



## Seedling Morphology of Four *Acacia* Mill. (Fabaceae) Species and Its Significance in Plant Taxonomy

Vijay K. Meena<sup>1\*</sup> and Soumana Datta<sup>1</sup>

<sup>1</sup>Department of Botany, University of Rajasthan, Jaipur, Rajasthan, India.

### Authors' contributions

This work was carried out in collaboration between both authors. Author VKM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SD managed the analyses of the study. Both authors read and approved the final manuscript.

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### ABSTRACT

*Acacia* species commonly identify by their reproductive characters such as indefinite number of stamens (more than 10) that are free or united only at the base and a calyx that is in valvate aestivation, pods, etc. In India *Acacia* species are found in all climatic regions but they are found to play a major role in arid and semi-arid areas and effect the environment and communities. The seedling is the very juvenile stage of a plant after germination. Seedling investigation give a good data for identify a particular species at juvenile stage or germination phase. In seedling taxonomy we do focus on wide range of characters such as root, hypocotyl, cotyledon, epicotyl, stem, phyllotaxy, eophyll, heteroblastic development of leaves etc. In *Acacia* seedlings, the number of leaflets, spines, and the shoot height are also important characters. Seedling taxonomy as a tool gives a very significant knowledge about the process of establishment of stable adult traits in mature plants from transition to juvenile stage. *Acacia* species seeds covered by thick seed coat that inhibit the germination of seeds so to reduce the dormancy period various pre-germination treatment methods are used such as soaking in boiling water, mechanical and chemical

\*Corresponding author: E-mail: Meenavijay56@gmail.com;

scarification of the seed coat. After germination we observe seedling characters and make a dichotomous identification key to distinguish them. As mature *Acacia* are usually identify and distinguished from other plants by inflorescence and pod's characteristics. So there is a need for their distinction at earlier stages where these reproductive characteristics are absent.

**Keywords:** Germination; inflorescence; juvenile stage; phyllotaxy.

## 1. INTRODUCTION

Since 14<sup>th</sup> century the name *Acacia* Mill. has been utilized in herbals. Phillip Miller 1754 is the author of the name *Acacia*. The original diagnosis included 24 species in the genus and described *Acacia* as having: "a tubulous flower, consisting of one leaf, with many stamina or threads, which are many of them collected into a kind of sphere or globe: the pistil of the flower afterward becomes a pod, in which are included several seeds, each of which is separated by transverse diaphragms, and are generally surrounded with a sweetish pulp" (Miller 1754). In the latest comprehensive classification of Fabaceae Lindl., the Mimosoideae comprise 3270 species in four tribes [1]. This subfamily is subdivided into four tribes: *Acacieae*, *Ingeae*, *Mimoseae*, and *Mimozgantheae* and *Acacia s.l.* is placed in tribe *Acacieae* [1]. *Acacia* Mill. species were selected due to their multiple uses and values, as well as wide distribution in the arid regions. Seedlings are defined as plant with up to three to ten post cotyledonary nodes [2].

There is great difficulty of *Acacias* in identification of species at the seedling stage because the reproductive organs, by which species of *Acacias* are usually identified, are absent. Seedling morphology is thus very important tool to easy identification at juvenile stage. Seedling description at the juvenile stage gives valuable data to classification of these plant species. In modern era, we are loosing any important plant species due to high pressure of urbanization, industrialization and deforestation. Seedling morphology is very important to conserve these plants permanently and for easy identifications. The seedling stage is arguably the busiest phase in a plant's lifetime (Farnsworth, 2008). Seedling morphology should be thoroughly investigated for a better comprehension of germination, establishment and juvenile growth during the natural regeneration of vegetation (Troup).

*Acacia* species have major role in livelihood of local community of arid and semiarid area such as it provides timber to make furniture's, food for humans, fodder for animal, fibers, gum or resin, medicine, in apiculture, energy fuel, Kattha, tannins and also give contribution in soil erosion control, nitrogen fixation, soil improvement, intercropping, boundary or barrier support and provide shade of trees to give relief from sun rays. The concepts of juvenility and heteroblasty are potential applications for taxonomy. The sequence of explanation follows morphological details of Seedling stature, Roots, Hypocotyls, Cotyledons, Epicotyls, Upper internodes, Leaves, etc. This paper focuses on four commonly found species of *Acacia* that are mostly found in arid, semiarid, tropical and subtropical region of India: *Acacia mangium* Willd., *A. auriculiformis* A.Cunn.ex Benth., *A. polyacantha* Willd and *A. farnesiana* (Linn.) Willd.

## 2. MATERIALS AND METHODS

*Acacia* seeds are thick and have a very hard seed coat that protects their embryo from unfavorable harsh environmental condition and without pre-germination treatment their seed germination is not possible. Seeds of all *Acacia* species were collected from identified plants and verified seeds from different locations of Rajasthan and India. The seeds usually have a fleshy outgrowth called an aril where the seed attaches to the pod. The arils may be white or brightly coloured and are often attractive to ants or birds that help disperse of the seed [3]. *Acacia auriculiformis* seeds are encircled by a long red, yellow or orange aril. *Acacia polyacantha* and *A. farnesiana* seeds don't have any aril structure. *Acacia mangium* seed attached with yellow-orange Aril. Seed coat of *Acacia farnesiana* is comparatively hard than other three *Acacia* species. These seeds show different shape and size pattern that given below in image.



Fig. 1. Seeds of different species of *Acacia*

An important problem encountered in using *Acacia* species in afforestation programs is the poor germination of their seeds if untreated. This is due to their water impermeable testas, which exerts a physical exogenous dormancy [4]. To accelerate germination of *Acacia* seeds, various pre-germination treatment methods have been assessed including soaking in boiling water and sulphuric acid scarification (Doran and Genn 1987). One of the simplest and most direct methods is to cut, drill or file a small hole in the seed coat before sowing. This was done on *Acacia* seeds in Honduras (Willian 1985). In other work soaking the seed in cold water for many hours gave an effective treatment for *A. farnesiana* (Doran and Gunn 1987). The seed coat of *Acacia* species are very hard so these were germinated by pouring boiling water over the seeds, incubating for 10-15 minutes then allowing to cool down to room temperature, then placed in fresh water and left to soak overnight or additional day. Imbibed seeds were scarified with blade and cutter. These were then planted in soil mixture of pot at 20° to 25°C for effective germination [5]. All these species were observed at different stage of seedling development for their taxonomic description. Some minor seedlings morphological characters were observed by Nikon eclipse e400 light microscope with 4x and 10x resolution such as glandular hair or trichome. Each seedling morphological characters were described by following the terminology proposed by Burger [6]; Hickey [7]; Dilcher [8]; Vogel [9] that was followed by many authors for seedling description (Paria et al. (1990); Kamilya and Paria [10]; Ahammed and Paria [11]; Singh [12]; Malik [13]). These taxa seedling specimens have been deposited in the form of herbarium sheets at Department of Botany, University of Rajasthan. The Images were taken with a Nikon Coolpix 4500 digital camera. The images were edited for clean background spots, brightness, sharpness and contrast adjustment in Adobe Photoshop. Two adjacent pictures near both sides of seedling images were photo merged using Adobe Photoshop.

### 3. RESULTS

The identification key of *Acacia* species based on seedling morphology is given below:-

#### 1. Leaves bipinnate with phyllotaxy alternate; cotyledons orbiculate or elliptic-ovate

2. Cotyledons orbiculate, petiolate  $\pm 0.3$ cm length ..... *A. polyacantha*.
2. Cotyledons (as a paracotyledon), elliptic-ovate
3. Phyllodisation of petiole at 4th and subsequent leaves present.....*A. auriculiformis*.
3. Phyllodisation of petiole at 9th and subsequent leaves present, on germination seedlings give pink and red color appearance on outer surface of hypocotyl and cotyledons.....*A. mangium*.

#### 1. Leaves pinnate with phyllotaxy opposite in the first two leaves

2. Cotyledon oblong, coriaceous, 7-8 leaflet pair in first leaf, spinous stipule found at and above 4th leaf stage, actinodromous venation.....*A. farnesiana*.

1. ***Acacia auriculiformis* A.Cunn.ex Benth. In hook. London J. Bot. 1: 377.1842; Chatterjee in Bull. Bot. Soc. Bengal 12: 107. 1958. Chakrabarty & Gangopadhyay, J. Econ. Taxon Bot. 20: 599-633. 1996. Maheshwari, The Flora of Delhi 149. 1963.**

**Vernacular name:** Bengali babul (In Hindi), Akashia (in Marathi), Akash mono in Bengali.

**Flowering:** Nov. - Jan. Fruiting: July-Sept. Next Year.

**Seedlings type** epigeal, phanerocotylar (PEF),  $\pm 7.3$ cm total height at first two leaves and  $\pm 3.3$ cm above collet. **Roots(at first leaf)** tap root, primary root comparatively thin, wavy,

±4.1cm length, white turning yellow, smooth, collet present, numerous lateral roots at 1st leaf stage and branched, filamentous, curly, glabrous. **Hypocotyl** epigeous, erect, elongating, slender, length ±5.5cm, thickened at base slightly disk shape collet, terete, color pale green with reddish purple half upper part, glabrous. **Paracotyledons** two, opposite, assimilating, foliaceous, epigeous, equal, sessile, exstipulate, actinodromous, glabrous; blade shape elliptic, somewhat membranaceous, apex rounded, base somewhat auriculate, entire, above surface light green, lower surface pale green and suffused with purple, slightly distinct nerved, glabrous. **Epicotyl** short, first internode length ±0.3 cm, second internode length ±0.6 cm, third internode length 1.4cm, slender, subsequent internodes elongating, erect, hard, green, tapering toward above node, spiral obtusangular internodes connection, terete, pubescent or trichomatous. **Phyllotaxy** alternate, 1<sup>st</sup> leaf uniparipinnate and 2<sup>nd</sup> leaf biparipinnately compound so first two leaves have pinnate: bipinnate phyllotaxy (alternate to each other), higher leaves distichous alternate, from 4 th node phyllodisation of leaflet petiole or primary rachis present. **Leaves 1st two leaf (including 1<sup>st</sup> and 2<sup>nd</sup> leaf)** alternate, supracotyledonary, uniparipinnate, compound; stipulate, two stipule, leafy; petiole or primary rachis length ±1.1 cm, inflated, trichomatous; 4-5 pairs of leaflet, opposite, very shortly petiolulate, ±0.2 cm, blade shape oblong with index 0.3-0.6 cm x 0.6-0.12 cm, lamina asymmetrical, thin, apex acute, base asymmetrically rounded, no. of primary veins three Actinodromous, above surface dark green, beneath light green, glabrous. **3<sup>rd</sup> Leaf** alternate, biparipinnate, stipulate, two stipule, leafy; primary rachis or petiole ±1.8 cm, inflated, petiole, secondary rachis ±2.1 cm, slightly thickened at base, inflated, above surface dark green, lower surface light green, one pair of pinnae, opposite, 5-6 pairs of leaflet, petiolulate, opposite, blade small, blades oblong, asymmetrical, largest leaf blade size in middle, thin, apex acute, base asymmetrically obtuse, actinodromous, entire, glabrous, above dark green, beneath light green. **4<sup>th</sup> leaf** alternate, Alternate, biparipinnate, stipulate, two, leafy, primary rachis modify into phyllode, phyllodes have two or more conspicuous nerves and tapering to both ends, secondary rachis ±1.9 cm trichomatous; one pairs of pinna, opposite, 7-8 pair of leaflet, shape oblong, asymmetrical, middle leaflet largest then apical, apex acute or minutely apiculate, asymmetrical obtuse base, actinodromous, entire, glabrous. Ahead 5<sup>th</sup> and subsequent

leaves leaflet convert to phylloclade (leaf like green lanceolate structure that narrow at both end).

2. **Vachellia farnesiana (L.) Wight & Arn.**  
**Synonym *Acacia farnesiana* (Linn.) Willd.**  
**Sp. Pl. 4 : 1083. 1806; Baker in Hook. f., Fl. Brit. India 2: 292. 1878; Ross Bot. Surv. S. Afr. 44: 1-150. 1979; Kumar, J. Econ. Taxon. Bot. 21: 381-391, 1997.**

**Vernacular name:** Vilaiti Babul.

**Flowering:** March - june. Fruits: july - Dec.

**Seedlings type** epigeal, phanerocotylar(PEF), stinking, ±11.5cm total height at first two leaves.

**Roots (at first leaf)** tap root, primary root thin, hard, wavy, elongating, ±5.6 cm long, color white turning yellow, fine smooth, collet present, numerous lateral roots at 1st stage, filiform, soft, unbranched, glabrous. **Hypocotyl** epigeous, erect, length ±5.5 cm, elongating, straight, terete, thickened at base, slightly disk shape at collet, glabrous, smooth, slender, erect, white to green from lower to upper half part. **Cotyledons** two, opposite, oblique, persistent up to 5-6th leaf stage, exstipulate, petiolate ±0.3 cm long, fleshy, glabrous, light green, upper surface dark green; blade oblong, (0.8-1.1 cm x 0.3-0.6 cm), apex rounded, an arrow shape based or sagittate, margin entire, indistinctly nerved, glabrous, beneath surface convex and upper plain. Epicotyl first internode length ± 0.4 cm long, terete, second internode slightly angled, length 1.5-1.7cm, third internode length ±1.1 cm, subsequent internodes elongating, green, glabrous, slender, erect, spiral obtusangular internode connection, tapering toward above node. **Phyllotaxy** alternate, but 1st two leaves have pinnate: pinnate phyllotaxy (opposite to each other).higher leaves distichous alternate. **Leaves first two leaves (including 1<sup>st</sup> and 2<sup>nd</sup> leaf)** opposite, supracotyledonary, uniparipinnate, pinnately compound; stipulate, two stipules, needle shape, linear, free lateral, petiolate, petiole or primary rachis length ±0.8cm long, inflated, green, glabrous, dorsally channeled, 7-8 pairs of leaflet, opposite, very shortly petiolulate, blade shape oblong 0.6-0.13 cm x 0.4-0.7 cm, largest leaflet size in middle, thin, leaflet base obtuse, asymmetric, leaflet apex acute, entire margin; actinodromous. **3<sup>rd</sup> Leaf** Subsequent leaves alternate, biparipinnate, stipulate, two stipule, spinescent, petiolate primary rachis or petiole length 0.5 cm., secondary rachis length 1.1 cm., slightly thickened at base or inflated, narrow dorsal channel upon rachis present, one pair of pinnae, opposite, 12-14 pairs of leaflet, petiolulate,

opposite, blade shape oblong, leaflet apex acute leaflet base obtuse and asymmetric, blade thin, entire, glabrous above surface dark green, beneath surface light green, largest leaflet blade in middle. **4<sup>th</sup> and subsequent leaves** alternate, biparipinnate, stipulate, two, spiny in subsequent leaves, primary rachis  $\pm 0.6$  cm, secondary rachis  $\pm 1.6$  cm in length, trichomatous, one pair of pinna, 13-16 pairs of leaflet, opposite, blade oblong, apex acute or apiculate, base asymmetrically obtuse, entire. Subsequent leaves alternate, have more pairs of pinna, increasing size of leaflet, stipules modify in to spines.

**3. *Acacia mangium* Willd. Sp. Pl.ed. 4 (Willdenow [14]) 4(2): 1053. 1806; Merrill, An Enumeration of Philippine Flowering Plants 2 (3): 241-323. 1923; Chakrabarty & Gangopadhyay, J. Econ. Taxon Bot. 20: 599-633. 1996.**

**Vernacular name:** Black wattle, Hickory wattle, Sabah salwood.

**Flowering:** Feb.- june. **Fruiting:** July-Oct.

**Seedlings type** epigeal, phanerocotylar (PEF), not stinking,  $\pm 8.1$  cm total height at first two leaves, maroon-red color appearance of seedlings on outer surface. **Roots (at first leaf)** tap root, primary root comparatively thin, slender,  $\pm 4.2$  cm length, white turning yellow, smooth, disk shape collet present, numerous lateral roots at 1<sup>st</sup> stage of leaf and branched. **Hypocotyl** epigeous, erect, straight, length  $\pm 3.9$  cm, thickened at base slightly disk shape, terete, hard at fourth leaf stage, glabrous, pale green.

**Paracotyledons** foliaceous, two, persistent up to fourth or fifth stage, epigeous, equal, exstipulate, sessile, thin, glabrous; blade shape narrow elliptic, blade thickness at margin and centre  $\pm 0.2$  cm., coriaceous, apex rounded, base somewhat auriculate, indistinctly nerved, entire, upper surface dark green, lower surface pale green. **Epicotyl** reduced at first leaf stage, first internode length  $\pm 0.4$  cm, second internode length  $\pm 1.1$  cm, third internode length  $\pm 1.9$  cm, **Subsequent internodes** elongating, slender, green, hard, tapering toward above node, spiral obtusangular internodes connection, terete, angular near top, green pubescent. **Phyllotaxy** alternate, 1<sup>st</sup> leaf uniparipinnate and 2<sup>nd</sup> leaf biparipinnate, compound so first two leaves have pinnate: bipinnate phyllotaxy (alternate to each other), higher leaves distichous alternate, after 9<sup>th</sup> node phyllodisation of leaflet petiole or primary rachis present; **Leaves 1<sup>st</sup> two leaf (including 1<sup>st</sup> and 2<sup>nd</sup> leaf)** alternate, supracotyledonary, compound, paripinnate,

stipulate (two stipule, herbaceous, free lateral).

**1<sup>st</sup> leaf** uniparipinnate, petiolate, primary rachis length  $\pm 1.7$  cm, trichomatous, inflated or slightly thickened at base; 5 pairs of leaflet, opposite, very shortly petiolulate  $\pm 0.1$  cm, lamina asymmetrical, blade shape oblong with index  $\pm 0.6$  cm x  $\pm 0.3$  cm, thin, apex acute, base asymmetrically rounded, labrous, upper surface color green, lower surface color light green, pubescent. **2<sup>nd</sup> leaf** alternate, biparipinnate, stipulate, primary rachis length  $\pm 1.5$  cm, 2<sup>nd</sup> leaf secondary rachis length  $\pm 1.9$  cm, slightly thickened at base, trichomatous; 5 pairs of leaflet, opposite, very shortly petiolulate,  $\pm 1.7$  mm, blade shape oblong with index  $\pm 0.8$  cm x  $\pm 0.4$  cm, asymmetrical, thin, apex obtuse, base asymmetrically rounded, pinnately nerved, glabrous, upper surface color green, lower surface color light green, glabrous. **3<sup>rd</sup> Leaf** alternate, biparipinnate, primary rachis or petiole  $\pm 1.9$  cm, inflated petiole, secondary rachis  $\pm 2.3$  cm, slightly thickened at base, trichomatous, color light green, one pair of pinnae, opposite, 7-8 pairs of leaflet, petiolulate, opposite, blade smaller, blades oblong, asymmetrical, largest leaf blade size in middle, thin, apex obtuse, base asymmetrical rounded, pinnate venation, entire, glabrous, upper surface dark green, lower surface light green. **4<sup>th</sup> and subsequent leaves** alternate, increasing in pair of pinna and leaflet pair, other characters are same. After 9<sup>th</sup> node leaflet petiole modify in phyllode, in subsequent leaves leaflet completely absent and phyllode of lanciolate shape with three clear primary veins are present.

**4. *Senegalia polycantha* (Willd.) Seigler & Ebinger, synonym *Acacia polycantha* Willd. Sp. Pl. 4: 1079. 1806; Chakrabarty & Gangopadhyay, J. Econ. Taxon Bot. 20: 599-633. 1996.**

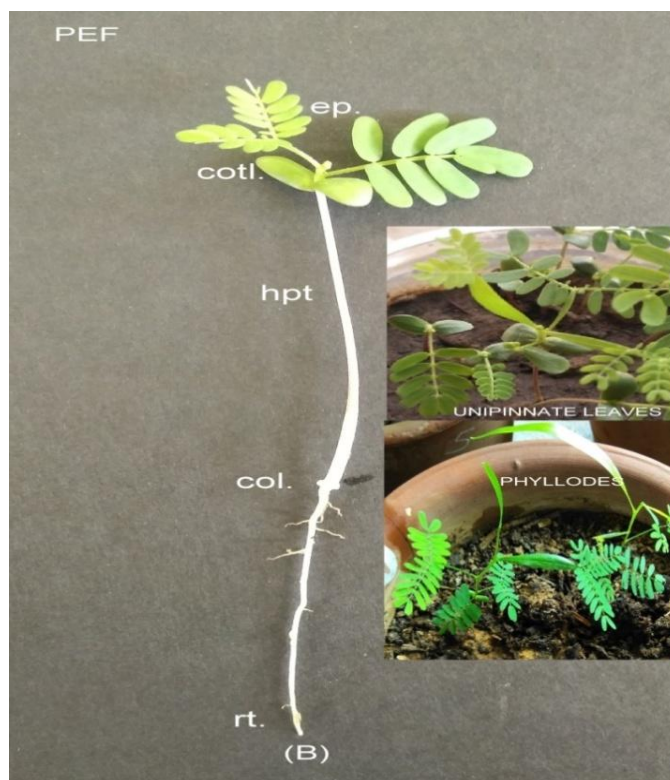
**Vernacular name:** kumtia, sonkhairi, white thorn.

**Flowering:** May-July. **Fruiting:** July-sept.

**Seedlings type** epigeal, phanerocotylar (PEF), foliaceous, total height  $\pm 9.1$  cm at first two leaves, **Roots (at first leaf stage)** tap root, thick, wavy,  $\pm 4.9$  cm length, white turning yellow, smooth, saucer shaped collet present, many sec. lateral roots at 1<sup>st</sup> stage, curled, branched, and glabrous. **Hypocotyls** epigeous, erect, length  $\pm 4.2$  cm, thickened at base, terete, projecting rim at collet, tap root originated from collet rim, color pale green at upper half and white at base, glabrous. **Cotyledons** two 2, epigeous, equal, opposite, coriaceous, petiolate (normal), length  $\pm 0.3$  mm, glabrous; blade orbiculate, blade

margin entire, apex rounded, an arrow-shaped base sagittate, exstipulate, indistinctly nerved, above surface dark green, lower surface light green, glabrous, blade concave above and convex beneath, persistent up to four to seventh leaves stages. **Epicotyls** developed, elongating, first internode length  $\pm 1.4$  cm, Second internode length  $\pm 0.6$  cm, third internode length  $\pm 1.6$  cm slender, **Subsequent internodes** elongating, erect, green, hard, glabrous, tapering toward above node, angular internodes connection, terete, angular near top, green. **Phyllotaxy** alternate, but 1<sup>st</sup> two leaves have pinnate: bipinnate phyllotaxy (opposite to each other), higher leaves distichous alternate. **Leaves** 1<sup>st</sup> Leaf alternate, compound supracotyledonary, uniparipinnate; stipulate, glabrous, two stipule, leafy, free lateral; petiolate, petiole or Primary rachis length  $\pm 1.7$ cm, inflated, 5-6 pairs of leaflet, opposite, very shortly petiolulate(normal)  $\pm 3$ mm, lamina asymmetrical, blade shape oblong with index 0.5-0.6cm x 0.5-0.12cm, thin, apex acute, leaf base obtuse, actinodromous, margin entire, green. 2<sup>nd</sup> Leaf alternate, compound

biparipinnate, stipulate two leafy, herbaceous, petiolate, primary rachis length  $\pm 1.2$  cm, secondary rachis length  $\pm 1.5$  cm, two pair of pinna, 6-7 pair of leaflet, petiolulate, lamina asymmetrical, blade shape oblong, leaf apex acute, leaf base obtuse asymmetrical. 3<sup>rd</sup> Leaf alternate, biparipinnate, stipulate, two stipule, leafy; primary rachis or petiole  $\pm 1.4$  cm, secondary rachis  $\pm 1.7$  cm, slightly thickened at base, one pair of pinnae, opposite, 6-7 pairs of leaflet, petiolulate, opposite, blade smaller, thin, blades oblong, asymmetrical, largest leaf blade size in middle, apex acute, base obtuse asymmetrical, entire, glabrous, above surface dark green, lower surface light green. 4<sup>th</sup> Leaf alternate, biparipinnate, stipulate, primary rachis  $\pm 1.5$  cm, secondary rachis  $\pm 1.7$  cm, 2 pairs of pinna, opposite, shape oblong, shortly petiolulate  $\pm 1.5$  mm, asymmetrical, middle leaflet largest then margin, apex acute minutely apiculate, asymmetrical, obtuse base, entire, glabrous. Ahead in subsequent leaves pair of pinna and leaflet increases.



**Fig. 2. Seedling stage of *Acacia auriculiformis*. Seedling germination period 7-16 days. Seed source Identified adult plants and verified seeds. (rt.root, col.collet, hpt.hypocotyl, cotl. Cotyledon, ep. Eophyll, PEF. Phanerocotylar epigeal foliaceous seedlings)**



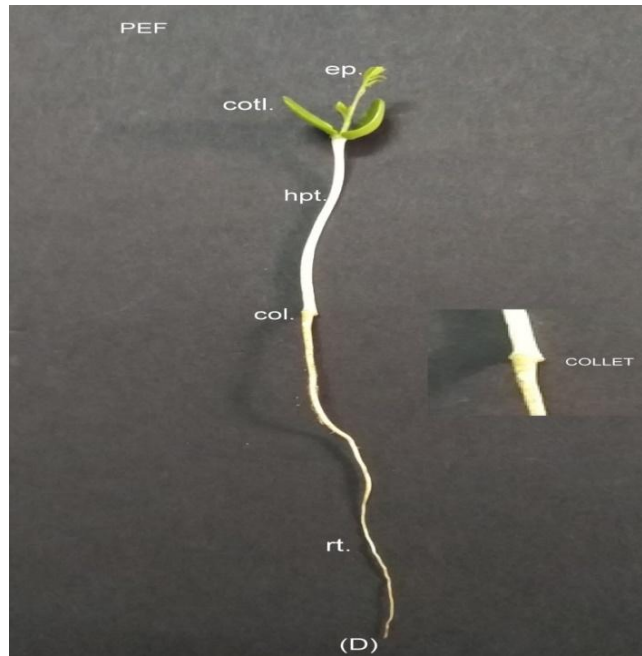


Fig. 3. Seedling stage of *Acacia farnesiana*. Seedling germination period 10-20 days. Seed source-Identified adult plants and verified seeds. (rt.root, sec.rt. secondary root, col.collet, hpt.hypocotyl, cotl. Cotyledon, ep. Eophyll, PEF. Phanerocotylar epigeal foliaceus seedlings)

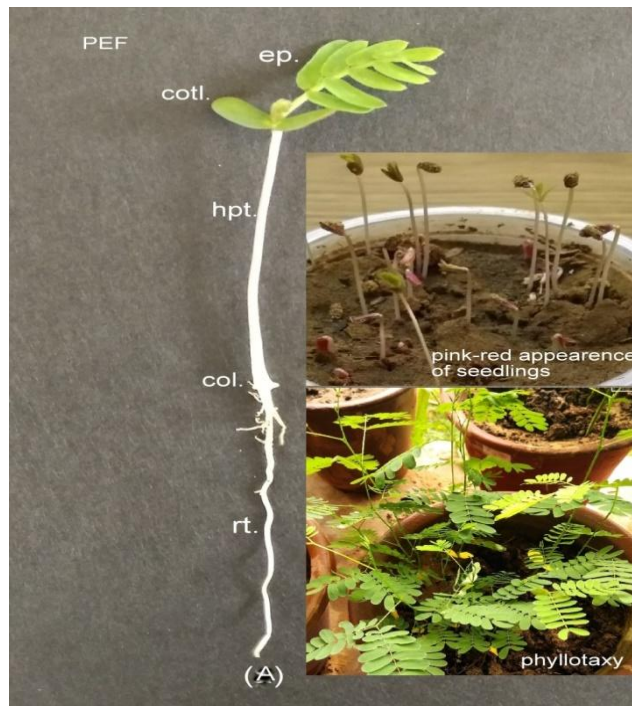


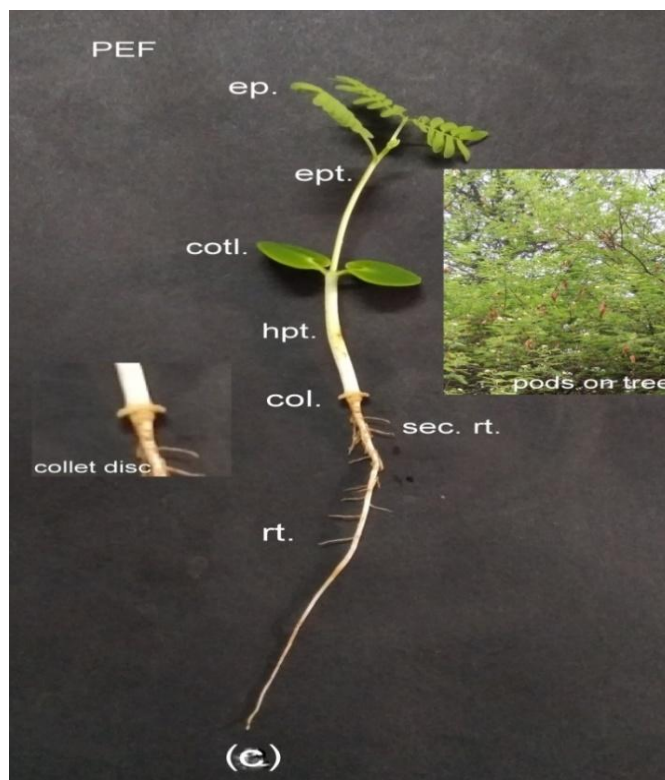
Fig. 4. Seedling stage of *Acacia mangium*. Seedling germination period 8-18 days. Seed source-Identified adult plants and verified seeds. (rt.root, col.collet, hpt.hypocotyl, cotl. Cotyledon, ep. Eophyll, PEF. Phanerocotylar epigeal foliaceus seedlings)

#### 4. DISCUSSION

The present study of this paper show that *Acacia* species show very unique morphological characters at juvenile stage. *Acacia mangium* seedlings give maroon-red color appearance on germination. Their hypocotyl and cotyledon have translucent appearance at cotyledonary stage and have five pair of leaflet. As shown in Table 1 in *Acacia auriculiformis* at 4<sup>th</sup> leaf stage petiole of biparipinnate leaves convert in to very flattened structure called phylloclade and after 5<sup>th</sup> or 6<sup>th</sup> leaf stage leaflet are absent and modify phylloclade structure appears that is linear lanceolate in shape. *Acacia polyacantha* seedlings have a well develop saucer shaped collet, orbiculate cotyledons and  $\pm 1.6$  cm epicotyl. *Acacia mangium*, *A. auriculiformis*, *Acacia polyacantha* seedling have same phyllotaxy pattern at first two leaf stage that is uniparipinnate: biparipinnate, alternate. But *Acacia farnesiana* have uniparipinnate, opposite

phyllotaxy pattern at first two leaf stage of seedlings. In this pattern two uniparipinnate leaves found on opposite side to each other and each have eight pair of leaflet and also have needle shape spiny stipules that ascendingly grow in height in subsequent leaves. *Acacia* Mill. Species that have pinnate: pinnate phyllotaxy have identical number of of leaflet pair on their first and second leaves [5].

But as a genus *Acacia* has some common characteristic feature that commonly found in all species of this genus such as disk shape collet, blade with auriculate or sagittate base, phyllotaxy alternate, stipulate leaves, stipules whether or not spinous, first two leaves have one pair of pinna, leaflet opposite, shortly petiolulate. After seedlings observation an artificial dichotomous identification key has been prepared for identify these plants at juvenile stage and herbarium sheets were deposited at Department of Botany, University of Rajasthan.



**Fig. 5. Seedling stage of *Acacia polyacantha*. Seedling germination period 10-20 days. Seed source-identified adult plants and verified seeds. (rt.root, sec.rt. secondary root, col.collet, hpt.hypocotyl, cotl. Cotyledon, ep. Eophyll, PEF. Phanerocotylar epigeal foliaceous seedlings)**



Table 1. Taxa characteristics

Taxa→ characters ↓	<i>A. mangium</i>	<i>A. auriculi-formis</i>	<i>A. polyacantha</i>	<i>A. farnesiana</i>
Seedling type	Epigeal, phanerocotylar	Epigeal, phanerocotylar	Epigeal, phanerocotylar	Epigeal, Phanerocotylar
Seedling stinking	Not	Not	Yes	Yes
Root collet	Tap root Present	Tap root Present	Tap root Present, saucer shape	Tap root Present
Hypocotyl Cotyledon	Glabrous, slender Paracotyledon, Opposite, persistant up to fourth or fifth stage.	Glabrous, slender Opposite	Glabrous, slender Opposite	Glabrous, slender Opposite
Shape	Narrow elliptic	Elliptic	Orbiculate	Oblong
Apex	Rounded	Rounded	Rounded	Rounded
Base	Somewhat auriculate	Auriculate	Sagittate	Auriculate
Petiole	Petiolate	Sessile	Petiolate	Petiolate
Surface	Glabrous	Glabrous	Glabrous	Glabrous
Color	Above pale green, beneath maroon-red	Above green, beneath pale green	Above green, beneath pale green	Above green, beneath pale green
Epicotyl	Very short, not evident ±0.4 cm	Very short, ±0.2 cm	Evident, ±1.6 cm	Short, ±0.4 cm
Subsequent internodes	Erect, pubescent, green	Erect, green, pubescent	Erect, green, glabrous	Erect, green, glabrous
Phyllotaxy 1 <sup>st</sup> and 2 <sup>nd</sup> leaf	Pinnate: Bipinnate, alternate	Pinnate: Bipinnate, alternate	Pinnate: Bipinnate, alternate	Pinnate: pinnate, opposite
3 <sup>rd</sup> leaf phyllotaxy	Alternate, biparipinnate, one pair of pinna	Alternate, biparipinnate, one pair of pinna	Alternate, Biparipinnate, one pair of pinna	Alternate, biparipinnate, two pair of pinna
4 <sup>th</sup> leaf phyllotaxy	Alternate, biparipinnate	Alternate, biparipinnate	Alternate, biparipinnate	Alternate, biparipinnate and two pair of pinna
Venation	Actinodromous	Actinodromous	Actinodromous	Actinodromous
Leaves Petiolate /sessile	Petiolate, from 9 <sup>th</sup> leaf stage petiole modify in to phyllodes	Petiolate, from 4 <sup>th</sup> leaf stage petiole modify in phyllodes	Petiolate	Petiolate
Stipules	Stipulate, two	Stipulate, two	Stipulate, two	Stipulate, two
Stipule shape	Leafy herbaceous	Leafy	Leafy	Spinescent
Rachis	Pubescent	Pubescent	Glabrous	Glabrous
Leaflet pairs	5 pair	5 pair	5 pair	8 pair
Lamina	Asymmetrical	Asymmetrical	Aymmetrical	Asymmetrical
Leaflet shape	Oblong	Linear-oblong	Oblong	Oblong
Margin	Entire	Entire	Entire	Entire
Surface	Glabrous	Glabrous	Glabrous	Hairy
Apex	Acute	Acute	Acute	Acute
Base	Rounded	Rounded	Obtuse	Obtuse

## 5. CONCLUSION

Therefore we can conclude that Seedling taxonomy as a tool gives a very significant knowledge about the process of establishment of stable adult traits in mature plants from juvenile stage. The seedling establishment of *Acacias* is technically feasible and provides methodology that useful to arid restoration projects [15]. The parameters of seedling morphology give unique pattern of characters such as Roots, Hypocotyls, Cotyledons, Epicotyls, Upper internodes, Leaves, etc. have great importance to identification, classification and delimitation of taxa.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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