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Rejuvenating old, senile orchards of tropical and subtropical fruits for enhanced production and improved quality: A review

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ABSTRACT

Fruit production addressing the challenges of nutritional and livelihood securities, needs strategic planning and proper interventions for higher productivity and improved quality. In this context harnessing full production potential of perennial fruit crops, is necessary for ensuring sustainability and competitiveness of the industry and profitability to the growers. Majority of the perennial fruit crop orchards across vast tract of the country are characterized by the prevalence of old and unproductive trees with reduced fruiting potential (30-35%). The prolonged neglect in their management practices virtually make them unproductive. Replacing the old orchards through a new plantation is a more demanding process. Rejuvenation technology encompassing reiterative pruning, top-working and canopy rebuilding for augmenting productivity could be a viable option to be exploited for restoring health and vigour of the trees to ensure profitability of the orchards. Rejuvenation techniques confers multiple benefits such as early transformation and quality production from old unproductive, senile trees by better sunlight interception, utilization and efficient use of open space and applied inputs. The productivity augmentation is found to the tune of 2 - 6 times in various fruit crops through this technology has been demonstrated successfully in the recent past. Besides reiterative pruning, cultural operations like nutrition, irrigation, intercropping, mulching and plant protection measures need to be carried out properly and carefully to help improving soil health, tree vigour and production efficiency. However, faster adoption of this technology warrants that some physiological apprehensions of the growers that the old perennial trees will die after heavy pruning and they require abnormally long time to rebuild their canopy and bear profitability need to be removed through large scale field demonstrations. The technology is economically viable and can bring noticeable change in productivity of declining old orchards. Further research on physiology of shoot growth and bearing of severly pruned trees will not only help refinement of actual pruning process but also the associated cultural practices that are essentially required to expedite the whole re-invigorating process.

Key words : Canopy managment, Perennial fruit crops, Profitability, Rejuvenation, Reiterative pruning, Senile trees

Fruit orcharding is somewhat expensive and skillful job but high productivity of fruit trees gives higher economic return per unit area apart from being the means of livelihood security and usefulness in the preservation of the environment (Chadha *et al*. 2013). It is logical that higher production also increases the availability of nutritions and healthy food for human consumption from the unit area. Though, the perennial nature of fruit trees take longer period to come to bearing stage and thereafter annual production, many a times compels the orchardist to wait for the entire year for the produce. In case of the annual production of these fruit crops, growers are to depend on the whims of the nature and adoption of proper management practices, provided other factors of production system are favourable. Fruit orchards have different production phases like pre-commercial bearing stage (new plantations), commercial bearing orchards and old senile declining orchards even up to the stage of unproductive ones (Baba *et al*. 2011). The factors that limit fruit production are both biotic and abiotic factors, if not managed properly. The yielding capacity of a perennial fruit tree is dependent on variety, tree age, tree size, seasonal conditions and previous cropping history (Singh 2003). Commercial fruit production with increased quality production has made significant contribution to economic development of the growers and those associated with fruit trade in the growing region.

Present status and production constraints

Today, our country is the second largest producer of the fruits in the world, yet the per capita availability of fruit is below the recommended level (Chadha *et al*. 2013). The major reason for low per capita availability of fruits in India is poor productivity of the fruit trees. In addition, the pressure of burgeoning population and ever increasing demand also results in reduced availability of fruits. The production of fruit crops are highly intricate in nature and are function of

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interaction of so many interdependent factors. The problem of low productivity of fruits is compounded by several environmental, genetic and conditional factors. At present, there exist a wide gap in between actual fruit yields and their potential yield in almost all the tropical and subtropical fruit species, particularly in those, which are perennial and woody in nature.

There is a great diversity in perennial fruit crops which permits considerable manipulation for various purposes. Although, India is the leading mango producer globally, with an annual production of 15.19 million tonnes from 2.29 million ha, representing 36.0 % of the total area under fruit production, the average productivity of the crop is around 6.8 tonnes/ha only, which is quite low as compared to other mango producing countries (Mishra 2013). In case of litchi, our country is the second largest producer after China in the world. It is cultivated in an area of about 82 700 ha and the production is about 580 100 metric tonnes and the productivity is about 7.10 tonnes/ha (NRCL 2014). In India the area under guava is about 2.36 lakh hectares, producing 3.12 million tonnes with productivity of 13.22 tonnes per hectare and this crop is the fourth most important fruit crop of this country (Mitra 2008, Singh *et al*. 2013, ICAR-DataBook-2014). Aonla or Indian gooseberry is an indigenous fruit of Indian subcontinent and ranks first in area and production in this country, it is found growing in an area of 49 620 hectares and the production is about 150 000 Mt (Pathak 2003). The yields often reflect irregular annual bearing patterns even with poor quality and they vary greatly from season to season, apart from the other associated problems. Cashew is being grown in an area of 9.91 lakh hectares with an annual nut production of 6.92 lakh Mt in this country. The national productivity comes to 7.49 q/ha (Hubballi and Jnandevan 2012) against the target of 20.00 q/ha (Dora and Sethi 2013). There is observed decline both in quality and quantity of produce after some period of time, making orcharding economically non-viable and non-remunerative. In India citrus fruits are grown in an area of about 10.43 lakh hectares with an annual production of 100.90 lakh metric tonnes (ICAR-DataBook-2014). Different types of citrus species have different region specific dominance of quality production in the country. Pomegranate is also one of the important, high priced tropical/semi-arid fruit crop grown in India and its annual fruit production is about 745 000 tonnes, from an area of 113 000 hectares, the average productivity of the crop is around 6.6 tonnes/ha only (ICAR-DataBook-2014), which is quite low as compared to other pomegranate producing countries (Hiwale 2009).

The fruit production over the past few years, has been showing an increasing trend in our country but the productivity is still much below the productive potential and that too of poor quality dominance in quite few important fruit crops like mango, litchi, guava, citrus, aonla, pomegranate and cashew is of major concern. Low productivity of these perennial fruits has been attributed to various factors, like small size of holdings, preponderance of old and senile trees and poor management of inputs such as water, nutrients and pesticides. Thickly shaded mango orchards in the Malihabad areas of Uttar Pradesh (Kalloo *et al*. 2005, Mishra 2013), lanky as well as sick tall unproductive litchi orchards in Muzaffarpur and its adjoining areas in the state of Bihar (Kumar 2008), seedling orchards of guava and citrus fruits throughout the country, including disease affected aonla and other perennial fruit tree plantations are commonly seen in large tracts in different parts of the country (Pandey *et al*. 2013, Singh 2007). In case of pomegranate the old orchards become non productive due to incidence of pest and diseases and neglect (Hiwale 2009). These have brought down even the average productivity. The other production constraints are, lack of information regarding canopy management, non-adoption of appropriate agro-techniques and timely management practices, leading to large number of existing old and senile orchards turning even unproductive (Hare Krishna 2012). In-spite of the fact that our country has made rapid strides in fruit crop production but in reality so far below the potential in comparison to other countries. Our country is still technology deficit and whatsoever the technologies available are very poor in their adoption level.

In the recent past declining productivity of old and dense orchards existing in abundance has become a matter of serious concern for the orchardists, traders as well as scientists. According to Singh (2007), there are many causes which make the orchards uneconomical are i. growth of wild shrubs and grasses (as weeds), ii. unsystematic planting at initial stages, iii. inferior varieties, iv. heavy infestation of pests, diseases and parasites, v. damage due to adverse weather conditions, rodents and other enemies, vi. old trees with advanced age have tendency to develop hollows in their trunks and main branches starting from crotch or from the point of bifurcation. Extensive survey reports undertaken for many fruit crops revealed the fact that there is considerable increase in area under old senile orchards to the tune of 30-35% (Lal *et al*. 2000, Kumar 2008). It has also been observed that loss of tree vigor in older trees results in falling of the foliage and low yields of small fruit, and is usually accompanied by dieback of twigs and small branches, risk in harvesting of fruits from upper canopy of lanky and height. This decline may be due to age, disease, soil pests, water induced root damage, and other causes. Old trees often produce fruits and are difficult to harvest due to their size. Moreover old trees harbor pest and diseases and it is difficult to reach the whole tree while spraying to control them. This chunk of old senile orchards, apart from being highly uneconomical, act as source of disease and pest infestation and their uprooting must be vigorously enforced by the state through new legislations.

Need for rejuvenation

Rejuvenation technology in fruit trees is visionary approach to save the old senile declining trees for future and sustainable quality fruit production. This technology is unique integration of invasive exhaustive operations and skillful management for bringing real desired transformation and that too for potential and profitable outcome. This technology is for old senile fruit trees, which is an ultimate option not only to save the declining plants/trees but also concerted efforts to transform it from unproductive to productive ones by restoration of youthful vigour. The technology is strategic and innovative approach advocates the change through scientific skillful operation. The rejuvenation of old senile fruit trees particularly deals with many issues like restoration of youthful vigour, enhancement of quantum and quality fruit production, period of sustainability, economic feasibility etc. All these have been proved with sound experimentation, implementation and success stories, hence needed a wide level adoption (Kalloo *et al*. 2005, Kumar 2008, Lal *et al.* 2000, Singh and Mishra 2007, Pandey *et al*. 2013)

For overcoming the problem of unproductive and uneconomic orchards existing in abundance, large scale uprooting and replacement with new plantations (rehabilitation) will be a long term and expensive strategy. Therefore research efforts initiated at various pioneer institutes/ SAUs to standardize a technology for restoring the production potential of existing plantations by a technique called rejuvenation. Rejuvenation of old orchard is very vital under orchard management, which needs careful, visionary and scientific approach and it should be followed in skillful manner. Reiterative pruning and canopy rebuilding for rejuvenation of perennial fruit trees is medium term strategy requires scientific skill and technique, for transformation of old senile unproductive orchards to young productive ones by restoring the youthful vigour with enhanced quantum of quality production in sustainable way within a time gap of three years for mango, litchi and cashew nut (Lal *et al*. 2000, Kumar 2008), while two years for guava, aonla and pomegranate (Singh 2007, Hiwale 2009) without any economic loss to the growers. The old fruit orchards need to be rejuvenated as they show decline in yield and quality of produce for bringing active change and transformation scientifically by enhancing the photosynthetic canopy surface area by more penetration of sunlight due to well monitored spaced branches, invigorating more number of productive shoots, significantly controlling the incidence of insect pests and diseases as well as enhanced quantum of quality production without any economic loss. Those trees/plant are rejuvenated which have attained a stage where they are no more profitable from the grower's point of view (Singh 2007, Srivastava 2007).

There is an estimated area of about 25-30% (Kalloo *et al*. 2005, Kumar 2008, Hiwale 2009) under fruit crops cultivation have become old, senile and unproductive, while the quantum increase in present level of production through horizontal expansion (i.e. through new plantation) will be a long term venture but the existing orchards turned or turning to unproductive and uneconomical ones can be brought back productive ones through rejuvenation techniques, which in turn help in restricting the deterioration of the health of the plant and thereby extending their life, aims at improving the yielding capacity of quality production with renewable ability and situation under minimum period of time as compared to establishment of new orchard, which attains the commercial bearing stage after 8-10 years (Kalloo *et al*. 2005, Lal *et al*. 2000, Kumar 2008, Singh 2007, Hiwale 2009, Pandey *et al*. 2013).

Physiology and mechanism of rejuvenation

Perennial fruit trees build their woody architecture with some building blocks, i.e. modular units, known as metamer or phytomer (White 1979, Room *et al*. 1992, HareKrishna 2012), it consists of meristems initially an apex. When a meristem faces periods of dormancy during low temperature or pruning. Later it appears as bud, whenever active, as such bud produces a growing point with sequence of meristematic tissues simultaneously called a sprout, i.e. extension unit or growth unit (Halle *et al*. 1978, Bell 1991). The driving mechanism behind the pattern appears to be auxin production (and basipetal transport) when the new shoot and leaves developed and are exposed to light (Sterck 2005). Other features of trees are to produce more xylems relative to phloem, accumulate xylem over time and may thus produce thick woody branches and stems. Furthermore, studies suggested that attaining reproductive phase and reproduction processes compete with vegetative functions, depleting resources necessary for maintenance and growth (Fakhri *et al*. 1987). The idea that reproduction, growth and defence interact within the individual and compete for limited resources is now considered an established principle. Because there are trade-offs between a plant's various functions and the concept of source and sink helps to explain allocation patterns at both the physiological and evolutionary levels. Logical approaches have extended this hypothesis to an explicit as source and sink frame-work in which the effects of defence allocation on rates of consumption can be weighed against the effects on growth (Coley *et al*. 1985, Mooney and Gulmon 1982, Fakhri *et al*. 1987). The allocation to vegetative structures has compounding interest for plant growth, as plant life cycles begin with pure vegetative growth (Abrahamson 1979), also consistent with the idea that perennials must forego some reproductive expenditure to retain sufficient resources for perennation. Perennials have varying levels but in higher reproductive allocation (Hickman 1977, HareKrishna 2012). The reproductive characteristics are among the most conservative traits in plants, but the prediction trends for reproductive allocation are less where morphological constraints on resource allocation are similar in case of perenation. Photosynthesis either directly or indirectly provides the building blocks for all biomass production and growth. However, plant growth and productivity is not determined alone by photosynthetic activity but also by the way, in which the product of photosynthesis are allocated and utilized during plant growth and development.

The decline in productivity of orchards is largely due to poor photosynthetic efficiency besides several other physical compounding factors including age of the orchard, dense and intermingling branches, neglect and poor management, bearing poor quality fruits, attaining unproductive stage. This requires formative or corrective pruning to reinforce the tree to solve the bearing problem of old orchards, i.e. making again productive. It needs adoption of rejuvenation technology (Kalloo *et al*. 2005, Kumar 2008, Singh 2007). The technology requires reiterative pruning, which is of invasive nature, because fruit trees are often lopped extensively through skeletisation to encourage further re-growth, simultaneously, causing a growing sense of anxiety to the farmers that their trees will eventually die. However, hardly reports are available about the death percentage of trees subjected to such a severe salvaging / resuscitating treatment going for rejuvenation, if followed scientifically. Some studies suggest that tree survivability to frequent pruning may be related to tree age and the relationship between age of tree and pruning intensity on survival and biomass production (Duguma *et al*. 1988, Keerthisena 1995, Tipu *et al*. 2006). Although the elucidation of this relationship remains unrealised, some insights in research results have been provided but still needs scientific studies and pursuance. After severe pruning, the left over thick branches of the tree are the primary sources of reserve carbohydrates in the absence of shoots and leaves (HareKrishna 2012). Here, rejuvenation refers to the process of change, which occurs during the reversion from old to adult to juvenile (HareKrishna 2012). The appearance of sprout, giving rise to shoot and young leaves emerging on the pruned/cut branches of the old trees depend on imported carbohydrate (sucrose) from the sieve tubes of the phloem and other tissues to provide metabolism and carbon skeletons for metabolic inter-conversions and bio-synthetic process. The pathways that mediate carbohydrates regulation in pruned trees have been studied in some perennial crops. Vegetative re-growth as sprout emergence is a sink for re-sources, and so allocation to it must be under ecological controls similar to those that govern sexual reproductive allocation. The effects of specific types of stress seem to vary widely, but clonal growth does appear to be tied to resource availability (Ashmun and Pitelka 1984) and plant size (Grace and Wetzel 1981). Despite the widespread occurrence of this physiological integration in emergence of vegetative sprouts, our understanding of the ecological and evolutionary, source and sink study is still minimal. Debate continues over whether re-growth represents reproduction or only vegetative growth and perenation continues taking a certain gap period for phase conversion (Kumar 2012). Phytohormones regulate maturation in plants and the ratios of abscissic acid, gibberellins, auxins and cytokinins, rather than their absolute concentrations play a primary role in causing maturation, as these phytohormones probably do affect changes in the maturation state and the pruned plant successfully integrate several environmental signals to undergo developmental transition (Mallik and Srivastava 1985, Singh 2003, HareKrishna 2012). Until vascular connections to new sprouts, vegetative re-growth are provisioned during adverse conditions. There is existence of meristematic tissues in the left over trunk portion after heavy pruning, which are capable of active cell division and differentiation into specialized tissues as shoots and leaves at initial stage importing stored carbohydrates (Singh 2003, HareKrishna 2012). Emergence of vegetative sprouts, leading to shoots, becoming older as stem and branch but does not possess flower buds (panicles) for one or two years. The developing new shoots (pre-formed growth) of current season, continue growth, taking enough time to mature to go for phase change. It experience dormancy period due to winter exposure (low temperature) for one or two seasons are probably changing to floriferous condition, as its vegetative meristem has differentiated into inflorescence (Singh 2003, HareKrishna 2012, Kumar 2012). Since, flowering in perennial fruit crops is complex and cannot be described as a single trait, physiology and molecular mechanisms involved in the integration and regulation of some perennial specific traits, which prevents floral induction until certain developmental stage has been reached, thus ensuring that the plant has sufficient resources to be able to sustain flower and subsequent fruit production (HareKrishna 2012).

It is important to develop a framework sufficiently strong to bear the weight of quality yield. The consequences of the severe pruning, the method as well as time gap of rejuvenating old trees along with cultural practices required to support the reinvigoration process (Kumar 2012). Thinning of shoots after six months of growth, along with selection and allowing of the primary scaffolds to be properly trained outward to grow fast. Scaffolds should be headed during the dormant season of first two years to promote continued lateral branching to be stiffen and strengthen, as well as for maturing the scaffolds for shaping desired framework (canopy). Often interactions between environmental stimuli and endogenous developmental factors exert some regulatory effect, causing phase change to floriferous condition (HareKrishna 2012). Floral induction in some perennial fruit crops (mango, litchi, guava, some citrus etc.) occur in response to cool temperatures perceived by mature leaves largely regulated on physiologically mature shoots (Menzel and Simpson 1995, Menzel *et al*. 2000, HareKrishna 2012, Kumar 2012). Contribution of only some percentage of primary flushes in blooming rather than whole still needs further investigation which may involve biochemical and hormonal assays of shoots (HareKrishna 2012, Kumar 2012).

Periodic monitoring of this pruning operation, emergence of re-growth and its maintenance avoid complexities and disappointments due to undesired framework development or chances of mortality (Kumar 2008). Although genetic re-combination does not occur in the production of new sprouts in meristems and vegetative growth does serve many of the same functions of reproductive phase after attaining perennation and maturation and further in sustainable manner. The physiology and mechanism behind to make the older trees perform parallel to those of well maintained adult trees or even more still require experimentation at precision level to deal with more authenticity in the form of recommendation (Kumar 2009, 2013).

Technique

It is required to take up productivity improvement programmes in the senile plantations, with fresh stock supported with appropriate and integrated combination of inputs, pruning and grafting as well as training techniques. This require proven technology implementation through individual farmers, farmers' cooperatives, self-help groups, NGOs, growers' associations and commodity organizations. However, the technology will be depending upon the nature and requirement of particular fruit crop. Particular technology for transformation of old senile orchards into revitalized productive ones in sustained manner require well planned and concerted efforts. Though processes and procedures require scientific skill with precision in application/implementation as these important commercial crops has been associated with livelihood of many farmers/growers, i.e. why the economic production is of utmost important for the growers as it holds true for all the region specific important commercial fruit crops in general.

For the successful translation of the rejuvenation technology in old senile orchards sequential operational steps should be followed in scientific manner, as detailed below.

Identification/Selection of old orchards : The cause of decline should be determined and corrected if possible; otherwise, response to rejuvenation pruning will be temporary. If the trunk and basic scaffold limbs of trees are not structurally sound due to disease, heart rot, and cold injuries, such rejuvenation procedures are not justified. A limited root system due to a high water table, a hardpan or poor subsoil can result in early tree decline with trees being more readily stressed by drought. When this occurs, the top becomes out of balance with the more limited root system with consequent insufficient uptake of water and nutrients by the roots. Topping these trees should temporarily restore them to a more favourable top to root ratio, but not alleviate the long-term problem. The severity of pruning for rejuvenation will depend on the cause and degree of decline.

It has been observed in general that orchards of mango, litchi and cashew, after attaining the age of 30-40 years and spaced at 10m × 10m turns dense, compact top canopy cover with bare (devoid of leaves), long-high branches at the bottom and bearing fruits only on the high-tops. It becomes uneconomical to maintain above 30-40 years of age due to bearing of poor quality fruit at high up canopy, pose problem in harvesting and the obtained yield loss due to physiological disorders, incidence of pests and diseases, lack of resources and facilities and developing tendencies of alternate/biennial bearing. It also poses problems in proper management. In case of guava, citrus and aonla orchards after attaining the age of 10-20 years and spaced at 8m × 8m (aonla), 5m × 5m (guava, citrus) turns dense, compact top canopy cover with bare (devoid of leaves), long-lanky braches from the bottom and bearing very less fruits only on the tops. Such orchards need to be rejuvenated for further higher production of quality produce. But it is important to look for the health, location and value of the fruit trees, which should be determined before going for rejuvenation (Kalloo *et al*. 2005, Lal *et al*. 2000, Kumar 2008, Singh and Mishra 2007). Sometimes in cases the condition of the orchard is so poor that is not at all profitable to rejuvenate, should be replaced with new plantation rather than to go for rejuvenation otherwise it should be emphasized finally to shift the programme of reiterative pruning and efforts should be made for satisfactory growth maintenance by other required cultural and management practices (Singh 2007).

Training to orchard owners/Awareness to growers : The initial level of adoption, the invasive rejuvenation technology for old senile fruit trees, presents many (a variety) cross cutting issues on the theme of restoration of youthful vigour, enhancement of quantum of quality fruit production, period of sustainability and above all the economic feasibility. The technology is invasive in the sense, its operations require skeletisation and hard core pruning in reiterative manner (Kumar 2008). It encompasses aspects of scientific, suitability, productivity, sustainability and economic feasibility. All these require proper implementation leading to success stories. This concern for the awareness to the growers and enough knowledge base through training, convincing the economic feasibility is very vital to increase the level of adoption (Kumar 2008).

For better understanding of principles and practices of intensive pruning, it would be imperative to trace out its historical background of growth and developmental processes of fruit plants for the required pruning practices – their principles and techniques. During the past few decades large data have been added for the operation of light pruning, reiterative pruning and training to enhance the production efficiency of orchards which have been responsible for purposeful interpretations.

Considering the various pros and cons of rejuvenation, it will be pragmatic to undertake this programme only after giving proper training for acquiring knowledge to the orchardists to understand and apply the methodology in a scientific manner. They should be described about that the based on numerous investigations, it could be elaborated that the fruiting potential of the tree is largely governed by its architecture, canopy density and photosynthetic efficiency. Decline in productivity of orchard could largely be due to poor photosynthetic efficiency besides several other compounding factors including age of the orchard, dense and intermingling branches, neglected and poor management of the orchard. Productivity status is further affected due to compounding problem of insect-pests and diseases, which perpetuate in abundance in such orchards, should be properly dealt in the programme.

Reiterative pruning

There is major need of knowledge concerning the rejuvenating old senile trees with proper techniques. Pruning plays an important role in regulating and controlling growth, flowering and fruiting in perennial fruit trees (Crane *et al.* 2009, Singh *et al.* 2012). In high density planting (HDP) trees are pruned regularly to control size and shape (Iyer and Kurian 2006). Different system/patterns of hedging or pruning is used. Rejuvenation is vital to a tree's health, especially when our goal is to produce enhanced quantum of high quality fruits over a number of years in a sustained manner by transforming the old senile unproductive trees with the help of proper pruning and training techniques. The principle is creating a crown on dwarf fruit tree by transforming size of the old, lanky (tall) fruit tree.

Many mistakes are made when people prune large or heavy branches. In many cases, the pruning process often results in damage to the tree. When deciding which branch to cut and where to cut it, utmost care, skill and expert hands are required. Remove suckers, water sprouts and most competing branches growing straight up into the tree. Pruning of large or heavy limb (any limb greater than 2 inches in diameter) should be three to four steps process in order to avoid tearing or ripping of the bark while making the cut. When single cut in a hurry is used, the weight of the branch or limb may cause the limb and bark to tear several feet down the trunk before the cut is completed. The stepwise reiterative pruning cuts should be made as the first cut is made underside or bottom of the limb/branches, approximately one fourth to almost half way deep. The second attempt of pruning cut is on the upper side top of the limb, just opposite or may be slightly outer side but in no case underside or bottom side of the trunk. The final and finishing cut is made at the trunk marked at the desired height, since the weight of the limb/branches has been removed, this final cut can be made with precision and without the risk of damage to the bark of the trunk. Use of pruning paints and dressings at the cut/wound portion is very important to act as defences against disease and pest infestation.

Downward bending branches eventually lose vigor and not contribute to the canopy, produce almost no fruits; cut off the part hanging down (Dunn *et al.* 2002). Do most of the pruning in the top of the tree so that the lower branches are exposed to sunlight. Sun exposed wood remains fruitful and produces the largest fruit. Shaded branches eventually stop fruiting and will never produce without drastic topping and renewal of the entire tree. Make clean cuts without leaving stubs. In case of abandoned or neglected fruit trees, which have started declining or turned unproductive, pruning may look like a difficult task. In such cases, these trees can be reiteratively pruned in phase manner and made functional carefully in the orchard. Although the trunk and general framework may be sound, the functional portion of the tree is usually a solid canopy of weak, crowded branches at the top or periphery of the tree's canopy. Trees may have annual shoot growth, properly trained with framework. Although pruning is one of the oldest horticultural practices, the principles on which it is based are not always understood. The novice tends to focus on minor details at the expense of some well-accepted principles. Whether the task is to prune neglected, mature trees or simply annual pruning of trees under regular care and maintenance, the certain laid out principles should be taken care off.

In orchards, fruit trees are often lopped to encourage re-growth and to maintain a smaller size tree for ease of picking fruit (Dunn *et al.* 2002). The pruning regime and its extent in orchards is more planned and the productivity of each tree is an important factor. In case of rejuvenation, heavy reiterative pruning of almost all perennial fruit trees is done at the certain effective height of 1.5 meters to 3.0 meters depending upon the nature and growth of the fruit crops as well as girth and type of main trunk. About 2 to 3 main branches with outward growth from the base are marked for pruning at required/recommended height, with the plan of developing umbrella like or semi circular frame work of tree canopy to enhance bearing surface area. Increase light and reduce wind resistance by selective removal of branches throughout the canopy of the tree. This is a common practice which improves the tree's strength against adverse weather conditions as the wind can pass through the tree resulting in less load being placed on the tree (Dunn *et al.* 2002). Reiterative pruning can be done either with manual saw or power operated saw in phase manner from the top. Machine pruning is fast, inexpensive and a large amount of acreage can be pruned with single machine. It is required to be more vigilant about the objectives of reiterative pruning more particularly for tall perennial fruit crops and the crew member's skill and expertise in successful operation, otherwise chances of tree mortality, accidental risks and other complexities will increase. Care should be taken to avoid bark splitting or debarking at the cut end due to falling of heavy branches at the time of pruning. To avoid any external infection at the cut portion, it should be pasted with Bordeaux mixture or Copper-oxy-chloride immediately after pruning.

Mango: The rejuvenation of mango is rather critical and somewhat difficult, as such under high rainfall condition/ areas is not recommended, since the tree may not recover after pruning, requires much care and attention. The technique is common in sub-humid and semi-arid production areas. However, reports say that in warm humid tropical areas this technique is not widely used because of subsequent loss of fruit production and excessive re-growth (3-4 vegetative flushes per year) that occur (Crane *et al.* 2009). Rejuvenation pruning studies conducted in old non-bearing trees of mango cv. Alphanso revealed that heading back operation along with paclobutrazol @ 7.5 g a.i./tree and canopy rebuilding has been found beneficial for earliness of flowering and getting higher fruit yield (Mistry and Patel 2009, Kumar and Kavino 2012). Depending on the extent of pruning, there are four model approaches that have been in practice at various locations to take up rejuvenation in mango (Hackett 1985, Kumar and Kavino 2012).

Model-I, in this case the tall central trunks are cut back to about 3-4 m height from ground. It is a partial rejuvenation, where one half of the tree (all around) is cut back and the remaining trunks and leaves will help protect the stump from sunburn (Crane *et al*. 2009). Stassen (1999) compared the different systems of pruning with unpruned controls under high density orchards of mango and concluded that about closed vase system (informal pyramid) performed best.

Model-2, this is the form of skeletonizing the tree, i.e. cutting back the branches of the tree till only basic frame is left. Particularly large unthrifty trees would benefit from more severe skeletonizing.

Model-3, the extent of pruning decided on the basis of first, second (CISH, Lucknow), third and fourth order branches (IIHR, Bangalore) gave the significantly higher yield. It has been found that for rejuvenation the pruning treatment with paclobutrazol application recorded significantly higher quality fruit yield in fourth and fifth order pruned trees than the control and succeeded in restoring health, vigour and sustainable fruit yield in declining mango orchard (Burondkar *et al*. 2000, Lal *et al*. 2000, Shinde *et al*. 2002).

Model - 4, reiterative pruning in phase manner up to height of 3-4 m from the ground level of old senile unproductive trees (40-50 years) in the farmers field and later canopy rebuilding (open umbrella shape) with intensive care and management successfully has transformed the tree from unproductive to productive phase with enhanced quantum of quality fruit production within a gap of three years onwards (Kalloo *et al*. 2005, Kumar and Kavino 2012).

Litchi : In case of rejuvenation, heavy reiterative pruning of litchi trees is done at an effective height of 2.0 meters to 2.5 meters depending upon the nature and growth as well as girth and type of main trunk (Kumar 2008, Singh *et al*. 2011). Pruning can be done either with manual saw or power operated saw or by the combination of both in phased manner from the top. Care should be taken to avoid bark splitting or debarking at the cut end due to falling of heavy branches at the time of pruning.

Guava: The heavy pruning in guava involved the heading back of exhausted trees (showing marked decline in annual production) to the extent of 1.0 to 1.5 meter height from the ground level during May with the objective of facilitating production of new shoots below the cut point during the monsoon months have been found to give promising effect. The skillful pruning operation (even for modifying tree canopies) and time of pruning (April) have been found to give significant effect on fruit set, fruit yield and quality and proved successful in rejuvenating an old guava orchard (Kalloo *et al*. 2005, Singh *et al*. 2005, Basu *et al*. 2007) while the beneficial effect of pruning for rejuvenation with the integration of IPNM and VA-Mycorrhizal fungi have been recorded up to a significant level on shoot emergence, fruit yield and fruit quality in guava (Chandra *et al*. 2012).

Aonla : Old and unproductive trees of aonla can be subjected to hard core pruning for rejuvenation. The plants are headed back during the dormant season to the extent of 2.0 meters to 3.0 meters above the ground level with the main intention to go for top working with superior varieties (Kalloo *et al*. 2005, Basu *et al*. 2007, Singh *et al*. 2007, Singh and Mishra 2007). Rejuvenation pruning to restore the canopy and enhance fruiting in old and senile aonla orchard has also been found successful at CISH, Lucknow and HARP, Ranchi (Nath *et al*. 2008).

Citrus : Extent of pruning in the culture of citrus should be looked upon as a measure that may be helpful under a specific set of circumstances or as part of a well rounded program of citrus management (Intrigliolo 1984). Pruning should never be indiscriminate, since removal of more than moderate extent seriously delays growth and fruiting, reduces the yield of trees. There is specific need to remove unproductive branches (water shoots). Pruning schedule for rejuvenating different commercial citrus species played a key role in improving the health of declining citrus plants by influencing plant height, trunk girth, canopy area and fruit yield considerably (Hackett 1985, Ansari *et al*. 2011). Fruiting wood declines in productivity after 2-3 years and pruning of declining old fruiting wood. Removal of dead, dried and diseased wood is necessary to check the further spread of the diseased and mechanical injury of fruits. Heavy hand pruning called skeletonization is given to old and neglected citrus trees to rejuvenate them (Naik 1963, Reddy and Patil 2004). Fruit grade was improved (i.e. substantially larger), thus increased net cash returns to the level of declining / unpruned ones. In case of citrus, severe pruning for rejuvenation has yet to give significant and consistent result (Lewis *et al*. 1963).

Cashew : Rejuvenation of old declining trees in cashew is done by heading back (mostly limb pruning of overlapping branches) of the exhausted tree at 1.0 meter to 1.5 meters height before the onset of monsoon (Kalloo *et al*. 2005, Suharto *et al*. 2012).

Pomegranate : In case of pomegranate, 15-20 years old orchard showing the signs of decline mainly due to drying of old branches resulting in sparse flowering and fruiting, non-selective pruning up to a height of 30 cm to 120 cm from ground level are headed back but pruning plants up to 30 cm from the ground level was the best to rejuvenate the old pomegranate orchard (Hiwale 2006, 2009). The pomegranate trees should be pruned to a multiple – trunk system so that if one scaffold is damaged, the tree can be reshaped and white washing is preferred to protect frost/freezing injury (Stebbins 1985).

Time of reiterative pruning

In principle, prune perennial fruit trees when they are in dormant phase more particularly practiced in winter season or after the monsoon season is over (Lonsdale 1999). By adopting and following all the required scientific procedures, the best time to go for reiterative pruning for rejuvenation is also the vital aspect (Table 1). Rejuvenation

Table 1 Recommended height and time for rejuvenation of old senile orchards of some perennial fruit crops

Fruit crop	Recommended height for pruning	Time for pruning	References
Mango	3.0-5.0 m	November-December	Kalloo *et al*. 2005
Litchi	2.0-2.5 m	August-September	Kumar 2008
Guava	1.0-1.5 m	May-June	Kalloo *et al*. 2005
Citrus	1.0-1.5 m	May-June	Kalloo *et al*. 2005
Aonla	2.0-2.5 m	December-January	Kalloo *et al*. 2005
Cashew	1.0-1.5 m	May-June	Kalloo *et al*. 2005
Pomegranate	1.0 m	May-June	Hiwale 2009

is labour intensive operation and it is extremely necessary to complete the operations in time for achieving the desired results. It is also to be aware about the time when not to go for rejuvenation pruning. The misbalanced root-shoot ratio can be corrected by judicious pruning. The branches which have died, broken or one which interferes with natural growth, and water sprouts should be removed any time but not before flowering period. If the exposed wound are big enough, they should be disinfected with arsenical paste and treatments time to time.

Rejuvenation by top-working

Top working can be easily adopted in pruned trees to upgrade seedling plantations and inferior varieties of mango with superior commercial cultivars or newly introduced selection/hybrids suitable for domestic and export needs. Scions of desired variety can be grafted on the newly emerged shoots developed on branches of pruned trees by adopting veneer or soft wood grafting during July-August with all care and procedural precision. Only 4-5 grafting per branch/trunk should be performed. For budding operation, the scion shoot should be selected from the mother plants, which are desirable and prolific bearer and free from disease and pest incidence. The scion shoots of superior variety can be budded on the newly emerged shoots developed on the beheaded branches by adopting T-budding in case of citrus and patchs/modified ring budding during May to September in aonla. After successfully top worked trees side shoots which emerge on the pruned branch should be removed regularly as and when they emerged, so that the tree of superior variety is obtained.

The old unproductive and inferior seedling trees (mango, aonla, cashew) which are found in large numbers can be rejuvenated and improved by the process of top-working. The selected scaffolds limbs of inferior or unproductive trees, desired to be top worked are headed back in February-March. The cut ends are treated with Bordeaux paste. Many shoots emerge within a short time below the stubs. Out of these, 2-3 vigorous shoots per branch or limb are selected and remaining are removed. These shoots make fast growth and become suitable for grafting by August-September of the same year. Select the best sprouts on each stub and graft them with the desired cultivar. Remove the rest of the sprouts gently by giving a clean cut close to the stub so that these may not re-sprout. If any of these shoots are left they will overpower the new sprouts of grafted scion portion. This way one will have to go for grafting operation on 8-10 shoots. These scion portion of grafts sprout within 20 days of grafting operation. The shoot sprouted on scion should be headed back by keeping only one whorl of developed old leaves in November. These leaves provide food to the newly sprouted shoot. New sprouts on grafted scion portion should be covered with rice trash or plastic bags to save the portion from frost or severe winters in December. The covers may be removed in February-March. While removing the covers, the polythene sheet used for tying the graft union should also be gently removed. The old sprout above the graft union should also be re-cut, keeping only the newly sprouted grafts. Care should be taken that grafts should not get damaged since these cannot tolerate even small pressure or jerk. For at least two years no sprout should come up on the tree limbs other than the grafted shoots. Top-worked trees come into bearing within three years, depending upon the grafted cultivar (Singh and Mishra 2007). Topworking is also used to rejuvenate unproductive and mature cashew trees of 5-20 years age. The reiteratively pruned tree's trunk/branches, the emerged shoots should be grafted with scions of high yielding cultivars using the soft wood grafting technique. The top worked trees start giving fruit from the second year and third year from initiation of reiterative pruning operation (Janik and Paull 2008). It has been found that the side grafting technique of two scions combined with two productive branches remaining on the tree proved to be the quickest and most effective technique to rejuvenate cashew trees (Suharto *et al*. 2012).

Application of manures and fertilizers

Non application of nutrients or their inadequate application was also one of the important reasons for reduction in productivity of the orchard and development of deficiency symptoms in the orchard making it unproductive and poorly developed tree stature. There should be integrated nutrient management for maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining the desired growth and further productivity level. As such, it is necessary that fertilizer applications are made using both organic and inorganic forms in pruned orchard with the main intention to boost initiation of new shoots with vigour at an early date. After the reiterative pruning, the tree should be fed with optimum fertilizer doses, followed by irrigation near the root zone, just like the commercial bearing orchards. The manures and fertilizers should be applied through ring/trench method. The dose per tree as an adult bearing stage has been presented in Table 2.

Soil properties, nature of crop and management practices greatly influence the availability of soil micronutrients to plants. Based on soil and leaf nutrient

Table 2 Dose of manures and fertilizers

Crop	Particulars of dose of manures and fertizers	References
Mango	120 kg well rotten FYM, 4 kg neem cake, 2.50kg urea, 3.0 kg single super phosphate and 1.5 kg muriate of potash per tree (apply preferably in two split doses one during the end of February and remaining half dose in June).	Kumar and Adak (2013)
Litchi	75-80 kg well rotten FYM, 2 kg neem/castor cake, 1.00kg urea, 1.5kg single super phosphate and 500g muriate of potash (apply preferably in two split doses one during August-September and another in February-March). The micronutrients like zinc ($ZnSO_4$ @ 2-3g/l) and Boron (Borax @ 2g/l) may be applied through foliar application from one year after the reiterative pruning	Kumar (2008, 2012) Menzel and Simpson (1990)
Guava	50 kg well rotten FYM, 2 kg neem cake, 1.50 kg urea, 2.00 kg single super phosphate and 1.0 kg muriate of potash per tree (apply preferably in two split doses one during the end of May-June and remaining half dose in September).	Singh and Mishra (2007)
Citrus	50 kg well rotten FYM, 2 kg neem cake, 1.50 kg urea, 2.00 kg single super phosphate and 1.0 kg muriate of potash per tree (apply preferably in two split doses one during the end of May-June and remaining half dose in September in tree type species).	Srivastava and Singh (2004) Srivastava and Singh (2007)
Aonla	50 kg well rotten FYM, 1.50 kg Urea, 2.00 kg single super phosphate and 1.0 kg muriate of potash per tree (apply after one month of rejuvenation preferably in two split doses, one during the end of February-March and remaining half dose in August, while another recommendation manuring may be done in July-August and second in December January)	Singh and Mishra (2007) Maity and Das (2004)
Cashew	50 kg well rotten FYM, 750 g N, 325 g P_2O_5 and 750 g K_2O per tree.	Janik and Paull (2008) Veeraraghavan *et al*. (1985)
Pomegranate	20 kg FYM, 250 g N, 325 g P_2O_5 and 250 g K_2O per tree each tree every year at the onset of monsoon.	Hiwale (2009) Gaur *et al.* (1971)

analysis, micronutrients deficiencies can be corrected by soils application of micronutrients (single element) containing fertilizer. Further soil application of zinc and boron is found much efficient in correcting deficiencies and leaves residual effects for succeeding production, while foliar sprays also proved efficient and economic too in emergent conditions. Therefore even in cases of acute single element deficiency application of specific micronutrient formulation may be beneficial in yield and quality of fruit production.

Thinning and canopy development

After pruning to improve productivity of old and unproductive perennial fruit orchards, rebuilding canopy is very vital (Srivastava 2007). The reiterative pruning for top off, brings invigorating effect and subsequent emergence of numerous shoots on the entire body of trunk requires proper thinning. Thinning of shoots and canopy development should be skillfully done by just removing the extra, overlapping, down growing, week shoots after a certain gap period (of at least six months for mango, litchi, aonla and cashew, while one month for guava, citrus and pomegranate), then the operation is repeated 3-4 times with the same time interval but just before the onset of rainy and winter season. The enormous number of branches come out and cover the entire body of the pruned plant. In this attempt it is required to thin out the excessive branches as well and keeping only 3-4 numbers nearly top-side portion on each pruned limbs of the trunk projecting towards all the directions and further training for acquiring desired shape. The thinning operation is required to be done carefully with the ultimate aim of developing solid, semi-circular or open umbrella type canopy. After this operation, there is generally a rapid period of shoot elongation and leaf expansion followed by a period of leaf maturation before the next period of shoot growth. The duration and interval of growth are strongly related to temperature and irradiation (Batten and Lavah 1994, Olesan *et al*. 2002). The air and light must have access to all the parts of the tree. In case of guava and citrus, studies indicate that the overlapping of fruit growth developed as a result of pruning, makes it possible to harvest 3 crops in a year (particularly in guava), with proper management of new shoots and flower initiation. The young shoots can be forced again to flower and fruit in the next season. The success of this technique depends upon the proper management of shoots through precise and timely pruning.

As reported by many workers, a sort of tree training is required for canopy rebuilding to make a semicircular/open umbrella shape canopy with enhanced surface bearing area (Kumar 2008). Strategic thinning and pruning helps to control tree size but it must be carried out at the right time to ensure shoot maturity, panicle emergence, flowering and cropping (Olesan *et al*. 2002, Kalloo *et al*. 2005, Kumar 2013). Pruning and training of the shoots of the canopy outer surface is very important for shoot maturity and phase change from vegetative to reproductive stage in the third year after the reiterative pruning operation. Many subtropical and tropical evergreen fruit trees (e.g. litchi and mango) grow by recurrent flushes (Olesen *et al*. 2002) can flower profusely but set relatively few fruit (McConchie and Batten 1991, Anila and Radha 2003) and are large trees with a high

Table 3 The recommended time gap to thin sprouts on the pruned scaffold branches for canopy development in rejuvenated trees counted from the date of pruning

Fruit crop	Recommended time gap for thinning	Remark	References
Mango	06 months		Kalloo *et al*. (2005)
Litchi	06 months		Kumar (2008)
Guava	01 month	Concurrent for new fruiting shoots	Kalloo *et al*. (2005)
Citrus	01 month	Concurrent for new fruiting shoots	Kalloo *et al*. (2005)
Pomegranate	01 month	Concurrent for new fruiting shoots	Hiwale (2009)
Aonla	03 months		Kalloo *et al*. (2005); Singh and Mishra (2007)
Cashew	03 months		Kalloo *et al*. (2005)

leaf area to canopy surface area ratio (Menzel *et al*. 2000). There have been relatively few studies on the response of tropical and subtropical evergreen fruit trees to pruning, in contrast to the abundance of studies for deciduous species (Mika 1986, Singh 2010, Srivastava 2007). Since cashew produces fruits only in the periphery of the canopy, the massive supporting branches beneath is of little value as far as increasing productivity is concerned, hence pruning technology coupled with thinning and training attempts are made to develop enhanced canopy surface area per unit land area (Nalini *et al.* 1999, Iyer and Kurian 2006).

Canopy management and reproductive manipulation vary according to climatic conditions, cultivar and available technology (Davenport 1993). Pruning being a proven technology is an integral part of canopy architecture management. It requires effective foliar applications, fertigation, integrated plant nutrient management and pest management to achieve higher yield and quality in various perennial fruit crops (Mishra and Kaushal 2013). The litchi plant has the tendency to bear fruits on outer surface of the canopy receiving maximum solar light and the economical yield is confined to 2/3rd of the lower middle canopy (Singh *et al*. 2011). Studies conducted by Nath *et al.* (2008) clearly indicated that normal fruiting in litchi with quality fruits can be obtained by opening of the centre portion of the plant and facilitating more light penetration inside the tree canopy which indicates that once litchi trees begin to bear, the fruit production become simply a function of the effective canopy surface area of outer and inner side of the crown structure. There is a linear relationship between total leaf area and canopy surface area passing through the origin (Menzel and Waite 2005). Fruit development in litchi has been found sensitive to light conditions (Yuan and Huang 1988). Therefore, being a very crucial component of productivity vis-à-vis the all management practices, crown structure and canopy size in litchi is of paramount significance. The nutrient application is also very vital in case of litchi for canopy development leading to the sustainable production and productivity. Keeping this in view, many attempts have been made to see the combined effect of pruning practices and nutrient application to create a congenial / healthy canopy environment for quality litchi production which resulted significant outcome (Kalloo *et al*. 2005, Lal *et al*. 2000, Kumar 2008, Singh and Mishra 2007, Singh *et al*. 2011). There is occurrence of dominance of vegetative phase over reproductive phase in these perennial evergreen fruit trees. Evergreen trees bound to grow continuously due to abundant sunlight throughout the year. Dominant vegetative phase can affect the reproductive phase especially under tropical regions, if not regulated properly (Srivastava 2007).

Canopy management has direct correlation with dry matter production, flower bud initiation and fruit quality. The canopy physically supports the fruit load and markedly influences the yield and quality of fruits. Innovations in the production system have witnessed significant variations in tree canopy forms. Huang *et al.* (1992) studied the relative productivity of old orchard (in Fujian) with different sized canopies and showed that yield was strongly correlated with the diameter of the tree crown and concluded that best yields were associated with trees that had two to four main branches and a trunk girth of at least 1.0m. Canopy rebuilding by proper and corrective cutting, pruning and training system optimize the production of assimilation and its conversion into economic yield. Proper understanding of canopy development and management is of paramount importance to achieve optimum efficiency of orchard after rejuvenating the declining unproductive trees. Therefore in order to optimize the utilization of light for increased yield of quality fruits, canopy management deserves greater attention by exploiting the various available techniques.

Training systems have drawn considerable attention over the past 40 years since they combine different purposes. Further, improvement and precision in practices under this system have occurred over time. The main purposes, especially in intensive orchards, are the following: (1) a rapid achievement of a developed canopy structure to reach orchard maturity and maximum fruit production within a few years; (2) an optimal capture of light to optimize carbon gain and fruit yield per hectare; (3) a fair distribution of intercepted light within the aerial system of the tree to minimize the spatial heterogeneity of local vegetative growth and fruit quality; and (4) management of tree shape and fruit load with minimal pruning, to take advantage of the natural trends of the cultivar and reduce the cost involved during this manual operation.

This last point is of major importance since training systems initially conceived to improve light interception by the tree may stimulate growth of vigorous water-shoots, i.e. reiterated complexes, on the upper side of scaffold branches. If not removed, these shoots acting mainly as assimilate sinks may also thwart the benefits of high illumination within the tree by decreasing light interception by fruiting shoots. On the other hand, an unpruned tree, in which vigour is well-distributed to fruiting shoots, quickly begins production but, in most cases, results in an overcrowded canopy after some years and eventually fruit size and quality are reduced. Training methods have then been particularly developed at the tree scale to manipulate both the vegetative and the fruiting components. Pruning vegetative shoots at different positions in the tree or/and at different phenological stages is used both for the building of the tree structure, according to a specific tree shape, and to optimize light distribution within the canopy as in cherry (Flore *et al.* 1996) or in apple (Barritt 1992). It is preferred to heading back for the control of tree growth and shape by proper training procedures. Citrus trees are self shape forming. Growers should select the correct time of their pruning because citrus trees are evergreens, they donot have a period of true dormancy but less active period is just after the fruit harvest. Pruning to create a scaffolding network helps assure maximum fruit yield. Pruning for removal of water sprouts from young and old tree is important (Srivastava 2007). In case of cashew, the new flushes arise from the dormant buds on the trunk. These new sprouts form the canopy within a period of at least 10-11 months depending on the variety and soil type (Kalloo *et al.* 2005). From the research it has been ascertained that canopy management through advance training systems in fruit plants has been found more effective. The canopy model also influence the water use efficiency. The objective of canopy management lies in the fact, as to how best we manipulate the tree vigour and use of the maximum available light and temperature to increase productivity and quality and minimize the adverse effect of the weather. The approach requires a high degree of horticultural skill to manage the canopy of the tree.

Irrigation

Irrigation timings in perennial fruit crops (mango, litchi) is very important for its effective utilization and its should be applied before attaining the stress. The physical factors in the method of irrigation or its system selection include soils, climate, topography, water quality and availability, water table depth, orchard size, system performance, maintenance and repair etc., while irrigation practices are influenced by available technology and cost, soil type and depth, rainfall amount and distribution, fertilizer practices and production objectives (Crane *et al.* 2009, Menzel and Waite 2005, Singh *et al*. 2012). Rejuvenated trees require immediate irrigation if any dry spell occurs just after the reiterative pruning operation is over, as to avoid drying out of the trees. Irrigation is must after the manure and fertilizer application. Preliminary research suggest that irrigation at 7-day intervals during the period of fruit development in mango increases fruit size, earliness and yield (Larson *et al.* 1989). In principle, optimum soil moisture should be maintained after the emergence of new shoots on pruned trees. Almost in all perennial fruit crops except aonla, depending upon the temperature, soil type and soil moisture status, pruned trees must be irrigated at regular interval of 08-10 days during hot summer season and 15-16 days during winter season helps the fast vegetative growth and good canopy development. Irrigation applied to the intercrops also gives the added advantage to the rejuvenated trees. In case of aonla and pomegranate light irrigation just after manure and fertilizer application, as this fruit crop is highly susceptible to waterlogging condition, while irrigation is required in summer approximately at fortnightly intervals, and in citrus no irrigation / water logging condition near trunk is suggested (Maity and Das 2004). Among the various irrigation systems, basin system is well suited but drip irrigation has also given better response.

Irrigation to maintain the enough moisture content for two years is very crucial. The irrigation schedule should be started just after one month of pruning operation along with nutrient application. During the third year, application of water through irrigation is restricted/withheld from November and onwards till February end of the next year (mainly during winter months). Soil water content influences the frequency of flowering, the number, length and panicles, yield and quality of mango fruits (Chang and Lu 1995). Till date, irrigation practices are based on observation and experience particularly in case of citrus plantations (Crane *et al*. 2009).

Mulching

Mulching is a practice of covering surface of the soil with organic and polythene to check evaporative loss, modify soil thermal regime, check weed population and their growth and improve the availability of water and nutrients to the plants. It is advisable to do mulching in the basins around the pruned tree trunk for conserving soil moisture in the basins during April to June and November to January. Various mulches in rejuvenated plants in the orchards have been found better with paddy straw, sugarcane trash, dried grasses, mango/litchi/banana dried leaves etc applied thick enough (10-15cm) to prevent weed growth simultaneously not stopping rain water penetration to the root area or rhizosphere. Black polythene (200/400 gauge) sheet might also be used for mulching in most befitting manner. As of late, plastic films have come into use for purpose of mulching due to its inherent advantage of efficient moisture conservation, weed control and maintaining of soil temperature. Besides, the volume of plastic material to be used per unit area is much less or than that of traditional mulch material and, hence, plastic films are easy to handle, transport and lay in the field and it has been successfully experimented in rejuvenated plots of many perennial tropical and subtropical fruit crops (Singh and Mishra 2007, Singh 2005, Janik and Paull 2008, Singh 2010). Mulching at the base immediately surrounding the main trunk of the pruned trees during the months of April-May and September-October have been found beneficial in conserving soil moisture beneath the tree canopy, reducing the frequency of irrigation and enhancing growth rate of vegetative flush. In case citrus organic mulches in sweet orange, dry leaf mulching in Coorg mandarin and sod mulch in mosambi orchard have been found influencing soil tilth and enhancing quality fruit yield (Maity and Das 2004).

Intercropping

During initial 2-3 years after rejuvenation, there is excellent opportunity for economic utilization of inter-space in the rejuvenated orchards. The open interspaces between the plants/trees is created in the orchard like newly planted orchard. Intercrops during summer season and during *rabi* season have been found most suitable. Apart from the significant income obtained by the intercrops in rejuvenated orchards, the added advantages like improvement in the soil tilth (health), almost complete check over weed population/growth as well as less incidence of pests – diseases are also received. In general, if rejuvenated plants / trees attain full growth again and start giving commercial viable yield, intercropping may be discontinued. Even though, some of the important principles should be observed particularly for growing of intercrops in the open space created in fruit orchards after reiterative pruning, are as 1. Inter-crops should not occupy or disturb/interfere the area where the roots of the fruit trees are concentrated, 2. Soil fertility should be maintained or improved when intercrops are grown, 3. Water requirements of the intercrops should not clash with those of the main fruit trees (The intercrop may require an irrigation at a time when it would be detrimental to the rejuvenated trees), 4. Intercrops should be selected with reference to their effect on soil moisture, 5. Grain crops should be avoided as they remove excessive moisture to the detriment of fruit trees and the intercrops selected should not exhaust the soil water and nutrients and should not demand more water than is allowed for fruit trees. The most important aspect is that intercropping should be started at least after some gap period of one (guava, citrus, pomegranate) to three months (mango, litchi, cashew), when reiterative pruning operation is over. Intercropping with suitable crop and crops sequences have been found very encouraging and beneficial. In case of mango, the intercrops like red gram, moong, blackgram and other leguminous pulse crops, while in *rabi* season mustard, potato, pea, cowpea etc., have been found beneficial (Kalloo *et al*. 2005, Alila 2012). The crop sequence for two years tried in the experimental plot (rejuvenated) of litchi starting from December as Mustard >Elephant foot yam> Mustard >Moong >Maize and followed for next term of two years have been found very remunerative and profitable (Kumar 2008). A great deal of open space is created after heading back pruning in guava can be preferably be intercropped with crops such sweet potato, Bengal gram, blackgram, chilli and many other vegetables (Maity and Das 2004). Vegetables like okra, cauliflower, coriander, elephant foot yam and turmeric, flowers like gladiolus and marigold have been found well suited for intercropping in rejuvenated aonla orchards (Singh and Mishra 2007). Intercropping received little attention in cashew. Depending upon soil and climatic conditions and local situations, annual tubers and spices like tapioca, turmeric, ginger etc, can be grown as intercrops. When plants become sufficiently tall, pepper can be taken as mixed crop (Pradeepkumar *et al.* 2008).

Plant protection

Successful pest management programmes have been developed in different high value fruit crops. The principles of fruit pest control have led to the evaluation of damage to express population trend and extent of damage. In principle, disease management is to reduce the inoculums density in nature and to restrict the spread of inoculums for infestation, which has been attributed to cultural method, regulatory method, chemotherapy and bio-pesticide control. Controlling the insect-pests, the restoration of vigour and keeping the tree more healthy help in enhanced and sustained quality fruit production (Kalloo *et al*. 2005, Kumar 2008, Singh and Mishra 2007, Singh 2010)

Intensive care to control the infestation of important pests like stem borer, bark eating caterpillar, mite, leaf roller and leaf cutting weevil etc. and the diseases like microbial infestations are required (Dodd *et al*. 1997, Masarrat *et al*. 2000, Ploetz and Prakash 1997, Ploetz 2003). Control methods may be biological, mechanical or chemical or the combination depending upon the growers preference and specific circumstances. Leaf roller, leaf miner and leaf cutting weevil starts damaging right from the beginning of the rejuvenated trees, hence care is required from that moment itself, as these are attracted to new vegetative growths, i.e. leaf flushes from June to October and the spray schedule of Monocrotophos @ 2ml/l or Cypermethrin @ 1ml/l 2-3 times during new flush emergence, i.e. during the month of August-September can save the damage from these insects. The mite can be controlled by applying miticide like dicofol/omite @ 3ml/l atleast 2 to 3 times during the months of September-October and February-March or at every emergence of new flushes. The serious damage is being observed by the attack of bark eating caterpillar, which tunnel into the branches and trunk causing decline and even death in many fruit crops (Masarrat *et al*. 2000) can be controlled by the spray of insecticide at initial stage but tunneling stage, it is required to clean the fresh frass and webbing, finding the hole, notching the hole with hard pointed spoke/poker, plugging with DDVP/Nuvan (0.1%)/ kerosene oil soaked cotton and ultimately sealing the hole with mud. Spraying of copper fungicide during the month of October and March takes care of most leaf spot and other algal/fungal diseases. Brushing/pasting of Bordeaux paste to the main trunks/branches up to one meter from the bottom keep the plant clean and saves the crop from many pests infestation. In case of cashew the chiseled surface needs to be treated using either carbaryl suspension (1.0%) or chloropyriphos solution (0.2%) to check repeated infestation of treated top worked trees. Care should be taken to prevent the cashew stem and root borer (*Plocaederus ferrugineus*) damage to pruned trees as they are most vulnerable to this insect (Kalloo *et al*. 2005).

Fruit yield and quality

Fruit yield and physicochemical characters of mature fruits were found to be better in fruits obtained from rejuvenated trees came into bearing. Maturity period is found to be slightly delayed in rejuvenated plants. Fruit yield in the 2nd year in case of guava, citrus and aonla, while 3rd year in the rejuvenated trees of mango, litchi and cashew obtained with enhanced quality production and the categorization of fruit under different quality class revealed high percentage under extra class and class I as compared to un-pruned trees. The quantum of fruit yield with enhanced quality increased significantly every year onwards after the start of bearing in rejuvenated trees.

In case of mango, fruit production starts from the third year and the productivity increases up to about four times after proper canopy development of about 7-8 year of the operation. In this fashion, productivity is restored and with progressive increase in fruit yield (Fig 1) making the orchard productive and remunerative (Kalloo *et al*. 2005, Lal *et al*. 2000, 2001, Lal and Mishra 2007, 2008, Reddy and Kurian 2011, Kumar and Kavino 2012, Mishra 2013). An enhancement of about 22.35 per cent to 45.65 per cent in fruit yield (Fig 2) and that too of superior quality in different cases have been recorded from the rejuvenated trees (compared to un-pruned ones) in litchi (Kumar 2008) and that of guava cv. Allahabad Safeda and Sardar (Fig 3) after the first year of pruning (Nimbalkar *et al*. 2010, Singh 2010, Baba *et al*. 2011, Singh *et al*. 2012, Mishra 2013). Pruning schedule for rejuvenation in different citrus species played a key role in improving fruit yield considerably (Ansari *et al*. 2011). In case of aonla, all the old senile trees responded well to rejuvenation and the technology helped in securing quality yields in the range of 35 to 40 kg/tree in demonstration plots after second year of rejuvenation (Singh and Mishra 2007). In case of cashew, yield levels during the first season after pruning are slightly lower but the yield from second year onwards increases at significant level. The result of rejuvenation in pomegranate showed that the fruit yield per plant found surpassing control even in second year itself and the increase was in progressive manner (Hiwale 2009).

Economics

The various operations in rejuvenating old senile trees is not quickly in a single operation, but usually done effectively in several operations over a period of 2-3 years and later maintenance and management of the tree continue. In case of litchi, the cost of reiterative pruning and subsequent operations in one hectare of old senile orchard have been calculated over the five years of operation. It has been found that the old senile orchard can be rejuvenated back just like young bearing orchard within a time gap of 2-3 years without any income loss in-between by adopting and following the technology (Kumar 2013). Economics of rejuvenation of old senile orchard in some of the perennial fruit crops have been clearly worked out in -5 consecutive years with the set particulars of operations like sale of fruit before rejuvenation, cost of reiterative pruning, sale of woods, cost of intercropping, and profits from intercrops. Sale of fruits from rejuvenated trees and finally gross income have been found very encouraging with high benefit cost ratio, with other added advantages. The experimental attempts of pruning proved to be successful in rejuvenating old guava orchards and the economics also suggested gain in returns compared to senile orchards (Singh *et al.* 2012). For example, economics of rejuvenation of old senile litchi orchard is given in Table 4 and 5.

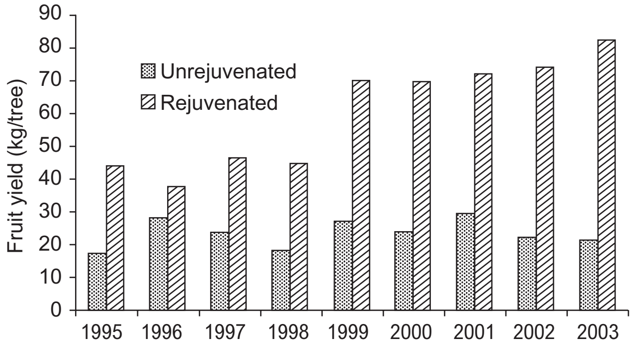

Fig 1 Fruit yield pattern of rejuvenated Dasheri trees
Source : Kalloo *et al.* (2005)

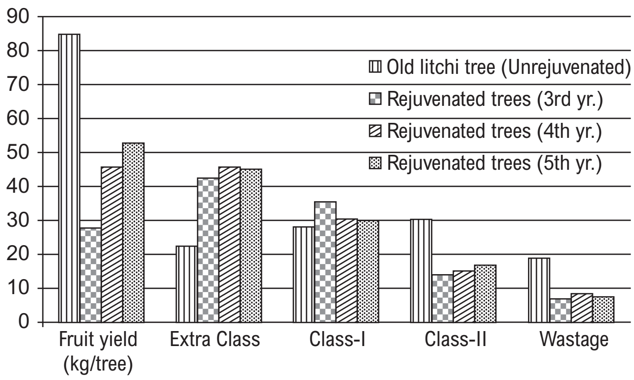

Fig 2 Fruit yield pattern of litchi cv. Shahi and its categorization of fruits under different quality class (%) in different rejuvenation technology treatments
Source : Kumar (2008)

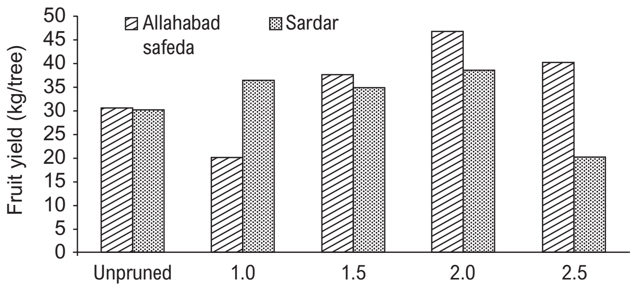

Fig 3 Response of pruning on fruit yield of guava cultivars
Source: Singh and Singh (2007)

Table 4 Expenditure incurred in rejuvenating senile litchi orchard (1 ha)

Operation	Expenditure (₹)
Charges for reiterative pruning in phase wise manner. (80 mandays @ 175.00/head and 45 skilled mandays @ 196.00/head)	24 500.00
Cost of cleaning, ploughing and levelling of the orchard floor	3 500.00
Cost of manures and fertilizers	5 600.00
Cost of application of manures and fertilizer through ring method	2 500.00
Cost of irrigation (3 irrigations each of 6 hours @ 250/hr	4 500.00
Cost of chemical pasting on trunk and spraying (including mandays)	3 750.00
Cost of thinning shoots on trunk and other operations (each year)	12 250.00
Miscellaneous operation (hiring different types of pruning saw, blade, rope, bamboo pieces, tractor trolley and rickshaw etc.)	2 400.00
Total	59 000.00

Table 5 Economics of rejuvenation of old senile litchi orchard (one hectare) during 2008-12

Items/particulars of operations	Year wise proceeds of operations and outcome (₹)				
	2008	2009	2010	2011	2012
Sale of fruits before rejuvenation	15 500.00				
Cost of rejuvenation and cleaning of orchard floor	(-) 59 000.00				
Sale of woods	375 000.00				
Cost of intercropping	(-)8 500.00	(-)45 500.00	(-)23 500.00	(-)21 000.00	(-)17 000.00
Profit from intercrops	21 200.00	88 000.00	64 500.00	56 000.00	47 000.00
Sale of fruits from rejuvenated trees (excluding cost of harvesting)				56 500.00	85 500.00
Gross income	383 700.00	42 500.00	41 000.00	91 500.00	115 500.00

Source: Kumar (2013)

Constraints in adoption of the technology

The reports of survey and investigations made by the institutes/SAUs and Government departments have clearly indicated that there exists a wide gap between technology availability and technology adoption. High commercial yield with quality production depends on high level of technological convergence and adoption (Kumar 2012). Depending on the need and profitability, farmers/orchardists generally integrate new technologies with their ongoing management and cultural practices. There is not any hitch in adoption of safe, secure, non-invasive, short term, efficient and profitable technologies and these type of efficient and economic technologies are giving good impact within short gap only. It is difficult to achieve the desired outcome through the use of single technology centric approach or the use of component technology in isolation. The rejuvenation technology is having sound blending of the series of measures and practices developed for integration of reiterative pruning, followed by nutritional, irrigation, mulching, thinning of shoots and training for canopy rebuilding in desired shape, plant protection along with intercropping in the open space created after pruning for a period of three years without any economic and existing plantation loss. The rejuvenation technology is a medium term strategic programme for old senile, woody perennial fruit crops, with sound blending of series of practices developed for making complete transformation from their unproductive old senile phase to young productive economical phase in sustainable manner (Kumar 2008, 2013, Lal *et al.* 2000). The technology envisages to exploit potential of the productive (commercial) phase of the perennial fruit crops to generate maximum output, profit, quality along with resource use efficiency with maximum environmental protection. Minimizing yield gaps, increasing profits and quality fruit production are need of the hour to ensure food and environmental security.

In-spite of the vital, viable and economically feasible technology, the invasive nature of operation of the technology posing major hindrances in the speedy adoption of the rejuvenation technology. There is risk involved during the operation of heavy pruning for topping off big/tall trees. The only hitch at the initial stage is lack of trained people and required proper tools/equipments with operator to complete the operation successfully. The efforts have been made to organize several onsite interactions and practical demonstration trainings by the state departments, SAUs and research institutes, which has successfully created enough awareness and tendency to go for this technology for their old senile unproductive fruit orchards. The only hitch in adoption is that lack of team of skilled persons ready to be available on demand to translate this invasive technology in efficient and effective manner. The lack of skilled work force and poor technology transfer mechanism in this regard invites the urgent need for strong technology implementation or transfer system (Kumar 2013). The efforts are required to constitute team of personnel (trained and expert hands) for skillful and successful operation of the technology in coordinated way on demand and payment basis in an economically viable manner. The central and state level institutions and organizations are now involved for monitoring the technology by providing training with financial assistance as well as subsidy plan (National Horticulture Board, National/State Horticulture Mission, ICAR Institutes, State Agricultural Universities and their Krishi Vigyan Kendras and even some NGOs). The hindrances in significant adoption is lack of implementing team equipped with required machineries (Singh *et al.* 2011, Kumar 2012). The Hi-tech tools and machines required for this technology with expert operators should be provided with the team for effective and efficient technology implementation and operation with beneficiary's utmost satisfaction and will for fast pace of technological adoption (Kumar 2012). This type of strategic plan and effort will take care of psychological fear of the beneficiaries in convincing way that their trees will not die due to severe pruning of thick (main) branches of trees (Bongers and Winter 1992, Karasek and Theorell 1990).

Impact

Hence, with the scientific skill and approach, complete transformation have been brought about by resurrecting the declining status of perennial fruit crop orchards to behave and bear like young commercial orchard with sustained performance. This transformation gave great impetus and boost to the enhanced quality fruit production having high economic returns. This wonder became possible only with the adoption of scientific approach. This is of great importance for the aged and declining perennial fruit trees, as it also addresses conservation and sustainability. It has indeed became an example, when the utmost transformation tried through rejuvenation pruning of old senile, unproductive orchard, without destroying the actual identity and fortunately, only in time gap of two to three years it started behaving like young commercial orchard with sustained economic returns. The resultant increase of production and productivity of quality fruit yield in sustained manner paved the way for wider adoption of the technology developed scientifically by various National Research Institutes/State Agricultural Universities/Government Departments. Region-specific various on-site training programmes and demonstration trials have been conducted and still going on to increase the level of adoption by the actual beneficiaries (Kumar 2008, Singh *et al.* 2011). Realizing the need and importance of rejuvenation technology, the National Horticulture Mission (NHM) of different states have included the particular technology package in its action plan. The National Horticulture Board (NHB), Gurgaon, Haryana has funded projects and National Banking for Agriculture and Rural Development (NBARD) has already initiated programmes with enough subsidy to take technology to farmers field. The mass communication media particularly local newspaper published and flashed and even regional TV channels have made many telecasts this successful technology transfer with various success stories. Overall, the success of rejuvenation technology in transforming the old senile orchards into revitalized commercially bearing orchards has now become an important government intervention to improve productivity of fruit in the country.

CONCLUSION

Rejuvenating old, senile and unproductive perennial fruit orchards is the only viable option left to save the orchard by restoring the youthful vigour and enhanced quantum of quality production in sustained manner, rather than to go for a long term venture of new plantation and wait till attaining of their commercial bearing stage. It is in this context, critical assessment of the available information, study and recommendations assume special significance to the fruit growers. Rejuvenation techniques confers multiple benefits such as early transformation and quality production from old unproductive, senile trees, due to better sunlight interception, utilization and efficient use of open space and inputs including labour. It has also been suggested that steps like nutritional, irrigation and canopy management along with mulching, intercropping and crop protection practices, can help to improve soil health and orchard productivity. Besides, enhanced productivity, profitability and sustainability, this technique, also integrates well with the ecology of the area. Still, there are constraints in widespread adoption of the technology. There is need to encourage and motivate growers for adoption of this technology.

In spite of distinct advantages in terms of productivity, profitability and sustainability, the rejuvenation technique is not gaining desired popularity amongst the farmers due to its medium term strategy with series of procedures, lack of proper knowledge and enough courage. The cost and quality of advantages of this technique has not been properly propagated and disseminated amongst the farmers by the scientist fraternity. There is limited or non-availability of task force of skilled gang who have mastered in this technique, from where provision of one stop solution to the needy farmers by *in situ* demonstration of the rejuvenation technique and even to impart training to the farmers for developing local skill set for future or other declining orchards. Law of Inertia, which inhibits farmers from adopting any process of change from the prevailing practices, due to fear of failure. Predictably, its invasive nature, creating abundance of suspicious interpretations of its impact should be addressed properly with definite scientific and planned policy support. However, proper information and data base has not been created about the death percentage of trees subjected to such a severe salvaging /resuscitating treatment going for rejuvenation, needs priority. The understanding of the physiology and mechanism of rejuvenation process requires scientific studies and pursuance for proper documentation and final recommendation. As this technology is a visionary approach, requires convincing attitude of the grower for adoption with scientific knowledge base and success story. The future research should focus on developing techniques that can investigate multiple constraints and the relationship between proximate and ultimate controls on source sink allocation. Ultimately, this is a non-invasive solution which in turn work out more economically and environmentally friendly in sustainable manner.

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