VITRI / ETFRN / IUFRO –SPDC WORKSHOP

Trees, Agroforestry and Climate change in Dryland Africa (TACCDA), Hyytiälä, Finland, 29 June – 4 July 2003 [1].

Plea for the use of suckering and layering in dry tropical and Mediterranean zones. During certain periods, on some sites, and with certain species [2].

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Summary

When it comes to improving the woody vegetation cover of a degraded site, the three traditional methods usually considered are: artificial or natural seed germination, plantation establishment, or the pruning of existing trees so as to encourage sprouting. However, there is a fourth alternative, which has not yet been well investigated and to which attention needs to be drawn. In some regions (particularly semi-arid, temperate) before the total disappearance of existing trees, layering and moreover, suckering, allow for the economical propagation of woody plants, particularly benefitting rural people.

The present partial study exposes data, in relation to temperate regions, which is self-explanatory. However, it could be difficult to convince people working in semi-arid regions to use these methods because of the habits which die hard. The amount of work done on Natural Vegetative Propagation study is incomplete, if not insignificant, with regard to some countries and regions. When compared with sexual propagation, the socio-economic advantages of vegetative propagation are important. The authors conclude with the necessity to record the traditional knowledge on the natural layering and suckering phenomena and to start case studies on pilot local indigenous species which show this ability.

Key words : root-suckering; sucker; layering; layer; root cutting; vegetative propagation; asexual regeneration.

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Introduction

The suckering phenomenon generally speaking has not really been investigated except for rare cases of poplars, cherries, ailanthus, or certain fruiters, etc, and mainly in temperate countries. In the tropical west African subregion, it has not been analysed or studied (Bellefontaine *et al.* 2000); even though with some species the territorial coverage of suckers from the mother tree within one year can extremely be surprising: from 1 to 2 meters, but usually 15 to 20 m, and even 80 m (Fernandez *et al.* 1994; Alignon 1999). This dynamism is transmitted to subsequent generations and therefore some suckers are able to form small colonies (Clair-Maczulajtys, 1985; Coates-Palgrave 1998; Hasnaoui 1991; Pagès 1985; Schier 1973-a).

This phenomenon occurs on certain sites such as clearings, well exposed dawn slope areas, or submerged soils which have good drainage (Sharma *et al.* 1999; Deiller *et al.* 2003) when for example the reserved carbohydrates (Clair-Maczulajtys 1985, 1986; Schier and Zasada 1973) are high either in the root collar, or in the primary root system. Not all tree species have the ability to sucker; some do so prolifically while others do so sparingly (Troup 1921; Schier and Campbell 1976; Bellefontaine 1997; Bellefontaine *et al.* 1999).

From data related to "natural" vegetative propagation found in scientific literature, this article suggests some research alternatives for the process of inducing artificial propagation (Bellefontaine *et al.* 2000; Kimariyo 1990; Schier 1973b and 1973c; Schier1975, 1982), without resorting to tissue culture, grafting or propagation with cuttings. It is based, but not exclusively, on root suckering of poplars on which the literature is extensive.

A World-wide Phenomenon

In the North European countries, profuse suckering of certain poplars (*Populus tremula*) has been controlled by the use of herbicides. The utilisation of which for weed control has been questioned for environmental protection reasons (Bärring 1988). According to that author, site disturbance is necessary for that species to give rise to suckers, while it seem that it America related species, *P. tremuloides*, produces suckers without external stimuli.

In France, the wild cherry (*Prunus avium*) is a tree species characterised either by scattered isolated single trees, or groups of trees, or trees in well established stands. In the latter case the stands can be "normal", in which the cherry represent more than 20 % of the stems regularly distributed in an area of more than 0.5 hectare, or the stands can be described as border line, where over a length of 10 to 50 m, cherry represent more than 10 % of the stems. In the case of groups, "clump stands which are generally spaced one to another comprising few to many dozens of stems, (…) sometimes by suckering over a radius of nearly 15 meters. These suckering clumps (…) can cover a surface area of about 700 square meters (…). The greatest distance between two trees of the same genotype is 81 metres" (Fernandez *et al.* 1994). To gain a better understanding of the balance between sexual and asexual regeneration strategies and to access the role of seed bank in regeneration, Deiller *et al.* (2003) have compared three hardwood forest stands with different flooding conditions. Some species present in the flooded stand are absent from the seed bank. They conclude that environmentally restrictive conditions such as flooding, fire or drought limit the establishment and growth of plants to those who are able to develop strategies (layering or production of root-suckers) ensuring successful regeneration in spite of the constraint.

The Holly Oak (*Quercus ilex*) forests of Mediterranean regions are sometimes the result of natural vegetative propagation. In Tunisia, Hasnaoui (1991) counted 127 to 228 suckers *(Q. suber)* on 30 plots of 100 sq.m. These suckers had varying dimensions (height and diameter) and ages. Their appearance after clear cutting of the adult trees did not happen immediately but over a period of time. In Gabès (Tunisia) on a gypsy crust and with an annual rainfall of 100 mm, the *Acacia salicina* grown from seeds collected in Tunis Botanical Garden, have given rise to a real forest constantly expanding by suckering, in contrast to the surrounding degraded populations (A. Franclet, pers comm.,1999).

At Atlit in Israel, from a *Faidherbia albida* planted in 1913, in 1961 25 suckers were counted within a 22 m radius around the tree. In the sixties, these suckers and the mother tree were cut out to establish an apricot orchard. The mother tree and the most vigorous sucker vigorously resprouted and produced many individual suckers within a 20m radius. In the seventies, the apricot trees were replaced by a banana plantation after mechanical preparation of the soil. This resulted in a temporary reduction of the number of the *F. albida* suckers. However, the clone has continued expanding around the outside and in 1974, 37 plants were recorded (Karschon 1976).

In West Africa, the *Daniellia oliveri* (Bellefontaine *et al.* 2000), *Detarium microcarpum* (Bationo *et al.* 2001), or *Isoberlinia doka* (Dourma *et al.* 2003) woodlands seem to be to a large extent the result of regeneration from suckering. From the existing literature it would appear that in the Soudanian-Sahel region, if more than 100 woody plants species sprout from the stump, 56 % of them may have the ability to produce suckers (Bellefontaine 1997) [8]. In West Africa (up to mean annual rainfall > 1000 mm) 115 indigenous or naturalised woody plant species produce suckers (Bellefontaine *et al*. 1999), but very few appear to produce air-layering *naturally* (Bationo 1994; Ichaou 2000; Karim 2001; Bellefontaine *et al.* 2001).

In East Africa, the roots of *Baikiaea plurijuga* are considered to be a resilient reservoir of suckers (van Gils 1998; SARCDC 1993). Desanker *et al.* (1997) considered that in the miombo, trees are difficult to eradicate, because almost all the woody plants sprout vigorously either by stump sprouts or by suckers production. Meg Coates Palgraves (1998) is convinced that in the natural woodlands of Zimbabwe, with the present climatic conditions, the number of trees that grow from seeds is infinitesimal but many species regenerate vegetatively (*Ochna pulchra, Brachystegia boehmii, Dichrostachys cinerea, Acacia erioloba, Baikiaea plurijuga, etc.*) (Coates-Palgrave and Tiffin 1997). Also, some species become suffrutices as soon as the ecological conditions deteriorate (increased aridity, low rainfall for example, and also increased browsing pressure as in the case of some suffrutex formations of *Colophospermum mopane*, short cool periods, etc.) and it must be admitted that this new concept is often difficult to accept (Coates Palgraves 1998). According to Chidumayo and Frost (1996), most of the miombo trees species have the ability to produce suckers. In Tanzania, regeneration of *Milicia excelsa, Ocotea usambarensis, Brachylaena hutchinsii, Dalbergia melanoxylon* has occurred as a result of sucker production (Kimariyo 1990).

Introduced in Mayotte peninsula during the second half of 19 century, *Litsea glutinosa* proved its invasive character due to its suckering ability. Jacq (2001) recorded an average minimum suckering rate of 42 % for the peninsula stands.

On the Indo-Asian continent, *Populus euphratica* is widely used because of its productivity and its ability to survive under harsh environmental conditions, particularly when submerged. Within

[8] Nearly 600 species have this ability (Bellefontaine 2003; unpublished).

three years, seven hectares, which had been submerged, were replanted with root cuttings, and have subsequently produced a lot of suckers (Sharma *et al.* 1999). In Central India (Govindgarh Forest), Awasthi (1986) observes the relatively good suckering ability of *Diospyros melanoxylon* and suggests the utilisation of the species in fallow and marginal lands to cover the soil surface. Troup (1921) quotes more than 120 Indian tree species.

In the North American continent, large mixed poplar and coniferous forests were destroyed by fire, but because of their ability to increase vegetatively (principally from stump sprouts and suckers), the poplars have regenerated and become invasive (Schier 1973a; Jones and Trujillo 1975; Bartos and Mueggler 1982; Corns and Maynard 1998).

Definition of the subject matter to avoid confusion

In the French dictionary "Le petit Robert", "drageonnage" and "drageonnement" are synonymous. It is suggested that "drageonnement" should be restricted to natural events (windburches, storm damage, animal damage, etc.) while "drageonnage" should be used for growth as a result of human operations (such as grafting and cutting) which are aimed at inducing sucker production. For this reason we think that the term "drageonnage" or suckering should be adopted. A sucker is "a stem which grows from a preexisting root, irrespective of whether the root is inside or outside the soil (connected or not connected to its origin ?)" (Bellefontaine *et al.* 2002).

Suckering is a means of vegetative propagation which allows some plants species, woody or shrubby, to propagate, and possibly to spread, by producing adventitious shoots from the root system. These newly formed sprouts are generally from lateral or superficial roots, making them different from "stump or coppice shoots" which develop from a stem. They can be from the aerial or underground part of the stump, bearing in the mind the ambiguity that can occur when classifying shoots arising from the root collar; that relationship is not yet understood (Barnola *et al.* 1987; Barnola and Crabbé 1991) [9].

As opposed to the suckers, there are the "layers" (*marcottes* in French) which arise from the newly formed roots that come up from a flexible branch which is in contact with soil, or from branches which are still attached to the mother tree; the primary function of the layers are not that of ensuring vegetative multiplication unlike "stolons" [10].

The occasional spontaneous character of these newly formed shoots can lead to erroneous conclusions. In suckering, layering and eventually the division by tuft or stump explosion, the separation from the mother tree occurs progressively naturally and even, after a long period. In the case of "cutting", there is a clear separation between the cutting and the mother tree prior to any formation of a new individual. It can be some newly formed adventitious roots from the stem cutting or newly formed shoots arising from roots segments in the case of "root cuttings". The success of establishment after cutting will depend on the maintenance of the viability of the

[9] This paragraph and the following three are extracted or inspired from a former communication (Bellefontaine and Monteuuis 2002).

[10] Stolon : aerial stem, crawling or curved, with a particular morphology, aimed at ensuring vegetative propagation of certain tree species by producing, continuously away from mother tree, roots and leafy buds

segment, until the formation of the collinear or root pole, necessary for the new individual to establish itself.

From the existing literature, it appears that the distinction of "root segments (cuttings)" which are widely used to propagate certain plant species such as cultivars of raspberry, …, from "suckers" is not well defined. The fundamental difference between a root segment and a sucker is that, in a root segment the separation from the mother tree occurs before the neo-formation of the buds, which develop and give rise to the shoot. The confusion is justified by the fact that natural root cuttings can occur, for example during retreat of water in clay soil, the soil cracks which causes roots to break into individual pieces (Bellefontaine and Monteuuis 2002). Depommier (1996) observes that in *Faidherbia albida* parklands, roots remaining in the soil after the windburch of old trees, produce a lot of suckers within a few weeks of the decayed stem falling.

"Vegetative multiplication" is the asexual reproduction of a plant from certain tissues or organs, while "vegetative propagation" is a spatial dynamism, which operates closer and closer, a process during which a land area is colonised by vegetation without intervention of sexual reproduction (definition inspired from Da Lage and Métailié 2000). In French the term "regeneration" is not really precise, it evokes the idea of stand renewal on the one hand (either naturally by seeds, stump sprout, or natural layering or suckering; or artificially by planting, sowing, induced vegetative multiplication) or the already grown stand on the other hand.

The aspen as an example

Various exogenous factors influence suckering, for example apical dominance suppression, period since being cut, competition for light, ground cover, with or without slashes, fire, etc.

The suppression of apical dominance is sometimes responsible for intensive sucker production (Eliason 1971a and b, cited by Bärring 1988; Schier 1982; Steneker 1972a *in* Perala 1974b). Sucker density in an aspen (*Populus tremuloides*) stand one year after clearfelling can vary from 55,000 (in slashes condition) to 200,000 (without slashes) stems per hectare in Central-East of Saskatchewan in Canada (Bella 1986). Bartos and Mueggler (1982) cited the results obtained by Smith *et al*. (1972) who counted 74,000 to 120,000 suckers per hectare. One year after clearfelling of *P. tremuloides* (Ontario), all the stems (55 to 70,000 per hectare) were suckers, none of them had come up from seeds (Kemperman 1978).

Depending on whether the clearfelling occurs during the period of dormancy or during vegetative growth, sucker density and development are very variable (Zasada and Schier 1973; Perala 1974b; Bella 1986). In Canada (Saskatchewan), two fellings took place in an aspen stand (*P. tremuloides*) of 70-80 years old, one in winter (March) and the second in summer (mid. July): sucker density after the first year's growing season in the area cut in summer was twice as thick as that cut in winter. After 17 years the differences as a result of two treatments declined (Bella 1986). Bartos and Mueggler (1982) studied the same species in Northern Utah (USA) and compared the development of the number of suckers : in the control plot this number remained more or less constant varying from 1,400 to 4,300 per hectare during the three years of observation, while felling increased the sucker production from 2,300 per hectare prior to felling, to 8,500 during the first year after cutting and to a maximum of 44,000 in the second year. However, according to Corns and Maynard (1998), most of suckers appeared in the first year after felling (from 85,000 the first year, with the number falling to 35,000 in the third year). The

application of three chipped aspen residue and three levels of soil compaction (with the skidder) they found that the sucker density was greater on the control plot, and with the shallower residue (5 cm) there was a better ground cover and sucker stocking, while repetitive passage of the skidder stimulated an increase in suckers. In Sweden, Bärring (1988) noticed on *P. tremula* that many of the suckers appearing in the first year did not survive the second year. However every year it appears that the new suckers are regularly browsed by wildlife animals. Poplar roots remain alive in the soil for many years after the exploitation of the mother tree (up to forty years for *P. grandidentata*, according to De Byle 1964, cited by Bärring 1988).

By natural selection, their number however decreases rapidly and becomes constant at 20,000 to 35,000 suckers per hectare a few years after exploitation (Bartos and Mueggler 1982; Crouch 1983; Bärring 1988; Corns and Maynard 1998). In Arizona, 22 years after a forest fire, 23,500 suckers per hectare are found on the stand of which 77% are still alive (Jones and Trujillo 1975). In Minnesota, studies carried out on *P. tremuloides* show that sucker growth has a negative correlation with fire intensity. The long term effect of fire on sucker growth is not yet understood, but two year old suckers were all killed by fire on May 1967 and the suckers which later appeared although larger in number were much less vigorous. If fire has to be used as a "management tool", aspen stands should be burnt during the first year period of dormancy following felling (Perala 1974a). In the same plot that he wanted to convert to a coniferous stand, Perala (1974b), after a repeated prescribed burning, two and four growing seasons (May 1969 and October 1970) after the first growing season, concluded that on a sandy soil, prescribed burning can be used particularly during the growing period.

Kemperman (1978) maintained that it is in the upper 6 to 8 cm (peat and humus) that the suckers appear and 80% to 85 % of the suckers examined originated from roots with diameter less than 1.5 cm.

The maximum distance between suckers and the poplar mother-tree is 31.7 to 33.5 m (Buell and Buell 1959, Petrov 1967, cited by Bärring 1988). In old stands suckers generally appear within 20 m (Bärring 1988).

Cuttings from segments of root

Many authors consider plants propagated from segments of roots planted in a medium either horizontally or vertically, as suckers (Zasada and Schier1973; Lhoir and André 1996; etc.). These are not suckers in the real sense, but root-cuttings. The technique allows for the propagation of a clone irrespective of any particular difficulties related to individual species. In Belgium *Populus x canescens* has a lateral rooting system. It is well known that this is difficult to propagate from (stem) cuttings. However, under certain conditions, the adult *Populus x canescens* produces "suckers" [11] : "root segments, of 8 cm long and 1 to 2 cm in diameter were buried vertically in a hot greenhouse (…). After three weeks, the first aerial shoots (suckers) appeared. Suckers can be classified in two groups according to their observed rooting system:
- suckers that develop their own root system and become severed from the mother tree giving rise to an independent plant;

[11] We should remind that the two term "sucker" and "suckering" should be considered with precaution

- suckers which develop and are still dependent on its root origin on which a new rooting system develops. This happens more frequently. They have a rapid growth, but do not have an independent root system.
At this stage of development the propagation of the second type of suckers from herbaceous cuttings can be successful (…). This is the only way in which *Populus x canescens*, stem cuttings give a very good result, with the rooting rate of 90% to 100 % success. It is essential that the juvenile micro-cutting must be done at this stage, after which it becomes problematical" *(*Lhoir and André 1996*).*

In order to conduct this experiment, the authors collected root segments in a natural environment at a depth of between 20 and 50 cm deep from secondary roots, because for vegetative multiplication, primary roots hardly ever give satisfactory results. However, they mentioned that "the root collected does not always have the same predisposition for sucker development: the prominent places on the root are situated at the roots bifurcation or around small swellings: without doubt they are very active meristematic zones. The smooth areas, without any swellings, remain lifeless and decayed rapidly in the substrate (Lhoir and André 1996*).*

Sharma *et al*. (1999) noticed that the survival and growth rate of *P. euphratica*, of plants propagated from root-cuttings was better than those of the plants propagated from stem cuttings. After 160 days there was a survival rate of 65 % against 47 % for the plants grown from root cuttings, and after four years, the gain in the diameter and height, was 59% and 54 % respectively.

Johansson and Lundh (1988) carried out some work on root segments, collected from *P. tremula*, 10 to 15 years old. The roots segments with a 10mm mean diameter, were planted horizontally in green house at five different depths, at temperatures of 10° and 25°C, and four different light intensities. After 83 days of observation, the number of "suckers" obtained was higher for those at a 4 and 6 cm depth and their dry weight was higher at 25°C for the same depths. The number of cuttings producing suckers increased with the increasing light intensity.

Sucker production in *P. tremuloides* is partially regulated by apical dominance (Eliason 1971a and b; Schier 1973b; Perala 1974a). The rate of auxins in the roots has a seasonal variation. Therefore, regeneration was not observed after a summer fire or clearcutting, which can be explained by the actions of seasonal growth inhibitors (Jones and Trujillo 1975). In many clones, complete inhibition of sucker development on the roots of a healthy plant, becomes a partial inhibition in the roots segments (Schier and Zasada 1973). Undoubtedly, there is genetic variation between clones in relation to sucker production (Johnsson 1942, Farmer 1962, Maini 1972, cited by Bärring 1988; Schier 1973b; Schier and Zasada 1973; Zasada and Schier 1973; Schier 1975).These variations may also be correlated with the ability of a sucker to sever from the mother tree and develop its own roots system. In Moscou area, 23 % of the suckers appearing in a 4 m radius around the mother tree were severed (Petrov 1967 cited by Bärring 1988). Of 12 clones of *P. tremuloides*, only one has been found to develop independent adventitious roots (Schier 1982). Clones might also show differences in the reserved carbohydrates which concentration varies from one clone to another in relation to the seasons (Schier and Zasada 1973).

The effect of gibberellic acid on *P. tremuloides* has been determined conducting treatments on two types of root-cuttings, one producing suckers from the primordia, which are newly formed

or at initial stage of development (EP[12] roots), the other producing suckers from primordia which were visible and well developed (LP roots). Gibberellic acid stimulated sucker development on LP roots at all the concentrations (25-400 mg/l), while the production of suckers from EP roots (collected at different dates) was inhibited (inhibition being more pronounced on primordia of the roots collected in July than those collected in October at Utah) (Schier 1973c).

The primordia of pre-existing shoots, phellogen protuberances, seem to appear on the roots of *P. tremuloides* in all its distribution areas. These pre-existing primordia whether they are dispersed or concentrated in one area, are difficult to identify and may be in different stages of development. There is co-existence between suppressed primordia and the currently formed primordia. The occurrence of suppressed shoots indicates that at any time, elongation can be suspended even though the growth has been initiated. These primordia resemble circular microscopic rounded mounds, which however show a relatively high degree of tissue organisation and polarity. The primary cells cannot be identified unless they appear at predictable locations. From a total of 541 suckers obtained from two different clones, anatomical examinations revealed that none of the suckers had vascular traces that penetrated the annual layers of the xylem. This confirms that on at least for these two clones, the suckers do not arise from buds imbedded in the periderm, but from currently initiated or pre-existing primordia (Schier 1973a).

Using segments of root cuttings put in the greenhouse for 21 days, Schier and Campbell (1976) compared the ability of *P. angustifolia, P. deltoides, P. balsamifera, P. tremuloides*. Only the last mentioned species produced suckers from the periderm at pre-existing suppressed primordium which arise from the phellogen area (surface suckers), while on the other three species, the suckers arose from the periderm, and also from the cambium exposed at the end of the cutting (end suckers). These end suckers appeared only on the one end of the cutting, but seldom on both ends. It is only when roots are subjected to stresses that exposed the cambium, that suckers developed from currently formed buds, which resemble those appearing at the end of the cuttings. However, for these three species, most suckers developed from suppressed buds embedded into the periderm. *P. deltoides* produced more shoots at the proximal end of the cutting then on the distal end, but the distal end present more roots than the proximal, which demonstrate that there is a polarity on the root segments.

It is clear that to fully understand the suckering phenomenon, experiments should be conducted with both root segments and with the suckers obtained therefrom. Field observations are also essential for the understanding of the mechanism.

Where are suckers originated ?

On a stem nodes and inter-nodes are distinct. On a root there is apparently no morphological marker. Also, if the distinction on the stem or on a stump between adventitious and proventitious buds is not obvious, how much more difficult it will be if these organs are in the soil? The distinction of these two organs seems to be essential. Nowadays, proventitious buds are hardly mentioned. Guinier *et al.* (1947) was definite that proventitious buds on the stems "remain apparently lifeless" but "give rise every year to a few cells, which form a very, small shoot embedded in the wood and the shoots bark. The bud finds itself cut off and can maintain itself on the surface of the shoot, even there is an increase in diameter". Poskin (1939) assimilated

[12] EP = early primordium LP = late primordium

proventitious buds to a resting phase (period of dormancy) of the bud prior to flushing, this phase is reactivated by "the abundance of sap and a strong light influence. This evolutionary faculty is conserved during early years but reduces progressively as the tree becomes old". On a stump it gives rise to proventitious shoots, which, due to their growth on the stump and their close relationship with the stump, are less exposed then the adventitious shoots to physical damage (by snow, trampling by wildlife, by windbruch*)*. Also, when they are in contact with the soil, they have the rooting ability and become independent to the mother tree thus differing from the adventitious shoots. The proventitious buds are characterised by being connected to the pith and have potential as they are free from inhibiting factors correlation.

Also on the stump, they are many adventitious shoots. These shoots produce stems capable of supporting a good growth for a limited period before most of them disappear because they failed to establish a conductive system. According to literature consulted by Pagès (1985), the adventitious buds may originate from newly formed meristem from "i) a permanent tissue; the bark parenchyma in lime tree or the pericycle in the black locust, various poplars and *Liquidambar styraciflua*; ii) very well specialised and differentiated meristems: cambium in ash trees and poplars, the willow (*Salix*) and phellogen in many poplars; iii) the callus : healing buds".

Studying the suckers produced by *Ailanthus altissima*, Clair-Maczulajtys (1985) observed various types of buds. In addition to "adventitious buds which appear on root section", she distinguishes between "buds localised in cortical parenchyma of the collar zone, arising from the development of pre-existing meristematic territories". She also talks about "buds already existing in the lateral roots bark which can only develop exceptionally". To find and identified these two different types of buds is difficult.

During a first meeting on vegetative propagation, held on 10th May 2001 at Cirad (Montpellier-France) (Bellefontaine *et al.* 2002), the participants agreed that it seems that suckers generally originate on the young structures of the pericycle (if they happen to arise from an old root, it will be from the peripheral cortical parenchyma; in that case it will subsequently have its own inward connection). The sucker is therefore an stem anatomical structure which becomes newly formed on a root structure. It can only be adventitious. While the lateral roots, their neo-formation occurs later, far away from the meristem, root, meristem not being organogene. It is also at the pericycle where ramifications and lateral roots are formed (opposite to either woody or phloem poles according to the species) (pers. comm. Cl. Atger, *in* Bellefontaine *et al*. 2000).

Nowadays, proventitious buds are seldom mentioned. That may be a field of interest that needs to be investigated by researchers.

Why not investigate suckering and layering in dry climatic zones?

In dry climatic zones (tropical, Mediterranean, soil's crusting or glacis), water is a determining factor, but sometimes unfortunately, a rare commodity. Without water, plantations and natural and artificial seedlings do not have chance of survival. The identification of lateral roots (of the plant species one desires to propagate, for animal feed or for fruits), and the stimulation by the various appropriate techniques [13], at the right time (during the year - the best season - or during

[13] 1/ Root suckers : by digging a field; by partial uprooting of senescent trees (later, root suckers sprout); by forcing : after cutting the tree, cover the stump with a black plastic in order to favour suckers (and not stump sprouts); after felling, suckers appear (*Detarium*

the ontogenic growth period of the tree), will stimulate the production of suckers, facilitating propagation on site, at minimum cost (Bellefontaine *et al*. 2000). Compared with the stump sprouts, this territorial covering capacity of the suckers or layers, which are recognised as having the reputation of running out from the stump and overcrowding the surrounding vegetation cover at low cost, has great potential particularly when the suckers or layers become independent of the mother tree. Also, the suckers and layers ensure the sustainability of the stump of the mother tree and the renewal of the roots systems (Bellefontaine 1995), but also play an important role in combating erosion and desertification.

Induced vegetative multiplication (by sprouting from the stump, by root-suckering or by layering (Bellefontaine *et al*. 2001) can be an economically viable method, which can guarantee independence vis à vis national nurseries which are seldom found in remote areas and do not always offer a choice of species. Local people (farmers, herders, traditional healers, women gather firewood, …) will then have available the choice of the woody plants species, which they need to propagate. Again, the suckers and layers do not require additional care like watering (therefore a saving of time and money), and also transport of seedlings over long distances is avoided. Much of the literature referring to the growth of plants resulting from natural vegetative propagation pointed out the rapid growth of suckers when compared to that of plants raised (naturally or artificially) from seeds and to that of plants raised in plastic bags (Bellefontaine 1998).

Consequently, vegetative regeneration from suckering or mound layering can lead to an improvement in the living standards of local communities: soils increased productivity, restoration and protection, sales of forest co-products (firewood, fruits, fodder, traditional medicines). With vegetative propagation the genotype properties of organisms are fully reproduced, which can be an interesting aspect, producing clones especially in the case of fruit trees and trees having leaves with a high nitrogen content. Trees with leaves with a high nitrogen content constitute an important source of fodder for the livestock animals during the dry season.

Propagation from suckers or layers is a method that can be used for trees that produce very little or no viable seeds, or only produce seeds during a reproductive cycle that only occurs periodically, or when the number of trees per hectare for a given species is low (phenological spacing between different trees is wide and renders cross-pollination very problematical), or when the sex-ratio is negative (Bärring 1988) and sexual reproduction is disadvantaged. This method of propagation can also be used when seed dormancy is of consequence (Bellefontaine *et al.* 1997) and seed requires rare climatic conditions or other factors for germination.

The use of fire (and the subsequent heat that it will generate - Monnier 1968) in tree stands of temperate regions like poplars stands, has been a stimulating factor of suckers production which resulted in an regeneration of stands (Zasada and Schier 1973; Perala 1974a and b; Jones and Trujillo 1975; Bartos and Mueggler 1982; Johansson and Lundh 1988). Nevertheless in tropical and sub-tropical areas fire should be used with extreme caution as some trees which are sensitive to fire often grow closely associated with trees which may benefit from its judicious use (Pierce 1992). And large scale burning can cause immeasurable damage (Coates Palgrave, pers.com.; Calvert 1990).

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microcarpum); fire or successive fellings might provocate a knot of buds.

2/ Layers : just before the rainy season, by covering creeping branches or stems with soil or by breaking branches or stems to favour contact with the soil.

The phenomenon of suckering and layering can be used in certain forests and woodlands as methods of maintaining or changing the dynamics of an ecosystem to satisfy some of the ecological, economical, social and cultural needs. For example, suckering has been used to improve the wildlife habitat at the same time providing for ecotourism (Jones and Trujillo 1975; Crouch 1983; Bärring 1988), to stabilise a fragile ecosystem (Awasthi 1986; Sharma *et al.* 1999; Bellefontaine *et al.* 1999), but also to maintain genotype potentials of some particular plant species. The principle is thus to exploit the suckering (or natural layering) ability of some plant species and manipulating factors affecting sucker production to obtain the targeted results. Among those factors, the slashes condition on the site influences the number of suckers that may sprout after forest exploitation (Bella 1986; Corns 1998). Considering these acquired results, one may ask if the practice, of leaving on site the slashes resulting from fire wood exploitation in Sahel tiger-bush (d'Herbès *et al*. 1997), with the aim of maintaining the particular dynamics of those ecosystems, does not have influence on both sexual and asexual reproduction.

Correlation to be found between different factors

The ideal situation will be to find correlation between some endogenous characters of woody species and their ability to produce suckers (or layers). The following ideas are some worth further investigation.

- Do species, with a high degree of seed coat dormancy, have a high suckering or layering potential?
- Some tree species produce a lot of seed without endosperm, but very few of them survive. Does this physiological "handicap", stimulate a propagation strategy of sucker or layer production? This might be the case in some poplars.
- Some species (*Populus tremuloides*, *Litsea glutinosum*, etc.) seed prolifically and also produce suckers abundantly; these two species are dioecious, is it there any relationship?
- A root *initium* does not occur randomly; it is connected to vascular tissue (pole) and originates from the parenchyma. Wood is a dead tissue, but in some woody species it remains alive because of the high parenchyma content. Thirty per cent of tropical woods (C. Edelin, pers. comm. 2000) remain alive throughout their lifetime, e.g. "cheese tree" (*Ceiba pentandra*). Is it there any relationship between species which are rich parenchyma and species which produce suckers?
- Do bushy species, generally speaking, have an increased ability to produce layers (and to produce suckers – Coates Palgrave 1998) more so than tree species?
- It will be interesting to study the suckering and layering ability of tree species, which are recognised as being unable to produce stump sprouts or coppice. The quaking aspen seldom produces stump sprouts or coppice, but Perrin (1963) pointed out, that "in quaking aspen, after exploitation or the death of the main stem, the root segments frequently remain dormant, but if cut, and provided with heat and light, the dormant roots give rise to a sudden sucker invasion in the areas where the species seemed to have disappeared".
- The dicotyledons generally have a pivoting root system, while the monocotyledons might have a fascicular root system. Does the later have a particular ability to produce suckers?
- Classification according to the family (Bellefontaine *et al*. 1999) does not seem to bear any relationship to suckering ability. Would it be possible to find any relationship between different types of tree architecture and the sucker producing ability (Edelin 1991)?

Conclusions

It is very important that investigations should be carried out urgently on local and traditional knowledge (Bellefontaine 2002-b) of the natural phenomena of suckering and layering of trees.

Women who collect firewood and other non-woody forest products, herders, nomads, traditional healers, and farmers are all holders of knowledge on vegetative propagation on certain tree species. By collecting such information, local knowledge, which up to now has not been expressed will become available. "Grey" literature (thesis, internal reports, etc.) should be analysed in particular in Eastern and Southern Africa.

From the ecological point of view, particularly that of population dynamics, it is vital that one should have knowledge of natural vegetative propagation of the tree community he is going to manage (Pierce 1993; Bellefontaine *et al.* 1997; Coates Palgrave and Tiffin 1997). The efficiency of this natural phenomenon and the species composition of the tree community can be evaluated with the present genetic molecular markers, if the resources (techniques and money) are available. The consequences of forest management strategies can be analysed from the best biodiversity and conservation point of view.

Without adequate funding, it is important to start to understand the various plant life strategies, to understand the determinant and the fundamental mechanisms behind the development of layers and suckers. Two approaches are necessary; the morphological approach (How the plant organises itself ? At which ontogenic stage does the plant give rise to suckers? What is the chance of the survival of these newly formed stems?) and the anatomical structural approach (Where in the plant these do these organs originate? How and when did they become independent?). A summary of researches protocol has been designed (Bellefontaine *et al.* 2000). Studies of physiological responses to climatic, hormonal, or reserved carbohydrates variations would also be useful but is more costly.

Many questions are yet to be answered (Bellefontaine *et al.* 2002; Bellefontaine, unpublished) and these questions will increase as long as the existing literature continues to be analysed. Studies on different tree species that can produce suckers or layers can be conducted by restricting them , initially to one to two tree species that are recognised as producing abundant suckers or layers particularly those that later become independent of the mother tree.

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