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Growing seed

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POTENTIAL AND TOLERANT GENOTYPES: SOURCES FOR IMPROVING PRODUCTIVITY IN LITCHI

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Litchi (*Litchi chinensis* Sonn.) a member of the Sapindaceae family (Lal *et al*., 2017a) is evergreen an important fruit crop associated with root mycorrhizal association (Lal and Nath, 2020a). It is a good source of Vitamin-C (Lal *et al*., 2018a) and phenolics (Lal *et al*., 2018b). Litchi is highly specific to its climatic requirements particularly low temperature for bumper flowering and fruiting, and this is the reason of its restricted cultivation in few countries and limited states in India. Now, it has been reported that litchi is performing well in Southern parts of India, where litchi available during December (Nath *et al*., 2015). A single inflorescence carries hundreds to thousand flowers (Lal, 2018) and phenol content in plants boost flowering in litchi (Lal *et al*., 2019e). Pollen grains of M2 flowers are more viable, and fruit set depends on the sources of pollen grains (Lal *et al*., 2019a and 2019b). However, fluctuation in temperature significantly affects fruit retention (Lal *et al*., 2017b). Litchi suffers from many problems viz., fruit drop (Lal *et al*., 2017c and d), seed and fruit borer (Lal *et al*., 2019c), sunburn and fruit cracking (Lal *et al*., 2018c), pericarp browning (Purbey*et al*., 2019) which are responsible for low productivity of litchi. Aberrant weather also influences the productivity and quality of litchi (Lal and Nath, 2020b). There is a need to improve productivity and also widening the genetic base. Concerted research efforts are required to develop suitable cultivars for various climatic conditions. It is also essential to develop promising lines/clones/ hybrids, which have larger fruit size, small/chicken-tongued seeds, higher pulp content, tolerance to sunburn and fruit cracking and having varied maturity groups to avoid the market gluts. Litchi has a very narrow genetic base, and it has to be widened through the selection of genotypes from the existing population. To keep the above points, ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar has started extensive works on improvement in litchi and identified promising genetic stock/genotypes and has released three cultivars of litchi (GandakiSampada, GandakiLalima and GandakiYogita). During selection, the focus has been

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given on the most important traits which are responsible for influencing the productivity and quality of fruits. For genetic improvement in litchi, emphasis should be given on length and girth of panicle (Lal *et al*., 2020c), large fruit (Singh and Nath, 2012), number of fruits per panicle (Nagraj *et al*., 2019), higher pulp content, precocious in flowering and regular bearer(Lal *et al*., 2019c), sunburn (Lal *et al*., 2014, Lal and Sahu, 2017; Lal *et al*., 2018c), seed and fruit borer (Lal *et al*., 2017d).

Varieties developed at ICAR-NRC on Litchi

Gandaki Sampada

- Fruits are large in size (36.85 g), conical in shape, vermilion to carmine colour and crack resistant.
- Fruit consist of creamy-white, soft and juicy pulp with 80 to 85 % pulp recovery.
- It is attractive to consumers.
- It has a very high percentage of shrivelled and small-seeded fruits.
- Suitable for the industry due to high pulp content.
- Good yield potential (120-140 kg/tree).
- Panicle girth is high.
- Tolerant to sunburn and fruit cracking.
- A late maturing strain ripens during mid-June.

Gandaki Lalima

- A highly nutrient efficient strain possessing dark green leaves and the capability to withstand climatic aberrations.
- Fruits are conical, bright marigold-orange red in colour.
- Fruit contain creamy white pulp and weighs between 28-32 g.
- Heavy yielder with average yield of 130-140 kg/tree.
- Tolerant to sunburn and fruit cracking.
- It does not show hunger symptoms on a leaf near fruit bunch.
- Late maturing cultivar ripens in the second week of June.

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- It is attractive to consumers.
- Good compatible with many cultivars in hybridization.
- Good fruit retention capacity as female parent.

Gandaki Yogita

- It is slow-growing and dwarf plant, tolerant to hot waves and fluctuations in soil moisture.
- The fruit is free from fruit borer, sunburn and fruit cracking.
- Fruits are round in shape; tyrant rose in colour with creamy-white and juicy pulp.
- Good yield potential (70-80 kg/tree).
- It can be recommended for high-density planting as a speciality variety.
- Very late maturity (5^{th} – 15^{th} June).

Genetic stocks identified at ICAR-NRC on Litchi

NRCL-29

- It is drooping and dwarf growth habit.
- It is most precocious in flowering (3^{rd} year of planting).
- It is early ripening genotype.
- It has compact flowering panicle.
- It can be grown under HDP.
- It is easy in peeling.
- The high content of anthocyanin (94.62 mg/100 g)

NRCL-59

- Flowering and fruiting started during 5^{th} year onward.
- Leaves are similar to Shahi, but fruits are similar to China.
- It is a deep pink colour.
- It is attractive to consumers.

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- It is tolerant of sunburn (6.23) and fruit cracking.
- It is late maturing genotype having fruit weight 22.56 g,
- TSS: 21.59 Brix, and high anthocyanin content in peel (96.56mg/100g).

NRCL-83

- It is slow-growing and dwarf.
- It can be used in HDP.
- Leaves are small, which curved upward from the midrib.
- Average fruit weight is 17.31 g, and the yield is 12.43 kg/plants at 7 years.
- Pulp content is 72.48 %, and seed is small, with an account of 8.73%.
- It is tolerant of sunburn and fruit cracking (3.54%).

NRCL-85

- It is fast growing with very vigorous growth.
- Trunk surface is very rough.
- High nutrient efficient and does not show hunger symptoms in leaf near fruit bunch.
- It can be grown in marginal land.
- Heavy fruit-bearing intensity (30-40 fruits/cluster).
- Panicle girth is high.
- Tolerant to sunburn and fruit cracking.
- The pulp is dull white, acidic in taste, juicy and is highly suitable for processing industries.

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NRCL-86

- Plant height (5 m) during 12 years old.
- It can be grown under medium density.
- It is regular and heavy bearer (heavy bunch).
- Fruit weight (24.25 g).
- Panicle girth is high.
- High content of pulp (72 %).
- Suitable for the processing industry.
- Chicken tongue seed (6.9%).
- Tolerant to sunburn and fruit cracking.

NRCL-87

- It is a regular and heavy bearer.
- High fruit weight (29.69 g).
- Panicle girth is high.
- High pulp content (>70 %).
- Tolerant to sun burning and cracking.
- It can be used as a female parent in hybridization.

NRCL-88

- It is slow-growing, and the plant is dwarf having spreading branches.
- It can be grown under HDP.
- Leaves are small, which curved upward from the midrib.
- Average fruit weight is 16.22 g, and the yield is 16.48 kg/plants.

- Pulp content is 76.38 %, and seed is small, with an account of 7.63%.
- No sunburn is found, and fruit cracking is 6.45%.

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NRCL-89

- It is a regular bearer.
- Leaves were small like Bedana which curved upward from the midrib and a fruit-like Shahi, but the shoulder is similar to Kasba. Fruit shape is oblong, and the colour is pinkish-red at maturity.
- The number of fruits per panicle is 15-18.
- The average fruit weight is 25.63 g, peel weight-3.73 and seed weight is 3.75g.
- The pulp content is more than 70%.
- It is late-ripening genotype which matures in mid-June.
- No sunburn and fruit cracking is observed.

Conclusion

The limited numbers of cultivars are available in Indian, which is mainly seedling origin and shows a narrow genetic base. The available cultivars are severely affected by fruit drop, sunburn and fruit cracking, seed and fruit borer and possessed low pulp content. There is a need to widen genetic diversity and to select superior genotypes over existing. The breeding efforts have been made by the group of scientist, and three promising cultivars and eight genetic stocks are identified which are precocious, tolerant to sunburn and fruit cracking, early and very late maturing, high pulp content and attractive to the consumers. These genotypes are free from sunburn and fruit cracking which would help to enhance the productivity of litchi.

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ROOTSTOCK AND SCION RELATIONSHIP IN FRUIT CROPS

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Fruit crops are mainly propagated by vegetative means (cutting, budding, grating, layering etc.). Rootstock and scion are used to in budding and grating process, and they express different effect on each other when stock and scion are compatible to form a good union. The resultant of the good union gives a complete single plant. Rootstocks are used to propagate scions of preferred cultivars, improve fruit tree tolerance to environmental stress, and to control tree size. Size-controlling rootstocks are economically important for high-density plantings that may produce larger fruit and more fruit per hectare. Rootstocks affect the tree size and vigour, fruit set, yield and quality of the scion. Rootstock also imparts winter hardiness and tolerance/resistance to biotic and abiotic stress to the scion. Similarly, scion has also effect on rootstock. Rootstock–scion interactions demonstrated that rootstock had more influence than scion on tree weight and growth rate.

Controlled multiplication of plants is known as plant propagation. Plant propagation can be broadly classified in two categories: sexual and asexual. In sexual propagation, the fusion of male and female gametes (Zygote) gives rise to a new plant, whereas in asexual propagation (vegetative propagation) the development of new plants takes place without the fusion of male and female gametes, the new plant develops from vegetative plant parts. Various techniques of asexual propagation are adopted in plant propagation, such as: cutting, budding, grafting, layering, etc. In cutting and layering, only one plant (mother plant) is used and root develop on it whereas in budding and grafting, two plants are used. One which form root is known as rootstock and other form shoot are known as scion. After joining of both parts, they acted as a single plant and performed all the physiological and biochemical activities.

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Plant propagation is both a science and an art. The science of plant propagation requires knowledge of plant physiology, nursery cultural practices, and characteristics of the particular plant that we want to grow. The art of plant propagation can learn only through experience in the field. It requires specific technical skills that must be acquired through innate ability or experience and often requires a certain feel. The relationships of the scion with rootstock are very important to develop a single plant and for further flowering and fruiting. Stock and scion must be compatible to form a good union. Rootstocks have many advantages in fruit culture because it is resistant to many biotic and abiotic stresses, and have many beneficial effects on fruit yield and quality. A few studies on rootstock have been conducted in many fruit crops. Some rootstocks are available in mango, citrus, grape, sapota, apple and pear but in many fruit crops rootstocks are still searching. In litchi, some dwarf genotypes viz., GandakiYogita, NRCL-29 (Lal et al., 2019), NRCL-83, NRCL-86and NRCL-88 have been identified which can be used as rootstock to assess the effect on different parameters. Many traits associated with dwarfness in fruit plants. High bark wood ratio, small leaf, small fruit, close arrangement of leaf and higher percentage of bark area are important traits for dwarfness in litchi. The growth patterns of budded or grafted plant are different from those that would have occurred if each part had been grown separately (Hartmann *et al*., 2002). Some of these effects are very important in horticulture. These altered characteristics may result from:

(a) Some of the specific character of scion or rootstock not found in each other, e.g. resistant to certain diseases, insects or nematodes

(b) Interactions of rootstock and scion alter size, growth, yield, fruit quality

(c) Incompatibility reactions.

The rootstocks provide growers with a useful tool to manipulate the vigour and performance of orchard trees. Tree size, precocity, fruit production and maturity influences by scion and rootstock are resultant of complex interrelationships between roots and canopy of the plant. The capability of plants to take up water and nutrients from soil is directly affected by rootstock. They are also able to significantly alter canopy structure and photosynthesis in leaves.

Characteristics of good rootstocks

Once orchard is developed by heavy investment to use rootstock, changing in plantation causes serious losses (Rajput and Haribabu, 1995). Rootstock affects plant growth

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and development, tree life, adverse conditions (soil, disease, and climate), fruit quality, yield and so on. Rootstock should possess the following characteristics:

- It should be compatible with scion cultivars and give maximum productive life to the trees.
- It should be well adapted to the agro-climatic conditions of the particular locality like frost, cold and heat.
- It should be resistant to diseases and pests prevalent in the concerned area.
- It should be tolerant to adverse soil conditions like salt, alkalinity, acidity and drought.
- It should have a positive effect on bearing and quality of scion variety.
- It should possess good germination capacity, a high degree of polyembryony, ability to attend graft-able size in a short period and free from excessive branching.

Stock -Scion Relationships

A rootstock is part of a plant, often an underground part, from which new above-ground growth can be produced, and the plant part grafted onto the rootstock is usually called the scion. All the desired quality should have in the scion. A grafted or budded plant makes a good union to establish a composite plant when stock and scion is fully compatible. Sometimesgrafted or budded plant can produce unusual growth patterns which may be different from what would have occurred if each component part of a graftage. This different aspect of rootstocks will influence the performance of a scion cultivar or vice versa is known as stock-scion relationship.

A. Effect of Stocks on Scion Cultivars

1. Tree Size and Vigour

The specific rootstock can be used to regulate the size of the tree. In apple, rootstocks can be classified as a dwarf (2 m height), semi-dwarf (3-4 m height), vigorous (5 m height)and very vigorous (>5 m height) rootstocks based on their effect on a scion cultivator. The influences of rootstock on the size and vigour of a tree has been demonstrated in apple and citrus. If a scion is grafted on dwarf rootstocks, the graft combination will be dwarf while the same cultivar grafted on vigorous rootstock would grow very vigorously. Dwarf rootstocks (e.g. M 9) impart dwarfness in the scion. On the other hand, if the same scion is grafted on vigorous rootstock (e.g. M2), the scion grows very vigorously. Red Delicious, Jonathan and Rymer, when grafted on M 13, attend maximum girth, highest plant height, larger spread and higher plant volume. Trifoliate orange is the most dwarfing rootstock for

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sweet oranges and grapefruit. Rootstockskalarady, Olourof mango has been found to impart dwarfness in the scion cultivators. *Psidiumpuminum* is dwarfing rootstock of guava. Guava rootstock 'PusaSrijan' imparts dwarfness incv. Allahabad Safeda.

2. Precocity in Flowering and Fruiting

The time taken from plating to fruiting (Precocity) is influenced by rootstocks. The dwarfing rootstocks exhibit precocity and vigorous rootstocks delay in fruiting. In general, vigorous rootstock results in vigorous growth of the scion, which in turn offers more effective sites for blossom bud differentiation. Mandarin, when grafted on Jambheri rootstocks are precious than those grafted on sweet orange or sour orange or acid lime rootstocks.

3. Fruit set and yield

The production of flower and fruits set is directly influenced by rootstock in Persimmon (*Diospyrous kaki* cv. Hachiya). It produces more number of flowers when grafted on *D. lotus* but only few mature into fruits. Fruit set is very high when *D. kaki* is used as the rootstock. The effect of rootstock on yield has been reported in many fruit crops. Acid limes budded on rough lemon found 70 % improvement in yield as compared to budded on troyer citrange, rangpur lime or its own rootstock. Sweet orange var. Sathugudi gave higher yield when budded on Kichili rootstock than others. Trees on dwarfing rootstock may yield higher per unit area because more plants can be accommodated per unit area. The yield an increase of certain varieties of American grapes (*Vitislabrusca*) has been noted when they are grafted on vigorous rootstock than they are raised on their own roots. Golden Delicious produced more fruit per tree than gold spur on all three stocks (M 7, MM 106 and M 26).

4. Fruit size and quality

Sathugudi sweet oranges produced large fruit when grafted on gajanimma rootstocks, but the quality was poor while on its own roots they produced fruits with high juice content and quality. Sweet orange exhibited the highest granulation when budded on rough lemon whereas granulation was very low on Cleopatra mandarin. Rootstock *Pyruscommunis* did not show any symptom of physiological disorder black end in Bartlett Pear but*Pyruspyrifolia*exhibited this disorder and affected fruit quality. Washington navel oranges are found largest on Troyer citrange and smallest on Cleopatra mandarin. In general, when sour orange, sweet orange and grapefruit rootstock are used for sweet orange, fruits are

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smooth, thin-skinned, juicy with excellent quality and store well without deterioration, while sweet orange fruits on rough lemon are usually thick-skinned, coarse and inferior in quality having low acid and low sugar.

5. Nutrient status of scion

Rootstocks also influence the nutrient status of the scion. Root stock *C. volkarimariana* exhibits all nutrients in leaves of Sathugudi orange as compare to own rootstock or Cleopatra mandarin stocks.

6. Winter hardiness

Rootstocks are found to impart winter hardiness to the susceptible scion variety. Rangpur lime tolerated winter injury when grapefruit budded on it than on rough lemon or sour orange. Sweet oranges and mandarins on trifoliate stocks were colder hardies. Trifoliate orange is the hardiest rootstock of citrus. Apple rootstock, M-9 and M16 are resistant to winter injury.

7. Disease resistance

Rootstocks also exhibit variability in their response to diseases and nematodes. Rough lemon is tolerant many diseases like *Tristeza,* xyloporosis and exocortisbut susceptible to gummosis and nematode. Similarly, Troyer citrange is tolerant of gummosis but susceptible to exocytic virus disease. Guava rootstock Chinese guava (*Psidiumfriedrichsthalianum*) exhibits resistant to wilt diseases and nematodes. Rootstock MM 106, MM104, MM 109 and MM 111 of apple are resistant to wooly aphids. Myrobalan B is used as a rootstock for plum is resistant to bacterial canker. Similarly, Mahaleb rootstock is reported to be useful for cherries because of its resistance to the buckskin virus.

8. Ability to resist soil adverse conditions

Trifoliate orange is poorly resisted excess salt whereas sweet oranges, sour orange, rangpur lime rootstocks moderately resist excess salts in the soil. Rootstocks exhibit different response to excess soil moisture or excess boron in the soil. Rootstock Myrobalan plum tolerates to excess moisture and boron than Marianna plum, peach, apricot or almond.

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B. Effect of scion on rootstock

1. Vigour of the rootstocks

Apple produced a very fibrous root system with few tap roots when budded on apple cv. 'Red Astrachan' and when Goldenburg budded on the seedlings, they produced few tap roots without a fibrous root system. If the scion is less vigorous than rootstock, the growth and stature of the tree is determined by the scion rather than the rootstocks in citrus. Eureka lemon budded to sour orange seedling is killed along with the rootstock in severe winter, while the unbudded sour orange seedling suffers little from winter injury.

2. Cold hardiness of the rootstock

Scion affects cold hardiness of citrus roots. Unbudded sour orange seedlings are least affected from winter injury whereas when it is budded on Eureka rootstock, suffered much more from winter injury.

3. Precocity in flowering

A six month or one-year-old mango rootstock seedlings exhibited flowering when its branches were inarched from the old tree.

Conclusion

The scion-rootstock relationship is very important for optimal growth, nutrient uptake, flowering, fruiting and quality. A deficiency in mineral nutrients and water might cause suppressed growth of the scion and low carbohydrate concentrations in the root will decrease root growth, contributing to low water and nutrient uptake, and decrease the availability of carbohydrates as energy resources for the active uptake of ions. The scion– rootstock interactions may be exploited to obtain trees with particular architectures such as reduced branching but wide-angled trees. These stock-scion relationships are important from a horticultural point of view because they provide a basis for selecting the best graft combination for particular environmental conditions and high fruit quality. Selection of an appropriate graft combination is crucial for the production of deciduous orchard species because the scion–rootstock interaction influences water relations, leaf gas exchange, mineral uptake, plant size, flowering, fruit set, fruit quality and yield efficiency.

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MANAGEMENT STRATEGIES OF MEALY BUG: A BIG THREAD TO AGRICULTURE

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Mealybug (*Drosicha spp.*)is a polyphagous pest which attacks on a wide range of fruit crops, vegetable crops and as well as ornamental crops (Ganjisaffar*et al*., 2019; Chowdhuryand Sontakke, 2015). It is cottony in appearance, small oval, soft-bodied sucking insects. This is found on new emerging leave as well as mature, stems, panicle, fruits and roots and is covered with white mealy wax, which makes them difficult to eradicate. They form colonies on the panicle, pedicel, stems and leaves developing into dense, waxy, white masses. They suck the cell sap from leaves and stems with the help of piercing/sucking mouthparts. The excess sap is excreted as honeydew which attracts ants and develops sooty mould on entire leaves surface, which inhibit the photosynthesis activity of plants.

It has been reported that mealybug causes economic damage to many crops. Losses are estimated to be in the range of 10-60 per cent depending on the crops. Mealybug is a major pest of grapes which reduces yields 50 to 100 per cent. It sucks the saps and causes serious damage and losses to the crops. Mealybugs secrete honeydew, which encourages the growth of sooty mould on leaf and photosynthesis process drastically reduces.

Host range

It affects many agricultural crops including mango, guava, citrus, grape, fig, date palm, apple, avocado, banana, anona, mulberry, coffee, coconuts, soursop, peanut, beans, tomato, brinjal, okra, maize, sugarcane, soybean, cotton, rose, chrysanthemum, acalypha, hibiscus, croton (Bhau *et al*., 2017). It also affects litchi leaf, shoot, panicle and fruit, causing fruit drop and deteriorate the quality of fruit.

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Morphology of mealybug

Adult mealybugs are soft-bodied, elongate oval and slightly flattened, segmented insects covered in white powdery wax. Mealybugs are white to pink in colour and measure 1.2-1.5 cm in length and 4-6 mm in width. Eggs, as well as crawlers (small mealybug), are pink in colour. The crawlers measure 0.3 mm in length. Adult females are 2.5– 4.0 mm long.

Fig.1 Mealy bug shape and size Fig.2 Mealybug on litchi panicle

Mode of transport

Young mealybug (Crawler) is highly mobile. They crawl from infected plants or soil to non-infected plants. Small 'crawlers' are easily transported by wind, rain, birds, ants, clothing and vehicle and may settle in cracks and crevices, usually on new plants. Animals, people and equipment used in the field also acts as a carrier to bugs. Long-distance movement is mostly possible through carrying infested planting material and fresh fruit and vegetables across the country or even from one end of a farm to the other. Honeydew secreted by bugs attracts ants which carry mealybugs from one plant to others.

Life cycle

Reproduction is mostly parthenogenetic. Eggs are laid in the egg sac of white wax, mostly in clusters on the twigs, branches, or bark of the host plant but sometimes on the plant's leaves. About 600 eggs are present in the egg sac, and they are mostly female, resulting in the explosive outbreak. Eggs are minute, varying from 0.3 to 0.4 mm in length. Egg development takes between 3 and 9 days. Eggs hatch into nymphs called crawlers and are very mobile. In appearance, nymphs of both sexes resemble female adults. The three and four nymphal instars are found in female and male, respectively, which lasts for 22–25days. The last male instar is inactive within a cocoon of mealy wax. Individual mealybug may take

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as long as 30 days to grow through all the nymphal stages under normal conditions. They survive in cold conditions both on the host plant and in the soil. In warm climates, the insects stay active and reproduce round the year.

Fig. 3 Mealy bug scrawling on the trunk

The female crawls down the mango tree in the month of April-May and enter in the cracks in the soil for laying eggs in large number encased in white egg sacs. Just after hatching, the minutes newly hatched pink to brown coloured nymph crawl up the tree. The eggs lie in diapauses state in the soil till the return of the favourable condition in the month of November-December.

Nature of damage

- Both adults and nymphs suck the plant sap and reduce the plant growth, destroy inflorescence and cause fruit drop.
- Plants become stunted and swollen when infested on the growing tip of young plants.
- Heavy clustering of mealybugs can be seen on fruit panicle and under leaf surface giving the appearance of a thick mat with a waxy secretion.
- They excrete a large amount of honeydew that attracts ants and helping the development of black sooty mould which inhibits the photosynthesis capacity of plants.
- Both nymphs and adults suck the cell sap from flowering panicle, fruit pedicel and leave, causing withering, yellowing and dropping of flowers and fruits.
- Severe infestation can cause defoliation and even death of the plant.
- Infested fruits can be entirely covered with the white, waxy coating of the mealybug.

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- Infestation can lead to fruit drop, or fruit may remain on the plants in a dried and shrivelled condition. Mealybug infected fruits do not fetch a good market price.

Fig.4 Mealy bug promoting sooty mould

Association with ants

Mealybug infestation is associated with a high number of ants. The ants effectively 'farm' the mealybugs, feeds on their secretions of honeydew and in return, protecting them from predator ladybird beetles, parasites and other natural enemies. Options for controlling ants are limited, but the best are those that contain an attractant and a low concentration of toxicant so that foraging ants deliver the toxicant to the ant nest.

Management of mealybug

Cultural and mechanical Control

- ✓ Physical barriers such as ant fences can be applied parallel to the periphery of the field to keep ants away from the field and subsequently help in controlling mealybug populations.
- ✓ Orchard floor management: Cover crop plants between and under rows of fruit crops which provide alternative habitats and hosts, and pollen and nectar as alternative food sources for parasites and predators may help maintain these beneficial populations when mealybug numbers are low.
- ✓ All crop residues in the orchard should be removed and burnt. Crop residues and grass left in the orchard may harbour mealybug populations which may invade the new crop.
- ✓ The field should be free from weeds and crop residues. Weeds also provide an alternative host for ant populations between periods where mealybug infestations are small.
- ✓ Do not move any plant material with suspected mealybugs.
- ✓ Equipment should be thoroughly washed before moving to a new plant or new field.

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- ✓ Manual picking of mealybugs can be done in small plants or where the infestation is in an early stage or apply a strong jet of water to remove bugs.
- ✓ Flooding of orchards with water in October kills the eggs in mango orchard.
- ✓ Ploughing the orchards in November exposes the eggs to sun's heat.
- ✓ Apply sticky bands like 'Track-trap' on the main stem to prevent crawlers of mealybugs reaching the bunch.
- ✓ Fasten 400 gauge alkathene sheets of 25 cm width to the tree trunk besides raking the soil around the tree trunk.
- ✓ Destroy ant colonies during land preparation because their nests are located near the soil surface.
- ✓ Cover crops have been used to improve soil health and lower pest densities by increasing natural enemy diversity. In vineyards, parasitoids that attack mealybugs could utilize floral nectaries found on some cover crop species as a food source to increase adult longevity.

Physical Control

After pruning, the cuttings infested shrubs or trees lying around must be immediately burnt to control further dissemination of mealybug.

Chemical Control

- ✓ Chemicals are not very much effective against mealybug because of its habit of hiding in crevices and the waxy covering of its body which protect mealybug and because pesticides cannot penetrate the heavy waxy layer of waxes that shield the body. Systemic insecticides are used to control heavy infestations, whereas most of the granular pesticides are not effective.
- ✓ In case of old trees remove loose bark to expose hiding population of mealybugs and swab stem and arms with dichlorvos 76 EC @ 2 ml + 2 g of fish oil in a litre of water.
- ✓ Mixing of 2 per cent methyl parathion dust or 1.5% chlorpyriphhos dust @ 250 gm per tree.
- ✓ Spray 0.04% monocrotophos or 0.06% dimethoate if nymphs have already ascended the tree.

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- ✓ Destroy ant colony with a drenching of chlorpyriphos 20 EC @ 2.5 ml/l or apply 5% malathion dust @ 25 kg/ha as the ants provide them protection from parasitoids and predators helps in spreading the crawlers to other plants.
- ✓ Neem kernel extracts and a commercially produced neem extract-based product (Rakshak) induces mild ovicidal action and appreciable nymphal and adults mortality.

Biological Control

Biological control is most effective and long-term solution to the mealybug infestation (Ghosh 2020) because the parasites and predators are self-perpetuating, persists even when the mealybug is at low population densities, and they continue to attack the mealybugs, keeping populations below economicinjurylevels.

- ✓ The coccinellid beetles such as *Cheilomeness exmaculata*, *Rodoliafumida*, *Scymnus coccivora* and *Nephusre gularis*are important predators of mealybug nymphs.
- ✓ Biological control by the release of natural enemies has proved very successful. Among the biological control agents introduction of *Cryptolaemusmontrouzieri*(Australian Ladybird), *Anagyruspseudococci*, *Leptomastixdactylopii*, *Hypoaspis*sp., *Verticilliumlecanii*and *Beauveriabassiana*are effective in managing the infestation.
- ✓ *Hypoaspis*is a small mite that feeds on crawlers.
- ✓ Soil application of the spores of the fungus, *B. bassiana* reduces the further reduction of the pest population.

Mating Disruption

The synthetic sex pheromone can be used to disturb the mating process in mealybug**.** The significant reduction of the males can be achieved by mass trapping.In fact, males are attracted from a distance of at least 100 m from the pheromone source

Ant control

Ants are associated with mealybug and it may disrupt the activity of natural enemies of pests, parasitoids. There are documented 295 ant species in citrus orchards, but not all of them establish mutualistic relationships with honeydew producers. Some species, when present in high densities, disrupt the biological control of mealy bugs. Therefore, disrupting the activity of ants is a practical tactic to enhance the biological control of mealybugs. Tactics

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available to manage ant populations include: (i) insecticide-treated baits; (ii) sticky bands strapped or taped around the tree trunk; (iii) spraying the trunks or placing insecticide-treated bands around them; and (iv) ground or foliar treatment with insecticides.

Conclusion

The mealybug is still a major problem and causes severe damage in many crops due to the presence of a vast range of host and persistence round the year, but its significance has not been realized. Alteration of environmental factors may affect their life cycle, thereby effecting the time of infestation. A very little work has been done towards implementing Integrated Pest Management to control the mealy bugs.To mitigate the fruit loss due to mealy bug infestation, the integrated approaches can be very useful.

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INDUCED POLYPLOIDY IN CROP IMPROVEMENT

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Chromosomal doubling occurs in plants naturally, however its rate is very low and a slow process. Since time is important, chromosomal doubling/ polyploidization can be induced in a short period at a high rate by using antibiotic agents like colchicine, oryzalin etc. The concentration and duration for treatment of the explant differ with the crop and hence an efficient polyploidization protocol has to be developed for the concerned crop. The induced putative polyploids can be selected by various morphological parameters cytological and flow cytometric techniques. The exact chromosome complement can be obtained by studying the mitosis or meiosis.

Polyploidy refers to the presence of more than two complete sets of chromosomes per cells, and it plays a major role in crop evolution and diversification. Such polyploids can be obtained naturally by the interspecific or intraspecies union of unreduced gametes. But the rate is very slow, whereas artificial polyploidization is quick and can be induced by using antibiotic agents like colchicine, pronamide, oryzalin *etc*. Such genome duplications result in greater variation when compared to specific gene mutations. Polyploidizationis employed in several plant species however major work is done in medicinal plants, horticultural plants and few forage crops. Polyploidization has begun after the experimental work of Eigsti. O. J with colchicines.

Methods of polyploidization

There are three major methods of polyploidization *in-vitro*, *in-vivo* and *ex-vitro*. Among those three methods, *in-vitro* is most popularly used and quicker method for polyploidy induction in limited space under aseptic conditions. However, it demands more skill. The factors effecting the *in- vitro* induction of polyploids is given in Figure 1 (Niazian and Nalousi; 2020). In contrast, *ex-vivo* requires less skill and does not require expensive laboratory settings. It generally involves seeds or roots as explant. *In-Vivo* system of polyploidy induction can be

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achieved by applying the antibiotic agents to the intact plant parts like seedling apex (cotton) or inflorescence (Jatropa).

Induction of polyploids

Synthetic polyploids production can be achieved by interfering the cell cycle by a variety of chemicals. Those chemicals which act at the end of the S-phase and before the cytokinesis are the effective candidates for polyploidization. Most of the antimitotic agents are metaphase inhibits acting on the alpha and beta tubulin dimers. Nitrous oxide was the first putative antimitotic agent employed for genome doubling. The most commonly used antimitotic agent is colchicine, an alkaloid extracted from the bulbs and seed of *Colchicum autumnale*. However, it causes sterility, chromosomal loss and abnormal growth in many plant species. Another major disadvantage of colchicines is its high affinity to microtubules of animal cells, hence very toxic to humans. Alternatively, some of the herbicides and phosphorothioamidates have low toxicity for humans unlike colchicine. Hence these herbicides can be used as alternatives for colchicines.

The concentrations of the antimitotic agent depend on the explants used, *i.e.*Callus, buds or shoot tips, seeds, seedlings and tubers. The induction percentage is also genotype-dependent. Besides the explant, the concentration and duration of the treatment also play an important role in polyploidization. It is crop-specific, and hence standardization of the optimum concentration and duration of the treatment has to be done. Lower concentrations are not successful, while higher concentrations are lethal. The solvent used for dissolving the anti-mitotic agent is also very important. In many cases, anti-mitotic agent are dissolved in DMSO, which increases cell permeability allowing enhanced absorption of the chemicals. Alternatively, 70% ethanol, NaOHand Acetone can also be used.

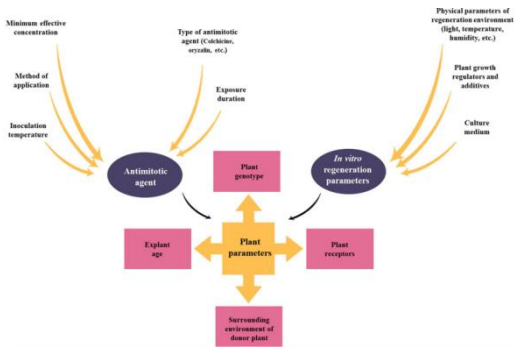

Fig 1: Factors affecting artificial polyploidization under *in vitro* conditions

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Identification and confirmation of polyploids

Morphological and anatomical studies such as stomatal measurements are simple and indirect methods of polyploidy conformation, but they are often inaccurate. Stomata of polyploids are large in size when compared to their diploid counterparts. Besides the size of the stomata, the change in density can be observed. The polyploids were recorded to have a lower stomatal density (Compos *et al.*, 2009). Pollen size, similar to stomatal size, can also be used for polyploidy detection, but it is rarely used. Flow cytometry is a very common method for ploidy analysis (Dolezel *et al.*, 2007). The nuclei are extracted from the leaf tissues, and the DNA is stained using any fluorescence (mostly PI). The flow cytometry uses a light source to illuminate the stained nuclei and the emitted fluorescence is detected. The amount of fluorescence in the nucleus is proportional to the DNA content. It is a rapid method for testing ploidy and a large number of plants can be analyzed. Early-stage detection is possible and hence its time and space-saving.

Although morphological and flow cytometric studies can be used for primary screening; however, exact confirmation is often necessary. Sometimes polyploidization results in mixoploids (different ploidy level). Therefore, to know the exact ploidy level, cytological studies (mitosis/meiosis), involving the chromosomal counts is the perfect and ultimate method.

Applications of polyploidy in crop improvement

Approximately 40% of the cultivated species are polyploids (Simmonds 1980). Polyploidy induction is attempted in several crops like Rye, Brassica *sps*, Clover, Pearl Millet Napier Hybrids and many Ornamental and Medicinal plants. In ploidy induction, reduced fertility is a major drawback, when the reproductive organs (seeds/fruits) are of interest. However, for ornamental plants fertility reduction is not a problem as the larger flower are advantageous, and these are mostly vegetatively propagated.

Among the cultivated crops, the first allopolyploid obtained by polyploidization was Raphano brassica, but it was a failure. The first successful synthetic allopolyploid was triticale obtained by chromosome doubling of sterile F_1 by using colchicine. Several Red Clover varieties are produced by polyploidization. These varieties showed tolerance to diseases, winter hardness and high forage dry matter yield. Similarly, tetraploid ryegrass varieties were

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developed, that showed tolerance to diseases, drought and improved palatability.In Pearl millet Napier grass, the F_1 (Pearl millet x Napier grass) are sterile, and the fertility restoration is done by using antimitotic agents like colchicine, oryzalin and trifluralin. Various applications of induced polyploidy were depicted in Fig. 2 (Sattler *et al.*, 2016).

Polyploid induction is more popularly employed in ornamental plants, which results in increased flower size, deep coloured flowers and extended flower longevity. In medicinal plants increased genome content by chromosomal doubling results in overexpression of genes that are involved in biosynthetic pathways, thus increasing the productivity of desired pharma molecules.

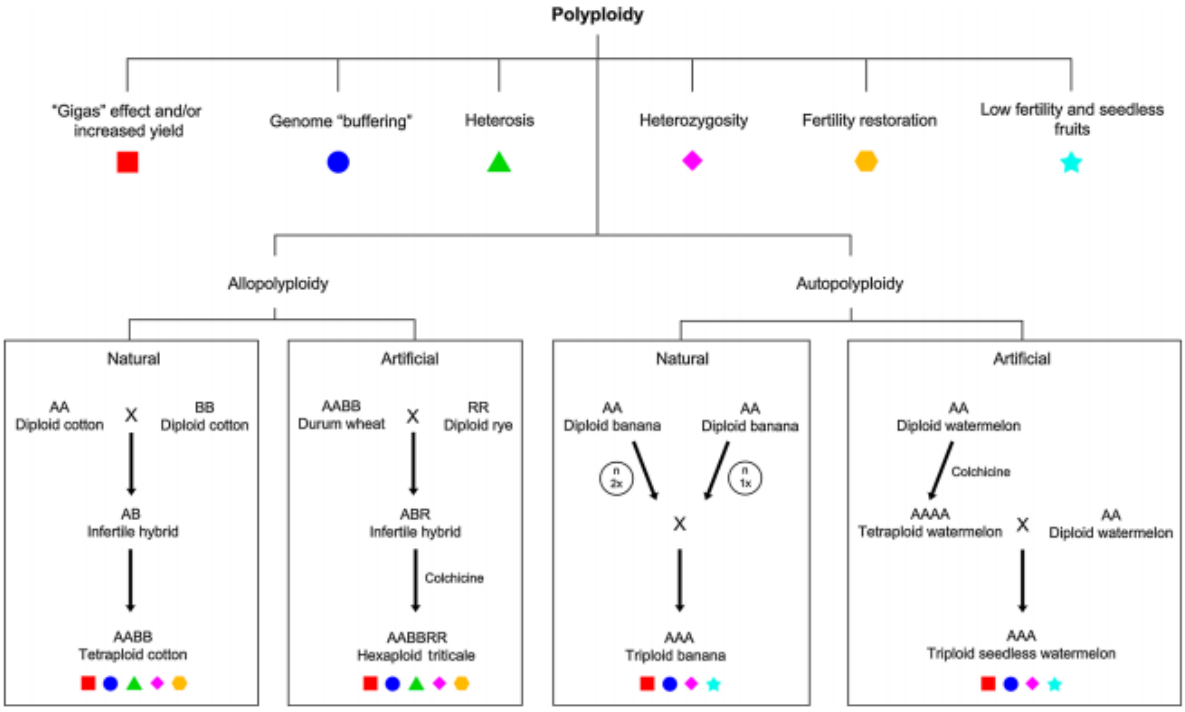

Fig 2: Schematic representation of cultivated species and the main polyploidy consequences for application in crop improvement. The symbols ‘‘n 1x’’ and ‘‘n 2x’’ refer to reduced and unreduced reproductive cells, respectively

Conclusions

Polyploidization, though a complex process has a greater impact on crop improvement. The natural polyploids have drawn a greater interest in the plant breeders, thus making them to imply artificial polyploidization for crop improvement.

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AGROFORESTRY: SOLUTION TO ADDRESS FOOD SECURITY AND CLIMATE CHANGE

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Agroforestry, the cultivation of trees and shrubs along with agricultural crops and livestock simultaneously or sequentially, is a land-use system that has been a way of life and livelihood in many developing as well as developed countries for centuries to attempt assured interactions among the components with the objective of achieving a more environmentally diversified and socially productive output from land than is obtainable through traditional agriculture. It is a practically acceptable and minimal cost way out for implementing several aspects of integrated land management practices to reduce human interference on productive landholdings and contributing towards a green economy through encouragement of long term, sustainable, and renewable forest management, more specifically for small scale producers. Notwithstanding, the advanced conception of agroforestry became visible in the early 20th century, but the adoption of woody perennials in agrarian structure is quite antiquated, with documented descriptions of the principles and practice dating back to the ancient Roman era. Agroforestry has captivated the enthusiasm of researchers, scientists and developmental planners as it contributes a variety of products for fulfilling miscellaneous requirements of people, providing insurance coverage against risks and disturbances resulted by aberrant weather conditions, controlling erosion hazards due to water and wind effects and ensuring sustainable production of the intercrops (Nair, 2007). India has been at the cutting edge since standardized agroforestry research has commenced throughout the globe and progressed vigorous agroforestry science, innovative technologies and package of practices that are fascinating global interests.

What is agroforestry?

Agroforestry is defined as an integral component of productive agriculture and a flexible concept of management and integration of existing native forests and forests/trees established by small or marginal landholders, crops and/or livestock on the same plot or in

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other words; it may be referred to as a collective term for land-use systems and technologies and an intensive land management practice in which the woody perennials such as trees, shrubs, palms, bamboos, etc. are deliberately cultivated on the same land management units in the spatial arrangement or temporal sequence optimizing the advantages from biological associations created between them. However, agroforestry is a dynamic, ecologically viable and economically cost-effective, natural resource management system that accommodates with the social and cultural characteristics of local people and diversifies and sustains production level for enhanced social, economic and environmental benefits for land users at all strata.

Benefits of agroforestry

1. Produces a diversified and sufficient supply of nutritious foods to meet the global demand and satisfy the requirements of the producers as well; provide food, fibre, fuel, fodder, fruits, flowers, timber and shelter for livestock and serve other commercial purposes also including the contribution of a wide range of useful and marketable products from fruits/nuts, medicines, wood products etc.

2. Ensures the protection of natural environment to provide resources and environmental services to meet the needs of present generations without endangering the resource base for future.
3. Fundamental for land regeneration to improve soil health; build up soil organic matter or soil carbon; ameliorate soil structure through constant addition of organic matter from decomposed litter; reduce soil erosion resulted from the action of wind and water on unprotected soils by canopy cover, roots and leaf litter of naturally growing grasses; stabilise the soil; utilise nitrogen-fixing plants *viz.* legumes to restore nitrogen fertility etc.
4. Sequesters carbon from the atmosphere or increase carbon stocks in soil and woody biomass.
5. Brings up water and nutrients from deep in the ground.
6. Provides a framework for increased above and below ground biodiversity to flourish or a more diverse habitat than a conventional agricultural system in which the tree component creates ecological niches for a wide range of organisms.
7. Helps in bioremediation, drought resistance and increased crop stability.

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8. Obtains cleaner water through reduced nutrient and soil surface runoff by decreasing its velocity and increasing infiltration into the soil; higher nutrient uptake and reduced nutrient losses into streams; more efficient recycling of nutrients by deep-rooted trees; declined nutrient leaching; better protection of ecological systems; increment in soil nutrients through addition and decomposition of litterfall.
9. Results in odour, dust and noise reduction; green space and visual aesthetics; enhancement or maintenance of wildlife habitat.
10. As tree cover accounts for more than 75% of global carbon pool, it can significantly contribute to climate change mitigation along with adaptation benefits.
11. Additionally, the hedges serve as windbreaks to reduce wind velocity over and around crops thereby increasing yields through reduced drying of the crop or by preventing the crop from toppling in strong wind gusts.
12. Regulates or improves microclimates, such as lowering of soil surface temperature and evaporation through mulching and shading.
13. Innovates diversified farm enterprises, makes agricultural landscapes more resilient and enhances yields from staple food crops.
14. Reduction in incidence of total crop failure, increase in levels of farm income due to sustained productivity, improvement in rural living standards from employment generation and higher income, improvement in nutrition and health due to increased quality and diversity of food outputs, reduced poverty, stabilization of communities through elimination of the need to shift sites of farm activities are playing a vital role in promoting livelihood security.
15. It can check the development of soil toxicities like soil acidification, alkalinity/sodicity and salinity; can be employed in the reclamation of polluted soils, eroded and degraded lands and may augment soil water availability to land use systems.
16. They utilize solar energy more efficiently than monoculture systems; lead to reduced insect pests and associated diseases; reduce the need for toxic chemicals like insecticides, herbicides, etc.
17. Increased food security; improved human nutrition through more diverse farm outputs; reduced global warming and hunger risks by an increasing number of drought-resistant trees and the subsequent production of fruits, nuts and edible oils; reduced deforestation and pressure on woodlands by providing farm-grown fuelwood are other significant advantages.

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18. Trees may help to lower water tables, act as pumps to take up water from soil and then evaporate it into the atmosphere, thereby reducing soil salinity by this declined water tables.
19. Through water removal, established trees can substantially reduce waterlogging in their immediate area, which may result in improved land uses, *e.g.* pasture or crops.

Challenges/Barriers

1. Lack of developed markets, equipment, financial assistance as well as demonstration sites
2. Unfamiliarity with technologies and alternative marketing approaches
3. Lack of awareness, training or expertise, technical assistance and apparent profit potential
4. Competition between trees, crops and animals
5. Expense of additional management
6. Lack of knowledge about where to market products
7. Adoption/start-up costs, including costs of time
8. Unavailability of information about agroforestry
9. Apparent inconvenience and lack of scientific research
10. Lack of infrastructures such as buildings and sufficient land and unavailability of quality seed/seedling sources

Key Traits

To be termed as agroforestry, a land-use practice must satisfy the following four criteria:

1. **Intentional:** The integration of trees, crops and animals are intentionally designed and administered as a complete unit instead of considering it as an individual element.

2. **Intensive:** The system should be intensively controlled to sustain their productive and protective functions.

3. **Interactive:** It must manipulate the biological and physical associations between trees, crops and animals to increase the production along with providing conservation functions such as control of water pollution or maintenance of wildlife habitat.

4. **Integrated:** All the essential components should be structurally and functionally aggregated into a single and horizontal or vertical (above or below ground) integrated

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management unit thereby balancing the economic production in addition to natural resource preservation.

Types of agroforestry systems

1. **Structural basis**

a) **Agri silviculture: A**gricultural crops are intercropped with tree crops

b) **Silvi pasture: P**roduction of woody plants along with pasture

c) **Agri silvi pasture: P**roduction of woody perennials with annual crops and pastures

2. **Functional basis**

a) **Productive functions:** Provides food, fibre, fuel, fodder, timber, fruits, and flowers, spices, shelter, medicines, non timber forest products or NTFPs etc.

b) **Protective functions:** It acts as windbreaks and shelterbelts, helps in soil improvement and conservation

3. **Socio-economic basis**

a) **Commercial:** The scale of the production is the major aim

b) **Intermediate:** It prevails between commercial and subsistence systems

c) **Subsistence:** The use of land is directed towards satisfying the basic needs and is managed mostly by the owner and his family

4. **Ecological basis**

a) **Agroforestry in humid/sub-humid lowlands:** Home gardens, trees on rangelands and pastures, improved fallow in shifting cultivation and multipurpose woodlots

b) **Agroforestry in semiarid and arid lands:** Various forms of silvopastoral systems, windbreaks and shelterbelts

c) **Agroforestry in tropical high lands:** Plantation crops like coffee, tea, use of woody perennials in soil conservation and improved fallow etc.

Conclusion/Way forward

Agroforestry is obligated to perform a huge responsibility in distant future, not only for its significance in food and livelihood security but also for its vital role in combating the ecological constraints. It can possess a fundamental consequence in furnishing a widely accepted solution to global warming, climate change, enhancement of per unit productivity of land and conversion of degraded and marginal lands into productive ones. The National Agroforestry Policy formulated various recommendations which will go an extended route in

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motivating large scale embracement of agroforestry system by the peasants and provide the indispensable raw materials to wood oriented industries as well as play a huge role in energy and environmental security. The major concentration of investigation in the forthcoming years will be imposed upon the development of agroforestry techniques for crucial domains such as arid and semi-arid regions and other frangible ecosystems like Himalayan and Coastal areas to endure those tracts of lands areas for obtaining higher productivity and natural resource management.

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MESOCOSM: AN OVERVIEW

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Species heterogeneity is the foremost approach for the sustainable development of aquaculture. For successful domestication of any species, larval rearing is the major constraint; therefore, the adaption of proper protocols is fundamental. Larval rearing is classified into two types based on their rearing densities, i.e., intensive rearing and extensive rearing. In intensive rearing, larvae are reared at higher densities under disciplined conditions with well sound knowledge of their biological requirements. In extensive rearing, larvae are reared at lower stocking densities in large tanks under natural conditions with an internal bloom of wild zooplankton. Subsequently, the probability of success is more than intensive rearing. Extensive rearing is already employed for more than 20 fish species. But the major constraint for large scale adaption extensive rearing is low productivity. To solve the larval rearing problem of several species, mesocosm is one of the major solutions.

Mesocosm

In 2002 mesocosm hatchery was installed at Centro de Maricultura Calheta (CMC), Madeira island depending on the environmental stability of the large rearing tanks with the use of **Green water** technique in low stocking densities to produce healthy fish larvae at low cost. Mesocosm is a semi-intensive (combination of both intensive and extensive) technology that promotes larval rearing of multiple species solving their biological, technical, and economic consequences. Mesocosm is a culture system of larval rearing enriching the pelagic ecosystem in hefty tanks size ranging from 1 to 10000 m3. This aquatic ecosystem comprises multiple species, the innate food chain of phytoplankton, zooplankton, and culturing fish larval species. In these pelagic system fish larvae acts as a predator which feeds on its prey, i.e., phytoplankton (Diatoms, Dinoflagellates. Etc,)and zooplankton (Copepod, Brachionus. Etc,)

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Difference between intensive, extensive, and mesocosm

Parameters	Techniques		
	Extensive	**Mesocosm**	**Intensive**
Rearing Enclosures	Ponds or bags	Tanks or bags	Tanks
Localisation	Outdoor	Indoor	Indoor
Rearing volume (m3)	>100	30-100	<20
Rearing density (Ind/l)	0.1-1	2-8	30-200
Food chain	Endogenous	Mixed	Exogenous
Infrastructures	Light	Medium	Sophisticated
Environment	Natural	Mixed	Controlled
Autonomy and autarky	High	Medium	Low to nil
Dependence on man and technique	Light	Medium	High to very high
Need for specific biological knowledge	Light	Medium	High to very high
Validity for new species	Very high	High	Medium to low

Mesocosm Protocol

Drying of tanks/ponds for 4 days

↓

Disinfection with the chemical to kill predators and pathogens

↓

Filling of tanks/ponds with adjacent seawater rich in plankton

(Note: While filling seawater inlet is fitted with a 350-500µm filterto prevent the entry of pathogens)

↓

Fertilizing filled water with N:P ratio 5-10(Seawater)

(Note: For freshwater poultry manure with additional fertilization for every 3days with chemical fertilizer)

↓

Stocking of fish larvae after adequate development of plankton

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In mesocosm, various types of plankton will develop one by one and this process is succession. The time of addition of fish larvae into to mesocosm system is after adequate development of plankton and when larvae start feeding.

Types of mesocosm

There are two methods to develop a mesocosm system for larval rearing.

Advective method

It is entirely dependent on the external processes of the system. In the first system, water is frequently exchanged. In this system, intaking water is filtered to prevent the entry of pathogens allowing Phyto and zooplankton. Similarly, outgoing water is filtered to avoid the exit of fish larvae.

Semi-intensive method

It is entirely dependent on the internal processes of the system. This system is convenient for aquaculture, as this system does not require technical knowledge. This system is further divided into four types based on the enclosures used for water retainment. They are

Pold system

Pold system is an isolated enclosure of fjords or lagoons and dams in isolated bays. Enclosures are treated with chemicals (Rotenone) before every cycle to make the culture system predator-free. An alternate method for the removal of predators is emptying and drying. After treatment and fertilization of the enclosure, microalgae are added as inoculum for the promotion of phytoplankton bloom. Copepod eggs resist rotenone treatment and help in the promotion of zooplankton bloom. Pold system is ready for stocking with fish larvae after an ample amount of copepod nauplii is developed. In the case of zooplankton depletion, zooplankton collected from nature can be introduced into the system.

Bag system

This system is a simplified version of the pold system. In this system, enclosures are polythene or PVC bags tied to the floating wharf. After filling the bag with filtered water, microalgae are added as inoculum to the system. Screened zooplankton is added to the bag after the successful development of phytoplankton bloom. When an ample amount of zooplankton is reached, fish larvae are introduced into the system. Water exchange can be carried at the rate of 1-2% for the first two weeks and then 10-100% of the bag volume per

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day. These bags have a conical bottom with an outward hose from the bottom to the surface for water renewal. These bags are used in Norway for the rearing of turbot, halibut, and cod fingerlings.

Pond system

This system is straightforward and cheap in construction, maintenance, and operation in this system enclosures are human-made ponds. This system is used in rearing freshwater cyprinid fish larvae in Denmark, Norway, and China.

Tank system

In this system, tanks are used for rearing fish larvae and copepod separately. The main idea of this system was to maintain abiotic (nutrient level, pH, temperature, light intensity,) and biotic (phytoplankton and copepod production, number of predators, bacterial turn-over, regeneration of nutrients from copepods and fish larvae)components separately and synchronize them in such way that one trophic level matches the predation by the higher level.

Benefits of mesocosm

1. The larval survival rate is high.
2. Fish larvae reared using mesocosm have more incredible growth performance and lower deformities.
3. Constant availability of lived feed to the fish larvae
4. Less vulnerable to technical failures.
5. Lower cost and simplicity in installation.

Challenges of mesocosm

1. Regular sorting of larvae to prevent size variation.
2. Synchronization of mesocosm setup and fish egg production.
3. Due to excessive plankton bloom production surface lipid film is formed.
4. Little control over the rearing environment.

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Conclusion

The Mesocosm system is a semi-intensive technology that has the advantages of more productivity and survival rate. The effectiveness of mesocosm for new species is similar to extensive rearing. This technology is an excellent adaption to achieve species heterogeneity and future weapon for larval rearing the most difficult species.

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MICROPLASTIC IN MARINE ECOSYSTEM AND ITS IMPACT IN HUMAN HEALTH

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Plastic production has increased and exponentially reached 322 million tonnes in 2015 since the early 1950, and additionally production of synthetic fibres which consider for 61 million tonnes in 2015. It is expected that by 2025 production of plastics will be double and continue to increase in the expected future. Contamination of freshwater, estuarine and marine environments increased consistently due to insufficient management of plastic waste. It has been roughly calculated that in 2010 between 4.8 million to 12.7 million tonnes of plastic waste entered the oceans. Microplastics are generally defined as a group of plastic items which measure less than 5 mm, and this definition also includes nanoplastics which consist of particles less than 100 nanometres. It is evaluated that, in the marine environment, plastics take hundreds to thousands of years to degrade, with reporting the presence of microplastics in lake sediment that had been accumulating for 38 years. In wild and marine aquatic organisms, microplastics have only been observed within the gastrointestinal tract. The risk of microplastic ingestion in human can be limited by the eradication of the gastrointestinal tract in most species of seafood consumed. But most species of seafood such as bivalves and many species of small fish are consumed entirely, without removing G.I. tract, which may lead to microplastic exposure to human. A rough case estimate of exposure to microplastics after consumption of a portion of mussels (225 g) would lead to ingestion of 7 micrograms of plastic, which would have a minor effect (less than 0.1 percent of total dietary intake) on chemical exposure to certain PBTs and plastic additives. Microplastic contamination of aquatic environments will continue to increase in the expected future due to anthropogenic activity, and at present, there are remarkable knowledge gaps on the occurrence of smaller sized microplastic less than 150 µm in aquatic environments and organisms. Currently, there are no methods available for the examination and quantification of nanoplastics in aquatic environments and organisms.

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Plastic in ocean

Plastic materials are used in boat construction, boat maintenance, fishing gears (nets, trawls, dredges, traps, floats, lures, hook and lines), fish crates and fish hold insulation. A range of plastics, including PP, PE, PVC, PS and PA, are used for the manufacturing of nets and floats, and the choice of fishing method or gear type is critical depend for both its use in fishing and its impact on the environment. Plastic materials are used for the seafood industry for packaging and transportation, ropes, floats, fish crates and boxes, fish cages, pond lining, fish feeders and fish tanks. Plastics are used for the manufacturing of cages, nets, ropes, lines and buoys: this includes small domiciliary facilities to highly technical systems used in fish culture and processing.

Around the globe, plastic items are consistently the most abundant type of marine debris identified in the marine environment, and can contribute to more than 80 percent of reported debris. Unprotected landfills and dumps located near the coast or to riverine systems that directly inlet by metro cities, general public litter in shorelines, accidental loss, harbour activities, improper management of sewage systems are the Land-based sources of marine pollution. Plastic litter can be generated from all types of boats, ships and offshore platforms in the ocean are Oceanic based source of marine pollution. This can be occurred by accidental loss, indiscriminate disposal or illegal dumping. The disposal of waste from vessels now prohibited by the International Convention for the Prevention of Pollution from Ships.

Lost or otherwise discarded fishing gears are the main source of plastic waste into the ocean. Irregularities on the seafloor will most commonly affect the Trawls, dredges and pots. A significant component of Abandoned, lost or otherwise discarded fishing gear (ALDFG) are geared such as gillnets, trawls, handlines and longlines. Loss of fishing gears in the ocean can be a result of enforcement on fishers to strand gears (e.g. illegal gears or illegal fishing), operative pressure (e.g. use of a large number of gears in restricted time periods) and environmental conditions (e.g. weather, seabed irregularities). Derelict fishing gears dominate the seafloor, for eg., estimated that overall debris on the seabed of the Mediterranean Sea and Northeast Atlantic was contributed mainly of plastics (41 percent) and ALDFG (34 percent), but in some places, such as north of the Faroe Islands, the Norwegian continental shelf, ALDFG contributes more than 75 percent of marine debris in the marine environment. ALDFG is a major issue for fisheries and marine conservation, its presence in

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the marine environment can have a significant impact on shellfish industry and commercial fishing and also on the environment. It can lead to ghost fishing, the capture of non-target aquatic species, stock exhaustion, conservation discuss, the threat to other vessels, and it is costly to remove.

Fig 1: Crabs and different aquatic organism caught in ALDFG in the ocean. (Source: FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER 615)

Uptake of microplastic by aquatic organism

A broad range of species fishes that were reported to be contaminated with microplastics and occupy a large variety of habitats in marine environments. Microplastics exhibit considerable differences in colour, shape, and polymer that detected in these wild-caught fishes also. The most commonly detected shapes of microplastics in fish are fibre and fragment, which go in accordance with their prevalence in global waters. The most produced polymers around the world are polyethene, polypropylene, polyester, and polystyrene, are also usually present in the digestive tracts of fish. After ingestion of microplastics, it retained in the digestive systems of fish, including the stomach and intestine. Additionally, microplastics can also attach to the skin of fish or migrate to other tissues, such as gills, liver, and muscle. It has been considering that very fine plastic particle could migrate across living cells into the circulatory or lymphatic system, resulting in dispersion of microplastics

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throughout the whole body. Scientific reports showed that plastic fragments and fine particles blocked the movement of food materials in the gut leading to reduced food intake, increase starvation, physiological stress, reduction in fertility, pseudo-satiety sensation, fecundity and finally increase in morbidity and mortality.

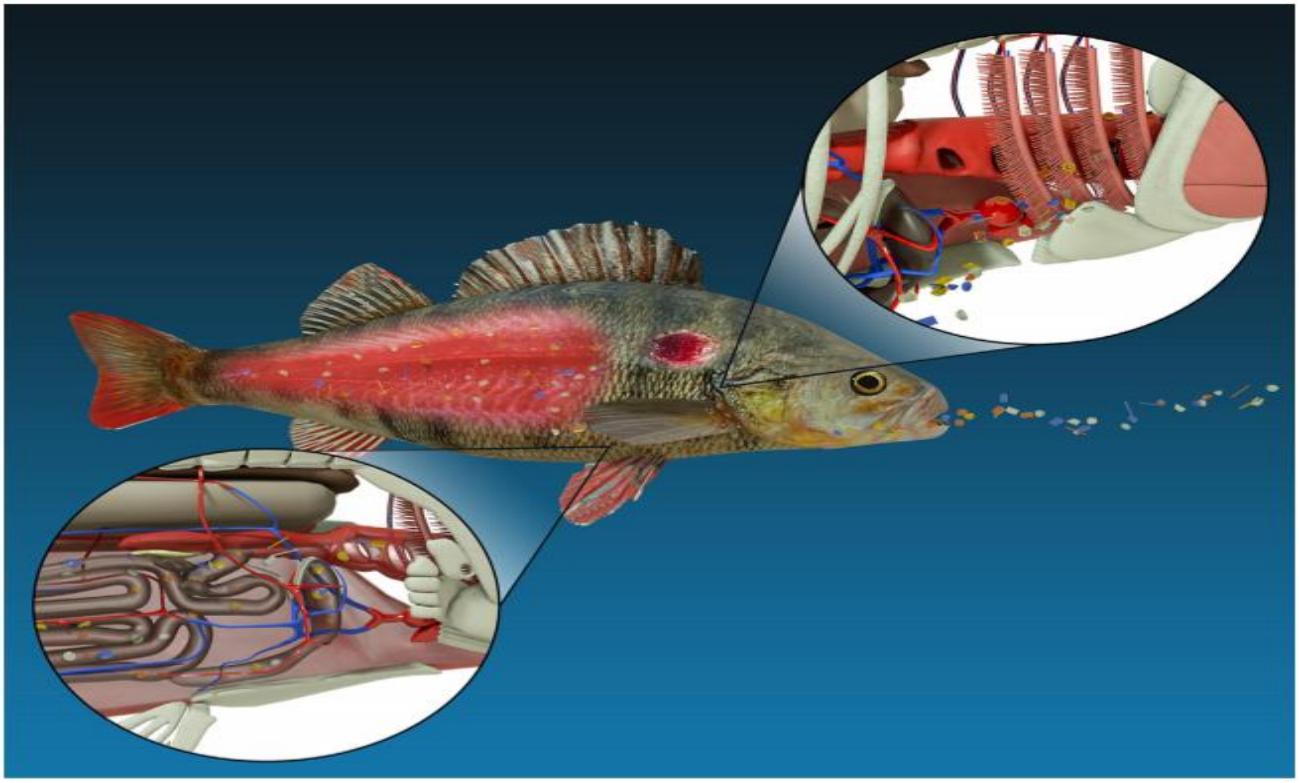

Fig 2: Microplastic uptake by fish. (Source: Barboza et al., 2020)

Accumulation of microplastics through trophic transfer

Persistent, bioaccumulative and toxic substances **(**PBTs) build up in the tissues of organisms and accumulate up the food chain, leading to increased body burdens in higher trophic levels or in higher animals. If the trophic transfer in the food chain were to occur regularly, animals at higher trophic levels such as carnivorous animals, human etc. would be at increased risk of bad impacts and results, such as damage to and irritation of the gut lining and reduced nutrient uptake. Microplastics have been noticed in large pelagic fish, and it has been proposed that microplastics present in these species may have transferred from prey items rather than from directly feeding in the environment.

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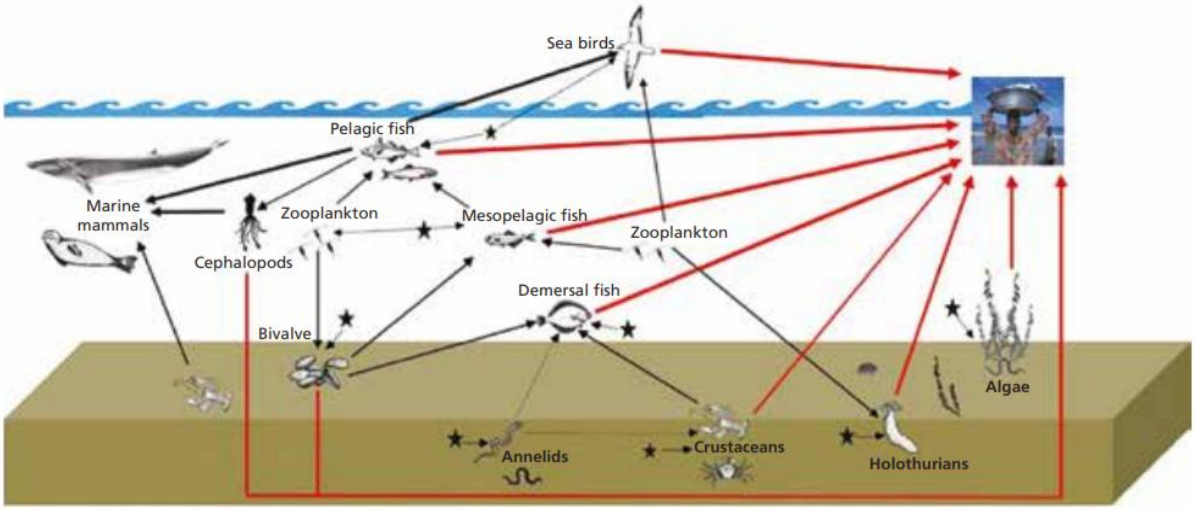

Black stars represent microplastic particles and the black dotted arrows indicate an observed interaction between organism and particle (direct ingestion/uptake). The black arrows indicate indirect ingestion of MPs (potential trophic transfer). The red lines indicate potential route of microplastics to humans following ingestion of seafood. Finally, arrow thickness represents potential bioaccumulation of particles through the foodweb

Fig 3: Micro biota, microplastic, possible trophic pathways interaction. (Source:FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER 615)

Microplastics in foods

The increased production of fisheries and aquaculture products has resulted in increased per capita consumption globally. In 2014, for human consumption, 87 percent of total marine capture production was used and the remaining 23 percent, which accounted for 21 million tonnes of total production, was used for non-food products, especially fishmeal and fish oil. World per capita noticeable consumption of fishery products averaged around 9.9 kg, increasing to 14.4 kg and reached a value of 19.7 kg, in the 1960s, 1990s, 2013 respectively.

Ingestion of microplastics has been noticed in a relatively large number of fish species and products used for human consumption from the Pacific, Atlantic and Indian oceans. According to one research, microplastics have been observed in the gastrointestinal tract in 11 out of the 20 most important species and genera of finfish that contribute to global marine fisheries. These species are chub mackerel (*Scomber japonicus*), Atlantic mackerel (*Scomberscombrus*), Japanese anchovy (*Engraulis japonicus*), Atlantic cod (*Gadusmorhua),* Atlantic herring (*Clupea harengus*), European pilchard (*Sardinapilchardus*), blue whiting (*Micromesistiuspoutassou*), king mackerel (*Scomberomorus cavalla*) from the Scomberomorusspp group, European sprat (*Sprattussprattus*), shortfin

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(*Decapterusmacrosoma*) and Amberstripe (*Decapterusmuroadsi*), and Indian oil sardine (*Sardinella longiceps*).

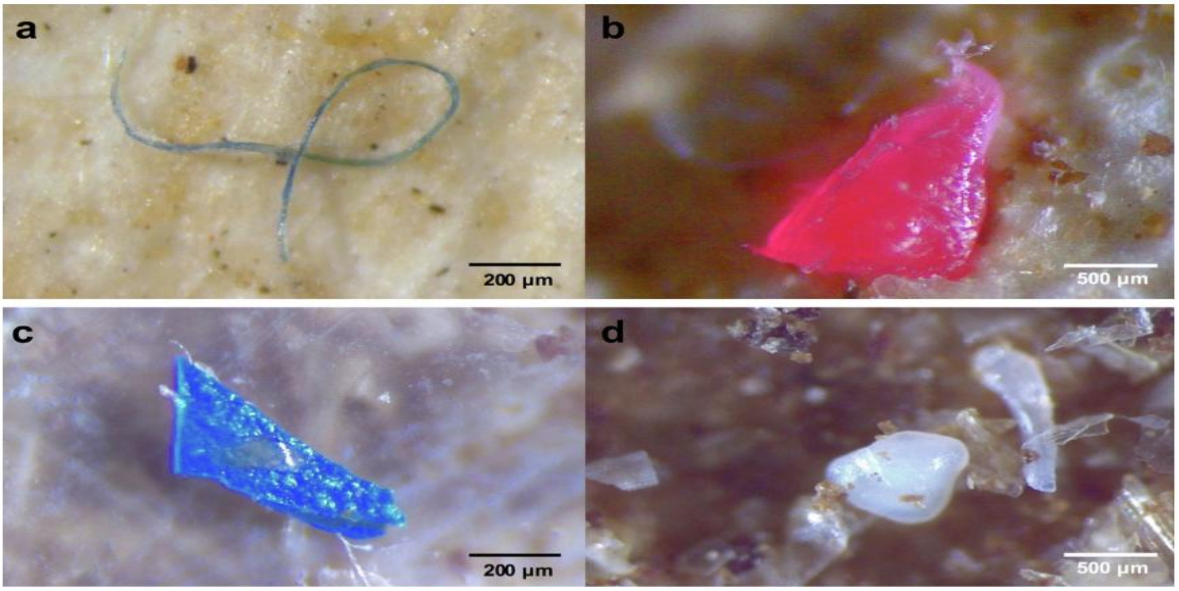

Fig 4: Microplastic recovered from different fish species, (a- fiber, b and c- fragment, d- pellet). (Source: Barboza et al., 2020)

Human exposure to microplastics through fish consumption

One major source of dietary microplastics to humans is seafood. According to one research, human intake of microplastics from seafood has been calculated from 1 particle per day to 30 particles per day depending on seafood consumption habits of the individual person. According to one study, the highest amount of microplastics is carried by Chinese bivalves: overall value of 4 particles/g of tissue. Thus, it will lead to consumption of about 900 microplastic particles by the consumption of such a portion of bivalves (225 g). It can be estimated that microplastics contribute only a very small fraction of the total dietary intake of contaminants: Polycyclic aromatic hydrocarbons (PAHs) from 0.02 % to 0.1 %, Polychlorinated biphenyls (PCBs) from 0.007 % to 0.03 %, and DDT from 0.0000002 % to 0.004 %. The contribution of microplastics in compare to the dietary intake of additives is even smaller: Bisphenol A (BPA) from 0.000005 % to 0.00002 %, and Polybrominated diphenyl ethers (PBDEs) from 0.0007 % to 0.003 %. After ingestion by marine organism, these particles could be absorbed in the small intestine by specialized M-cells, covering an intestinal lymphoid tissue – Peyer's patches, and also adherence to the gastrointestinal mucus, where high adherence increases particle clearance rate.

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Seafood Safety

The largest quantities of microplastics contain by the digestive tract of marine organisms. However, this part of marine fish is normally removed before consumption, except for most bivalves and mussels, several small species of fish which are eaten whole. A rough case estimates the exposure of 7 µg of microplastics after consumption of a portion of mussels (225 g). Based on this calculation and taking into account, the highest concentrations of additives or contaminants reported in microplastics; the microplastics will have a minor effect on the total dietary exposure to PBTs and plastic additives. These contaminants of microplastic are calculated to contribute only <0.1 % of the total dietary exposure to these plastic compounds.

As far as it is known, only microplastics which are less than 150 µm may penetrate across the mammalian gut epithelium, causing systemic exposure. However, the absorption of these microplastics is expected to be restricted (≤ 0.3 percent). Only the smallest microplastic fraction or segment (size ≤ 20 µm) may translocate into organs and cause systemic exposure in human body. Nanoparticles can penetrate across the gut epithelium of mammals resulting in systemic exposure and damage, and a very wide distribution in all organs is likely.

The overall human health risks posed by microplastics in seafood at present appear to be very less, it is important to consider the unavoidable increase of micro- and nano plastics in the future as a result of degradation of plastics already released in the marine environment as well as future inputs.

Implications for human health

Even though scientific evidence and research demonstrate the presence of microplastics in several food products, there is no information available about the fate of microplastics in the human body following ingestion of the particles. Scientists postulate that microplastics with size bigger than 150 µm probably will not be absorbed by the organism while microplastics smaller than 150 µm may penetrate from the gut cavity to the lymph and circulatory system, causing systemic exposure in the mammalian body. However, the absorption of these microplastics by food products is expected to be limited (≤0.3%). Only microplastics with size ≤ 20 µm would be able to translocate into human organs while the smallest fraction (0.1 > 10 µm) would be able to approach all organs, the blood-brain barrier,

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cross cell membrane and the placenta. If so, it is possible that the penetration of microplastics in secondary tissues, such as liver, muscle, and brain, may occur. Moreover, it is expected that interactions of micro-and nano plastic with the immune system may potentially lead to immunotoxicity and consequently trigger adverse effects in the mammalian body (i.e. Immunosuppression, abnormal inflammatory and immune activation response).

Conclusion

The increasing outbreak or use of microplastics in the environment, especially in marine environments, and their very small size on the other, have made these polymer particles to be abused by marine organisms. In this way, their access to the food chain has increased through exposing by marine biota such as phytoplankton and zooplankton. After entering the body, bioaccumulation start or microplastics can accumulate in different parts of the body in the mammalian body such as gill, gut and liver and/or cause toxic effects and bad impact by using different mechanisms that are mainly oxidative stress. Highest microplastics accumulation occur in the intestine of the organism. The natural microbiota of the gastrointestinal system in marine animals can be altered by the accumulation of microplastic.

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