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Review Article

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Abnormal growth in the plant (fasciation)

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Abstract

Fasciation (or cristation) is a morphological alteration in plant organs that involves widening of the shoot apical meristem, flattening of the stem, and changes in a leaf arrangement. A multitude of natural and manmade events can generate physiological fasciation. Insect assault, mechanical pressure and/or tension during growth in some species such as asparagus and liana species, and sowing time and density are all-natural environmental influences. One of the original seven Mendelian pairs of traits was the fasciated variety of *Pisumsativum* L. (formerly known as *P. umbellatum*; Synonyms: mummy pea, crown pea, poisturk, poiscoronne). In many species, it is genetically determined. FASCIATA is the name of the gene that causes fasciation to occur (FA). Because of the great level of control over the plant material and growth circumstances that in vitro produced fasciated plants provide, they can be useful models for investigating the causes and development of fasciation.

Keywords Fasciation, plants, roots, *pisumsativum* L.

Introduction

Fasciation (or cristation) is a morphological alteration in plant organs that involves widening of the shoot apical meristem, flattening of the stem, and changes in a leaf arrangement. Fasciation is derived from the Latin *fascis*, which means bundle. Fasciation is a widespread phenomenon in the plant kingdom. There was a greater interest in aberrant organ shapes during the nineteenth century. Teratology was the name given to the subject (Binggeli, 1990).

Many authors have described fasciation as an excrescence or fusion of organs caused by departures from normal meristematic processes and bud crowding, while others have suggested that real fasciations are the transition of a single developing point into a line. Fasciations have been found on trees, shrubs, flowers, and cacti belonging to at least 107 plant families, with the Rosaceae, Ranunculaceae, Liliaceae, Euphorbiaceae, Crassulaceae, Leguminosae, Onagraceae, Compositae, and Cactaceae being the most prevalent

(Binggeli, 1990). Fasciations are more common in species with ambiguous vegetative organ and inflorescence growth patterns (Binggeli, 1990). They are less prevalent in woody plants than in herbaceous plants, but they can be found in lianas, numerous broad-leaved species, and conifers. Fasciation has been observed in spruce and pine trees, among other conifers (Kienholz, 1932).

Altered growth and morphology of fasciated shoots

The formation of a flattened organ or plant part, most commonly a stem or an inflorescence, is a characteristic of fasciation. Gorter (1965) distinguished three types of fasciated shoots: linear, round, and radiating. The stem is flattened, and the shoot apical meristem (SAM) is expanded and flattened as a ribbon in linear fasciation (Ecole, 1970). As a result, the shoots show bilateral rather than central symmetry. Arabidopsis CLAVATA1 mutant plants have expanded apical vegetative and floral meristems, resulting in fasciation, aberrant phyllotaxis, and additional floral organs and whorls. Fasciation in peas is caused by an aberrant

expansion of the stem apical meristem, which causes structural deformities in the shoot (Sinjushin and Gostimsky 2008).

The number of vascular bundles in the epicotyl of a fasciated pea genotype was larger than in the wild type, causing the SAM to take on a ring-like structure. The merger of numerous meristematic growth cones results in the formation of a circular type of fasciated shoot, according to a detailed anatomical examination (Sinjushin and Gostimsky 2008). Moreover, the same authors discovered a large number of undeveloped leaves maintained in the top part of the stalk, as well as racemes with unopened flowers in their axils. Several higher internodes were frequently left shorter, giving the fasciated plants a distinctive form.

Any plant's leaf arrangement is species-specific, and fasciation does not interfere with its expression. The number of leaves in a node, on the other hand, appears to be dependent not only on the size of a primordium's suppression zone but also on the number of bundles in the leaf trace. This is linked to the increased specialization of primary leaf primordia (Szczesny et al., 2009).

The zone of suppression is missing in secondary primordia, i.e. those created as a result of cleavage of the parent primordium (Sinjushin and Gostimsky 2008). Fasciation in buckwheat results in a reduction in overall growth and viability (Sakharov 1986). In addition, fasciated plants in a hybrid population F2 in pea showed heterosis but had low seed output in sunflower (Jambhulkar, 2002).

While there are many reports on the appearance of fasciated plants in natural environments, there are just a few studies on fasciation production in vitro. In tissue culture, massive SAMs were found in the presence of high cytokinin concentrations (Iliev et al., 2011; Kitin et al., 2005). Calli enclosed by continuous meristematic bands that generated larger SAMs were found after cytokinin treatments. These SAMs were later separated into two regular SAMs (Chriqui, 2008).

Circular fasciations, which have a ring-shaped growth tip and create a hollow shoot, are much unusual. Some plants showed these characteristics after being treated with auxin transport inhibitors (Ecole 1970) or in the pin1 mutant, which has altered auxin efflux. Inhibition of auxin transport can result in fused leaf organs (Ecole, 1972), which is comparable to what happens with cuc mutants, who have organ separation problems (Chriqui, 2008). The SAM and the stem have a stellate shape in the transverse section in the radiate fasciations (Chriqui, 2008).

A fascinating finding was that a single fasciated shoot might create one to five additional in vitro shoots with no apparent fasciation (Iliev et al., 2011; Kitin et al., 2005). *Spiraea 9 vanhouttei* and *Salix udensis* 'Sekka' have both been observed branching regular shoots that had developed from fasciations

in the wild (Iliev and Kitin, unpublished results). The discovery that larger, fasciated floral primordia give rise to more organs, not bigger organs, is likely related to this phenomenon (Clark et al., 1993).

Physiological fasciation

A multitude of natural and manmade events can generate physiological fasciation. Natural environmental factors include insect attack, mechanical pressure and/or tension during growth in some species such as asparagus and liana species, time and density of sowing; earlier sowing appears to produce more fasciated plants, while higher planting density appears to decrease the percentage of fasciated plants (Binggeli, 1990), temperature fluctuation; low temperature followed by high temperature caused fasciation in *Hyacinthus* (Binggeli, 1990), and a variety of other factors (Stange et al., 1996).

Transfer of a gene from the bacterium to the host cell caused fasciation in *R. fascians*, according to research. The propensity for fasciation was disseminated to other plants as cuttings or grafts from the gene-infected plants after the bacterial gene was introduced to a host plant. It's also been discovered that the presence of nematodes is linked to stem fasciation in *Lilium henryi* and strawberries.

Artificially applied variables can also cause fasciation. Fasciation was caused by decapitation and defoliation, as well as amputation of the main stem of seedlings just above the cotyledons during spring frost, crushing the young stems of *Viola tricolor* and cutting the root tips of *Vicia faba*, wounding of growing points, and heavy pruning of deciduous trees. Fasciation is more likely to occur because of improved nutrition, which includes high rates of manuring (Binggeli, 1990).

Plants with indeterminate inflorescences produced many fasciations when held under drought conditions before to flowering and then subjected to vigorous watering and high nutrition levels. Fasciation of stems and inflorescences was also triggered by ionizing radiation and chemical agents (Jambhulkar 2002; Abe et al., 2009).

Fasciation is caused by the application of certain plant growth regulators. TIBA (2,3,5-triodobenzoic acid), for example, causes ring fasciation and other anomalies such as organ deformities and fusion (Astie' 1963). Similarly, soaking dry and germinated buckwheat seeds in 0.1 percent IAA solution resulted in fasciated branches and changed phyllotaxy. Increasing or lowering the photoperiod can also cause fasciation (Abe et al. 2009).

Genetic fasciation

One of the original seven Mendelian pairs of traits was the fasciated variety of *Pisum sativum* L. (formerly known as *P. umbellatum*; Synonyms: mummy pea, crown pea, poisturk,

poiscoronae). In many species, it is genetically determined (Karakaya et al., 2002). FASCIATA (FA) was the name given to the gene that causes fasciation to occur (White 1917). A hypothesis on fasciation's monogenic nature was offered, and the feature was later described as mono-factorial with incomplete penetrance and fluctuating expressivity in a recent study (Sinjushin and Gostimsky, 2008). Furthermore, fasciation was caused by the gene FA2 in the recessive stage, and a notion of two polymeric genes was proposed (Swiecicki and Gawłowska 2004). All F1 hybrids were non-fasciated in Mendel's initial experiment, however, fasciation and normal phenotypic classes were detected in a 3:1 ratio in F2. However, because the gene that causes fasciation has imperfect penetrance, the feature may manifest in a variety of ways, thus fasciation inheritance could be non-Mendelian (Sinjushin and Gostimsky 2008).

Lilium sp. with flattened stems was found to have Phytoplasmas belonging to the aster yellows group (Bertaccini et al., 2005). Abe et al., (2009) discovered that *atrca2* mutant plants, which are susceptible to genotoxic stressors, have a low incidence of fasciation and aberrant phyllotaxy phenotypes, and that γ -irradiation greatly enhanced the ratio of plants with these phenotypes. MGO mutation in *Arabidopsis* causes delayed differentiation of meristematic cells into lateral organ primordia, which leads to fasciation, according to Laufs et al. (1998a) and later Guyomarc'h et al. (2004). According to a recent study, MGO1 works in tandem with WUS to maintain stem cells at all phases of the shoot and floral meristem development, and MGO1 influences gene expression via chromatin remodeling pathways, potentially stabilizing epigenetic states (Graf et al. 2010).

Another important function of the SAM is the regular synthesis of leaf primordia, which is represented in consistent phyllotaxis and plastochron. In *clv*, *rolC*, and *fas A. thaliana* mutants, as well as other mutants with enlarged SAM size, phyllotaxis, and leaf size are altered (Green et al. 2005). Although genes involved in fasciation are thought to play a role in leaf initiation, the initiation pattern of leaves is thought to be intimately linked to the size and shape of the SAM (Reinhardt et al., 2005). Leaves are not produced at random, but rather in a predictable pattern over time and space, resulting in the plant's regular phyllotaxis. This process has been linked to plant hormones. Auxin appears to be a key participant in the creation of leaves and flowers, as well as a component of phyllotactic patterning (Smith et al., 2006).

Effect of growth regulators on the induction of fasciations in vitro

Because of the great level of control over the plant material and growth circumstances that in vitro produced fasciated plants provide, they can be useful models for investigating the causes and development of fasciation. However, there is currently a scarcity of literature on in vitro grown fasciated

plants. Exogenous cytokinins promote fasciation in *Betula pendula* (Iliev et al. 2011), *Kalanchoe blossfeldiana*, *Prunus avium* (Kitin et al. 2005), *Fraxinus excelsior* (Mitras et al. 2009), *Mammillaria elongata* (Papafotiou et al., 2001), and *Pisum sativum*, *Kniphof* (McCartan and Van Staden 2003). Most of the tip explants provided one cristate shoot during in vitro propagation of cristated *Euphorbia pugniformis*, whereas only a handful reversed to a normal shoot, and the number of cristate shoots rose with the BAP concentration (Balotis and Papafotiou, 2003). The cristate form stability was impacted by a one-fourth reduction in nitrogen nutrient concentration in the medium. In terms of explant type and the effect of plant growth regulators on cristate shoot regeneration, cristated *Euphorbia pugniformis* behaves similarly to cristated *Mammillaria elongata* in vitro. In contrast to *E. pugniformis*, *M. elongata* cristated shoots were relatively stable at normal MS nitrogen concentrations (Papafotiou et al., 2001).

Conclusion

Artificially applied variables can also cause fasciation. Fasciation was caused by decapitation and defoliation, as well as amputation of the main stem of seedlings just above the cotyledons during spring frost, crushing the young stems of *Viola tricolor* and cutting the root tips of *Vicia faba*, wounding of growing points, and heavy pruning of deciduous trees. Fasciation is more likely to occur as a result of improved nutrition, which includes high rates of manuring. Because of the great level of control over the plant material and growth circumstances that in vitro produced fasciated plants provide, they can be useful models for investigating the causes and development of fasciation.

Consent for publication

The author declares that the work has consent for publication.

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