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PROSPECTS OF VERMICOMPOSTING IN ABIOTIC STRESS MANAGEMENT

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ABSTRACT

Climate change due to global warming and changing agricultural practices such as overuse of inorganic fertilizers, pesticides, herbicides etc., deteriorates the environmental stability. It creates abiotic stresses in the agricultural sector, especially in arid and semi-arid regions. The different abiotic stresses such as soil salinity, acidity, deficient or excess moisture, drought, metal toxicity, reduced soil health, land degradation etc., severely affect agricultural productivity and farmers' income. Hence, there is a need to find an environment-friendly and economically viable farming method that can eliminate the negative impacts of abiotic stresses on plant yield. Using organic fertilizers like animal manure and composted materials enhances a healthy ecosystem. Vermicomposting is now widely recognized for converting organic materials into nutrient-rich fertilizer and soil conditioner. This review summarizes the Importance of vermicomposting in managing different abiotic stresses through its positive impact on soil and ecosystem. Vermicompost application improves soil structure and microbial activity to combat soil stress. It reduces water stress by managing soil-air-water relation and maintain long-term soil fertility by providing macro and micronutrients in optimum quantity. The different experimental investigations suggested using vermicompost and vermiwash to mitigate abiotic stresses and can be helpful for sustainable agriculture.

KEYWORDS: Earthworms, Vermicomposting, Vermiwash, Abiotic stress

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INTRODUCTION

After the onset of the green revolution (1965-66), food production significantly increased due to intensive farming and imbalanced agrochemicals. This intensification of agriculture boosted food production but had a detrimental effect on the environment and society. Heavy use of agrochemicals destroyed soil's natural fertility, killed many beneficial soil organisms, and impaired the power of 'biological resistance' in crops, making them more susceptible to insect pests and diseases. In addition, several anthropogenic activities have released greenhouse gases, one of the major factors for climate change and, in turn, the frequent occurrence of abiotic stresses in agriculture.

Nowadays, abiotic stresses are major constraints in agricultural crop production across the globe. It includes physical and chemical stresses such as solar radiation, temperature (high and low), moisture (both excess and deficit), soil salinity, alkalinity, nutrient availability, agrochemical contaminations in soil and water resources etc., impacting the growth and productivity of the crop. Furthermore, abiotic stresses also interact with biotic stresses making the plant more susceptible to infestations (Mariani et al., 2017; Gull et al., 2019). Around 91% of the world's agricultural area is afflicted by abiotic stresses, leaving only 9% suitable for crop production (Minas et al., 2017). Thus, the scientific community worldwide is looking for viable options for managing agriculture in abiotic stressed regions for sustainable crop production.

The demand for 'natural and organic food' is increasing day by day. Therefore, organic farming is regaining momentum among the stakeholders as an alternate strategy for mitigating the effects of abiotic stresses for sustainable crop production. Vermicompost amendment is a well-known strategy to enhance the health of degraded soil, availability of mineral elements, increasing soil productivity, and reduce the effects of abiotic stresses via improving soil structure. In addition, vermicompost can reduce the harmful effects of various environmental stresses on plants due to its porous structure, high water storage, hormone-like substances and high levels of macro and micronutrients (Saeed and Raheleh, 2018).

WHAT IS VERMICOMPOSTING?

Vermicomposting produces compost by utilizing earthworms to turn the organic waste into high-quality compost consisting mainly of worm cast and decayed organic matter (Ismail, 2005; Devi and Prakash, 2015). Vermicompost is an organic fertilizer rich in NPK, micronutrients and beneficial soil microbes, a sustainable alternative to chemical fertilizers,

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an excellent growth promotor and protector to crop plants (Sinha et al., 2011; Chauhan and sing, 2015). Vermicompost is a finely divided peat-like material with excellent structure, porosity, aeration, Draining and moisture holding capacity (Ismail, 2005; Edwards et al., 2011). Vermicompost application is an effective way to maintain soil health and productivity.

PREPARATION OF VERMICOMPOST

Generally, the bed method is considered easy to prepare vermicompost in a pit or PVC sheet. The entire process of vermicomposting in PVC sheet of size 12×8×2 feet is mentioned below (Flow chart A and Fig 1-8).

Collect the biomass and dry it under the sun by keeping for about 8-12 days

⇓

Use this biomass for preparation as basal layer

⇓

Add (6-8) cm thick layer of soil or sand to ensure proper drainage

⇓

Prepare a layer of moistened loamy soil up to the height of 15 cm and inoculation of earthworms into it. For eg. *Eisenia foetida*

⇓

Scatter lumps of fresh or dry cattle dung over the moistened soil.

⇓

Cover the soil with dry grass clippings or farm waste up to 10 cm thickness

⇓

The unit should be covered properly to protect the earthworms from birds and sunlight

⇓

It should be kept moist by sprinkling water twice a week

⇓

Maintain proper moisture and temperature and avoid the compost from overheating

⇓

Turning should be done once a week to ensure proper decomposition

⇓

The compost would be ready within 60-90 days by decomposition.

Flow Chart A: Different steps to prepare the vermicompost

1. **Basal layer preparation using crop biomass**

2. **A layer of moistened loamy soil**

3. **Scattering lumps of fresh or dry cattle dung**

4. **Covering with dry grass clippings or farm waste**

5. **Sprinkling of water to maintain moisture**

6. **Turning to ensure proper aeration**

7. **Seiving of Prepared Vermicompost**

8. **Harvested Vermicompost**

Fig 1-8. Preparation of vermicompost

CHARACTERISTICS OF VERMICOMPOST

The nutrient content of vermicompost is generally higher than the compost prepared traditionally with the same raw material.

Table 1: Nutrient analysis of vermicompost

S. No.	Parameters	Content
1	Organic Carbon (%)	9.15 - 17.88
2	Total Nitrogen (%)	0.5 – 0.9
3	Total Phosphorus (%)	0.1 – 0.26
4	Total Potassium (%)	0.15 – 0.256
5	Total Sodium (%)	0.055 – 0.3
6	Calcium & Magnesium (Meq/100 g)	22.67 – 47.6
7	Copper (mg L^{-1})	2.0 – 9.5
8	Iron (mg L^{-1})	2.0 – 9.3
9	Zinc (mg L^{-1})	5.7 – 9.3
10	Sulphur (mg L^{-1})	128.0 – 548.0

(Source: Sreenivas et al., 2000)

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ROLE OF WORMS IN VERMICOMPOSTING

Aristotle referred to earthworms as "the intestines of earth and the restoring agents of soil fertility" (Shipley, 1970). A good population of earthworms are an indicator of healthy soil containing a large population of bacteria, fungi, viruses and insects (Lachnicht and Hendricx, 2001); therefore, they are also called as "Ecosystem Engineers". A status report prepared by CAPART recommended that *Eisenia foetida* is best-suited species throughout India whereas, *Eisenia Eugenie*, *Perionyx excavates*, *Perionyx sansibaricus* are best suited for southern parts of country (Kumar C.A., 1994)

Earthworm gut is an effective tubular bioreactor consisting of 73% gram-negative, facultative anaerobic, Vibrio sp. which degrade the ingested food and produce wormcast. The glands are present in the earthworm gut's anterior region that produces mucus, thereby providing a favorable substrate for symbiotic microorganisms to decompose complex organic compounds (Rajendran et al., 2008). Wormcast also contains enzymes like amylase, lipase, protease, cellulase and chitinase, which, even after excretion, continue to disintegrate organic matter (S. A. Abbasi, 2001). Earthworms rapidly convert waste into humus substances having finer structure and more diverse microbial activity (Atiyeh et al., 2000). A schematic diagram showing the beneficial role of earthworms (Fig 2).

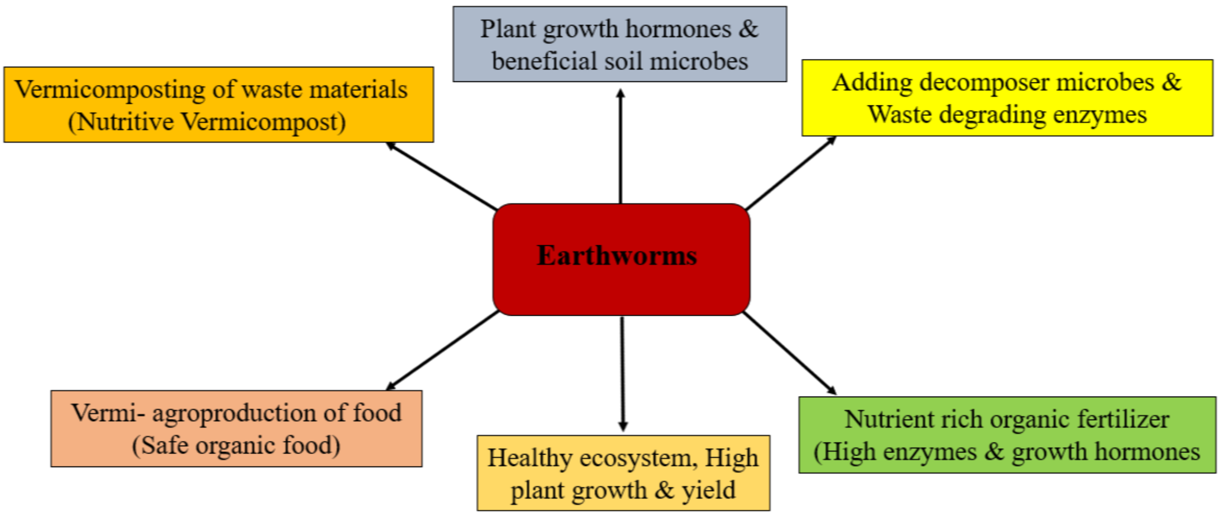

Fig 2. Role of Earthworm in vermicomposting

(Source, Adapted from Rajiv K. Sinha, 2009)

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VERMIWASH

Nowadays along with vermicompost, vermiwash is also gaining Importance in sustainable agriculture for its origin, cost-effectiveness, easy availability, reproducibility and eco-friendliness (Zambare et al., 2008). Vermiwash is a liquid collected after the passage of water through different layers of earthworm culture units. It contains not only the excretory products and mucus secreted by earthworms but also micronutrients associated with soil organic molecules. Vermiwash is a liquid fertilizer used as foliar spray to transport leaves, shoots and other plant parts. If collected properly, it appears like clear, transparent or pale yellow-coloured fluid (Ismail, 1997). Vermiwash possesses the inherent property of acting as a fertilizer and mild biocide (Pramoth, 1995). Vermiwash, the extracted body fluid of

Table 2: Nutrient analysis of vermiwash

S. No.	Parameters	Content
1	pH	7.39-7.5
2	EC	0.008±0.001
3	Organic Carbon	0.25 ± 0.03%
4	Nitrogen	0.01-0.001%
5	Phosphorus	1.70%
6	Potassium	26 ppm
7	Sodium	8 ppm
8	Calcium	3 ppm
9	Copper	0.01 ppm
10	Iron	0.06 ppm
11	Magnesium	160 ppm
12	Manganese	0.60 ppm
13	Zinc	0.02 ppm
14	Total heterotrophs (cfu/ml)	1.79 × 103
15	Nitrosomonas (cfu/ml)	1.01 × 103
16	Nitrobacter (cfu/ml)	1.12 × 103
17	Total Fungi (cfu/ml)	1.46 × 103

(Source: http//www.erfindia.org/vermiwash.asp)

earthworms, is nutrient-rich and possesses good plant growth-promoting components (Gorakh et al., 2009). Therefore, it can be effectively used for sustainable plant production at a low input basis green farming (Edwards et al., 2004). Weerasinghe et al. (2006) revealed that for tea, coconut and horticultural crops, vermiwash acts as a natural growth supplement.

IMPORTANCE OF VERMICOMPOSTING IN ABIOTIC STRESS MANAGEMENT

A) MANAGING SOIL STRESS

Soil stress includes several soil constraints such as soil salinity, alkalinity, structural deterioration, hard pans, shallow soils, surface sealing, metal contamination, low organic matter, etc. The use of vermicompost and vermiwash can mitigate these problems. Manivannan et al. (2009), through their experiment on beans, concluded that the treatments receiving vermicompost and vermi+NPK showed a significant decrease in particle density and bulk density than NPK alone. Vermicompost application enhances microbial population and activity, which form soil aggregates and thus increase soil porosity and thereby improving soil structure. Vermicompost had a considerable buffer capability as it increased soil pH in acidic soil and reduced it in alkaline soil (Fernandez-Bayo et al., 2009), thus found that its additions changed soil pH to neutral levels. Manivannan et al. (2009) experimented on clay loam soil and sandy loam soil and showed that application of vermicompost @ 5 tonnes ha^{-1} reduced pH (1 and 1.02 times) and EC (1.4 and 1.2 times), increased organic Carbon (37 and 47 times), in both soil types. Applications of osmoprotectants and antioxidants, i.e. vermicompost, glycine betaine and proline singly or in sequence, shows positive effect under irrigation with saline water stress condition. These also enhance ROS (Reactive oxygen species) scavenging and metal ion chelating, which forms a crucial part of abiotic stress responses in plant cells (Ezzat et al., 2019).

More than 800 million hectares of land throughout the world contain stressful salt ion concentrations for plant growth (FAO 2008). Soil salinity is one of the most severe environmental stresses which reduces productivity as well as the yield of agriculture. Excessive salt concentration leads to structural degradation, decreases soil microbial activity and alters soil osmotic and metric potential (Oo et al., 2015). It also affects plants' biochemical and physiological pathways. To overcome these problems, using vermicompost is one of the best solutions to present farming. Both vermicompost and vermiwash contain humic substances which act as activators of physiology as well as nutrient absorption and help to mitigate the stress of salinity (Reyes-Perez et al., 2014).

Table 3: Scientific evidence of vermicompost in managing soil salinity stress

Sr. No.	Findings	References
1.	Earthworms and Arbuscular mycorrhizal fungi cooperatively increased maize salt tolerance and growth under high salt stress by improving soil macroaggregates and decreasing salt concentration, followed by enhancing plant mineral assimilation (K, Ca, Mg), osmotic regulation and improving photosynthetic efficiency.	Zang et al. (2018)
2.	Earthworms reduced salt concentration in soil by increasing porosity, aeration, leaching of exchangeable Na^{+}, and adding organic matter. It also improves soil CEC and thereby increases Na^{+}- Ca^{2+} exchange.	Oo et al. (2015) and Wang et al. (2016)
3.	The survival of tamarind (*Tamarindus indica*) was only 20% after 80mM NaCl addition, but it was increased up to 85% with vermicompost. Without vermicompost, plant growth and photosynthesis were reduced by two-fold at 20mM NaCl, but with vermicompost, there was no inhibitory effect. Vermicompost limits salinity's negative effect on the tamarind plant's growth.	Maria et al. (2008)
4.	It was found that vermicompost is an appropriate growing media for vegetable seedling propagation during the nursery period even under salinity stress conditions due to enhanced plant physiological efficiency. In addition, a higher growth rate was provided during the stand establishment time.	Sallaku et al. (2009)
5.	The addition of Vermicompost and vermiwash in saline soil minimized the influence of salinity stress on growth parameters, viz. plant height, stem diameter, fresh and dry weight, and tuber characteristics such as pH and EC and total soluble sugars in potato plants. Furthermore, when NaCl concentration in soil increased, the total sugar concentration in potatoes also increased due to adaptive mechanisms in potato plants after the application of vermicompost.	Jose de Jesus Perez-Gomez et al. (2017)

6.	Commercial tomato seedlings showed improved root growth, higher no. of leaves, increased leaf area, increased total sugars and chlorophyll content and greater stem thickness after vermicompost leachate (VCL) treatment, even at high NaCl- tested concentration (100 mM). VCL- treated seedlings showed more tolerance to osmotic and oxidative stress due to the accumulation of compactible solutes such as proline.	Mayashree Chinsamy et al. (2013)

B) MANAGING WATER STRESS

Water stress is one of the plants' most frequent and damaging abiotic stressors, which highly reduces yield. The production of ROS (reactive oxygen species) might increase in plants under water-stress conditions. This ROS production may promote damaging processes and provide signals for adaptation to environmental changes (Jubany-Mari et al., 2012). Humic acid in vermicompost affects plant hormonal regulation and root growth pathways (Mora et al., 2010).

Table 4: Scientific evidence of vermicompost in managing water stress:

Properties	**Findings**	**References**
Grain Yield	At 50% field capacity, the control plot gives a 3.06 ton/ha grain yield. Application of Vermicompost increases yield up to 3.76 ton/ha and vermi.+ Biochar gives the highest yield of 4.38 ton/ha under water stress in saline-sodic soil due to its positive effect on soil physicochemical properties.	Emad M.H. et al. (2020)
Water retention	Application of Vermicompost increases macropore space in soil ranging from 50-500 μm, which improves air-water relation in soil and thereby favourably affect plant growth.	Marinari et al., (2000)
	Vermicompost contain absorbent organic matter which holds water according to plant roots requirement and thus increases water retention capacity of soil	Kumar A., (2005).

Plant traits	Addition of 30% vermicompost under moderate and severe water stress conditions increases plant height, no. of pods, leaf area, dry weight, carotenoids in chickpea and its water use efficiency over control.	Hamzeh Amiri et al. (2017).
	The application of humic acid protected cell membrane permeability in rice crop under water loss condition	Gracia et al. (2012).
WHC	WHC, Porosity and moisture content recorded initially were 41%, 34% and 36% respectively and the increased respective values were 49%, 44% and 46% after application of vermicompost and vermiwash.	Tharmaraj et al. (2011)
ABA Content	In water stress condition, the ABA content was increased in roots and leaves of rice plant. However, when water stress was associated with treatment humic acid from vermicompost, the ABA level was similar to those plants without water stress.	Gracia et al. (2014)
Growth and Yield	Vermicompost improved maize growth and yield but its effect was only significant when water availability was limited. This suggested vermicompost's promising role in improving agrosystem resistance to water stress.	Doan et al. (2015)

C) MANAGING NUTRIENT STRESS

Vermicompost has higher nutritional values than traditional compost because of increased rates of mineralization and degree of humification by the action of earthworms (Azarmi et al., 2009). It is ideal organic manure for the growth and yield of plants as it is a nutrient-rich organic fertilizer. It is rich in NPK, Micronutrients, plant growth hormones and enzymes. Therefore it acts as a ‘growth promoter' and 'plant protector'. It is highly porous and has a large surface area, retaining nutrients for longer than conventional compost. Also, it acts as a 'slow-release fertilizer', lowering the soil's nutrient depletion. The nutrients present in vermicompost in such a form that can be readily absorbable by plants, such as nitrates, exchangeable Phosphorus, soluble Potassium, calcium and magnesium (Manivannan et al., 2009, Prabha ML, 2009). Nitrogen in vermicompost is mostly present in Nitrates form rather than ammonical form (Atiyeh et al., 2001).

Singh M. and Kundan Wasnik (2013) concluded that the available NPK in the soil after harvesting of the crop was found to be highest in treatments receiving vermicompost (12 t ha^{-1}) + Fertilizer NPK (100:25:25 kg ha^{-1}) than NPK alone. This was due to the slow mineralization of nutrients from vermicompost than chemical fertilizers. Humic acids in vermicompost enhance nutrient uptake by the plants as it increases the permeability of root cell membrane, stimulating root growth and increasing the proliferation of root hairs (Pramanik et al., 2007). Vermicompost is a soil conditioner, and its continuous application improves soil quality and fertility, even in degraded and sodic soils. Application of Vermicompost @ 6 tons/ha increased available Nitrogen by 829.33 kg/ha and reduced sodicity (ESP) by 73.68 (Sinha et al., 2008).

D) IMPROVEMENT IN SOIL BIOLOGICAL PROPERTIES

Several authors have noted that the soil microbial community can be changed and improved by earthworms. Vermicompost not only adds useful microorganisms to the soil but also provides food for the existing microbes, increasing soil's biological properties and capacity for self-renewal soil fertility (Shiralipour et al., 1992; Ouedraogo et al., 2001). It consists of beneficial soil microbes like 'nitrogen-fixing bacteria' and 'mycorrhizal fungi, which acts as growth promotor and protectors (Sinha et al., 2009). The respiratory activity of the microbial community can be measured by dehydrogenase enzyme activity and was found to be greater in vermicompost than in commercial medium (Atiyeh et al., 2001).

Manivannan et al. (2009) reported that total microbial activity and population had been significantly enhanced in treatments where vermicompost and vermicompost +NPK were applied. Pramanik et al. (2007) demonstrated that vermicompost obtained from cow dung showed the highest abundance of the microbial population, i.e. total bacterial count was 73×10^{8}, cellulolytic fungi was 59×10^{6}, and nitrogen-fixing bacteria was 18×10^{3}. This vermicompost shows the highest urease activity (15.84 µg NH_4-N/g/h) and acid phosphatase activity (200.45 µg *p*-nitrophenol/g/h). Greater phosphatase activity indicates greater nitrogen content of the substrate, which in turn results in higher microbial activity. Organic treatments can stimulate soil biological activity due to the synergism of soil and microorganisms present in organic material or stimulation of microbial growth by organic compounds added with vermicompost and manure (Marinari et al., 2000). An introduction of vermicompost is more meaningful than the direct introduction of earthworms into filed. If vermicompost is applied in the field for longer, it shows the sustenance of the microbial population. There is an increase in the density of microbes except for actinomycetes, even after two months of crop harvesting (Kale et al., 1992).

Many diseases and growth of parasitic fungi such as Pythium, Rhizoctonia and Verticillium are suppressed after applying an ample quantity of Vermicompost (Sing et al., 2008). It also inhibits the incidence and abundance of plant parasitic nematodes in the soil, such as Meloidogyne incognita in tobacco plants (Swathi et al., 1998), egg mass of Meloidogyne javanica (Ribeiro et al., 1998) and also a significant reduction in the populations of spider mites (*Tetranychus urticae*), mealy bugs (*Pseudococcus* sp.) and aphids (*Myzus persicae*) (Arancon et al., 2007)

E) CROP QUALITY AND YIELD

Vermicompost is nutrient-rich, microbiologically active, porous material which acts as a gradual and constant source of nutrients (Chaoui et al., 2003); hence when added to soil influences plant growth and yield. Therefore, it improves the quality of agricultural produce by supplying sufficient nutrients in the available form to crops. Crop growth, yield and quality of different field crops, vegetables, flower and fruit crops were effectively enhanced after the application of vermicompost as it improves various physical, chemical and biological soil properties (Alemu Degwale, 2016).

Table 5: Effect of Vermicompost in improving quality parameters and yield

Sr. No.	Quality Parameters	Reference
1.	Sugar, protein and chlorophyll contents of the root, shoot and leaf of beans, as well as pod length, number of seeds per pod, number of pods per plant and pod weight were higher.	Manivannan et al. (2009)

2.	Vermicompost+ Vermiwash (100g + 100ml) application on okra showed maximum plant height, fat content, protein content and higher nutrient quality of fruits.	Ansari A. and K. Sukhraj (2010)
3.	Vermicompost @7.5 t ha^{-1} supplemented with inorganic fertilizers on strawberry increased plant spread (10.7%), leaf area (23.1%), dry matter (20.7%) and total fruit yield (32.7%). In addition, fruits harvested from this treatment were firmer and had higher TSS, ascorbic acid content and lower acidity.	Singh et al. (2008)
4.	Vermicompost @6 t ha^{-1} showed the highest fruit yield, no. of fruits per plant, fruit length and eggplant height.	Maral Moraditochaee et al. (2011),
5.	The grain yield of wheat and soybean increased by 47% and 51%, respectively.	Baker et al. (2006)
6.	Vermicompost @6 t ha^{-1} gives more potato yield (21.41 t ha^{-1}) over control (4.36 t ha^{-1}) even in soil sodicity stress.	Ansari A.A. (2008)
7.	Vermicompost @8 t ha^{-1} +NPK (150:25:25 kg ha^{-1}) produced optimum herbage and oil yield of rosemary under semi-arid tropical conditions in Bangalore.	M. Singh and Kundan Wasnik (2013)

Vermicompost not only has a positive impact on plant growth and productivity but also increases the nutritional quality of some vegetable crops such as spinach (Peyvast et al., 2008), strawberries (Singh et al., 2008), lettuce (Coria Cayupán et al., 2009), sweet corn (Lazcano et al., 2011) and Chinese cabbage (Wang et al., 2010).

CONCLUSION

Abiotic stress has already emerged as a new threat to agriculture, especially in arid and semi-arid regions. It includes soil stress, water stress, nutrient stress and deterioration in the quality of the produce. Moreover, climate change causes fluctuations in rainfall, high temperature, poor quality of irrigation water etc. This contributes to the formation of abiotic stresses, which largely influence the productivity and income of the agriculture sector. Therefore, there is a need to find a highly economical and ecofriendly way of crop production. Organic and vermicompost-derived products are gaining popularity among farmers because of their huge advantages over the soil and the environment. Vermicompost can replace costly inorganic fertilizers, and gives sustainable production without any harmful effects on soil, plants and the environment. The present issue of the world about the quality and nutritious food products can be solved with organic amendments. Furthermore, many global problems about soil, such as salinity, sodicity, improvement in soil fertility, physicochemical properties, soil health and reduction in pests and diseases, and stresses related to water availability, can be resolved with vermicompost. Nowadays, vermiculture technology is a big step towards sustainable development in agriculture.

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POPULAR ARTICLE

RECENT SOIL SCENARIO OF INDIA- PROBLEMS AND MITIGATION

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ABSTRACT

The soil is a crucial factor for better establishment and crop growth. The soil fertility, physical properties, chemical properties, and biological properties are vital for enhancing the productivity of crops. However, recently due to some problems like indiscriminate use of chemicals, lack of proper crop rotation, more industrialization, deforestation and other biotic or abiotic factors degrade the soil fertility and increase the problems like erosion, desertification, waterlogging, salinity etc. Adopting appropriate management strategies and government policies can help reduce the different problems of soil.

INTRODUCTION

Soil is three-dimensional (length, breadth, height) dynamic (Physical, chemical, biological) natural body that supports plant growth which has been formed by the action of climate and organism on parent material as conditioned by relief over some time. The soil composition contains 25% water, 25 % air, 5% organic, and 45% mineral matter. The soil is a crucial factor for better establishment and growth. The soil fertility, physical properties, chemical properties, and biological properties are vital for enhancing the productivity of crops. However, recently due to some problems like indiscriminate use of chemicals, lack of proper crop rotation, more industrialization, deforestation and other biotic or abiotic factors degrade the soil fertility and increase the problems like erosion, desertification, waterlogging, salinity etc. The different soil problems and their remedial measurements are discussed below:

DECLINING SOIL FERTILITY:

- Indian soils often have high potassium levels but low levels of nitrogen and phosphorus.

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- The Indo-Gangetic plains, Central India, and North East India have low phosphorus levels.
- Additionally, there is a national shortage of nitrogen; however, it is worse in central and southern India than in the Gangetic plains.
- Long-term unbalanced fertilizer use has also been documented to have a negative impact on soil health.

- According to a 2017 analysis by the Fertilizer Association of India, the optimal N:P:K utilization ratio is 4:1; however, from 6:2.4:1 in 1990 to 6.7:2.7:1 in 2016, this ratio has decreased.
- According to the 54th report of the Parliamentary Standing Committee on Agriculture (2017–18), the imbalance in the use of fertilizers in agriculture is caused by a lopsided subsidy policy in favor of urea and excessive prices for other fertilizers.
- Indian soil is becoming less fertile due to extractive agricultural methods such as crop waste clearance and in-field burning (common in north-west India).

Management of soil fertility: By using green manure or growing legumes to fix nitrogen from the air through the process of biological nitrogen fixation, applying micro-dose fertilizer applications to replace losses through plant uptake and other processes, and minimizing losses through leaching below the crop rooting zone, soil fertility can be further increased. These practises improve soil structure and foster healthy, fertile soil.

WATERLOGGING

- Waterlogging is caused by the flat, saucer-shaped depressions that slow surface water circulation and cause rainwater to accumulate.
- Additionally, seepage from unlined canal systems or channels causes adjacent agricultural regions to flooding.

- Waterlogging affects over 12 million hectares of land in India.
- Water logging might be avoided and surplus water disposed of by providing room for horizontal and vertical drainage.

MANAGEMENT OF WATERLOGGING CONDITIONS: The water logging conditions can be managed by improving the soil structure, raising the soil level or making a raised bed, by managing the moisture by using plants, cover crops, the addition of organic matter and subsoiling.

INDUSTRIALIZATION

- Agriculture, forestry, grassland and grazing, and undeveloped regions with wild flora are all being steadily displaced by industrialization.
- For instance, opencast mining is a special concern since it affects a place's socioeconomic characteristics and changes the soil's physical, chemical, and biological characteristics.

- Additionally, the soil on a large land degrades because of the massive amounts of trash, overburden, tailings, and slimes produced by the mining industry.

MANAGEMENT STRATEGIES: Following practices may be adopted to reduce the effect of industrialization:

- Adoption of Good government practices to protect the local industry.
- The government should actively participate in industrial growth through co-owning businesses.
- Transportation facilities should be offered to facilitate simple product evacuation.
- Industrial zone creation will also provide a favourable environment with all the necessary infrastructure for industrialization.
- The creation of industrial banks is necessary to give industrialists access to credit.
- Government stability: To draw in international investment, the government must be stable.
- Local raw material exploitation: There should be local raw material exploitation for industries.

SALINITY

- In irrigated areas, salinity occurs due to excessive irrigation. Conversely, farmers who over irrigate their fields cause salt deposits because capillary action causes the groundwater level to increase. For instance, due to intensive irrigation, the soils in Punjab and Haryana are rendered unusable by salt and alkalinity.
- Consequently, it is essential to use water supplies wisely.

MANAGEMENT STRATEGIES TO REDUCE SALINITY: Reducted use of salty water, increased utilization of desalinated, recycled, and rain-harvested water, and avoiding over-irrigation can help in the reduction of salinity. Apart from this addition of organic material and manure and use of mulch or cover crops may help to safeguard the ground surface against salinity.

DESERTIFICATION

- Due to human activity or climate change, desert-like conditions are spreading in arid and semi-arid areas. Excessive grazing, reckless tree cutting, societal pressures also aggravating this situation further.
- There is a chance that it will lead to increased wind erosion, decreased output, and more frequent droughts.

MANAGING DESERT LAND: Maintenance of soil fertility and health, promotion of resistance of land used for livestock grazing, increased biodiversity, better nutrient cycling, and minimising erosion may help to reduce the desertification process.

SOIL EROSION

- It is the loss of soil by natural factors, primarily water and wind, more quickly than its replacement can occur.
- It has an impact on the nation's overall economy and agricultural productivity.

MANAGEMENT STRATEGIES: Adoption of Contour farming, Reforestation, application of mulches, avoiding overgrazing, using plastic sheets and avoiding soil compaction may help reduce soil erosion.

CONCLUSION

The soil is a crucial factor for better establishment and crop growth. The soil fertility, physical properties, chemical properties, and biological properties are vital for enhancing the productivity of crops. However, recently due to some problems like indiscriminate use of chemicals, lack of proper crop rotation, more industrialization, deforestation and other biotic or abiotic factors degrade the soil fertility and increase the problems like erosion, desertification, waterlogging, salinity etc. Adopting appropriate management strategies and government policies can help reduce the different problems of soil.

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POPULAR ARTICLE

PHYTOREMEDIATION: A GREEN TECHNOLOGY TO CLEAN UP CONTAMINATED SOIL

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ABSTRACT

Phytoremediation, or the use of green plants to clean and regulate pollutants in water, soil, and air, is a critical component of the emerging area of ecological engineering. Site's soil and water parameters, nutrient sustainability, meteorological, hydrology, viable ecosystems, and pollutant characteristics determine in situ and ex-situ uses. In many applications, phytotoxicity and mass transport restrictions or bioavailability are crucial. Most applications are affordable since they rely on sunshine and in-situ nutrient recycling, however, treatments across vast land areas and longer treatment durations are mainly confined to root zones and shallow water. Wetlands, grasslands, crops, and tree plantations have been used successfully to treat a range of pollutants, often present in low quantities and are not highly phytotoxic.

INTRODUCTION

Heavy metal contamination has been identified as one of the key abiotic pressures causing environmental degradation in recent decades. Although heavy metals occur naturally in soil, geologic and human activities raise their concentration to levels that may be hazardous to both plants and animals due to their potential toxicity, which disrupts their physiology and development.

Metals are taken up by plant roots and translocated to the shoot system, where they can endanger human health when they reach the food chain. The phytoremediation process involves using plants and the bacteria that live on them to clean up the environment. This method uses natural mechanisms in plants and the microbial rhizosphere flora to break down and store organic and inorganic contaminants. A reliable method of cleaning up different organic and inorganic toxins is phytoremediation. Most organic contaminants in the environment are artificial and toxic to living things. Some of them are carcinogenic and many are poisonous. Through spills (fuel, solvents), military operations (explosives, chemical weapons), agriculture (pesticides, herbicides), industry (chemical, petrochemical), wood treatment, etc., organic pollutants are discharged into the environment. Depending on their qualities, organic materials may be taken up by plants or degraded in the root zone before being degraded, sequestered, or volatilized. Successful phytoremediation has been used to treat a variety of organic pollutants, including the most prevalent groundwater pollutant, TCE, herbicides like atrazine, explosives like TNT, petroleum hydrocarbons like oil, gasoline, benzene, toluene, and PAHs, the fuel additive MTBE, and polychlorinated biphenyls (PCBs). It is normal for inorganic contaminants to exist in the earth's crust or atmosphere. Their release into the environment is facilitated by human activities including mining, industry, transportation, agriculture, and military, which causes toxicity. Although inorganics cannot be broken down, they can be stabilised or sequestered in plant tissues that can be used for harvest through phytoremediation. Plant macronutrients like nitrate and phosphate, plant trace elements like Cr, Cu, Fe, Mn, Mo, and Zn, non-essential elements like Cd, Co, F, Hg, Se, Pb, V, and W, and radioactive isotopes like 238U, 137Cs, and 90Sr are examples of inorganic pollutants that can be remedied by phytoremediation. For solid, liquid, or gaseous substrates, phytoremediation is one option. At military sites (TNT, metals, organics), agricultural fields (herbicides, pesticides, metals, selenium), industrial sites (organics, metals, arsenic), mine tailings (metals), and wood treatment sites, for instance, contaminated soils and sediments have been phytoremediated (PAHs). Sewage and municipal wastewater (nutrients, metals), agricultural runoff/drainage water (nutrients from fertilisers, metals, arsenic, selenium, boron, organic pesticides, and herbicides), industrial wastewater (metals, selenium), coal pile runoff (metals), landfill leachate, mine drainage (metals), and groundwater plumes are examples of polluted waters that can be treated by phytoremediation (organics, metals).

Additionally, plants can filter out airborne contaminants, including NOx, SO2, ozone, CO2, nerve gases, dust or soot particles, or halogenated volatile hydrocarbons inside and outside. In the last 10 years, business and governmental organisations have been more interested in phytoremediation. Due in part to the comparatively low cost of phytoremediation and the restricted funding for environmental cleaning, this practice has become increasingly popular. Environmental clean-up comes with astronomical prices. Currently, $6-8 billion and $25-50 billion respectively are spent yearly on environmental cleaning in the US. Phytoremediation is, on average, ten times more affordable than engineering-based remediation techniques such as soil excavation, soil washing or burning, or pump-and-treat systems since biological processes are ultimately solar-driven. Additionally, the cost-effectiveness of phytoremediation is enhanced by the fact that treatment is often done in place. It could lessen how much of the contaminated substrate is exposed to people, animals, and the environment. Phytoremediation offers benefits but also has its drawbacks.

The plants that handle the cleaning need to be close to the contaminant and capable of responding to it. Soil characteristics, toxic levels, and climate should all promote plant development. If soils are toxic, they can be improved using amendments, as explained below, to make them more conducive to plant development because the plants need to be able to reach the pollution, phytoremediation is likewise constrained by root depth. For herbaceous plants, the normal root depth is 50 cm, whereas, for trees, it is 3 m. Pollutant breakdown by plants and flow via phytoremediation systems both function fairly quickly (days or months), while soil cleaning by plant accumulation sometimes takes years, limiting application. The contaminants' bioavailability may also put a cap on phytoremediation. Phytoremediation is not appropriate if just a small portion of the pollutant is bioavailable yet the legal cleaning criteria demand that all of the contaminants be eliminated. However, adding soil amendments—as explained below—can increase pollutant bioavailability. However, certain phreatophytes have been seen to tap into groundwater at depths of 15 metres or more, particularly in dry conditions. Bio/phytoremediation does not preclude non-biological remediation techniques. The most successful and economical remediation method may involve a mix of multiple methods, such as digging the most polluted areas and polishing the site with plants, because pollutant distribution and concentration are heterogeneous at many sites. A diverse team of skilled scientists is necessary for such an integrated remediation endeavour.

PHYTOREMEDIATION METHODS

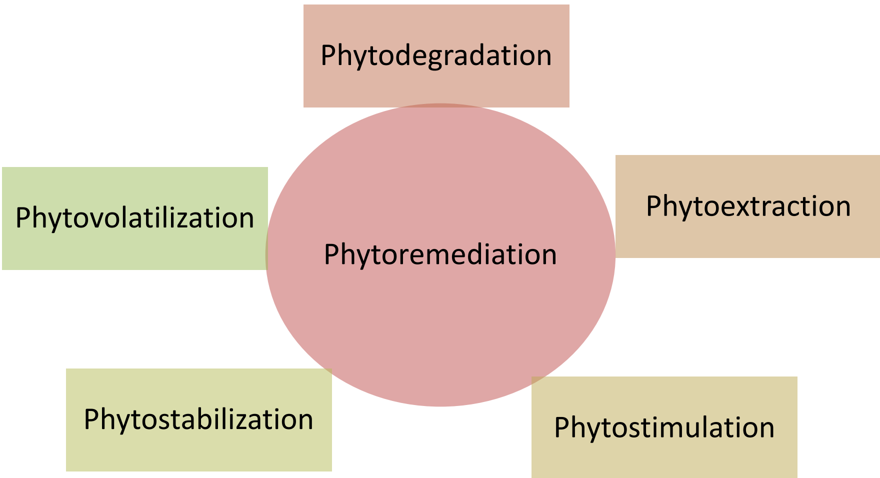
There are several ways to employ plants and creatures in their rhizosphere for phytoremediation. They can be employed as filters in hydroponic systems, such as rhizofiltration, or artificial wetlands. In order to prevent pollution from seeping below or from spreading horizontally, trees can be employed as hydraulic barriers to producing an upward water flow in the root zone. In hydroponic systems, referred to as rhizofiltration, plants and the creatures in their rhizosphere can act as filters.

Trees can be employed as hydraulic barriers to induce an upward water flow in the root zone, stop pollution from seeping downward, or stop a contaminated groundwater plume from spreading horizontally. Rhizofiltration is conceptually similar to phytoextraction, however, it focuses on treating dirty groundwater as opposed to polluted soils. Either the plant roots absorb the pollutants or they are adsorbed onto the root surface. Plants used for rhizoliltration are first acclimated to the pollutant before being planted at the intended location. Plants are hydroponically cultivated in clean water instead of dirt until they have a substantial root system. After the plant has established a thick root system, a contaminated water source is switched out for it to help the plant adjust. Once the plants have adapted, they are placed in the polluted region, where the roots absorb the contaminated water. Pollutants may be stabilised or decomposed in the rhizosphere, sequestered or degraded inside the plant tissue, or volatilized during phytoremediation.

The process of using plants to stabilise pollutants in soil—either by merely avoiding erosion, leaching, or runoff or by changing contaminants into less bioavailable forms—is known as phytostabilization (e.g., via precipitation in the rhizosphere).

This lessens or even stops pollutant mobility, reducing migration into the groundwater or air and contaminant bioavailability, inhibiting transmission through the food chain. The process through which soil-borne metal pollutants are ingested by plant roots and transferred to their tissues above the soil surface is known as phytoextraction. Many different plants can be employed since they all have varying capacities for absorbing and resisting high concentrations of contaminants.

This is especially crucial for sites that have been contaminated with several metal contaminants. The plants are collected and carefully disposed of once they have grown and absorbed the metal contaminants. This process is done numerous times to bring the contamination level down to acceptable limits. The metals can occasionally be recycled by a procedure called phytomining, but this is often only done with valuable metals. Zinc, copper, and nickel have all been successfully phytoextracted, but there is also interesting research being done on lead and chromium absorption plants. Phytodegradation is the breakdown or degradation of organic pollutants caused by a plant's internal and external metabolic activities. Ex-planta metabolic activities hydrolyze organic substances into smaller fragments that the plant may absorb. Some pollutants can be taken up by plants and subsequently degraded by plant enzymes. As the plant matures, it may utilise these smaller pollution molecules as metabolites, which would subsequently be integrated into the tissues of the plant. It has been shown that some plant enzymes break down organic pesticides, chlorinated solvents like TCE (trichloroethane), and waste from the manufacture of weapons. Plants absorb water soluble contaminants and release them into the atmosphere when they transpire water. This process is known as phytovolatilization.



As water moves from the roots to the leaves through the plant's vascular system, the pollutant may change along the journey and evaporate or volatilize into the air around the plant. Plants have various degrees of effectiveness as phytovolatilizers, with one research finding that poplar trees may volatilize up to 90% of the TCE they ingest. In the past ten years, phytoremediation—the use of plants and the bacteria that live on them—has gained popularity as an economical, non-intrusive substitute for or in addition to engineering-based remediation techniques. Utilizing plants for pollution extraction, degradation, or volatilization is possible. The case studies that are presented here in this chapter will help readers better understand the various phytoremediation techniques.

NEW DEVELOPMENTS IN PHYTOREMEDIATION

- One of the most dangerous pollutants endangering human health and ecosystems is mercury (Hg), which has been introduced from both natural and man-made sources. Recent calculations show that yearly global emissions range from 4800 to 8300 tonnes.
- An extremely poisonous organomercurial molecule called methyl Mercury is created when anaerobic sulfate-reducing bacteria methylate mercury, which is often discharged as metal or ionic form and accumulates in sediments.

- The form of mercury found in the environment has a significant impact on its toxicity. The fact that inorganic mercury forms bond tightly to soil constituents that lessen their availability and absorption helps explain why they are often less dangerous than organic mercury forms. Because of increasing tissue accumulation at higher trophic levels, the harmful effects of methyl mercury are further amplified. Organomercurials are strong neurotoxins that enter the bloodstream through the digestive tract at a rate of over 90%, whereas mercury salts and elemental mercury absorb less than 10% and 0.1%, respectively.
- Mercury tends to harm membrane transporters like aquaporins at the plasma membrane of plants, which disrupts the flow of nutrients and water.
- Organomercurials localise quickly to plastids where they build up and impair critical metabolic processes such as electron transport, oxygen evolution, photorespiration, the Hill reaction, and chlorophyll content.
- Mercury cannot be effectively detoxified or converted by plants into more benign forms. Genes from other species can be incorporated into plants through genetic engineering to improve their capacity for phytoremediation. MerAB is a well-characterized phytoremediation method built via the nuclear genome that uses the bacterial merA (mercuric ion reductase) and merB (organomercurial lyase) genes to genetically modify plants for Hg remediation.
- Organomercurial lyase promotes the protonolysis of organic-Hg to Hg2+, whereas mercuric ion reductase converts Hg2+ to Hg0, which is volatilized from plants.

CONCLUSIONS

A major problem for agricultural production and food safety is heavy metal contamination because of its harmful effects and quick buildup in the environment. A number of methods have been developed to stop or lessen heavy metal pollution and replant the contaminated soil.

Compared to other physicochemical procedures, phytoremediation offers several benefits and has been shown to be a potential method for replanting heavy metal-contaminated soil. The simplest method for phytoremediation is the use of heavy metal hyperaccumulators, and hundreds of these plants have already been discovered. molecules and signalling pathways will be crucial for creating the best plant species for genetically engineered phytoremediation.

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POPULAR ARTICLE

AEROPONICS: IMPORTANCE, NEED AND ADVANTAGES

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ABSTRACT

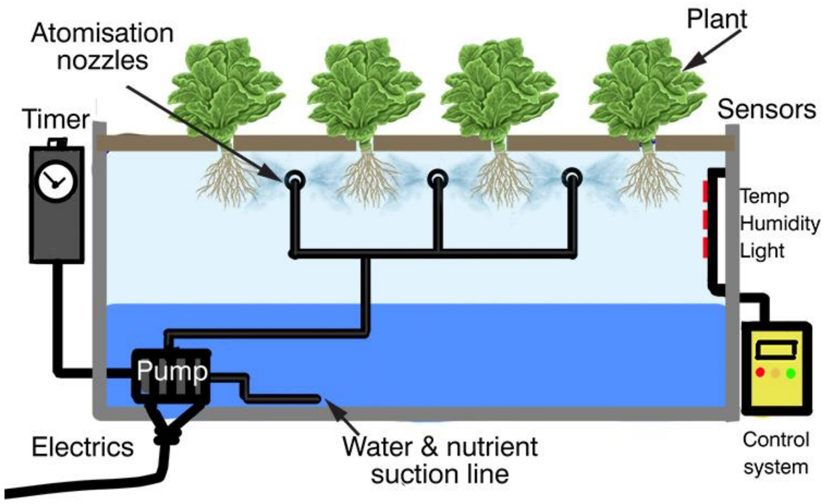
Agriculture without soil is known as aeroponics, the method of growing plants suspended in the air or mist in soilless media. Soil-less agriculture is a very new and advanced practice in which plants are grown without soil, and nutrient-rich water is delivered to the suspended roots via an atomized spray system. The panels form a sealed cage that keeps light out, initiating roots' growth and restricting algal growth. Next, the nutrient-enriched solution sprayed on the roots in a fine mist. Every 2–3 minutes, a few seconds of misting is performed. This will keep the roots wet and the nutrition solution aerated. This technology could be a viable option for supplying various types of vegetables while using less water; less fertilizer and space are required, resulting in a higher yield per unit area.

KEYWORDS Aeroponics, Growing system, Plant production, Soilless culture, Vegetables.

INTRODUCTION

In the next four years, the world's population is predicted to increase by more than 2 billion folks. It was discovered that the addition of almost a hundred hectares of traditional cropland would be necessary to feed them. Only 80% of the world's arable land is currently fit for agriculture. Poor management has rendered roughly 15% of this land unfit for cultivation, and climate change has claimed even more. As the world's population rises, there is a rising need for more food and more space to grow it. With the expanding global population, the need for agricultural output must rise. The increased demand for agricultural output is crucial as the world population continues to grow. A prime piece of agricultural land can be difficult to come to and can be rather costly. There is a good chance that soil illness and chemical pesticides are used, damaging the environment and being hazardous to one's health.

In contrast, in a growing country like India, it is critical to efficiently use resources such as water, sunlight, soil, and money. Rather than relying on technology, traditional agriculture relies more on nature, climate, weather, and seasons. Despite this, we rely significantly on open-field agriculture to survive. The high and inefficient use of water, massive acreage needs, high concentrations of fertilizers consumed, and soil deterioration are only a few of the negative effects of traditional agriculture. Aeroponic farming systems could be a viable option for producing various crops with reduced water, fertilizer, and space requirements, resulting in higher yields per unit area. Such farming takes place in a controlled environment. In order to achieve increased production and revenues, several requirements must be met. However, one of our key objectives is providing clean and fresh food for future generations, particularly given the world's rising population (Alexandratrs and Bruinsma 2012). Several soilless procedures have been used to cultivate the plant under controlled conditions. Singh(2010). When compared to traditional farming, The Aeroponic Growing System (Aeroponic System), which was chosen for its 90 per cent reduction in water use, 60 per cent reduction in nutrient use, stimulated crop growth, and higher density capabilities serve as the foundation of the Controlled Environment High-Rise Farm (CEHRF), an integrated solution of all currently available technologies. In contrast to conventional hydroponics, aeroponics optimizes root aeration, a crucial element in increasing productivity (Soffer & Burger, 1988).



IMPORTANCE OF AEROPONICS

The aeroponic system maximizes the uptake of nutrients while lowering plant stress, resulting in healthier output overall. Aeroponically produced plants have higher nutritional content and better colour, texture, and flavour. In order to improve plant growth, aeroponics is practiced in a closed environment where the grower has complete control over every system component. Traditional farmers have employed artificial life support systems for environmental management, seed germination, and non-damaging plant sustenance for decades. Advancement in artificial life support for strategies of environmental control, seed germination, and non-damaging plant support is aeroponics. Aeroponics' key advantage is its excellent aeration. The efficiency of aeroponics is also demonstrated by how fertilizers and water are provided. Only a small amount of water is required for the fertilizer solutions used on plants. Water is used in enclosed systems is even more diminished because they transform water into a thin mist, and nutrient distribution is more efficient using atomizing nozzles. Osmosis, selective absorption of substances across cell walls, allow plants to receive nutrients through their roots. Because nutrients are given by mist, roots can absorb them more readily.

Fig: Misting of Nutrient Water to Root Zone.

Pharmaceutical medicinal plants can be grown by using aeroponic bio-pharming. Inside a closed loop facility, the technology allows for total containment of remains. According to reports, the technology is 10 times more effective than traditional procedures, such as tissue culture and hydroponics, which are more time-consuming and labour-intensive. The technology is capable of conserving both water and electricity. Because the nutritional solution is recirculated in an aeroponics system, just a small amount of water is consumed.

In contrast, it uses less energy and water per growing area. Aeroponic cloning improves root development, survival, growth, and maturity. According to studies, when the same material is left to produce tubers using conventional techniques, the average tuber yield is lower than in

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aeroponics. Such results suggest that an aeroponics system may be utilized to propagate potatoes effectively. The root aeration in the aeroponics system is optimized. This is so that the plant's stem and root systems may access all of the available oxygen in the air, which encourages root growth. The plant is hung in midair to do this for better root growth. Because photosynthesis requires carbon dioxide concentrations between 450 and 780 ppm, plants in an aeroponics environment have complete access to these ranges. As a result, they grow quicker and utilize more nutrients than plants in a standard hydroponics setting. This agrees with Sun et al. (2004). According to the researchers, the aeroponics system increased leaf stomatal conductance, intercellular CO2 concentration, net photosynthetic rate, and photochemical efficiency.

This was commonly utilized in horticultural species such as tomatoes, lettuce, cucumber, and ornamental plants like chrysanthemums and poinsettias. The increasing need for higher-performing, more effective seed production technology has developed aeroponic seed production systems. Potato seed tuber production has been effectively achieved using an aeroponic method.

Fig; Aeroponic Potato Production.

Aeroponics as you may have guess that plant growth on steroids. As a result, it should come as no surprise that aeroponically produced plants develop greater fruit yields and roots. What's incredible is how many more fruits a plant can produce. Aeroponics has proven to be a good fit for urban gardeners. Because soil is typically scarce in cities, aeroponics is a viable solution for urban gardening. Raising food crops in apartments and on rooftops, for example, has many obvious benefits. Food prices have risen, making growing one's own food more appealing. However, those same food costs are determined by environmental risk. Each food item has a transit cost; let me explain the cost of transporting it and the resources used to make it from its origin to your dinner table environmental effect. Many supporters of the urban gardening movement believe that growing food close to home saves money and significantly decreases carbon dioxide emissions associated with relocating and local food production, especially in a communal aeroponic system in an apartment building, drastically lowering these effects.

Space plant

In September 1997, the space shuttle returned from the Mir space station carrying NASA life support GAP technology with beans that had not been treated (left tube) and beans that had been treated with biocontrol (right tube).

NASA has given these procedures additional attention since a mist is simpler to control than a liquid in a zero-gravity environment. NASA has reached similar conclusions. In 1997, the space agency innovated a variety of Asian bean seedlings grown in aeroponics to the Mir space station while simultaneously viewing an Earth-based control group developed aeroponically utilizing the same growth technique. Gravity was the only thing that separated the Mir and Earth crops. The Earth crop was cultivated under normal air, while the space bean seeds were raised in a neutral environment. The crops on Mir fared better than those cultivated on Earth. The test's success was significant to NASA. It proved that food crops could not be raised in the absence of gravity; you can not only grow but also thrive. Additionally, it showed how practical this aeroponics tool would be for extended space trips and missions. It may also be used when additional planets are colonized.

NEED TO ADOPT AEROPONICS

Aeroponics is a plant-growing method for persons who have limited space. Rather than being a commercially viable means of food production, the technique was mostly used as a research tool. Aeroponic technology, often known as soilless culture, allows plants to be grown in a controlled, pest-free environment. Due to improved disease-free yields, India will soon be among the top growers and exporters. Without the use of artificial hormones, pesticides, or insecticides, an aeroponic system has the potential to provide improved vegetative development. May be a more long-term solution for increasing access to local produce in the city core while also offering permanent work possibilities for residents. This technology can help you increase your profits. Because of the lower costs of soil, water, fertilizers, and space, smaller systems can compete with bigger conventional farmers. All of the limits present in soil culture production can be addressed with this soil-less culture. Once the system is in place, it lowers the cost of production.

To feed the growing population, food crop yield in existing arable land should be increased, and alternative farming practices must also be supported. Encouragement of Soilless Techniques in the Interest of Food Security fighting hunger and reducing the burden of malnutrition requires strengthening food production and distribution systems. If used on a large scale, this strategy can compensate for losses caused by erratic monsoons and other reasons. It will unquestionably enhance the situation of Indian farmers.

Although the Aeroponic system is an important step toward sustainable farming, there is still much work to be done to make it a realistic option for Indian farmers. Farmers face various issues, ranging from money to basic access to resources, poor credit records, and farming techniques, to name a few. For technology to become feasible for better production, it must be invested in.

ADVANTAGES OF AEROPONICS

Aeroponics is a modern farming method that produces greens and vegetables in a controlled environment. The following are some of the system's key advantages:

98% less land: Aeroponics requires 98 percent less land than conventional agricultural techniques because the system's design takes advantage of both vertical and horizontal space.

Year-round production: The Soil-less "Controlled Environment Agriculture" (CEA) includes aeroponics. This general term describes all techniques for growing plants inside in which the grower controls environmental factors like temperature and light. Growing in a controlled setting enhances a farm's ability to forecast crop timing, develop quality plants, and uphold strict food safety regulations.

95% less water: In a regulated environment, there is far less unpredictability, resulting in less waste and reduced costs. Aeroponic systems need water-based solutions to work properly, although they use 95% less water than conventional agricultural methods.

More efficient: To encourage their plants to flourish and produce as much as they can, growers design their systems and nutritional solutions. According to reports, the growth of plants in these indoor gardens is three times quicker than that of plants in open farms.

Safer for the consumer: The product is more organic because there is no need for herbicides or pesticides in a closed environment because there is no chance of soil contamination or contact with Mother Nature.

Benefits of oxygen in the root zone: Oxygen is necessary for the rhizosphere (root zone) for optimal plant development. Because aeroponics is carried out in air combined with tiny droplets of water, nearly any plant may mature in the air with a proper supply of oxygen, water, and nutrients.

Disease-free cultivation: Aeroponics helps prevent illness spread because there is little plant-to-plant contact, and each spray pulse can be sterile. In the case of soil, aggregate, or other growing media, the disease can spread across the medium, affecting several plants. Therefore, most greenhouses sterilize this solid medium after each harvest, and in many cases, they are just thrown away and replaced with new, sterile media.

Less fertilizer use: Because less nutrients are utilized, the plant roots are precisely treated at predetermined intervals with a spray mist of droplets that may nourish the plant most effectively by osmosis.

Nutrient uptake: Because interval and duration aeroponics are discrete, they allow for the study of nutrient intake throughout time and under varied conditions.

Alleviation of labour requirements: In soilless culture, all cultural methods of soil cultivation, including soil sterilization, weed control, and others, may be omitted, lowering labour input and necessary work hours.

Monitor plant nutrition: Instead of applying the nutrition elements in huge quantities, as in a traditional plantation, they are applied as solution forms in the precise proportions the plant needs. In soilless cultivation, it is possible to keep harmful compounds below acceptable doses without harming the plants. However, only plants grown in water cultures have a homogeneous distribution of the nutritional elements. In contrast to how difficult and expensive it is in conventional soil cultures, the PH and EC of the nutrient solution may be altered to fit the demands of the crop and the surrounding environment.

Easy system maintenance: All that needs to be maintained in aeroponics is the root chamber (the cavity that holds the plant's roots), which must be disinfected regularly, and the reservoir and irrigation channels.

Production at moon stations: Plants can be cultivated in zero gravity, such as on moon stations, using this approach.

CONCLUSION

It concluded that aeroponics might be useful in the future in areas without access to freshwater and rich soils. Therefore, it could potentially be used for food production in locations with huge amounts of unarable land, a small areas, a high population, and in arid regions. Additionally, it enhances per capita access to and consumption of fruits and vegetables. Almost every plant may mature in the air with an adequate supply of carbon dioxide, water, and nutrients when grown using aeroponics, which involves growing plants in air mixed with tiny drops of water. Aeroponics technology is the way of the future, making crop growing simpler. In addition, aeroponics helps preserve water, land, and fertilizers.

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POPULAR ARTICLE

ROLE OF VETERINARIANS IN THE POULTRY INDUSTRY: A PRACTICAL PERSPECTIVE

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ABSTRACT

Generally, most of the diseases caused in chickens are due to faulty management practices. Thus, a veterinarian should have keen observation, and he/she has to utilize all his/her senses to identify the key problem in the flock. Apart from routine diagnostic skills utilizing post-mortem and laboratory investigation, it is required to employ all the observations to find out the actual problem in the flock and rectify the issues at the initial stage to maintain health in the flock. Thus, a veterinarian should employ a multidisciplinary approach in solving the problems of the farm, thus ensuring the livelihood of the farmers and, in turn, boosting the economy.

INTRODUCTION

Today's poultry industry has been transformed from a mere backyard venture into a highly organized industrial sector and plays a significant role in people's food security worldwide. Poultry eggs and meat are the most consumed food among animal proteins, and still increasing demand for these products worldwide. This leads to promising opportunities for the growth of the poultry sector and makes it one of the dynamically evolving industries among the agricultural sectors. These opportunities can be realized through adapting sophisticated management, improved genetics, advanced nutrition and disease control measures.

POULTRY PRODUCTION SYSTEMS

Two basic poultry production systems are present in India:

1. An industrial poultry sector
2. a small-scale production system/backyard poultry rearing

Various factors impacting the production efficiency of modern commercial chicken strains include genetics (70%), Nutrition (10%), environment (8%), diseases (7%) and managerial skills (5%). Today India is the third largest producer of eggs, the nineteenth largest producer of broilers, and the sixth in chicken meat production in the world. The sector is valued at about Rs.80000 crores at present. However, one of the looming threats to this organized sector is the occurrence of diseases in poultry and the economic downfall it causes to both backyards and organizes poultry farms.

VETERINARIAN PERSPECTIVE

Several persons share the responsibility for monitoring the health-related issues in chickens. The poultry veterinarian is responsible for developing and implementing suitable poultry health programs depending on the necessity. This health program varies from farm to farm and must be custom-designed to suit local conditions. This effort will maintain the proper health of poultry by which the farmers benefit, boosting the country's economy. Thus the veterinarian plays a pivotal role in managing the overall health of the poultry and indirectly boosting the country's economy. The key veterinary services to the poultry industry generally fall under three main categories viz., diagnostic, prophylactic and therapeutic services. Veterinarians generally provide all these services.

To cater for the needs of fast-growing poultry industry, the in-charge veterinarian/poultry consultant of the farm should have sound knowledge in all aspects of poultry science, including bird's anatomy, physiology, biochemistry, nutrition, pathology and other accessory but important attributes like biosecurity programs, vaccination programs, disease surveillance programs and sanitation programs.

The veterinarian should have a keen sense of observation during his farm visits, as a single finding which deviates from the normal rearing practices could save the lives of thousands of birds and prevent incurring monetary losses in terms of medicine /management costs. As a farm in charge, the veterinarian's role starts from setting up appropriate farm outlay suitable for local conditions, selecting the right type of birds, and charting the right feed/water schedule with appropriate components.

Generally, most of the diseases caused in chickens are due to faulty management practices. Thus, a veterinarian should have keen observation, and he/she has to utilize all his/her senses to identify the key problem in the flock.

- Before entering the poultry farm, the veterinarian should ensure suitable bio-security measures are being employed (sense of sight);
- After entering the poultry farm, a veterinarian has to ascertain the amount/intensity of light being provided (sense of sight);
- A veterinarian should ascertain the type of gas being build up in the house (sense of smell);
- A veterinarian should see whether the right type of feed is being served to the birds;
- A veterinarian should also see whether the proper amount of water is being provided (sense of touch);
- A veterinarian should sense whether the birds exhibit any abnormal sounds (sense of sound).

After sensing any abnormalities, he/ she has to take initial remedial steps to prevent future occurrences of this issue. Some issues we generally ignore but costs much to the farmers include ammonia build-up in the farm, nipple flow rate, water quality (pH and TDS), and proper mixture of various components in the feed. Therefore, apart from our routine diagnostic skills utilizing post-mortem and laboratory investigation, it is mandatory to employ all the observations to find out the actual problem in the flock and rectify the issues at the initial stage to maintain health in the flock. Thus, a veterinarian should employ a multidisciplinary approach in solving the problems of the farm, thus ensuring the livelihood of the farmers and, in turn, boosting the economy.

CONCLUSION

Generally, most of the diseases caused in chickens are due to faulty management practices. Thus, a veterinarian should have keen observation, and he/she has to utilize all his/her senses to identify the key problem in the flock. Apart from routine diagnostic skills utilizing post-mortem and laboratory investigation, it is required to employ all the observations to find out the actual problem in the flock and rectify the issues at the initial stage to maintain health in the flock. Thus, a veterinarian should employ a multidisciplinary approach in solving the problems of the farm, thus ensuring the livelihood of the farmers and, in turn, boosting the economy.

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POPULAR ARTICLE

CLONAL ROOTSTOCKS IN ENHANCING PRODUCTIVITY OF APPLE UNDER NORTH-WESTERN HIMALAYAN REGIONS OF INDIA

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ABSTRACT

Clonal rootstocks are produced through vegetative propagation, account for the better light interception, have a high level of resilience to biotic and abiotic stress, yield early crops, and have a great deal of economic viability. However, the overall productivity of apple in India is quite low, as In India till date usage of clonal rootstock is at very small scale when compared to major apple-growing countries like Europe and America, where about 80 % of its apple cultivation is done on clonal rootstocks. In India high, density plantation is a new concept and the use of clonal rootstocks and harnessing their potential in terms of pest and disease resistance, precocity, and the production of high-quality fruit will directly contribute to improving apple productivity in the years to come.

INTRODUCTION

The apple is one of the most significant fruit crops cultivated in temperate areas of the world between 30 ° and 50 ° latitudes in both hemispheres (Westwood, 1993). In India, the apple cultivation is mainly confined to the North Western Indian Himalayan regions. However, these areas do not fall under the world's temperate zone, but due to high-altitude snowfall occurrence in these areas led to the prevailing temperate climate of the region which helps in meeting the chilling requirements of the crop. In India, commercial cultivation is confined mainly to the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand, and some parts of Sikkim, Arunachal Pradesh, Nagaland and Meghalaya with productivity of 8.8 MT/ha (Anonymous, 2020) which is quite low when compared with major apple growing countries like America and European countries, having productivity upto 50 to 60 MT/ha. The one of the main factor is that most of the apple orchards in India are still on seedling rootstocks and are planted in low densities, while in other major apple-growing regions (Europe and America), apple plantations are in high density plantations on clonal rootstocks (Table 1). In addition, the huge canopy area and improper management of the canopy in low density plantations results in inadequate light penetration and distribution into the canopy and produces fruits of poor quality.

Table 1. Status of use of clonal rootstocks in major apple producing countries

Country	Dwarf rootstocks	Per cent use of dwarf clonal rootstocks
China	M. 9, M. 26, SH. series, GM. 256 etc.	12 %
USA	M. 9, B. 9, M .26, MM. 106, MM. 111, G.16 etc.	50-55 %
Poland	M. 9–T337, B. 9, P Series, etc.	>80%
Italy	M. 9, M. 26, M.4, M.2, MM. 106 etc.	~90 %
Russia	B. 9, B. 118, B. 54-146 etc.	No data obtained
France	M. 9, M. 2, M. 5, M. 4, M. 26, CG. 30 etc.	~90 %
UK	MM. 106, M. 9, M. 26, M. 27, MM. 111, M. 4, M.25 etc.	~90%
Netherlands	M.9 T337, M. 1, M. 2 etc.	>70 %
Germany	M. 9, M. 4, M. 5, M. 7 etc.	~90 %
Japan	JM series, M. 26, MM. 106, M. 9, M. 7, MM. 111 etc.	>75 %

Note: M – Malling series (UK); CG or G - Geneva series (USA); P – Poland series (Poland); B – Budagovsky (Russia); JM series – Japan and GM series – China; SH – Shao series (China) (Source: Wang et al. 2019)

CLONAL ROOTSTOCKS FOR APPLE

Rootstocks produced through vegetative propagation known as clonal rootstocks, on the other hand, ensure homogenous trees with identical cropping properties and, in the case of apples, a variety of size-controlling clonal rootstocks (dwarf to vigorous) are available (Table 2). The genetically dwarf to semi-dwarf clonal rootstocks in apple, however, offer a great deal of potential for close planting, but the semi-vigorous and vigorous clonal rootstocks can also be a valuable source for enhancing productivity where high density plantation is not practical.

Advantages of using clonal rootstocks in apple:

- ✓ Uniformity
- ✓ Tree size control
- ✓ Precocity and Productivity
- ✓ Better nutrient uptake and nutrient use efficiency
- ✓ Improved fruit quality
- ✓ Resistance to some pest and diseases
- ✓ Tolerance to abiotic stresses like drought, cold

Table 2. Some promising clonal rootstocks for apple under Indian conditions

Rootstock	Parentage	Origin	Features
Dwarf			
M. 9 ('Jaune de Metz')	Chance seedling found in France	Reselected at HRI- East Malling, UK	✓ Most popular dwarfing rootstock ✓ Induces excellent yield precocity and efficiency ✓ Poor anchorage ✓ Can be us as interstock
M. 9 EMLA	Sub-clone of M. 9	UK	✓ The first M.9 sub-clone freed of all known major and latent viruses
M. 9 T337	Sub-clone of M. 9	The Netherlands	✓ Most often used of the virus-free sub-clones produced by NAKB ✓ Brings good productivity, good fruit size and good colour
B. 9	M. 8 × Red Standard	Michurinsk College, Russia	✓ Vigour between M. 9 and M. 26 ✓ Good yield efficiency, ✓ Anchorage slightly better than M 9 ✓ Winter hardy ✓ Greater resistance to crown rot
G. 41	M. 27 × Robusta 5	Cornell University,	✓ Vigour similar to M 9 T337; ✓ Very resistant to fire blight;

		Ithaca, NY (US)	✓ Tolerant to crown and root rot
Semi-dwarf			
MM. 106	Northern Spy × M. 1	East Malling, UK	✓ 60% the size of trees on apple seedling ✓ High yield efficiency ✓ Good anchorage ✓ Resistant to woolly apple aphid but susceptible to collar and crown rot
M. 7	Not known	East Malling, UK	✓ Tree 55 to 65% the size of apple seedling ✓ Similar to slightly more invigorating than MM. 106 ✓ Field tolerant to collar rot and fire blight
M. 116	MM. 106 × M. 27	HRI-East Malling, UK	✓ Resistant to collar rot, mildew and specific apple replant disease
Semi-vigorous			
MM. 111	Northern Spy × M. 1	East Malling UK	✓ Slightly more invigorating than MM. 106 ✓ Good anchorage ✓ Resistant to woolly apple aphid ✓ Easy to propagate ✓ Most tolerant of droughty soil conditions
EMLA 111	Northern Spy × Merton 793 [Northern Spy and M.2(Doucin)]	UK	✓ Virus free ✓ Semi-vigorous ✓ Two-thirds the size of a standard tree ✓ Anchored and tolerant of drought conditions
Vigorous			

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Merton (MI) 793	M. 2 × Northern Spy	John Innes Institute, UK	✓ Tree slightly smaller than apple seedling ✓ Resistant to woolly apple aphid ✓ Very suitable for replant apple problem

(M –Malling; MM – Malling Merton; B – Budagovsky; EMLA – East Malling Long Ashton; G – Geneva; MI – Merton Immune)

REQUIREMENTS FOR USE OF CLONAL ROOTSTOCKS

1. Dwarf and semi-dwarf Rootstock (M. 9, M. 9 T337, Bud. 9, G. 41, M. 116, M. 7)

- ✓ Deep soil, assured irrigation and flat land
- ✓ Support system for dwarf rootstocks

2. Semi- vigorous and vigorous rootstocks (MM.111, EMLA 111 and Merton 793)

- ✓ Deep soil and land with gentle slope

PROPAGATION OF CLONAL ROOTSTOCKS

Clonal rootstocks are usually propagated by vegetative means viz., mound layering, cuttings and through micro-propagation of clonal rootstocks in apple, which involve inducing part of the rootstock stem to produce adventitious roots while still attached to the mother plant (Webster, 1995). Cocopeat and sawdust are often used as a rooting medium for earthing up stool layer beds (Dvin et.al., 2011; Patial 2018). In particular, the application of plant growth regulators, particularly synthetic auxin (IBA - a rooting hormone) at concentrations of 2500–3000 ppm in apple clonal rootstock propagation through asexual means, plays a crucial role in the establishment of roots and the development of a fibrous root system (Hartmann et.al., 2015). The growth medium and auxin concentration act together synergistically to promote vegetative growth and responses in rooting by providing ambient conditions such as adequate moisture, fast uptake of nutrients, maintenance of root zone temperature, and pH.

SCOPE

In India, high density planting, which permits for more trees per hectare (2000–4000 trees), is a novel concept that has just been around for the past 5–7 years. In comparison to traditional planting methods, high density planting has a lot of potential for increasing fruit yield and productivity even while enhancing precocity. The main requirement for high density orcharding is the control of tree growth. The utilization of dwarfing rootstocks accounts for efficient high density orcharding by controlling tree size by reducing scion shoot growth (Parry and Rogers, 1972). Utilizing clonal rootstocks has become more common as a strategy to get around production and productivity obstacles (soil, climate, and pests), as well as to influence market demand (fresh or processed), shorten the juvenility phase, and increase fruit quality (Demirkeser et al., 2009). Furthermore, especially when planted in dense plantings, these clonal rootstocks are crucial for maintaining a proper canopy in order to encourage precocity, quality, and productivity (Table 3).

Table 3. Recommended stionic combination, planting densities and training system in high density planting in apple

Sr. No.	Clonal rootstocks (Type)	Planting Distance (row to row x plant to plant)	Training system	Number of trees
1.	Dwarfing rootstocks EMLA 9/M. 9/M. 9 T337 Geneva 41/Bud. 9 (Size: 25 % of standard tree)	2.5 m x 1.0 or 1.5 m (Standard cultivar)	Tall Spindle Vertical Axis	4000 or 2666
2.	Semi-Dwarfing rootstocks EMLA 7, M. 7, EMLA 106/MM 106, M 116 (Size: 45 – 60 % of standard tree)	2.5 m x 1.0 or 1.5 m (Spur cultivars) Or 3.0 m x 2.5 m (Standard cultivar)	Tall Spindle Vertical Axis Vertical axis	4000 or 2666 1333
3.	Semi-vigorous MM.111	3.0 m x 2.5 m (Spur cultivar)	Vertical axis	1333

Note: Optimal tree spacing depends on rootstock vigour, scion vigour and soil fertility

ACHIEVEMENTS USING CLONAL ROOTSTOCKS UNDER HIGH DENSITY PLANTATION IN INDIA

The several clonal rootstocks, such as M 9, M 7, MM 106, MM 111, and Merton 793, have been evaluated and shown to be promising for the climatic conditions, especially in

Himachal Pradesh. However, under the World Bank-funded HP-HDP project in Himachal Pradesh, new clonal rootstocks have recently been introduced, including M 116, EMLA 111, M 9 T337, EMLA 106, EMLA 7, Bud series, and Geneva series. These rootstocks have specific resistance to biotic and abiotic stress, which will account for increasing apple productivity in the coming years. Some achievements have been made with respect to clonal rootstock usage under high density plantation. Studies conducted at Mashobra on sixteen- years-old trees of Vance Delicious grafted on MM 106 and planted at a density of 2222 trees/ha produced as high as 75 MT/ha (Anonymous, 1996). The concept of high density planting in apple has been successfully demonstrated at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), India and was recommended for commercial adoption for the growers (Dhiman et al., 2018; Ladon et al., 2022). On the basis of long term studies, they obtained highest production of 24 MT/ha (Dhiman et al., 2018) after fourth year of planting and 41.52 Mt/ha (Ladon et al., 2022) after seventh year of planting at a spacing of 2.5 m x 1.0 m (4000 trees/ha) in cv. Jeromine on M 9 rootstocks and trained with tall spindle system of training. Similarly, Bhatia and Kumar (2009) while studying the performance of new apple cultivars, 'Red Fuji' and 'Scarlet Gala' on different rootstocks under high density plantation recorded highest yield of 16.9 t/ha and 15.6 t/ha, respectively with EMLA 111 clonal rootstock at a planting density of 1111 trees/ha (3.0 x 3.0 m). Under Kashmir conditions, apple cultivars such as Golden Delicious, Vista Bela and Mollies Delicious grafted on M 9 rootstock with a planting density of 2222 trees/ha (1.5 m x 3.0 m) and trained to central leader system exhibited significantly higher yields of 47.40, 42.50 and 33.50 MT/ha, respectively after 8 years of plantation (CITH, 2011). Bhat et al. (2011) recorded better fruit quality and higher productivity under high density plantation of Starkrimson/MM 106 with a higher yield efficiency of 0.36-0.39 kg/cm^2 in comparison to 0.25-0.28 kg/cm^2 in low density plantation.

CONCLUSION

Modern intensive orchards rely on dwarfing clonal rootstocks which are genetically designed to optimize maximum light interception, produce early crops and great economic viability. High density planting is a novel concept in India that considers for the exclusive use of clonal rootstocks and the utmost use of their capabilities in terms of pest and disease resistance, precocity, and the production of high-quality fruit. These traits will directly improve apple productivity in the coming years.

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POPULAR ARTICLE

POTENTIAL ROLE OF ANATOMY IN VETERINARY FORENSICS

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ABSTRACT

Anatomy is the branch of science that deals with studying biological structures. Veterinary anatomy deals with the structure and forms of organs and tissues of principal domestic animals and birds. These biological structures are studied in gross anatomy, histology, embryology, etc. These studies have been used to differentiate different species, and as a result, they have a critical role in forensic identification. The body's different systems can be studied in detail at gross or microscopic levels. Also, veterinary forensics is a newly emerging field where a veterinarian is expected to identify the remains of the carcass to solve veterolegal cases. Thus, the various forms of anatomical knowledge may be applied depending upon the carcass or specimen availability.

KEYWORDS: Forensics, Anatomy, Veterinary, Animal, Identification

INTRODUCTION

The term forensic refers to the implementation of scientific knowledge to solve legal problems. It is based on the scientific analysis of physical evidence from the crime scene, and thus it plays a crucial role in the investigation. It is emerging as a different branch in the veterinary sciences, but its application in veterinary science is not as standardized as in human forensics. Still, it continues to develop and attain recognition due to changes in veterinarian knowledge to investigate the cases of animals. This has been possible due to the availability of research publications and other educational opportunities in veterinary forensics. Anatomy plays an important role in veterinary forensic investigations. Also the forensic science needs collaboration among anatomists who are interested to deal with forensic aspects.

IMPORTANCE OF ANATOMY

Anatomy is the branch of life science which deals with the shape and structure of the organisms. Forensic veterinary anatomy intends to determine, examine and identify preserved or unpreserved body parts of the animal remains. It plays a major role in identifying sex, breed, age, height along with examining the cause of death. The anatomical knowledge may be remarkably useful along with forensic techniques to determine the identity of animal remains. Thus, it is vital to have deep knowledge of the actual aspect of forensic veterinary anatomy.

Animal identification in forensic science is crucial because it analyses animal remains, e.g. hair or bone. The animal remain investigation can be helpful to identify meat adulteration in restaurants. Thus, animal identification also plays an integral role in cases of illegal trades. There are various animal species identification methods, including bone identification, embryo identification, hair morphology, dental anatomy, iris biometrics, muzzle printing and DNA analysis.

BONE IDENTIFICATION

The skeleton of each species has a unique biological identity varying with shape, size and density of bone. The knowledge of the detailed structure of bones is of great importance in animal height estimation, sex determination, and determination of age and ancestry. The bones in different species have different features and characteristics to those species, and the knowledge of these features proves to be very beneficial in the identification of bones. Further, a thorough knowledge of bone anatomy at the histological level can be used to distinguish a mammalian bone from a non-mammalian bone.

The pelvic girdle and skull bones are commonly used for sex determination. Examining the pelvic girdle includes the measurement of conjugate diameter, transverse diameter, inclination of pelvis, ischial arch, size of the pelvic cavity and obturator foramen to determine sex with great accuracy. The examination of the skull includes the examination of the temporal line, the eye sockets, the supraorbital ridge, nuchal lines and the mastoid process for the determination of sex.

EMBRYO IDENTIFICATION

Comparative embryology deals with comparative ontogeny to learn the development process in various species. The different species have a different gestational age of the fetus;

thus, the development of organs also varies. Thus, by examining the remnants of the fetus, the idea of fetal age and species can be taken. Furthermore, the determination of dimensions of ossification centers has been identified as a most beneficial method for estimating the age of a fetus. Thus, a very important and applicable role has been played by embryology in forensic studies.

HAIR MORPHOLOGY

The gross and histological examination of hair is another important tool that can be used to identify animal species. Hairs are composed primarily of the protein keratin and defined as slender outgrowths of the skin of mammals. Hair cast is considered the simplest, accurate and cheap method for identifying species. The hairs in each species have typical length, colour, shape, root appearance and internal microscopic features that distinguish one animal from another. The microscopic features include the micrometric analysis of hair shaft, medullary diameter, cortex thickness and medullary vacuolated cells. The identification of these features plays a very important role in species identification.

DENTAL ANATOMY

The dental anatomy in forensics plays great role as each species have a unique dental formula and type of teeth. Dental morphology is also very useful to identify the age and gender of a particular species. The branch which deals with the comparison of morphology of various animal teeth depending upon differences in diet is known as Comparative odontology.

IRIS MORPHOLOGY

Iris is the annular region of the eye which the pupil and sclera surround. The iris pattern is unique to individual species and distinguishes between the left and right eye. Thus the animal species have been identified based on unique iris pattern. This uniqueness is due to randomly distributed immutable structures like connective tissue, stromal fibres, ciliary processes etc., which do not change appreciably over time. Thus, due to its high accuracy, iris recognition is reliable for forensic purposes.

MUZZLE PRINTING

The numerous grooves on the surface markings of muzzle has a definite pattern which may be used to identify the animal. This method is useful in identifying the animal as in human fingerprints and may also be employed on an organized farm to avoid frauds made in insurance. The main drawback of this technique is that the collection of paper-based muzzle prints is inconvenient and time-consuming, and the images formed by this technique do not have sufficient quality. Also, it needs special skills to handle and restrain the animal and get the pattern on paper. Still, this technique is beneficial for identifying an animal's age, breed characterization and production performance.

DNA ANALYSIS

DNA consists of a chain of nucleotides, forming an animal's genetic makeup. It can be accessed from any part of the body. However, it is mainly isolated from bone, blood, teeth and hair. The DNA profile of every animal is unique to them and thus may be used for their identification. Therefore, by adopting this method, the identification of individual animals at the molecular level can be done.

CONCLUSION

Anatomical science is vital in the forensic investigation or forensic education. It creates opportunity and collaboration among anatomists and other forensic scientists for the exchange of ideas. A collective approach of advanced forensic tools with different anatomical knowledge would be more beneficial in the field of forensic science in future. Thus this collaboration proves great for forensic investigations and employment opportunities.

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