Euphorbia tirucalli is a hedge plant with spreading, cylindric, rush-like, smooth, green, almost leafless branches. It belongs to the family Euphorbiaceae. It grows to a height of about 20 ft. It makes a good fence, as cattle avoid it owing to its acrid milky juice. The older stems are often used for rafters, as the wood is strong and not liable to the attack of insects. The plant shows vigorous growth during monsoon and produces a large number of branches.

**Shoot apex**

The shoot apex is dome shaped with two tunica layers enclosing a massive corpus (Fig. 1). The $T_1$ cells
undergo only anticlinal divisions, but the T2
cells show periclinal and other divisions during
leaf initiation. During a plastochron the apex shows
considerable changes in the structure, size, and
arrangement of the component cells. Based on the
structural and morphological features of the apex five
stages of the plastochron are distinguished as maximal,
minimal, early post-minimal, late post-minimal and pre-
maximal. The variations in height and width are
measured, considering the axil of the youngest visible
leaf primordium as the base of the shoot apex.

**Maximal phase**: The shoot apex shows an average
maximum height of 123 μm and width of 99 μm and
stratification of 5 – 6 layers (Figs. 1, 54). The cells
of the central meristem, CM, are slightly less stained
and larger than those of the peripheral meristem, PM
(Figs. 1, 54). The central meristem extends up to
4 – 5 layers and shows regular stratification (Figs. 1,
54, CM). The peripheral meristem shows more compact
arrangement of cells (Figs. 1, 54). One or two
periclimes are observed in this region. The rib meristem
cells with their characteristic alignment are light
stained, with smaller nuclei and high degree of
vacuolation (Figs. 1, 54, RB).
Minimal phase: $T_2$ and one or two outer corpus layers in a sector of the peripheral meristem show divisions in various planes resulting in the formation of a leaf buttress (Figs. 2, 55, L). The cells of the leaf buttress show more avidity for stains. The leaf trace procambium, PC, is observed below the site of the leaf buttress (Figs. 2, 55). The procambial cells are narrow, elongated and deep staining.

The area of the shoot apex is reduced because of the utilisation of the peripheral meristem in the formation of the leaf buttress. The cells of the central meristem are distinct because of their prominent nuclei and comparatively larger size (Figs. 2, 55). The rib meristem, RB, lacks the characteristic arrangement and shows high vacuolation and less stainability of contents (Figs. 2, 55).

The post-minimal phase: The cells of the leaf buttress undergo more rapid divisions; anticlines in the outer tunica layer and various types of divisions in $T_2$ and inner layers. This histogenetic activity results in the formation of leaf primordium, $L_1$ (Figs. 3, 56). The increase in the frequency of divisions enables the apex to attain more height and width. The rib meristem shows somewhat regular arrangement of cells below the...
first node. This is the early post-minimal phase of the shoot apex. The apex shows an average width of 55 μ.

In the later development the leaf primordium is elevated above the apical dome and the leaf trace procambium, LT, further differentiates acropetally (Figs. 4, 57). The apex shows stratification of 2 - 3 layers and an increase in height and width. The average height and width at this stage are 22 μ and 69 μ respectively. Thus in the late post-minimal phase, the peripheral meristem begins to reconstitute by more regular divisions of its constituent cells.

Pre-maximal phase : The shoot apex shows almost uniform staining of its cells. The stratification is increased up to five layers (Figs. 5, 58). The increase in height and width is attributed to the increased frequency of divisions in the shoot apex. The average height and width are 78 μ and 83 μ respectively.

Ontogeny of lateral buds

Usually one bud is present corresponding to a leaf. It develops from the flank of the apical meristem. During the early ontogeny the lateral bud is observed above the
axil of the leaf. It changes to axillary and finally to axililar position during its further development and growth. It develops into a vegetative branch. A second bud is also observed in elder nodes.

The early bud meristem appears as a group of deeply stained cells on the flank of the apical dome (Fig. 6, BM). It consists of 3 - 4 layers of cells. The outer two layers undergo only anticlinal divisions while the inner layers show periclinal and other types of divisions (Figs. 7, 59). As the bud increases in volume some cells in an arcuate band form a shell zone and separate it from the main axis (Figs. 8, 60, SZ). They are comparatively more vacuolated than the bud meristem cells and less vacuolated than the surrounding cells.

The bud meristem protrudes out by the increased histological activity of its cells (Fig. 9). The increased number of anticlinal divisions in the outer layers and various types of divisions in the inner layers are responsible for this. The shell zone, SZ, appears prominent and extends almost up to the leaf base (Fig. 10). At this stage vacuolation and differentiation proceed from the lower region of the bud (Fig. 11). The bud attains a structure similar to the main shoot apex.
In the bud the initial differentiation of the rib meristem starts from the lower central region. The histologic identity of the shell zone disappears along with these histological changes.

Prophyll formation: As the bud attains a structure similar to the main shoot apex, some T2 cells in a sector of the peripheral meristem, PM, undergo periclinal divisions indicating prophyll initiation (Fig. 12). The prophyll trace procambium, PT, is invariably observed (Fig. 12). The procambial cells are narrow, elongated and deeply stained. A single prophyll is produced at a right angles to the subtending leaf of the bud. At this stage the bud is in the axil of the leaf. After the formation of the prophyll the bud apex increases its height and width by various types of divisions. Simultaneous with these changes a gradual change in position is also observed. The bud at this stage is found on the foliar tissue (Figs. 13, 61). Figures 14 - 16 illustrate the change in position of the bud meristem during this development.

The apex of the bud attains a stratification of about 4 layers (Fig. 13). The initiation of the first leaf occurs at this stage (Fig. 17).
An accessory bud is also observed in some older nodes. It is differentiated as a detached meristem on the abaxial side of the main bud when some of its basal cells appear vacuolated. It is deeply stained and shows anticlines in the outer tunica and various types of divisions in the inner layers, during its early ontogeny (Fig. 18). The surrounding cells are highly vacuolated and unlike the main bud a shell zone is absent.

**Vascularization of the young shoot tip**

The vascularization of the young shoot tip is described in transections from the fourth internode upwards up to the summit of the shoot apex. The measurements given are from the summit of the shoot apex. The number of vascular bundles in an internode is 14, but it may vary. The bundles show variations in size and shape and are arranged in a ring.

At about 443 μ, at the level of the fourth internode 14 vascular bundles are observed (Fig. 19, AV). Figures 20 - 22 show the departure of the three traces of the fourth leaf; LLT, MLT and LLT. The median trace of the third leaf, MLT, departs from the axial vasculature, AV at 247 μ level (Fig. 23). At about 226 μ the two
vascular bundles flanking the median leaf gap of the fourth leaf show the formation of the two bud traces (Fig. 24, BT). The lateral leaf traces of the third leaf differentiate at higher levels (Figs. 25, 26, LLT). The bud traces, BT, of the bud (Fig. 25) corresponding to L₄ depart from the axial vasculature and at 198 μ level they form the provascular system, PV (Fig. 26). The two axial vascular bundles flanking the median leaf gap of the third leaf give rise to two bud traces, BT, at 170 μ (Fig. 27). There are 8 vascular bundles in the second internode (Fig. 28). The median leaf trace, MLT, and the lateral traces, LLT, of the second leaf, L₂, depart at higher levels (Figs. 29, 30). Figure 29 shows the horse-shoe shaped provascular system of the bud in the axil of the third leaf, L₃. It is formed by the differentiation of a strip of residual meristem in between the two arcs towards the adaxial side of the bud. The bud corresponding to the fourth leaf, L₄, shows two arc like provascular system with two procambium strands, PC, in each (Fig. 29). At the level of the second node the bud of the third leaf shows the ring like provascular system with one procambium strand, PC (Fig. 30). The bud corresponding to the fourth leaf, L₄, shows the horse-shoe shaped provascular system with four procambium strands, PC (Fig. 30). At 121 μ residual meristem is
observed in the axial vascular meristem (Fig. 31). Uniformly stained bud meristem, BM, is observed in between the second leaf and the axial vascular meristem (Fig. 31). The bud corresponding to the third node shows less stained central meristem, CM, and slightly more stained peripheral meristem, PM (Fig. 31). The bud of the next lower leaf, $L_4$, shows the horse-shoe-shaped provascular system with 6 procambium strands, PC (Fig. 31). In the first internode 5 procambium strands are observed in the ring of residual meristem, RM (Fig. 32). Figures 33 and 34 illustrate the departure of the median leaf trace, MLT, and the lateral leaf traces, LLT, of the first leaf, $L_1$. Early bud meristem, BM, of the first node is a detached meristem. The provascular system of the bud meristem of the fourth leaf, $L_4$, appears as a ring at about 100 $\mu$ level (Fig. 32). Single prophyll trace is observed at this stage. At a higher level the provascular system, PV, shows 3 procambium strands (Fig. 34) and the median trace, MLT, of the first leaf departs at 44 $\mu$ level (Fig. 35). The shoot apex shows less stained central meristem, CM, surrounded by deep stained peripheral meristem, PM (Fig. 35).
Procambialization of the lateral bud

The lateral bud is a detached meristem during its early ontogeny and it is without any vascular connection, procambial or residual meristematic at the first and second nodes (Figs. 31, 34, BM). The procambialization begins along with prophyll initiation. The early stages of the primary vascularization of the bud are already described along with the primary vascularization of the young shoot tip.

Procambialization of a bud with a well developed prophyll and a leaf: The departure of the leaf traces, LLT, MLT and LLT, from the axial vasculature, AV, is completed at 378 μ level (Fig. 36). The differentiation of the two bud traces, BT, from the two vascular bundles flanking the median leaf gap is illustrated in figures 37, 38 and 62. At higher levels the bud traces, BT, branch into two (Fig. 39). They are observed in association with residual meristem to form the provascular system, PV, of the bud (Figs. 40, 63, 64). The two arc-like configurations of the provascular system of the bud, PV, show two procambium strands, PC, in each up to 245 μ level (Figs. 41, 42). The number of procambium strands increases to three at still higher levels (Fig. 43). The horse-shoe shaped and ring like configurations of the
provascular system are further observed (Figs. 44, 45, 65, 66). The number of procambium strands increases to 10 (Fig. 46). Figures 47 and 67 show the departure of the median prophyll trace, MPT, at about 113 μ level. The lateral traces, LPT, of the prophyll depart at higher levels (Figs. 48, 49, 68). At the level of the first node one procambium strand departs to the first leaf (Figs. 50, 69, LT). The lateral traces differentiate at a later stage of development of the leaf. A transection at 21 μ level shows the apex with a part of the prophyll and first leaf (Fig. 51).

Vascular interrelationship

Figure 52 illustrates the interrelationship of primary vascular strands of four successive nodes and internodes. There are 14 vascular bundles, A - H, in the internode. Near the node P and H branch and give rise to P1, P2, H1 and H2. G is the median leaf trace of the node N1 and E and I are the lateral traces. H1 and P2 traverse up in the internode and during their upward course each gives rise to a bud trace, BT. L, J and N are the median and lateral traces of the node N2. Similar arrangement of the vascular pattern in the successive internodes and nodes is also observed. Thus the
relation of the leaf traces of a node is to the fourth node above/below it and not to the node just above/below it. There is no direct connection between the leaf traces of two consecutive nodes.

Figure 53 is a three dimensional diagram illustrating the vascular interrelationship of axis, leaf and lateral bud.
PLATE 43

FIGS. 1–5. EUPHORBIA TIRUCALLI

Figs. 1–5. L. s. shoot apex, maximal, minimal, early post-minimal, late post-minimal and pre-maximal phases respectively, X 480.

(CM — central meristem; L — leaf buttress; L₁ — first leaf; LT — leaf trace; PC — procambium; PM — peripheral meristem; RB — rib meristem.)
PLATE 44

FIGS. 6 - 18. **EUPHORBIA TIRUCALLI**

Figs. 6 - 17. L. s. bud, developmental stages, X 480. Figs. 6 and 7, early developmental stages; Figs. 8 - 10, shell zone; Fig. 11, rib meristem initiation; Fig. 12, prophyll initiation; Fig. 13, bud after prophyll formation; Figs. 14 - 16, stages in the change of position of the bud; Fig. 17, initiation of the first leaf.

Fig. 18. L. s. developmental stage of the accessory bud, X 480.

(A - axis; AB - accessory bud; B - bud; BM - bud meristem; CM - central meristem; L - leaf; LT - leaf trace; PM - peripheral meristem; PT - prophyll trace; SZ - shell zone.)
PLATE 45

FIGS. 19 - 30. EUPHORBIA TIRUCALLI

Figs. 19 - 30. T. s. vascularization of the young shoot and the lateral bud, X 150.

Fig. 19, fourth internode; Figs. 20 - 23, traces of the fourth leaf; Figs. 24 and 25, bud traces; Fig. 26, traces of the third leaf; Fig. 27, bud traces of the third leaf and the development of the provascular system of the bud corresponding to the fourth leaf; Fig. 28, arc-like provascular system of the bud corresponding to L₄; Fig. 29, horse-shoe shaped provascular system of the bud; Fig. 30, traces of the second leaf and the provascular systems of the buds corresponding to the third and fourth leaves.

(AV - axial vasculature; BT - bud traces; L₃, L₄ - third and fourth leaves; LLT - lateral leaf trace; MLT - median leaf trace; PC - procambium; PV - provascular system of the bud.)
PLATE 46

FIGS. 31 - 42. **EUPHORBIA TIRUCalli**

Figs. 31 - 35. T. s. young shoot, X 150. Fig. 31, early bud meristem and the provascular system of the bud of the fourth leaf; Fig. 32, first internode and the ring-like provascular system of the bud with prophyll and first leaf; Fig. 33, median trace of the first leaf and prophyll trace of the bud; Fig. 34, the lateral leaf traces and the early bud meristem; Fig. 35, apical summit and the median trace of the first leaf of the bud.

Figs. 36 - 42. T. s. node, differentiation of the provascular system of the bud, X 150.

(AV - axial vasculature; BM - bud meristem; BT - bud traces; CM - central meristem; L1, L2 - first and second leaves; LLT - lateral leaf traces; MLT - median leaf trace; PC - procambium; PM - peripheral meristem; PV - provascular system of the bud; PT - prophyll trace; RM - residual meristem.)
PLATE 47

FIGS. 43 - 53. EUPHORBIA TIRUCALLI

Figs. 43 - 51. T. s. developmental stages of the provascular system of the bud, X 150. Figs. 43 - 46, arc-like, horse-shoe shaped and ring like provascular systems of the bud; Fig. 47, the median prophyll trace; Figs. 48 and 49, the lateral prophyll traces; Fig. 50, the trace of the first leaf; Fig. 51, apical summit.

Fig. 52. Schematic representation of the relationship of vascular bundles of four consecutive nodes.

Fig. 53. Three dimensional diagram showing the interrelationship of leaf traces, axial vasculature and bud traces.

(1 - 4 - vascular bundles of the axis; A - N - vascular bundles of the internode; B - bud; BT - bud traces; L - leaf; L₁ - first leaf; LLT - lateral leaf traces; LPT - lateral prophyll trace; MLT - median leaf trace; MPT - median prophyll trace; N₁ - N₄ - four consecutive nodes; P - prophyll; PC - procambium; PV - provascular system of the bud; RM - residual meristem.)
PLATE 48

FIGS. 54 - 61. EUPHORBIA TIRUCALLI

Figs. 54 - 58. L. s. shoot apex, maximal, minimal, early post-minimal, late post-minimal and pre-maximal phases respectively, X 300.

Figs. 59 and 60. L. s. bud, developmental stages, X 500.

Fig. 61. L. s. well developed bud at the base of the leaf, X 300.

(A = axis; B = bud; BM = bud meristem; CM = central meristem; L = leaf; L₁ = first leaf; LM = leaf trace; PC = procambium; PM = peripheral meristem; RB = rib meristem; SZ = shell zone.)
PLATE 49

FIGS. 62 - 69. **EUPHORBIA TIRUCALLI**

Figs. 62 - 69. T. s. stages of differentiation of the provascular system of the bud, X 200.

(AV - axial vasculature; BT - bud traces; LT - leaf trace; LLT - lateral leaf trace; LPT - lateral prophyll trace; MLT - median leaf trace; MPT - median prophyll trace.)