

# The structure of buckwheat, *Fagopyrum esculentum* Moench

JUNE McCLEMENT AND BETTY P. JACKSON

*The School of Pharmacy, Sunderland Polytechnic, Sunderland,  
County Durham, U.K.*

The morphology and anatomy of the aerial parts of *Fagopyrum esculentum* have been described and the most important microscopical characters of value in the identification of commercial Buckwheat have been indicated.

Large quantities of buckwheat are cultivated throughout Europe and North America for the production of rutin. The species usually employed is *Fagopyrum esculentum*, a fast-growing annual from which a crop can be collected within eight to ten weeks of sowing. As the dried commercial material, consisting of the flowering shoots, is usually in a much-broken condition, the histology of the leaves, stems and inflorescence have been examined with a view to finding the diagnostic characters for the identification of this material.

The plant was first described by Moench (1794) and the detailed structure of the seeds was studied by Parkinson (1934). The surface characters of the leaves have been illustrated by Boratyńska (1959) and Miège (1910) investigated the source of the rutin in the stem and leaves but did not describe details of the anatomical structure.

## MATERIALS

Plants were grown in 1966 and 1967 from two different commercial samples of seed, and harvested when in flower. Also, a sample was collected from a growing crop in Northern Italy in July, 1969. All the plants used complied with the type description for the species (Hector, 1938).

## LEAVES

### *Macroscopical characters* (Fig. 1·1)

Leaves measure from 3 to 11 cm in length and 1·5 to 10 cm in breadth; those on the upper part of the plant are cordate to sagittate and the larger, lower leaves are cordate to ovate. The margin is entire or slightly sinuous; the apex is acuminate. The leaves are bright green and thin, with the upper darker than the lower surface. The surfaces are finely pubescent, especially over the veins, which are more prominent on the lower surface.

The venation is palmate, with a central vein (midrib) running to the apex and three main lateral veins on each side, all arising at the same point at the base of the lamina; these lateral veins anastomose about 2 to 3 mm from the margin. The subsidiary venation is reticulate. Most of the leaves are petiolate although a few on the upper part of the stem are sessile. The petiole, 0·5 to 8 cm in length and 0·5 to 2 mm in diameter, is cylindrical with a single longitudinal groove on the adaxial surface, along the two edges of which occur a row of papillae. There is an ochreate stipule at the base of each leaf (Fig. 3·8).

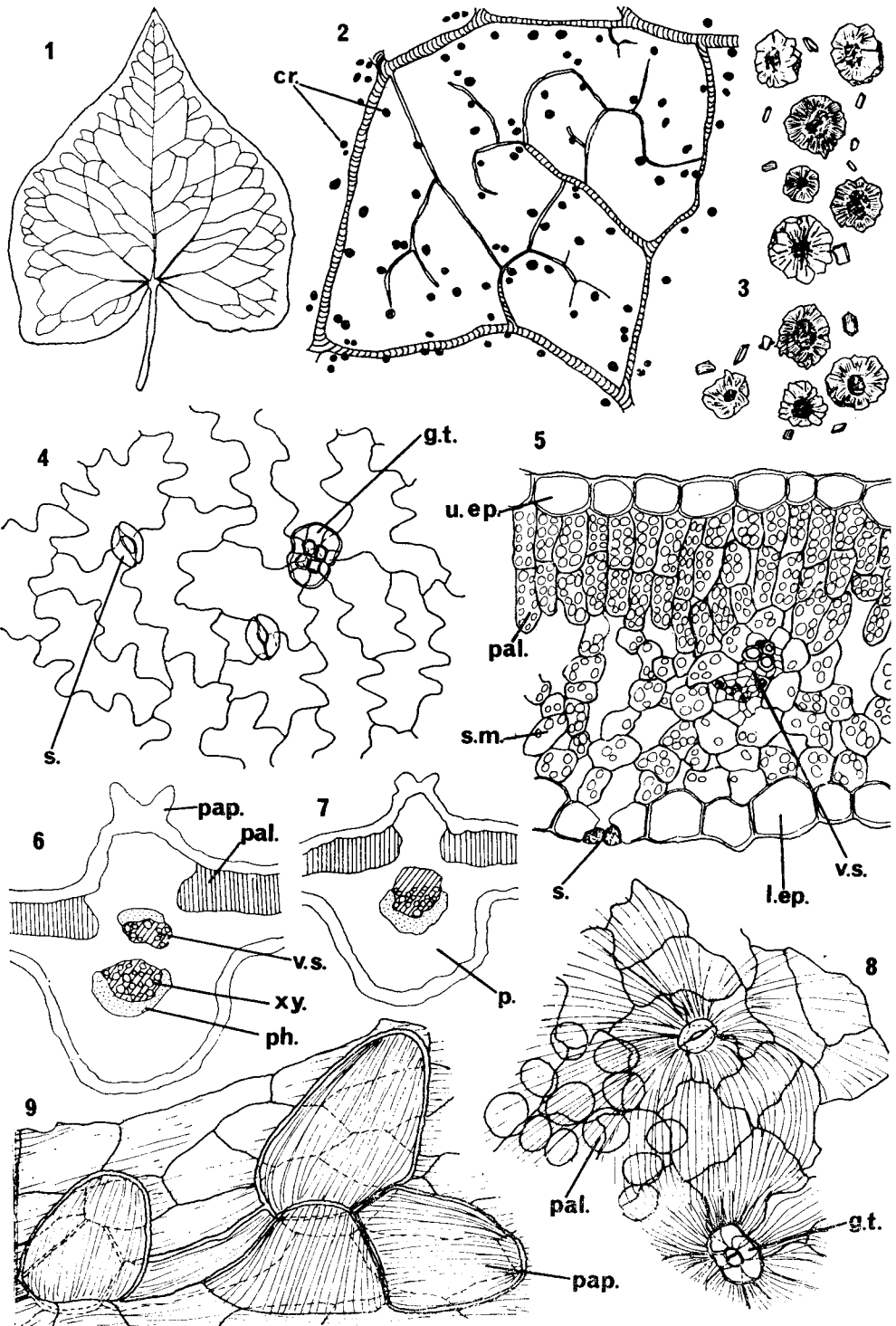


FIG. 1. *Fagopyrum esculentum*, leaf. 1, whole leaf  $\times \frac{1}{2}$ , showing the vein arrangement; 2, lower surface showing distribution of calcium oxalate; 3, calcium oxalate crystals; 4, lower epidermis in surface view; 5, transverse section of the lamina; 6, transverse section of the midrib near the apex; 7, transverse section of the midrib near the petiole; 8, upper epidermis in surface view; 9, upper epidermis over a vein in surface view showing papillae. 2, 6, 7  $\times 45$ ; 3-5, 8, 9  $\times 220$ . cr = calcium oxalate crystals; g.t. = glandular trichome; l.ep. = lower epidermis; pal. = palisade; pap. = papilla; ph. = phloem; s. = stoma; s.m. = spongy mesophyll; u.ep. = upper epidermis; v.s. = vascular strand; xy. = xylem.

### *Histological characters*

*Lamina.* The upper epidermis (Fig. 1·8) consists of a layer of thin-walled cells, polygonal to elongated in surface view with slightly sinuous anticlinal walls; the cuticle is strongly striated. Anomocytic and occasional anisocytic stomata are present. The scattered glandular trichomes have a stalk composed of four contiguous cells and a multicellular, sub-spherical to ovoid head; numerous short, bluntly-tapering papillae covered by a strongly striated cuticle, occur over the veins (Fig. 1·9). The mesophyll is clearly differentiated. The palisade consists of two (or occasionally three) layers of cells in which the length varies from one to three times the breadth; the cells contain numerous chloroplasts. The spongy mesophyll is loosely packed, with numerous intercellular spaces; the cells are irregular and contain scattered chloroplasts. Occasional cells contain cluster crystals of calcium oxalate up to about 45  $\mu\text{m}$  in diameter or, less frequently, prisms about 12–15  $\mu\text{m}$  long (Fig. 1·2, 1·3).

The cells of the lower epidermis (Fig. 1·4) are irregular and slightly elongated in surface view with thin, very sinuous anticlinal walls; the outer periclinal walls are slightly convex and covered with a thin cuticle which is not striated. Anomocytic and anisocytic stomata occur more frequently than on the upper surface but are not present over the veins. There are more glandular trichomes than on the upper epidermis and they are similar in structure. Papillae occur only rarely over the veins on the lower surface.

*Midrib.* In the region of the midrib the cells of the upper epidermis are larger than those of the interneural lamina and two adjacent cells immediately above the centre of the meristele are much enlarged and extended to form two rows of papillae (Fig. 2·1). The outer periclinal walls are covered, as on the lamina, by a striated cuticle which also covers the papillae. The cells are longitudinally elongated with nearly straight anticlinal walls; the cuticle is not striated. Immediately inside the upper epidermis, in the region of the papillae, there is a group of parenchymatous cells with slightly thickened walls. The remainder of the area between the upper and lower epidermises and the meristele is filled with thin-walled parenchymatous cells, some of which contain cluster crystals or, occasionally, prisms of calcium oxalate.

The structure of the meristele, as seen in a transverse section, varies with the position along the length of the leaf. At the base a small, additional group of vascular tissue occurs between the main central group and the upper epidermis (Fig. 1·6). This second vascular bundle continues up the leaf to a point approximately half way between the base and the apex (Fig. 1·7). In the main bundle the xylem forms an irregular to semicircular mass with the phloem occurring as a fairly wide band on the lower side. Where the second bundle is present it is orientated with the xylem forming an irregular compact mass on the inside and phloem towards the outside; thin-walled parenchymatous tissue separates the two groups of xylem.

The xylem is composed of vessels with thick, lignified walls, interspersed with small, thin-walled unlignified xylem parenchymatous cells. In transverse section the phloem appears as small, thin-walled cells, some of which contain dense contents. (Fig. 2·1).

*Petiole.* The epidermis consists of thin-walled polygonal cells, elongated in surface view with a strongly striated cuticle. Stomata are present and the subsidiary cells are much smaller than the remainder of the epidermal cells and are approximately

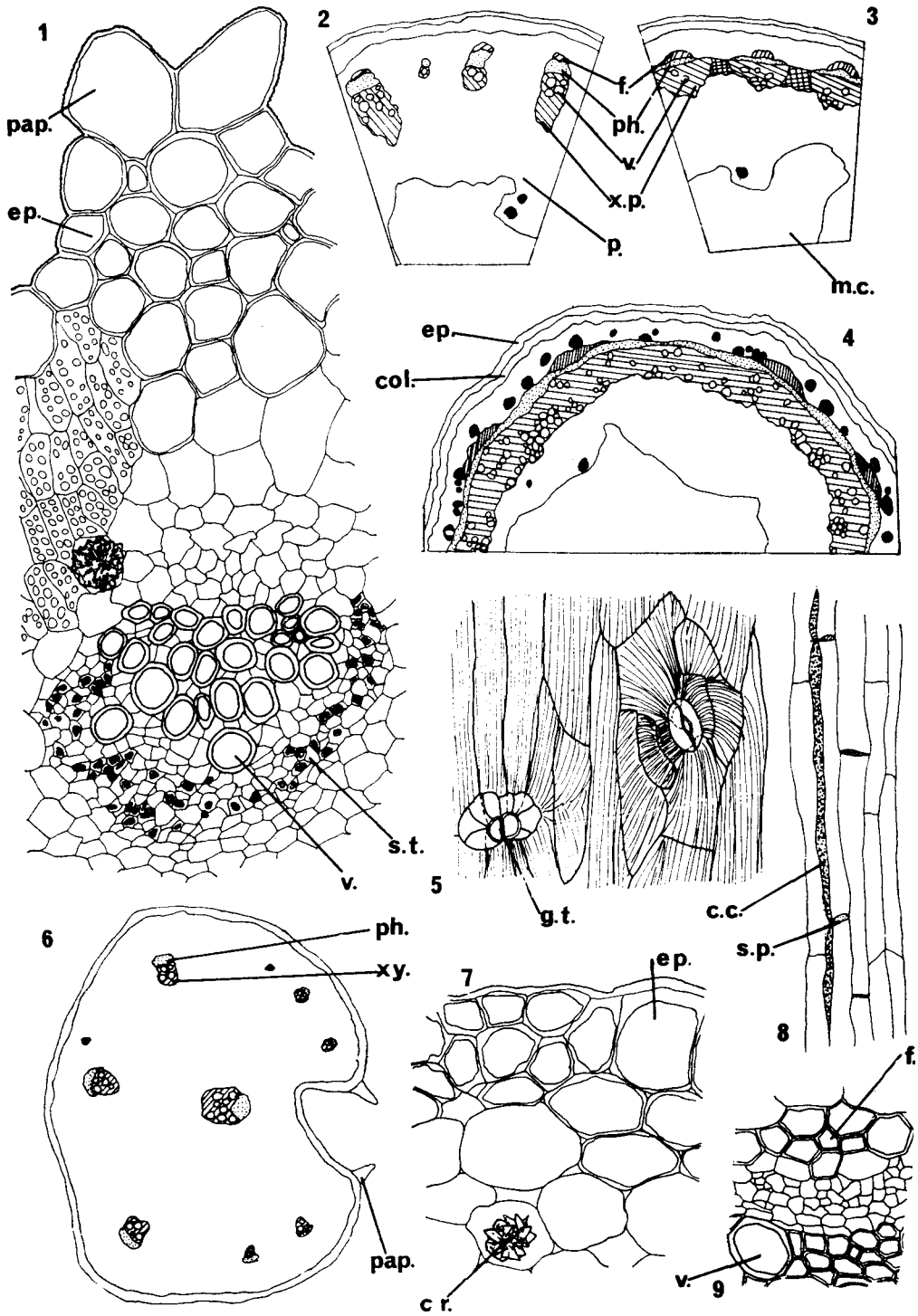


FIG. 2. *Fagopyrum esculentum*, leaf and stem. 1, transverse section of the midrib near the apex; 2, 3, 4, diagrams of transverse sections of young, older and fully mature stems respectively; 5, epidermis of the petiole in surface view; 6, diagram of a transverse section of the petiole; 7, transverse section of outer tissues of a young stem; 8, sieve tissue in longitudinal section; 9, transverse section through the vascular tissues of an older stem. 2, 3, 4 and 6  $\times 45$ , others  $\times 220$ . c.c. = companion cell; col. = collenchyma; cr. = calcium oxalate crystal; ep. = epidermis; f. = fibres; g.t. = glandular trichome; m.c. = pith cavity; p. = parenchyma; pap. = papilla; ph. = phloem; s.p. = sieve plate; s.t. = sieve tube; v. = vessel; x.p. = xylem parenchyma; xy. = xylem.

radially arranged (Fig. 2·5). There are scattered glandular trichomes similar to those on the leaves, and along each edge of the longitudinal furrow there is a single row of elongated papillae.

A transverse section through the petiole is sub-reniform in outline with the groove forming a well-marked indentation, on either side of which occur the papillae (Fig. 2·6). The ground tissue is composed of thin-walled parenchyma with occasional cells containing cluster crystals of calcium oxalate. The main vascular bundle occurs near the central region in line with the groove on the upper surface; it is composed of an irregular mass of xylem with a compact mass of phloem towards the outside. Other, similarly-constructed but slightly smaller, vascular bundles occur round the periphery; usually three such bundles are found in the lower part of the petiole and four much smaller bundles, composed of a few elements only, on each side of the groove (Fig. 2·6). The structure of the xylem and phloem in the bundles is similar to that of the meristele of the midrib except that a cambium is present in the larger bundles.

#### STEM

##### *Macroscopical characters*

The stems are cylindrical with a central hollow and measure up to 1 cm or more in diameter at the base. They are pale green or reddish and are glabrous except at the nodes, where they are finely pubescent.

##### *Histological characters*

The epidermal cells have slightly thickened outer periclinal walls and are covered by a thin, finely striated cuticle; in surface view they are axially elongated. Stomata, similar to those found on the petiole, are present but they are not abundant (Fig. 3·9). Glandular trichomes, similar to those found on the stipule, and papillae occur at the nodes, but the internodal regions are glabrous. Beneath the epidermis are one or two layers of collenchymatous cells and the remainder of the cortex is composed of thin-walled parenchymatous cells, some of which contain cluster crystals of calcium oxalate (Fig. 2·7).

The vascular tissue in a young stem is arranged in a number of discrete bundles (Fig. 2·2) but in a more mature stem it forms a complete cylinder when seen in transverse section (Fig. 2·3, 2·4). The medullary rays, which are unligified in the young stem, become lignified in the xylem region of a more mature stem and when the stem is fully mature the medullary rays are frequently difficult to discern.

In a young stem a group of fibres occurs outside each of the larger vascular bundles and as the stem matures additional fibres are developed but they do not form a continuous pericyclic layer. Individual fibres have moderately thickened, lignified walls with numerous pits and reach a length of about 1 to 1·5 cm (Figs 2·9, 3·12).

The secondary phloem is composed of groups of sieve tubes and phloem parenchyma traversed by fairly wide medullary rays. The sieve tubes are narrow with transverse or slightly oblique sieve plates and they are usually accompanied by small companion cells with dense contents. The phloem parenchymatous cells are also small and narrow and are very thin-walled (Fig. 2·8).

The cambiform tissue consists of two or three layers of thin-walled, tangentially elongated cells.

The secondary xylem is completely lignified and is composed of scattered vessels and fibres with a large amount of xylem parenchyma. The vessels are up to about 60  $\mu\text{m}$  in diameter and have moderately thickened walls; they are bordered pitted or reticulately-thickened. The xylem fibres are shorter than the fibres of the pericycle and they have fewer pits. The cells of the xylem parenchyma are longitudinally elongated and have thickened walls with numerous simple or bordered pits; the end walls are frequently oblique or slightly tapering (Figs 2·9, 3·5).

The pith is composed of thin-walled parenchymatous cells surrounding a central hollow which occupies about half to two thirds of the total diameter. A number of the cells contain cluster crystals of calcium oxalate.

#### STIPULE

##### *Macroscopical characters*

A membranous, sheathing stipule is present at each node; it is approximately triangular, measuring about 0·2 to 0·4 mm in height increasing to 0·5 to 0·7 mm at the highest point (Fig. 3·8a and b). Each stipule shows a fine, reticulate venation and at the base the inner surface is finely pubescent.

##### *Histological characters*

The outer epidermis is composed of thin-walled cells, elongated in surface view; the anticlinal walls are slightly sinuous and the cuticle is strongly striated (Fig. 3·6). Papillae, glandular trichomes and stomata are absent except at the extreme base, where a few papillae and stomata occur (Fig. 3·7). The inner epidermis is composed of cells with thinner walls than those of the outer epidermis and the cuticle is less markedly striated; each cell is about three or four times as long as broad when seen in surface view and the anticlinal walls are very finely wavy or minutely beaded (Fig. 3·10). Glandular trichomes are abundant on the inner epidermis and they show wide variation in size and form; some are similar to those occurring on the leaf, in others the stalk is unicellular and occasionally the multicellular head is much elongated and composed of many cells (Fig. 3·11). Abundant cluster crystals of calcium oxalate are present in the mesophyll, particularly in the cells near the veins; a few prisms also occur (Fig. 3·7).

#### INFLORESCENCE

##### *Macroscopical characters*

The inflorescence is cymose and the white or pinkish flowers occur in panicles. Each flower is small, about 6 mm in diameter when fully opened, and composed of five petaloid segments surrounding three styles and eight stamens. The ovary is superior and unilocular with a single ovule. The flowers are dimorphic, some having long stamens and short styles and others having short stamens and long styles. The fruits are three-sided, sharply angled and dark brown when ripe; they protrude from the perianth and are about 5 mm long.

##### *Histological characters*

*Petaloid segments.* The outer epidermis is composed of small, thin-walled cells, polygonal in surface view, each extended to form a small papilla; in the basal region the papillae are rounded and they become gradually more pointed towards the apex.

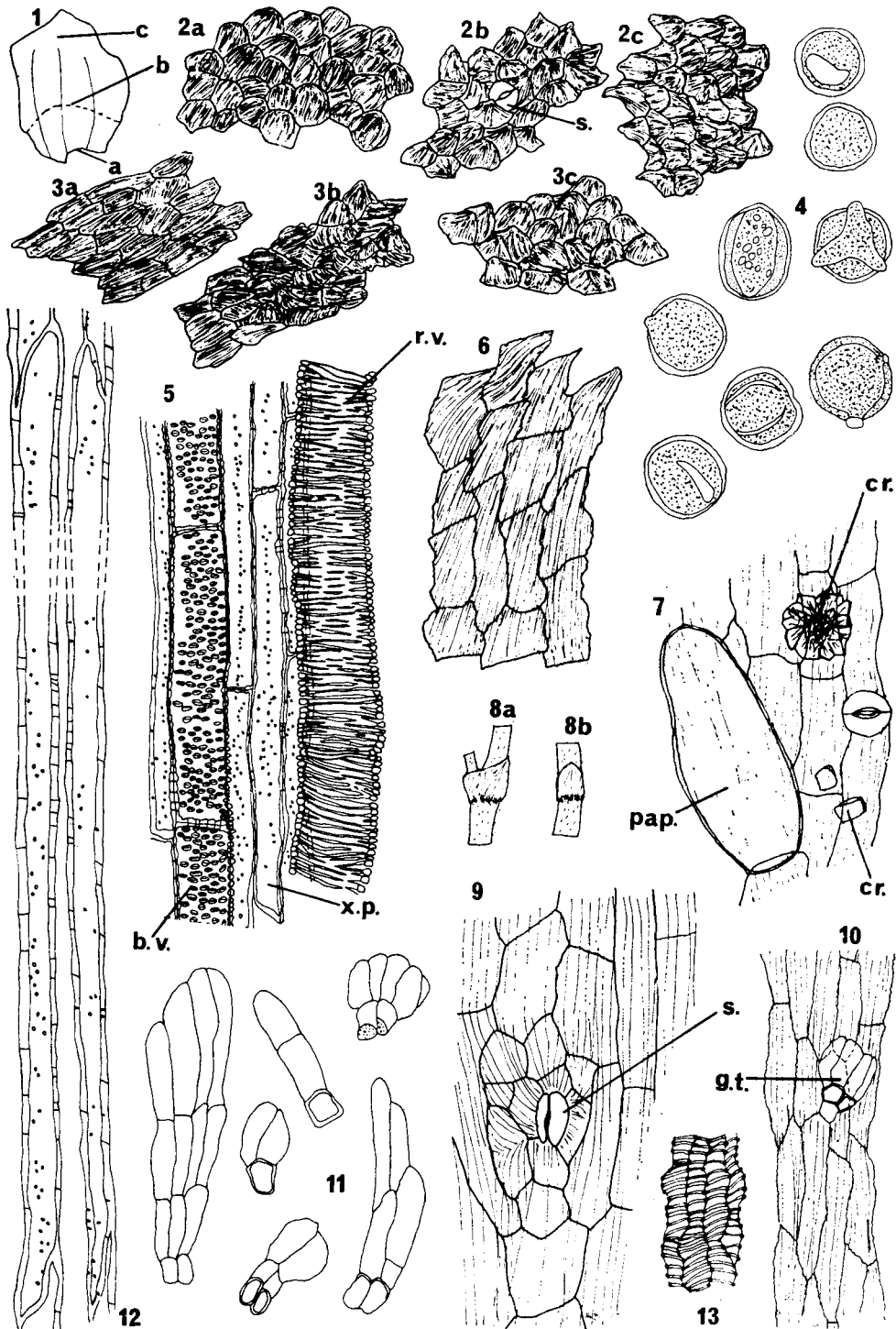


FIG. 3. *Fagopyrum esculentum*, stem and inflorescence. 1, diagram of a perianth segment  $\times 6$ ; 2a, 2b and 2c, outer epidermis and 3a, 3b and 3c, inner epidermis, of a perianth segment at the positions a, b and c marked on 1, in surface view; 4, pollen grains; 5, longitudinal section of the xylem of the stem; 6, outer epidermis near the apex of the stipule in surface view; 7, outer epidermis near the base of the stipule in surface view; 8a and 8b, diagrams of the stem showing the ochreate stipule,  $\times \frac{1}{2}$ ; 9, epidermis of the stem in surface view; 10, inner epidermis of the stipule in surface view; 11, glandular trichomes from the inner epidermis of the stipule; 12, pericyclic fibres from the stem; 13, fibrous layer of the anther in surface view. All (except 1 and 8)  $\times 220$ . b.v. = bordered pitted vessel; cr. = calcium oxalate crystals; g.t. = glandular trichome; pap. = papilla; r.v. = reticulately-thickened vessel; s. = stoma; x.p. xylem parenchyma.

The cuticle, which is continuous over the papillae, is strongly striated; very occasional stomata are present (Fig. 3·2). The cells of the inner epidermis show more variation than those of the outer epidermis; in the basal region they are axially elongated in surface view and are not papillose (Fig. 3·3a) whilst in the apical region the cells are polygonal and extended to form papillae (Fig. 3·3c); the transition from non-papillose to papillose cells occurs at approximately one third of the distance from the base (Fig. 3·1, 3·3b). As on the outer epidermis, the cuticle is strongly striated in all regions but stomata are absent.

*Pollen grains.* The pollen grains are spherical to ovoid with three pores, which are frequently indistinct, and a strongly pitted exine. Germinal furrows are not visible but occasional splits are seen in the exine in some of the grains (Fig. 3·4). Those from the flowers with short styles are about one-fifth larger than those from the long-styled flowers (Stevens, 1912); they measure 32·4–42·5–50·4  $\mu\text{m}$  in diameter (long-styled flowers) and 43·2–50·0–57·6  $\mu\text{m}$  in diameter (short-styled flowers).

#### SUMMARY

The microscopical characters of *Fagopyrum esculentum* Moench of value in identifying the aerial parts of the plant in the broken or powdered condition are as follows:

(a) The epidermis of the leaves; in surface view the cells of the upper epidermis with slightly sinuous walls and those of the lower epidermis with markedly sinuous walls; the cuticle over the upper epidermis strongly striated; anisocytic and occasional anomocytic stomata present on both epidermises but more numerous on the lower epidermis; glandular trichomes, composed of a biseriate stalk with two or four cells and a multicellular head, fairly abundant on both surfaces; covering trichomes absent but elongated papillae present, particularly on the upper surface over the veins. In transverse section the leaves show a dorsiventral structure with a two-layered palisade.

(b) The cluster crystals of calcium oxalate up to 45  $\mu\text{m}$  in diameter and fewer prisms, up to 15  $\mu\text{m}$  long, in the parenchymatous tissues.

(c) The lignified fibres, measuring up to 1·5 cm in length, in the pericycle and xylem of the stem.

(d) Lignified, reticulately-thickened and bordered pitted vessels up to 60  $\mu\text{m}$  in diameter, associated with lignified xylem parenchyma, in the stem and petiole.

(e) The membranous stipules, composed of very thin-walled cells covered with a striated cuticle; glandular trichomes similar to those occurring on the leaves (but frequently larger) abundant on the inner epidermis, but absent from the outer epidermis.

(f) The perianth segments composed of small, straight-walled cells with a striated cuticle, most of the cells papillose.

(g) The sub-spherical pollen grains with three pores and a finely warty exine, 32·4–42·5–50·0–57·6  $\mu\text{m}$  in diameter.

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