

NATURAL AND ARTIFICIAL REGENERATION

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The apparent existence of two schools of thought in silviculture, the first superficially identified with a bio-ecological orientation, the second more or less clearly defined as artificial or having a more technical background, has often lead to misunderstandings and to misconceptions concerning the position of stand regeneration.

Although the choice of regeneration type and regeneration technique is clearly linked with the basic characteristics of the management type and the underlying cutting practices, it would be a fundamental error to restrict, once and for all, natural regeneration to so-called natural forests and to absolutely identify man-made stands with artificial regeneration.

The reasonable practice of silviculture, aiming at the continuous obtainment of a maximal economical result over an undefined and unlimited period of time, always changes the original silvicultural situation profoundly. These changes vary from slight modifications of stand structure and stand composition over a reduction of the number of tree species, combined with a marked tendency toward structural uniformisation, to the creation, by planting, of pure or mixed stands with non-indigenous species after conscious destruction of the original undesirable stands or on sites where the forest disappeared a long time ago. Because of the wide scope of silvicultural influences, it is possible to distinguish between extreme situations, but, on the other hand, it is not quite so easy to draw a clear line between man-made forests and natural stands.

The situation, in reality, is even more complicated, due to the fact that, in a number of cases, natural regeneration can be favoured and obtained in artificial stands, whereas artificial regeneration is not to be excluded from stands, in which the original species combination is well preserved.

The choice between artificial and natural regeneration is essentially a question of bio-ecological, economical and technical

opportunity, highly influenced by continually changing production conditions.

In a future evolution it is to be expected, that the two systems of stand regeneration will be more and more intermixed by the abolition of all doctrinal prejudices, which, up to now, have only lead to an useless division of the silvicultural world. Only pure logic and more basic knowledge on the growing phenomén can bring about a higher degree of liberty in the silvicultural actions and interventions, so as to ensure a greater adaptability to varying situations and changing conditions.

1. The basic position of stand regeneration

The position of stand regeneration in the whole of stand treatments, technical measures and silvicultural systems, is assessed in a very different way.

Koestler (3) holds the opinion, that stand regeneration in Europe has always taken in a position somewhere between the conceptions of G.L. Hartig and his school and the fairly extreme views of the defenders of the selection forest in its concise form (Ammon, Dannecker, Balsiger). Whereas the former school tends to concentrate all silvicultural activity on stand regeneration, therefore often neglecting the normal stand treatment, the latter group sees in the regeneration no problem at all, as expressed by Moeller, the well-known protagonist of the « Dauerwaldbewegung » : « Der Dauerwald kennt überhaupt den Begriff der Verjüngung nicht » (The perennial forest does not even know the notion of regeneration).

As a consequence of the changing position of wood production in our time, as a consequence also of the amelioration of working technics, the intensification of forest management, the advancement of forest genetics and plant culture, the existence of numerous technical expedients, that allow a new approach to forestry, stand regeneration is no longer to be considered as the central problem of silviculture.

On the other hand, stand regeneration in the economic and thus deeply influenced forest, must not be taken for granted or easy to obtain without a well-planned sequence of preparatory measures, contrary to the convictions as expressed by the protagonists of the selection forest, which are mostly based on demonstrative show-case examples, that thorough analysis leads to consider as ecological and historical exceptions.

The often repeated reproach, that regeneration problems are unnecessarily created by man as a result of the misuse of the forest or as a consequence of unjustified modification of the original

forest situation, meaning essentially the unrestricted modification of the composition and the structure of the stands, can easily be met.

1° The concepts of stand regeneration, as they are accidentally realized in the European selection forests, are not suitable for far reaching generalisations. They are based upon specific phytogeographical, ecological and even socio-political conditions, which may apply to part, but not to all forests of the world and even not to most European forests.

The regeneration technics, used by Ammon and his following, are clearly justified by the obtained results; they have, however, only a limited validity.

2° Changes, even extreme modifications of the structure and the composition of the stands, are the logical consequence of the use of the forest for the production of maximal economical values. Every forest situation may and must be modified to such a degree as is judged necessary to attain a prefixed utilisation aim, on condition however, that the measures, that therefore are to be taken, do not endanger the conservation of the forest or the production capacity of the site.

If it is quite evident, that stand regeneration is not the central problem of silvicultural practice (Schaedelin: « Die Bestände sind nicht da um verjüngt zu werden » — « The stands do not exist to be regenerated »), it must also be assumed, that regeneration difficulties or even the complete absence of spontaneous natural regeneration are no measures for the degree of efficiency or validity of silvicultural interventions. Even the experiences in the selection forest most clearly show, that no short regeneration period and no abundant or quick regeneration is needed to obtain optimal results.

3° Artificial stand regeneration offers possibilities and advantages, that can not be reached by natural regeneration, or only as an exception. It is a fundamental error to proclaim, from too narrow a doctrinal point of view, that artificial regeneration stands, as a matter of principle, in direct opposition to an economically justified silviculture on a broad ecological foundation.

There are, with special reference to the adopted regeneration technique, still other reasons to reject the structure of the selection forest or of equivalent structures in the natural forest, as the only ultimate objective of stand treatment. Although the formation of well-equilibrated stand structures, the stabilisation of the increment in the management unit, the conservation of the growing stock at an optimal level, are of the utmost importance, it nevertheless must be admitted, that these aims can also be realized outside of the selection forest. By a growing number of silvicultu-

rists, the selection forest is no longer considered as the economical fixation of a common natural structure, but only as the fixation of a development phase, that, in fact, can be found in the natural forest. Recent research on the structural qualities of the virgin forest (2) and repeated analysis of stand structures made by Leibundgut (4, 5) in European natural forests, have guided the latter to formulate the following conclusions :

- a) In the natural forest, local regeneration on a restricted area, brought about by the disappearance of a single tree, is to be found as well as group regeneration on more extended areas, built up after general stand degradation in part of the forest due to the simultaneous aging of a considerable number of trees or to localized catastrophes.

In the first case an uneven-aged and irregular stand structure appears, whereas in the second case the young stands, whether sheltered or not by remnants of the older stand, are distinctly regular and more or less even-aged.

- b) In the natural forest, the irregular and uneven-aged stand structure is a localized and temporary phenomenon, to be considered as part of a continuous and dynamic evolution cycle, represented by Leibundgut in the following way :

Optimal phase	Uniformisation
Aging phase	
Degradation phase	Increasing irregularity
Irregular phase (uneven-aged)	
Juvenile phase	Uniformisation

If stand regeneration is not to be considered as the central problem of silviculture, it is even more senseless to speak of an existing polarity between regeneration and treatment or to accept the still more complex relation «Education of the stand—Control of growing stock and increment—Stand regeneration». It seems to be more logical to accept the basic idea of Schaedelin (9), who considers regeneration only as a simple link in a continually progressing and dynamic stand evolution. The real period of effective occupation of the surface by regeneration is in fact rather short compared with the age of stands and trees at the moment of exploitability. In the period, during which regeneration is effectively prepared, it is not absolutely necessary that stand treatment should reach a neutral point or severely reduce its interventions. Regeneration can easily be combined with normal stand treatment, from which it must be the logical consequence and an integral part.

A real split between treatment and regeneration can only arise from the extension, on too large a scale, of regeneration or from the categorical rejection, as a matter of principle, of artificial regeneration, unjustly considered as being incompatible with normal stand development.

The problem of the relation between treatment and regeneration can in reality be reduced to a question of organisation of silvicultural management and of logical dispersion, in time and space, of all necessary interventions.

The progressive breaking-up of the forest or of the stand into units of decreasing importance, based upon ecological differences, that have a direct impact on growth, tends to create a better and more fluent link between treatment and regeneration.

This applies to natural as well as to artificial regenerated stands.

2. The hypothetical contradiction between natural and artificial regeneration

A rich literature has repeatedly stressed the numerous advantages of natural regeneration. A more critical approach to these argumentations shows, that an important part of available papers is based upon preconceived ideas on regeneration or deals with concrete situations, from which further generalisations are deduced. On the other hand, comparative trials, made over a longer period of time, are rather scarce, so that it can not be denied, that, in many cases, the defense of natural regeneration is inspired by some kind of natural philosophy or by the disputable conception of the forest as an organism. This state of mind has been responsible for regrettable exaggerations, so that occasionally natural regeneration became a silvicultural aim in its own right. At the same time, artificial regeneration has quite often been rejected on the extremely doubtful grounds, that it should be incompatible with the concept of the forest as a complete ecosystem, with the formation of stabilized stand structures or with the unrestricted safeguarding of sustained yield.

The partial appreciation of natural regeneration on one side, the impossibility or inopportunity to use it in many cases on the other, have created a dangerous split in the general approach to silvicultural problems and a dangerous duality in the silvicultural conceptions that have aroused a lot of misunderstandings (7).

In favour of natural regeneration can be said in the first place, that it greatly helps to stabilize microclimatic conditions in the forest, that it gives a better and perennial shelter to the soil, that it furthers the formation of irregular or unevenaged stands and

that it leads to more supple silvicultural treatments, allowing to put to a maximal profit the growth potential of the individual trees.

A nearly exclusive advantage of natural regeneration is undoubtedly the deeper rooting of seedlings and their quick and much better fixation, from the start, in the mineral soil. This observation especially applies to the poorer soils of the podsol type, where a marked difference in root development between plantings and natural seedlings can be observed. This better rooting exerts a positive influence on soil conditions, particularly on aeration and permeability for water and gasses. In this way it helps to further or to maintain the potential productivity of the site.

The well-rooted seedlings, on the other hand, possess a higher degree of vitality and of resistance against outward biotic and abiotic attacks, which is extremely important in the juvenile stages of growth, whereas the plantings have to pass through several critical periods (recolting in nursery, transplanting, transport, definitive planting on the afforestation site) before their survival is relatively well secured. As a consequence, natural regeneration has a positive effect on actual and ultimate structural stand stability.

Natural regeneration is also better adapted to the normal evolution of the stand and to the dynamics of community development. It fulfils with more success its function of linking successive generations and stages of development, or, at any case, in a more fluent and more complete way as can normally be expected from artificial regeneration, even if the utmost precautions are taken.

Natural regeneration leads directly to the conservation of autochthonous tree species, typical combinations of species, ecotypes, local races and populations, thus furthering the stability of the forest and the maintenance of the site in a good condition for production.

However, whereas the choice of species and their mixing patterns can easily be manipulated by silvicultural treatment and is highly dependant from a series of decisions, that can be made at any stage of stand development, the alleged conservation of ecotypes and local races is important enough to deserve closer consideration.

In fact, little is known about the actual possibility and the objective value of the conservation of local types: The problem has an ecological and climatological as well as a genetical aspect. The first seems to be more real than the second. The local population is the survival product of the selective influence of total environment on a broader original population or on a population, already narrowed by previous actions.

It has no constant or definitive internal stability, as it tends to broaden again at the beginning of each new generation.

During its original building-up, the population has been primarily narrowed under the influence of the nearly invariable or very slowly changing soil conditions; the same factors continually react upon the broadened sub-population, that develops after each regeneration.

The primary trend of development is accentuated by the action of the complex of atmospherical factors, which are not entirely independent from the soil conditions. The annual or at least periodical manifestation of extreme weather conditions, combined with the regular action of the nearly invariable climatic conditions, provokes a loss of collective and individual vitality, eventually leading to the ultimate disappearance of the less resistant and poorly adapted elements. In this way a narrower local population, to be considered in the first place as the selection product of the abiotic environment, is built up in consecutive stages over a very long period of time.

It should however be understood, that such local populations are in no way invariable: They tend to broaden at the beginning of each new generation, without reaching, in most cases, the original composition, from which they started; at the end of each generation, the population has narrowed again, partly under the influence of the acting factors of the biotic and abiotic environment, partly also as a possible consequence of selective silvicultural treatment.

The dynamics of the formation of narrower or local populations have no direct significance for the silvicultural practices, as the real acting forces of selection are to be found in environmental influences, that can not be deeply influenced by silvicultural treatment. It should also be taken into consideration, that silvicultural and even forest management are conceived on quite a different time scale as would be required for the effective narrowing of a population.

This has been amply proven by the study of the time factor in the building-up of natural populations.

Even if this kind of ecological selection does not directly affect the practice of silvicultural treatment, its consequences are important enough to be studied and approached with realism. The surviving elements are, as a matter of fact, better adapted to local conditions and acting site factors, thus potentially creating a greater internal stability within the forest stands. At the same time, and although the selection goes out from the abiotic environment and primarily results into an organical and physiological similarity

between the survivors, all morphological changes are not necessarily positive : their importance and their desirability must be assessed in function of the technological timber quality and of the economic value they represent.

Practical silviculture nevertheless has repeatedly manifested a marked tendency to overrate the morphological and technological superiority of ecotypes and local races. From the enthusiastic study of specific situations and especially succesful site selections, very optimistic generalisations were often deduced concerning the positive effects of ecological selection and its economic consequences. It also leads to the introduction of seemingly good populations on new sites, eventually with some poor and even catastrophical results, because the dynamics of population building were not clearly understood and no thorough analysis was made of the equivalence of the site of introduction with the site of origin.

Still more doubtful is the ensuing concept, that the combination of ecological with positive silvicultural selection can produce a real and stabilized amelioration of stand quality after a restricted number of tree generations, even within the duration of a single rotation or management period. The unavoidable broadening of the population after each new regeneration is proof enough, that the effects of silvicultural selection are nearly completely limited to a single tree generation and that it has to start all over again with the first stages of each new stand.

The unsatisfactory results obtained with good ecotypes and local races outside of their natural area of dispersion, as well on better as on poorer soils, have repeatedly proven, that these selections are very closely linked with the site on which they originate, especially with regard to their morphological and physiological characteristics. Really good natural ecotypes and excellent local races are rather scarce, because they suppose an intimate genetical linking of desirable physiological, morphological and technological qualities in a larger number of individuals, which, at the same time and when used on other sites, have to possess a high degree of resistance against variable biotic and abiotic influences in their most extreme expression.

The conservation of desirable qualities and the integral maintenance of narrowed populations in optimal form after introduction on a new site are therefore still more exceptional. Individual deviations and internal degradations will be the more frequent as the differences between ecological conditions on the site of origin and the site of introduction are more numerous and more important. On the other side, silvicultural selection is not in a position to produce durable amelioration effects as long as the choice between individuals must be made on a morphological basis for which no

genetic foundations exist, because, especially in intensively treated stands, the phenotype of trees is influenced in a very high degree by accidental micro-ecological conditions as well as by the direct environment of the individual.

It thus becomes clear, that the only sure result of the formation of local races and narrowed populations seems to be, that they bring about a greater individual and collective vitality leading to a higher degree of stand stability, that, eventually, they can further the production of a more considerable economic value and that they create favourable conditions for the temporary amelioration of the stand through silvicultural treatment. The use of natural selections, outside of their normal area does in no way assure positive growth results.

From a critical study of natural regeneration and its alleged advantages can be quickly concluded, that the greater part of the positive results are in reality not a direct consequence of natural regeneration in itself, but are more closely related to the technical measures, taken during the regeneration period as well as to the characteristics of cutting practices and silvicultural management, linked with the chosen method of stand renewal. It is a fact, that supposed good local races with a real economic value are mostly reported in areas, where intensive silvicultural treatment has changed and considerably manipulated the environment.

This also means, that favourable conditions for the formation of local races can, to at least the same extent, be created by silvicultural treatment after artificial regeneration. The number of cases where this was done actively are rather restricted, because the preference for artificial regeneration often implies a state of mind, whereby the bio-ecological conception of silviculture gets lost and continuous treatment is neglected.

The concept of artificial regeneration is, as a matter of fact, given a restricted content by a number of foresters. But as well as « natural regeneration » is not synonymous with « selection forest », so « artificial regeneration » does not necessarily express an outspoken preference for a technical minded silviculture or for one-sided afforestations on a large scale.

Both natural and artificial regeneration can produce and have produced critical situations when put through on a large scale or untimely expanded over a great area. In either case, important expenses for execution and for the ensuing treatment of the young stands are required.

By their concentration over a short period, they tend to weigh heavily upon forest management under the actual social and economic conditions so as to become a serious treat to sound finan-

cial management, because they easily can provoke serious disturbances in the working and financing plans.

A great many alleged advantages of natural regeneration, especially the greater opportunities for individual selection as a normal consequence of the higher number of trees in the young stands, get completely lost as soon as early and intensive treatment becomes impossible for different reasons, especially when no sufficient labour is available or an unfavourable relation between expenses and produced surplus-value is unavoidable.

This critical situation already exists in part of Europe, where artificial group regeneration of quick growing species begins to replace natural regeneration on sites, where the latter would pose no ecological or biological problem at all.

An equivalent evolution is taking place with regard to afforestation and artificial regeneration over extended areas. Afforestation costs have risen spectacularly, a chronic labour shortage has developed in the industrialized and densely populated countries with a high standard of living, investments and expenses for goods and services have reached such a level, that their counter-balance by future economic surplus-values becomes rather doubtful. This situation is getting worse and it is thus quite understandable, that a reversion toward artificial group regeneration takes place, allowing for the spreading of silvicultural interventions as well as for economization on afforestation costs and expenses for regular treatment of overdense natural regenerated stands. This evolution is not a tragical one, because it includes considerable possibilities for the raising of production, the amelioration of stand quality and the organisation of stand transformation, that, up to now, have not been sufficiently studied.

Concurrently, artificial regeneration is not incompatible with a bio-ecological orientation of silviculture and it can easily be incorporated in most classical silvicultural systems or patterns of treatment.

A lot of misunderstandings has in fact been generated by an incorrect formulation of the position and the role of stand regeneration, as well as by the unilateral emphasis on particular aspects of one or the other regeneration method.

The opinion of Schaedelin (6), that stand regeneration is to be considered only as a binding link between generations in the continually evolving forest, is therefore not to be understood as an attempt to minimize the importance of regeneration. It really means that no superior and generally acceptable regeneration system exists, that no imperative regeneration scheme belongs to most silvicultural systems and that the choice of regeneration must

be made in each separate case as an isolated decision, taking into account the characteristics of the local situation and giving special attention to the fact, that regeneration must be introduced at the most opportune time and place, so as to become an integral part of normal and continuous stand evolution, that also takes place in the purely artificial forest. These general aims can be realized with natural as well as with artificial regeneration. However, where they are considered as quite normal in the first case, artificial regeneration has often been misjudged as not being compatible with the perennial forest or having as sole mission the rapid covering of extended clearcut areas.

A better understanding of the possibilities of artificial regeneration is necessary for a more realistic approach to most silvicultural and forestry problems.

3. The potential possibilities of artificial regeneration

The advantages of natural regeneration are not so exclusive as is often accepted and stated. An objective and thorough comparison between the two regeneration systems has only exceptionally been made, and they always have been linked with a different set of procedures. So, in fact, procedures were compared in the end, leading to a real controverse on the basic value of each system. An exchange of traditional techniques however, as is already done on a moderate scale, proves, that the differences are not so great and not so numerous as was generally assumed.

This means principally, that the practice of artificial regeneration must not necessarily be restricted to the afforestation of waste land or clearcut areas, but that it can fulfil many functions, considered, for a long time, as the exclusivity of natural regeneration. Artificial regeneration can in fact be used as an integral part of most silvicultural and management systems.

a. Artificial regeneration as a link between generations

It is evident, that natural regeneration, as it is prepared, introduced and conducted by silvicultural practice, stands comparatively close to the spontaneous renewal phenomena in virgin forests or in semi-natural stands, that are not deeply modified by treatment or exploitation.

The analogy however, is not complete, because practical silviculture not only endeavours to create a new stand, but at the same occasion tries to induce a well defined order in time and space, leading to an obvious concentration of regeneration on biological, as well as on technical and economical grounds.

The desirability to create such a specific order in time and space arises from the double necessity

- a) to regulate stand growth and increment during the active regeneration period;
- b) to build up a specific ecological situation, favourable not only, for the regeneration at the chosen time and place itself, but also for the ensuing development of the stand structure, which is profoundly determined by the basic condition from which it has to start.

As a consequence, regeneration has the character of a compromise on technical or economic grounds and difficulties necessarily must arise from imposed deviations from the spontaneous or natural evolution of stands.

Natural regeneration in the economic forest only puts to use a natural phenomenon, therefore creating a specific semi-natural or at least deeply modified environment.

As soon as regeneration difficulties arise, they are mostly due to the nevertheless advisable shortening of the active regeneration period. They are more frequent and more important as the regeneration period gets shorter and shorter, because the regeneration result becomes increasingly dependant from favourable ecological and biological conditions, that only prevail during a limited time period. In fact, if natural regeneration in its extreme economic form, is based upon a single seed year, eventual failures have far reaching consequences :

- 1^o Completion of the regeneration has to wait for another seed year, so that the possibility of linking the two regeneration stages depends from the frequency of a series of biological phenomena, that can not be provoked at will, and from the ability to maintain the soil in a good regeneration condition over a period of undetermined length.
- 2^o The regulation of stand growth can be entirely disturbed by cuttings made to ensure the good development of the initial stage of regeneration. If the regeneration is incomplete, a very difficult choice must be made between further growth regulation, eventually creating bad conditions for accessory regeneration, or the manipulation of the stand aiming at this accessory regeneration, and making sacrifices with regard to value production.
- 3^o After repeated failures or when seed years are too far apart, natural regeneration must be completed after all by planting. Also in this case difficulties with regard to growth regulation get more important if the ultimate decision is untimely made or postponed for too long a time.

On these grounds it is reasonable to conclude, that natural regeneration is not unconditionnally the only suitable link between generations in the economic forest. It is indeed feasible to replace natural regeneration partly or completely by planting or artificial seeding without having to change silvicultural interventions and cutting practices before, during and after regeneration, or without being forced to modificate fundamentally the preconceived order in time and space, the normal stand development or the silvicultural management during the period of partial or complete stand renovation. This means in fact, that most silvicultural systems can be conceived as having a double aspect, one based on natural, the other on artificial regeneration. In following either way, the same tree species can be used, the same time series followed and the same locations can be given to regeneration. Artificial regeneration, on the other hand, presents the possibility to shorten the critical period of establishment considerably.

The many disadvantages of artificial regeneration are well known. They are however sufficiently compensated, especially on poorer sites, by the following positive aspects :

- 1° Unavoidable planting costs are amply compensated by diminishing expenses for cultural treatment of regeneration groups and young stands.
- 2° The independance of regeneration from seed years furthers indirectly stand stability, as the period of insecurity, during which the regulation of growth and increment reaches a neutral point, is shortened. Much more attention can be paid to the remaining growing stock and to stands not in regeneration.
- 3° The critical period of flowering, seeding, germination and fixation of the seedlings becomes unimportant and the plant material can be chosen in function of the degree and the character of environmental concurrence.
- 4° As adoption of artificial regeneration as an integral part of classical silvicultural systems allows for a more subtle treatment of growing stock; it also can modifie silvicultural concepts in many other aspects. It can make real clearcutting and extensive afforestation unnessecary, lead to economize on investments and result into another kind of work organisation e.g. by the formation of constant groups of polyvalent forest workers, who would be afixed continually to a determined forest or forest area, where they would find work through the whole year.
- 5° Under no condition, natural regeneration must be prevented. It could be considered as a desirable complement of artificial

regeneration, resulting into better stand structures, better ecological stability, more intensive mixing, creating a certain degree of irregularity and enlarging the possibilities for choice and selection in the later development stages.

The optimal functioning of regeneration as a link between generations, can be made entirely independent from the choice of the regeneration system. Natural as well as artificial regeneration can be the ideal link, provided that favourable conditions are created by preceding treatment and a logical sequence of interventions is adopted. Although a certain analogy between spontaneous regeneration in the virgin forest and natural regeneration in the economic forest is evident, the identification of the two cycles of phenomena should not go too far. Natural regeneration in the economic forest is in fact induced, fixed and developed by a series of well-ordered interventions, that are clearly artificial in essence. Therefore, the solution of the problem of linking generations in a smooth way is not completely dependant upon the choice of the regeneration system. On the contrary, it is more closely related with the general organisation of silvicultural management, the sequence of cuttings and the realisation of a determined order during a well delimited regeneration period.

The sequence of silvicultural interventions can be the same in either regeneration system. The combination of artificial with natural regeneration can therefore be given greater importance.

b. *The conservation of ecotypes and local races.*

The application of artificial regeneration does not prevent neither the use nor the conservation of good ecotypes or valuable local races. It requires however a modification of forestry management and the adoption of the newest techniques in plant culture and selection outside of the forest. The creation of highly specialized local nurseries becomes absolutely necessary.

From excellent individuals the necessary material can be obtained for subsequent multiplication and selection using the most recent methods for seed production, grafting and vegetative propagation. It is also possible to follow a more conventional line, collecting seed from good mother trees, if possible from trees growing in the stand that must be regenerated, and using it subsequently in the local nursery to produce planting material in a sufficient quantity. It is evident, that the second method, although leading to a fairly important improvement of the genetic quality of the new stand as compared to natural seeding, does not offer the same opportunities for systematic selection and the production of closely related individuals as can be obtained by the more scientific

methods of modern propagation of excellent types. In both cases and as soon as the production of a sufficient quantity of good planting material is assured, the stand can be prepared for regeneration, following the most appropriate sequence of cuttings with regard to the adopted silvicultural system.

Optimal spacing must be chosen in function of the tree species, the size of the planting material, the site quality and the dispersion of already existing natural pre-regeneration.

The use, in such a way, of autochthonous material must give results, that are at least equal to those obtained by natural regeneration. The resistance of the local population against extreme site conditions and extreme climatic influences, built up over a very long period of time, is undoubtedly taken care of.

The selection possibilities, before regeneration and during stand treatment, are not less important than in the case of natural regeneration.

Selection, in fact, is done more directly in the nursery, so that treatment can concentrate on the creation of good phenotypes, having to consider only the environmental influences and the external growth characteristics of the individuals.

c. *The opportunity for selection.*

It stands to reason, that the higher number of trees to be found in naturally regenerated groups as compared to artificial regeneration, does not prove that greater possibilities for selection exist in the first case or that a more advantageous basic situation for stand amelioration is created.

1° Not the possibility, but the execution in due time of selection is important. The higher initial number of seedlings to be found after natural regeneration is therefore only of some value, if selection can be organized and is really put through. If, on the contrary, treatment of regenerations and young stands can not be as intensive or as frequent as is required by higher stand density and quick stand development, the higher number of young stems rapidly becomes inconvenient, resulting into poor development of the individuals as a consequence of sharper concurrence, into early stagnation of growth, ensuing stand degradation and a progressing diminution of individual and collective value.

Therefore, it is essential that intensive stand treatment is really secured, before proclaiming natural regeneration as superior or at least equivalent to artificial regeneration from a genetic point of view.

- 2° The potential value of a regeneration group is determined principally by the absolute number of individuals with desirable qualities that are found on a limited area. Whereas the actual methods of plant culture are in a position to evaluate objectively and accurately the genetical value of their products, it remains doubtful if the morphological and visual approach to tree and stand quality, as silviculture is often bound to do, really permits even a rather general appreciation of the genetical value of the individuals especially in the early stages of growth. It is highly probable that practical stand treatment loses a considerable number of trees of good potential quality and that the excellent results of intensive treatment are in the first place a consequence of the formation of well-equilibrated stand structures and of the sensible manipulation of environmental conditions.

Therefore also, the superiority of natural regeneration is to be found in the field of ecology; the superiority of artificial regeneration, if well done, must lay in the better condition for selection it creates.

- 3° There is no adequate and satisfying information on the genetic composition of regeneration groups and our actual knowledge on the dynamics of population development is rather poor. Silvicultural treatment, on the other hand, must continually take into account that, with regard to morphological quality, physiological characteristics and individual tree properties, the new stand always possesses a broader amplitude as the old stand or the mother trees by which it was generated.

Control of the progeny of selection stands and of seemingly excellent individual trees, has proven, that the superficial appreciation of the morphological properties of the mother trees does not permit to make previsions on the future qualities and characteristics of the regeneration result, as tree morphology is not exclusively genetically determined and is highly influenced by the environment and micro-ecological growing conditions.

In comparison to natural regeneration artificial regeneration offers at least the same opportunities for the fixation and the conservation of site-resistance, as it can proceed to a better progeny control and uses adequate selection methods. Artificial regeneration covers the regeneration area with a genetically more valuable and more uniform population, which is also superior to the best result intensive treatment could produce. It brings silvicultural treatment in a favourable position for continued morphological selection even if ecological conditions are not quite so good.

Finally, it must be taken into account that artificially regenerated groups need less treatment as optimal spacing prevents early concurrence. Because selection is already made outside of the forest, treatment can concentrate entirely on the transformation of environment and the creating of optimal growing condition, both for the stand as a whole and for the individual trees.

d. *The stand structure*

The possibility to create more complex and better equilibrated stand structures, particularly in relation to mixing patterns, desired stand irregularity, soil covering and regulation of growth, has always been considered as one of the more positive aspects of natural regeneration. A superficial comparison between naturally and artificially regenerated stands seems to prove this point : Irregularity, good dispersion of age and size classes and intricate mixing patterns are in fact most unusual in the artificial forest. They are difficult to provoke, especially if the stands cover a large area or are growing on rather poor sites. However, if artificial regeneration follows to a large extent the same pattern of dispersion and an analogous sequence of cuttings for establishment and expansion, if, in fact, only the principal tree species are planted without making other fundamental modifications and natural regeneration of the secondary or accessory species is not prevented but even favoured to a certain extent, on the planted area the final regeneration result, as expressed through the subsequent stand structure, can be made nearly completely independent from the chosen regeneration system.

This is especially the case when indigenous species are used; the differences tend to become more important if not only a change of regeneration technique is made, but a replacement of species is put through at the same time. The creation of intricate mixings in artificially regenerated stands will also be more expensive. It remains however a normal procedure to limit artificial regeneration to the principal tree species and nearly optimal regeneration results can be expected from the sound combination of planting with a supplementary spontaneous regeneration.

Because this option exists and is already put into practice for direct stand conversion, in which only the principal tree species is partly replaced, the better sheltering of the soil, more irregular stand structures and stabilized microclimatic conditions, must not be considered as an exclusive quality of naturally regenerated stands.

An analogous observation can be made concerning the supplementary individual increment, to be made at older stems of

exceptional quality after individualisation. This kind of increment can also be obtained when artificial regeneration is used, because it is not a consequence of regeneration in itself, but only of the system of cuttings adopted during the active regeneration period.

4. Conclusions

It is evident that natural regeneration must not be methodically replaced by the more controllable artificial regeneration. On the contrary, where natural regeneration is easy to provoke, a satisfying certitude exists that the regeneration result will meet requirements and subsequent silvicultural treatment can reach a high level of intensity on account of favourable ecological, economical and social conditions, it would be a fundamental error to replace it by artificial regeneration, that needs a more complicated organisation of silvicultural management.

However, as soon as the regeneration result is not so well assured on account of difficult ecological and technical conditions, whenever unsatisfactory disturbances in stand development are feared or are unavoidable and a serious doubt prevails on the economic value of the eventual regeneration result, natural regeneration must be replaced without hesitation by artificial regeneration. This decision does not necessarily imply, that fundamental modifications of the treatment system or of the sequence of cuttings must be taken into consideration.

In any case the practice of artificial regeneration is not to be restricted to the afforestation of new sites or the planting of clearcut areas.

It must, quite contrary, also be contemplated as an integral part of most silvicultural systems. It must therefore be adopted as soon as natural regeneration is uncertain.

Artificial regeneration puts to better use the results of contemporary research in the fields of applied genetics and plant culture. It can work with a purposeful restricted number of severely selected plantings of higher and more controllable quality.

As a consequence, it simplifies, to quite a large extent, the subsequent treatment of the younger stands as it allows to limit the number of silvicultural interventions and pays more attention, at an early stage of stand development, to the optimal shaping of environmental growing conditions.

Excellent regeneration results can be obtained by a supple combination of artificial with natural regeneration, especially on restricted areas or when group regeneration is planned. This combination, that eventually can offer certain technical difficulties,

does not prevent the realisation of more intricate mixing patterns of tree species and age or dimension classes. The opportunity of such a combination must be judged from a technical, economical and financial point of view in each case separately.

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