, margin spiny dentate…….....…… …….....…*Argemone mexicana*
1a. Paracotyledons petiolate, apex obtuse; first two leaves petiolate, margin pinnatisect…… ……*Fumaria indica*

**Amaranthaceae**

Key to the species under *Amaranthus*

1. First two leaves obovate, apex emarginate…… …….*Amaranthus gangeticus*

1a. First two leaves ovate-elliptic, apex retuse…… ……...*Amaranthus viridis*

**Chenopodiaceae**

Key to the species under *Chenopodium*

1. First two leaves ovate-elliptic, apex subrounded ..……*Chenopodium ambrosioides*

1a. First two leaves oblong-lanceolate, apex obtuse……. ……. ...*Chenopodium album*

**Apiaceae**

1. First two leaves trilobed, base subtruncate, margin entire, primary veins three; subsequent leaves compound…… *Oenanthe benghalensis*

1a. First two leaves not lobed, reniform, base subcordate, margin crenate, primary veins more than three; subsequent leaves simple….2

2. Paracotyledons oblong-rectangular…..…… ……*Centella asiatica*

2a. Paracotyledons ovate…….....…*Hydrocotyle sibthorpioides*

**Asteraceae**

1. Paracotyledons suborbicular; first two leaves elliptic; margin of subsequent leaves entire; first internode tomentose.....……*Gnaphalium polycaulon*

1a. Paracotyledons obovate-elliptic; first two leaves obovate-oblong; margin of subsequent leaves sinuate; first internode hirsute.....…… ……*Grangea maderaspatana*

**Solanaceae**

1. Hypocotyl hairy; paracotyledons ovate or ovate-lanceolate, apex acute, comparatively larger (4-9 mm × 3-5 mm)…… ……2

1a. Hypocotyl glabrous; paracotyledons suborbicular, apex rounded, comparatively smaller (1.5-2.5 mm × 1-2 mm)…..……*Nicotiana plumbaginifolia*

2. Parcotyledons ovate; base of first two leaves oblique…… ……*Physalis*

2a. Paracotyledons ovate-lanceolate; base of first two leaves subrounded…..…… *Solanum nigrum*

Key to the species under *Physalis*

1. First two leaves glabrous; first internode sparsely pubescent…… ……*Physalis minima*

1a. First two leaves pubescent; first internode tomentose…… ……*Physalis peruviana*

## Key to the genus/ species of Type II

**Molluginaceae**

Key to the species under *Glinus*

1. Paracotyledons ovate-suborbicular; first two leaves ovate-elliptic…… *Glinus oppositifolius*

1a. Paracotyledons obovate-suborbicular; first two leaves obovate-elliptic……*Glinus lotoides*

**Polygonaceae**

1. Apex of paracotyledons obtuse……2

1a. Apex of paracotyledons acute or rounded…… ……*Persicaria*

2. Paracotyledons sessile, linear-falcate; first two leaves linear, apex acute, venation hyphodromous……*Polygonum plebeium*

2a. Paracotyledons petiolate, narrowly oblong; first two leaves ovate, apex obtuse, venation hyphodromous……*Rumex dentatus*

Key to the species under *Persicaria*

1. Paracotyledons obtuse-suborbicular, venation camptodromous……*Persicaria hydropiper*

1a. Paracotyledons linear, venation hyphodromous…… ……*Persicaria orientalis*

**Fabaceae**

1. Paracotyledons falcate-oblong, base oblique; first two leaves simple, comparatively smaller (2.5-3mm × 3-3.5mm)…*Desmodium triflorum*

1a. Paracotyledons obovate-oblong, base auriculate; first two leaves compound, comparatively larger (13.5-16 mm × 12.5-14 mm)…..…… ……*Senna tora*

## Key to the genus/ species of Type III

**Caryophyllaceae**

1. Hypocotyl elongated (21-32mm); paracotyledons ovate-lanceolate, apex acute; first two leaves broadly ovate, base subtruncate, apex acute…… ……*Drymaria cordata*

1a. Hypocotyl reduced (±1mm); paracotyledons ovate-elliptic, apex subrounded; first two leaves obovate, base cuneate, apex subrounded……*Polycarpon prostratum*

**Amaranthaceae**

1. Hypocotyl comparatively longer (50-58mm); venation of paracotyledons camptodromouus; first two leaves elliptic-rhomboid…..…… ……*Achyranthes aspera*

1a. Hypocotyl comparatively reduced (6-9mm); venation of paracotyledons hyphodromouus; first two leaves oblanceolate or obovate……*Alternanthera*

Key to the species under *Alternanthera*

1. First two leaves oblanceolate, petiole longer (4-5mm)…….....….*Alternanthera paronychioides*

1a. First two leaves obovate, petiole reduced (1-1.5mm)…….*Alternanthera sessilis*

**Asteraceae**

1. Paracotyledons coriaceous, primary veins three, venation acrodromous…… *Xanthium strumarium*

1a. Paracotyledons herbaceous, primary veins one, venation hyphodromous or camptodromous…....2

2. Venation of first two leaves hyphodromous; subsequent leaves spirally alternate……..…… ……..…… *Centipeda minima*

2a. Venation of first two leaves acrodromous; subsequent leaves opposite decussate…...……3

3. Paracotyledons obovate-suborbicular, first two leaves with margin entire…..... *Eclipta prostrata*

3a. Paracotyledons ovate, first two leaves with margin serrate…… ……*Ageratum*

Key to the species under *Ageratum*

1. First internode pubescent…….....….*Ageratum conyzoides*

1a. First internode hirsute…….....……*Ageratum haustonianum*

**Boraginaceae**

1. Paracotyledons hirsute; base of first two leaves cuneate, margin dentate…… *Coldenia procumbens*

1a. Paracotyledons pubescent; base of first two leaves rounded, margin irregularly wavy…..…….…… ……..….*Heliptropium indicum*

**Scrophulariaceae**

1. Paracotyledons ovate or broadly ovate…..…2

1a. Paracotyledons elliptic or elliptic-suborbicular (exceptions *Lindernia ciliata, L. crustacea*)…… ……..….*Lindernia*

2. Apex of paracotyledons acute; venation of first two leaves camptodromous…….....……3

2a. Apex of paracotyledons obtuse; venation of first two leaves hyphodromous…….....…… ….....….*Mecardonia procumbens*

3. Base of paracotyledons subrounded; apex of first two leaves obtuse…….....….*Mazus pumilus*

3a. Base of paracotyledons cuneate; apex of first two leaves acute…….....….*Scopariadulcis*

Key to the species under *Lindernia*

1. First two leaves oblong-spathulate, hirsute, margin spiny dentate…….....….*Lindernia ciliata*

1a. First two leaves ovate, elliptic or ovate-elliptic, glabrous, margin entire or inconspicuously crenate…… …….....……2

2. First two leaves with three primary veins, venation acrodromous……...……*Lindernia procumbens*

2a. First two leaves with single primary vein, venation hyphodromous……...3

3. Paracotyledons elliptic, base cuneate; apex of first two leaves acute……4

3a. Paracotyledons ovate, base subtruncate, apex obtuse……*Lindernia crustacea*

4. Apex of paracotyledons acute, first two leaves petiolate…...*Lindernia nummulariifolia*

4a. Apex of paracotyledons subrounded; first two leaves sessile…….*Lindernia parviflora*

**Lamiaceae**

1. Hypocotyl comparatively elongated (18-26mm); paracotyledons oblong-rectangular; first two leaves narrowly elliptic, apex acute; first internode comparatively longer (6-12.5 mm)……..…….…… …… *Leucas aspera*

1a. Hypocotyl comparatively reduced (2-3mm); paracotyledons suborbicular; first two leaves ovate, apex obtuse; first internode comparatively shorter (3-5mm)……. *Salvia plebeia*

Key to the genus/ species of Type IV

**Euphorbiaceae**

1. Paracotyledons oblong-suborbicular, apex subtruncate; first two leaves broadly elliptic-ovate, apex obtuse, margin entire…….....…… ……*Acalypha indica*

1a. Paracotyledons narrowly oblong, apex obtuse; first two leaves ovate-lanceolate, apex acute, margin crenate…… ……*Chrozophora rottleri*

**Rubiaceae**

1. Paracotyledons elliptic, apex obtuse; base of first two leaves cuneate…….....*Dentella repens*

1a. Paracotyledons ovate-suborbicular, apex rounded; base of first two leaves attenuate…… …… …*Oldenlandia corymbosa*

## RESULTS AND DISCUSSION

The artificial key revealed that all the seedlings are of phanerocotylar epigeal types. In the artificial key, the sixty taxa from twenty four families of Magnoliopsida have been separated into four types based on naturally adapted characters such as phyllotaxy and presence of stipules of the first two leaves. Each type contains many families with exclusively all studied taxa but some types contain taxa not confined to it exclusively but to other types also. Thus, type I consists of families such as Papaveraceae, Ranunculaceae, Apiaceae, Chenopodiaceae, Convolvulaceae, Solanaceae, genus

*Amaranthus* of Amaranthaceae, genera *Grangea* and *Gnaphalium* of Asteraceae. Type II is represented by the families Polygonaceae, Molluginaceae, Malvaceae, Sterculiaceae, Fabaceae, Oxalidaceae and genus *Croton* of Euphorbiaceae. Type III contained families like Caryophyllaceae, Portulacaceae, Onagraceae, Boraginaceae, Scrophulariaceae, Acanthaceae, Lamiaceae, and the genus *Euphorbia* of Euphorbiaceae, the genera *Achyranthus* and *Alternanthera* of Amaranthaceae, and four genera of Asteraceae. At last Rubiacaeae, Urticaceae and two genera of Euphorbiaceae (*Acalypha* and *Chrozophora*) belonged to seedling type IV.

This classification is totally based on seedling morphological traits and showsed somehomology with other traditional system of plant classifications. For example, under type I, Amaranthaceae and Chenopodiaceae share some common characters such as narrowly oblong paracotyledons with obtuse apex and angular first internode. They also belong to the order Caryophyllales in Takhtajan's system (1997). Similarly, Malvaceae and Sterculiaceae under type II display common juvenile traits like simple subsequent leaves, suborbicular paracotyledons, obtuse apex of first two leaves they remain together in order Malvales under subclass Dilleniidae of Takhtajan's system and they differ from Fabaceae and Oxalidaceae having compound subsequent leaves. The latter two are belonging to subclass Rosidae. Under type III, Scrophulariaceae, Acanthaceae and Lamiaceae (subclass Lamiidae of Takhtajan, 1997) remain associated together having round hypocotyl, margin of subsequent leaves serrate or toothed, venation of first two leaves camptodromous or hyphodromous, angular first internode. Similarly, Urticaceae and Euphorbiaceae show close affinity based on hairy paracotyledons with camptodromous or acrodromous venation; first two leaves ovate with base subtruncate or rounded and venation actinodromous supporting quite parallel inclusion of them under subclass Dillenidae in Takhtajan's system (1997).

Juvenile characters have also supported few other botanical disciplines such as pollen morphology, cytology, phytochemistry, *etc*. of the studied taxa. Fatinah *et al.* (2012) worked on phylogeny of six members of Amaranthaceae using RAPD and showed that *Achyranthes* and *Alternanthera* tend to stay together while *Amaranthus* separated out from them. From juvenile traits, it has been seen that *Amaranthus* having sub-opposite to alternate exstipulate first two leaves belonging to type I seedling while the other two taxa having opposite, exstipulate first two leaves represented type III, thus supporting their phylogenetic correlation based on RAPD. A study on the pollen grains of a few *Chenopodium* spp. by Pinar and Inceoglu (1999) showed that *C. album* and *C. ambrosioides* share similar radial symmetrical, isopolar, pantopolyporate spheroidal pollen grains with scabrate ornamentation. In seedling morphology, these two taxa also share some similar characters such as first two leaves coriaceous, apex subrounded or obtuse; margin of subsequent leaves toothed and first internode hairy indicating the similarities between these two taxa. Rahman *et al,* (2013) investigated stomata and trichome characters of 36 species of Asteraceae and showed that while *Ageratum, Grangea* and *Gnaphalium* share similar characters such as anomocytic stomata and non-glandular multicellular trichomes but *Xanthium* displays anisocytic stomata and non-glandular unicellular trichomes. Our seedling study contradicts with their findings in such a way that *Grangea* and *Gnaphalium* represent seedling type I while *Ageratum* and *Xanthium* belonging to type III, thus partially supporting the above study.

Although this work was considered keeping in mind about the identification of weeds in seedling stage which is crucial for eradication and creating an opportunity towards integrated weed management (Chomas *et al.* 2001, Parkinson *et al.* 2013) but after the discussion it is clear that study of weeds at juvenile stage has some taxonomic values too. The morphological markers used for the identification of the taxa are useful for delimitation of the taxa into different taxonomic groups showing an insight about the usefulness of juvenile features. The traits are highly conservative and hence the key is viable independent of habitat, climate or soil nature. The comparison with an accepted existing system and a few other botanical disciplines gives new ideas about plant systematic which are vital in many a ways.

Furthermore, the most applied outcome of this work is weed management through seedlings. Since, number of seed production, seed production rate, seed viability and resistance to environment are higher in weeds compared to crops, vigorous germination of seeds occur during pre- or post- harvest periods establishing abundant seedlings. Even occurrence of flowering can be observed in these weeds at seedling stage indicating their partly ephemeral behaviour. This makes it a lot harder for their total eradication from the field because they immediately disperse enumerable seeds. However, eradication at the seedling stage minimizes the chance of further weed dispersal by limiting their life cycle before flowering.

Thus, proper identification of weeds at seedling stage may reduce the chemical herbicides proving it to be more economic and eco-friendly.

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