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WHY INSECT POLLINATORS IMPORTANT IN CROP IMPROVEMENT?

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ABSTRACT

Three out of four plants provide fruits or seeds for human consumption as crops rely on insect pollinators across the world. Many fruit and vegetable crops such as almonds, apples, cranberries, melons, broccoli, cherries and blueberries are dependent upon insect pollinator services Thus, healthy and nutritious diet to humans is offered by the bee pollinators. These natural servants help in the fertilization and seed setting of 87 major food plants. Crop pollinators are in danger, and modern agronomic practices can minimize the threat to flower foragers by changing the landscape and redesigning the ecological procedures. Safeguarding over 20000 wild bee pollinators will be of great importance as these have enhanced the economic value of crops up to $235- 577 billion. Herein, emphasized are the questions, why insect pollinators are significant in crop improvement technology? and how this is improving the quality and quantity in food production.

Key words: Insect, pollinators, crop, improvement, production, agriculture, behaviour, decline, human, challenges, sustainable

On the biodiversity in agricultural systems and ecological services of insect pollinators, intensive agriculture has unfavorable effects. To transfer pollen as they forage, many crop plant species rely upon many animals, among them insects are the great champions. Plants, offering the natural food gifts of pollen or nectar and they give them directions towards the crop flowers. Plants attract pollinators by their vibrant colors and alluring fragrances. This floral biotechnology has brought about strong relationships between flowers and the animals that pollinate them. Modern agribusinesses depend on bee pollinator's services globally. Honey bees, native wild bees, and flies offer billions of dollars (about $235 and 577 billion U S) in economic value in every pollination season and serve a significant role in the world economy (FAO, 2018; Tanda, 2019; 2021).

Because of the high scale and homogeneity of current agriculture industry, the majority of crops requiring pollination, rely upon managed pollinators, especially on managed services (Aizen et al., 2008). No other group of insects are more helpful to humans than bees. The world's most staple nourishments, including wheat, corn, and rice (comprising 65% of global food production) reproduce without insect pollination, still leaving as much as 35% depending on pollinating insects (Klein et al., 2007). Besides this most meat and dairy too rely on bees for pollination which play significant role in the pollination of clover and Lucerne (Dias et al., 1999). Numerous crops and the majority of wild plants are dependent on animal pollination through insects, birds, bats and others, with insects playing the major role for sexual reproduction. Hence, among the insect pollinator's solitary and social bees, help in crop production both in managed and natural ecosystems. World's most economic crops such as apple, citrus, tomato, melon, strawberry, apricot, peach, cherry, mango, grape, olive, carrot, potato, onion, pump-kin, bean, cucumber, sunflower, various nuts, a range of herbs, cotton, alfalfa and lavender rely upon insect bee pollination services (Tanda, 2019, 2020 a, b). The European honeybee (*Apis mellifera* Linnaeus) rules crop pollination worldwide, but native bee species also play a significant role. Crop pollination system is a biological management, food security and key to sustainable environment. Crops that do not even require pollination for seed setting such as those producing fibre or timber, still require pollination to produce further, and harvests, such as cotton that do not require pollination to produce more prominent yields when pollinators are accessible (Tanda, 2019; 2020 a-c; Tanda and Goyal, 1979). Bees are the key pollinators for many fruit and vegetable crops. In farming, particularly among pollen-limited crops is a method for expanding profitability without resorting to expensive agricultural inputs such as insecticides or herbicides. Bee pollination bolster efficiency in numerous crops without farmers even acknowledge it, so long as habitat and alternative pollinator forage are readily available as they often are in little holder agroecosystems. By creating bigger fields and landscapes for agriculture, the living space that pollinators may need becomes limited or finished. Expanding over-dependence on pesticides for pest and disease control is also highly destructive to beneficial insects such as pollinators, except if arranged and embraced with outrageous consideration (Tanda, 2019; 2021).

Crop pollination is a valuable insect service and we often do little to encourage them. As traditional faming systems are being changed to more man uses to meet out the increasing need of food security, we should know what pollination services are most significant for food security, and how we can protect bee services in sustainable farming systems. Bee pollinator varies from crops and cultivars. Numerous crops do not require insect pollinator, however may give rise to better quality fruit and seed if pollinated, and a number of others are strictly self-pollinated or cross-pollinated. Some flowers require specific pollinators while others are pollinated by a variety of foragers, and many crops are wind or water pollinated. Effective pollinators of the same crop may vary from one site to another. Honey bees (*Apis* spp.) alone pollinate crops that have an added economic value of over $14 billion to the agriculture (FAO, 2018; da Silva, 2018; Tanda, 2019, 2020 a, b, 2021). Honey bees are indispensable for the production of almond, alfalfa and sunflower seed, apple, cherry, melon, and berries. Only a few species of bees can be used for commercial pollination services, health and improved management is critical for agricultural productivity (da Silva, 2018; Tanda, 2019). Entpollinatology (from ancient Greek ἔντομον (entomon or ent), meaning 'insect', +pollination or pollinate, act of transferring pollen grains and -λογία (-logia), meaning 'study of') is the first time proposed technical term describing as branch of biology in which insects are involved or used to transfer pollen grains to the stigma of the flower for pollination which is very critical process in the fruit production of crop plants. Pollinatechnology is described as pollina= pollen + technology= the techniques or methods used in to transfer pollen grains from the male anther of a flower to the female stigma.

Apiculture in crop improvement

Apiculture industry is significant because it offers honey bees with a shielded place to work and make a colony to live. It's important to maintain the bee population healthy, as bees pollinate many of our food crops. Beekeeping also gives an environment in which to study bee habitat and their behaviour. US Department of Agriculture (2019) provided land managers and scientists with methods to evaluate the relationship between bees and the landscape. It offers a basis for making decisions about where to put their apiaries for the summer and fall after crop pollination ends so that the colonies will be in a position to build up strong healthy and in numbers in time for migration to California for almond pollination. As it produces honey, a unique product that is the honey bee is the most versatile commercial pollinator. By puzzling declines of honey bee colonies throughout the world, the impudence of honey bees for agroecosystem was severely challenged in the past several years (Aizen and Harder, 2009; van Engelsdorp et al., 2007). The chronic exposure to acaricides is required to control the parasitic mite *Varroa destructor*. Such uses negatively affects agriculture (Barnett et al., 2007; Desneux et al., 2007; Karise, 2007). Any decline of supervised honey bees and the loss of wild pollinators are of increasing concern as there exists a relationship between insect pollinators and food security. The global health of honey bees is at a great risk, doubtlessly. Significant negative effects on honey bees and other insect pollinators are there by the destruction and fragmentation of natural and seminatural habitats as well as land use escalation in agro-environment (Rathcke and Jules, 1993; Tscharntke et al., 2005; Kremen et al., 2004, 2007; Steffan-Dewenter and Westphal, 2008;). Honey bees are attacked by parasitic mites (*Varroa destructor, Acarapis woodi, Tropilaelaps* spp.), fungi (*Nosema* spp., *Ascosphaera apis*), bacteria (*Paenibacillus* larvae, *Melissococcus plutonius*), numerous viruses, and scavengers from beetles and mice to bears during life stages that is most important issue. While for others they remain elusive, but some of these parasites and pathogens the consequences for individual bees and colonies are known.

Non-Apis bees too need a particular crop species or can be manipulated in greenhouse agroindustry. Hence, the practices and techniques that support the commercialization of wild non-*Apis* pollinators are also in high demand. The most important requirements are the conservation and restoration of their habitat including managed farms, urban parks, and golf courses because many bees can nest in small habitat patches, in the natural areas, wild lands,Bottom of Form and human-dominated areas. These bees are threatened by shrinking habitat necessary for their biological requirements, or parasites and brood diseases. If they can be produced in adequate large populations and managed for pollination services, native species will be better used to enhance the pollination in crops. Since flower guests gain no direct benefit by pollinating flowers, rewards must draw them. The most widely recognized way plants draw in creatures to visit their flowers is by giving sustenance, for example, nectar, pollen or oils. While looking for these prizes in the flower, dust from the flower›s anthers may adhere to the body of the creature. At the point when the creature visits consequent flowers looking for more rewards, pollen from its body may hold fast to the stigma of these flowers and once more, new dust may adhere to the body of the creature. Pollination is a basic need in the sexual reproduction of crop flowering plants. Majority of the flowering plants dependent upon bees for the transfer of pollen dust (Nabhan and Buchmann, 1997; Renner, 1988). Pollination is a basic need for sexual proliferation in seed delivering plants (spermatophytes), taking into consideration hereditary recombination and the development of a hereditarily exceptional seed. This mingling of genetic material expands the capacity of probably a portion of a plant's posterity to get by in a universe of erratic ecological changes. Maintenance of this genetic variability in a population is necessary for Evolution by natural selection process to occur, and therefore is the ability of a plant population to adapt to changing environmental influences. The genetic variation in the next generation is larger by cross-pollination, in which pollen from the flower of one plant is transferred to the stigma of another flower plant. Reshuffling of genetic material also occurs in meiosis, to produce gametes. So even self-pollination, in which pollen grains are transferred from the stamens to the stigma of a same flower (or from one flower to another on the same plant) permits the maintenance of crop genetic variations (Tanda, 2019; 2021).

For some plants it has demonstrated invaluable to depend on pollination via animals. Numerous plants depend on wind or water resources for pollination, but must deliver a lot of pollen grains to ensure the chances of interception by the receptive stigma. By depending upon pollination by animals, the plant wastes less pollen as compared to pollination by wind or water. Then again, the plant may exhaust extra vitality to advance pollination by creatures; one model is the generation of nectar to remunerate pollinating creatures. Likewise, insect pollinators can transfer disease organisms from one plant to another along with pollen grains. Flowers contrast colossally in shading, aroma, size and shape; and they are visited by an equally diverse morphological and taxonomic array of creatures. Most common flower visitors are insects belonging to Hymenoptera, Lepidoptera, Diptera and Coleoptera orders. Yet, several species of birds, bats, and other mammals also regularly visit and pollinate flowers (da Silva, 2018; Tanda, 2019).

In pollination biology, a typical perspective is that plants should specialize on a small subset of these visitors in order to ensure effective pollination. Furthermore, undoubtedly, regardless of the enormous morphological and taxonomical diversity of potential interaction partners, flowers show trait combinations that seem to reflect the morphology, behaviour and physiology of certain pollinator types (Faegri and van der Pijl, 1979). Red coloured, odourless flowers with deeply hidden and dilute nectar seem to be adapted to hummingbirds or perch-ing birds; blue coloured bilaterally symmetric flowers with moderately hidden and relatively concentrated nectar combined with a pleasant odour are thought to be adapted to bees (Baker, 1975). Pollination syndromes are found across diverse taxonomic groups of plants and seem to be a consequence of specialization and convergence in evolution. Plants and animals have coevolved over millions of years, since the Cretaceous time frame. Plant pollination depends on the behaviour of many species of animals, from insects to birds to mammals, which transport pollen from stamens to pistils, a key step in the seed reproduction of most flowering plants. Pollinators provide a crucial ecosystem service that results in the out-crossing and sexual reproduction of many and improving livelihoods and by the role they play in conserving biological diversity in agricultural and natural community of living organisms. Lowered agricultural yields and deformed fruit often result from insufficient pollination rather than from a deficiency of other agrochemicals. In common biological systems, the visual clues of insufficient pollination are more unobtrusive than in agriculture, but the consequences can be as severe as the disappearance of a plant species. A perceptible reduction in fruit and seed eating animals, the loss of vegetation cover and ultimately, if keystone species are involved, the demise of healthy ecosystems and their services.

Natural eco environments and agricultural systems rely upon pollinator diversity to maintain overall biological diversity. A variety of materials, including dry wood (especially wood with empty beetle burrows), bare ground, vegetation-free embankments, mud, resins, sand (for some bees), carrion (for certain flies), host plants (for bees, moths and beetles) and caves (for certain bats) contribute to the diverse environment needed to maintain pollinator diversity. Pollinator diversity is gigantic which contain, more than 20,000 pollinating bee species in the world, as well as numerous insects and vertebrates. Pollinators differ from many other suppliers of essential ecosystem services because they are often part of highly specific pollinator-plant relationships. Where there are very specific niche requirements for the plants and their pollinators, loss of the pollinator can have falling effects across the agroecosystem. A few bees that pollinate small herbaceous plants depend on openings in dry wood to nest, and when the wood is removed plant fruitfulness is reduced (FAO, 2018).

Significance of honey bees

Managed honey bees are the most profitable pollinators as far as agricultural financial matters. All these hyper-efficient insects can provide pollination to virtually any crop. Almonds are almost entirely dependent upon honey bee cross pollination for better seed setting. The production of blueberries, squash, watermelon, and other fruits without honey bees, would be greatly lowered, driving up prices and disrupting the marketplace. According to the USDA, a honey bee colony is worth 100 times more to the community than to the beekeeper- meaning the value they deliver extends well beyond their actual price. Honey bee pollination has helped make fruits, nuts, and vegetables more accessible to consumers (USDA, 2018). The importance of pollination in agribusiness has been perceived for centuries (Kevan and Phillips, 2001), with male flowers to ensure that dates would form on their trees, ancient Assyrian temple carvings depict winged deities pollinating female date palms (Buchmann and Nabhan, 1996). To manage and propagate captive colonies of stingless bees in logs, is mentioned in Maya of Mesoamerica. In the history, the mechanism of flower pollination was investigated by Koelreuter (1733-1806) and Sprengel (1750-1815) in pollination ecology.

The irony, however, is that although the importance, and fragility, of pollination for agriculture and Nature conservation has been known for a long time, there appears to have also been a popular belief that flowering plants always somehow seem to get pollinated and bear fruits and seeds and carry on into the next generation. Thus, the science of pollination ecology has not advanced adequately, and this makes ample room for new and established researchers to contribute to knowledge about pollinators and the plants they pollinate, whether in natural or agroecosystems. Surprisingly, even the identities of major and minor pollinators for many major crops plants worldwide remain unknown. Pollination refers to the transfer of pollen from the male parts of the flower to the female parts. This is especially critical in plants where different sexes are found in different plants or flowers. Pollination is a resource that is vital to agricultural productivity. Insect pollinators for example are practically essential in fruit and vegetable crop production. This is especially because pollinators increase or enhance seed set, improve seed and fruit quality, as well as improve genotype progeny (Fig. 1).

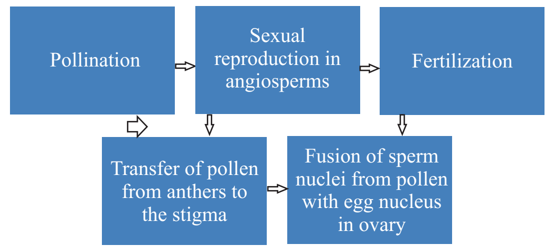

Fig. 1. A schematic model on sexual reproduction in angiosperms (designed by A S Tanda)

Pollination may be indispensable when all the other conventional inputs of water, fertilizer and pest control are taken into consideration. The pollinators however are currently under threat arising from: agricultural development, habitat fragmentation, agricultural chemicals (pesticides and herbicides), destruction of foraging and nesting sites, spread of pests and diseases. In USA, bee poisonings from pesticides result in annual losses of $14.3 million. We have a chance to avert a huge biological disaster - the large-scale loss of pollinator abundance as nature is rapidly disappearing all over the planet due to biological and climatic disturbances. All this is well known to apiculturists, biologists, ecologists, entomologists and other environment experts from many fields. Owing to a serious decline of bee pollinators, mostly decision makers are badly enlightened about the huge bio-ecological catastrophe worldwide. To eradicate utmost poverty in developing countries, recognition of the significance of bee pollination services will be an important ethical and practical drive in the world. Honey bees contribute fairly in rural development to secure and sustainable livelihoods, in addition to offering a critical role in crop pollination and thus improving the quality and yields (FAO, 2018).

Buzz pollination

Buzz pollination or sonication is a mechanism of vibrations performed by social /or solitary bees to release pollen which is firmly held by the anthers. Pollen can only be free when the stamens are shaken by vibrating movement of bees in many flowering plants. Not by the honey bees, buzz-pollination is carried out by bumblebees, carpenter bees and by the *Melipona* stingless bees. There implies a new dimension for the application of bees as pollinators crops that need to be pollinated in greenhouse environment in the absence of natural pollinators. For seed production in crops the honey bees are considered to be the most significant tool. For the pollination of greenhouse crops and ornamental plants, bumble bees and solitary bees are being utilized (Estes et al., 1983). Due to the habitat loss by land use changes, more monoculture practices and, ill effects of pesticides and herbicides, despite more recognition of their important role in pollination, the population abundance and biodiversity of honey bees is declining (Fig. 2).

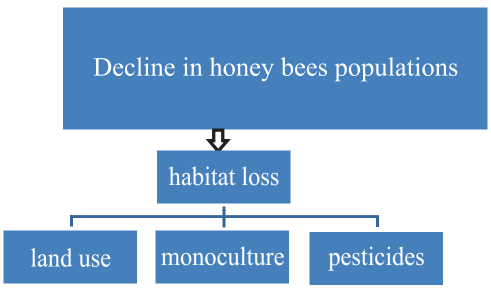

Fig. 2. Schematic decline in honey bee populations and diversity (designed A S Tanda)

Modern intensive agriculture and certain ways for managing our environment may have important consequences for the ecological position and the conservation of bees in this environment. Pollination is a threatened system from highly managed agriculture to uncultivated wilderness. Pesticides take their toll, insecticides directly killing pollinators and herbicides indirectly by reducing insect pollinators (Fig. 3). Certain improvements, the use of agro-chemicals and of genetically modified crops are considered to be detrimental for beekeeping (da Silva, 2018; Tanda,

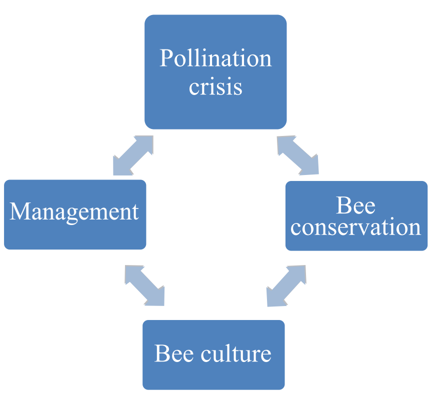

Fig. 3. Schematic model on bee pollination crisis solution (designed A S Tanda)

2019). There are several reasons why honey bees are perhaps one of the most studied insects probably next to Drosophila. The value of crops that require pollination by honey bees, in the United States alone, is estimated to be around $24 billion each year and commercial bee pollination was valued around $10 billion (FAO, 2018; da Silva, 2018). There is a tendency to consume more bee-pollinated crops, making honey bees more and more important in agriculture. The honey bees are not domesticated in true sense but one had to understand and adjust his methods to gain maximum from the hard labor of honey bees. Contribution of bee keeping to agriculture and horticulture is very valuable. Over 50 million hectares under crops are benefited by the bee pollination services in India (da Silva, 2018; Tanda, 2019). Due to pollination services by bee's yields are enhanced in oilseeds, pulse crops, vegetables and fruits. Considering the recurring shortages of edible oils, pulses and other food crops, the significance of pollination can be acknowledged (FAO, 2018). An ancient coevolved practice involving animals and plants in mutualism, bee pollination is basic to agricultural crop production.

To change the demography of beekeeping and availability of crop pollinators honey bee diseases are a big threat to the industry. As a part of conservation, forestry, agroforestry, sustainable agriculture and development, significant assistance of wild natural pollinators, domestication of unused potential pollinators, and more environmentally sensitive human exploitation of the biodiversity are urgently required. As reciprocal selective factors, pollinators and crop flowers, have been closely and mutually interrelated for 200 million years. To produce some amazing inventive pollination mechanisms, they have developed together. For example, figs to a wasp, *Blastophaga*; *Phlox* to a diurnal butterfly, *Hemoris*; Yucca to a tineid moth, *Pronuba*; red clover to bumble bees; Trollius to a blade fly, *Chiastochaeta*; etc, several entomophilous species of crops are adapted to certain insects for seed setting. The flowers have very striking resemblances with the females of certain wasp species of *Scolia,* in some orchids, eg. *Ophrys insectifera*. For the visual simulation of flowers resembling their females, thus pollinating them incidentally, male wasps visit the blossoms not for nectar or pollen. In organic evolutionary development, this considerable relationship between plants and their pollinators is one of the most important occurrences. To the agriculture world about 200 billion US dollars/year is the added potential economic value of insect crop pollination. On our planet in pollinating the 250,000 kinds of wild flowering plants, more than one lakh different animal pollinator species are valuable (FAO, 2018). As many as 1,500 species of birds and mammals give out the services as the flower pollinators in addition to bees, wasps, moths, butterflies, flies and beetles. Globally, perching birds, flying foxes, fruit bats, snails, slugs, possums, lemurs and a gecko serve as efficient crop pollinators, however, hummingbirds are the effective flower pollinators in many states of the US (Bartomeus and Dicks, 2019). At a very alarming rate, the population level of wild and domesticated bee pollinators is decreasing worldwide.

Globally they are about 500 insects including butterflies, moths, bees, wasps, ants, beetles are an important source of calories and proteins as natural supplements. Leading to death of nearly 20% of the caterpillars, in the U.S.A. at Cornell University, it was observed that monarch butterfly caterpillars eating Bt corn toxic pollen blown on to milkweed plants near Bt corn fields had suffered significant adverse effects. For moths and butterflies, and deplete nesting materials for bees, these toxins can finish nectar sources for pollination and affect larval host plants adversely. To minimize pollinator's exposures to poisoning chemicals, farmers can move to more insect pollinator-friendly practice of agriculture (da Silva, 2018). In India, due to the indiscriminate application of chemicals as well as environmental pollution, the abundance of approximately 1,500 butterfly species, is alarmingly fluctuating. By the eradication of larval as well as adult food sources, feeding areas and nesting sites, other human alterations such as deforestation, and extension of farming and unrestricted urbanization are also a challenge to butterfly species to extinction. Due to the wanton eradication of living habitats in many areas of the subcontinent, the Travancore Evening Brown, the Malabar Tree Nymph, Bhutan Glory and Kaiser-I-Hind Butterfly are under near elimination.

Under local law, most spectacular and endangered species have various levels of protection and safety measures. For the survival of human and animal bioecology, next to bees and moths only butterflies are most effective pollinators of crops to help turn flowers into seeds, food, fruits and fibers. To save endangered species like butterflies and their habitats, based on sustainable exploiting wild creatures, wildlife farming can assist. Over the past decade, the growers of the Himalayan region have been complaining about the reduction in apple fruit production and quality due to bee pollination difficulties (van der Sluijs and Vaage, 2016). During the apple flowering season they have all disappeared now, there used to be a lot of wild bees, butterflies and moths in the past. The shortage of insect pollinators has, therefore, become an evaluative factor in insufficient crop pollination. Augmenting the populations of honey bees, bumblebees, sting less bees, and solitary bees, the pollination problem can be solved. In Maoxian County of Sichuan, China, hand pollination of apples is a common procedure (van der Sluijs and Vaage, 2016; da Silva, 2018; Bartomeus and Dicks, 2019; Tanda, 2019, 2020 a, b). At all levels among policy makers, planners, bee-keepers and growers, the awareness about the value of honeybee pollinators has to be put up. For pollination of different crops growers are already utilizing honey bees and solitary bees in western countries. From conventional honey production to crop pollination, the center of attention of beekeeping requires to change (da Silva, 2018).

Recognition of insect pollinators

Pollination by insect's supplies basic support of the structure and function of a wide range of natural communities, and it increases aesthetic, recreational, and cultural aspects of human activity, its direct economic value to humans. Taking into consideration that economic and ecological importance, there is a need to identify species for which there is evidence of decline, analyzes the supposed causes of those declines, and discusses their potential consequences, need of monitoring, conservation and their restoration. The planet's most successful life forms are among angiosperms that produce seeds often enclosed within an edible fruit. Flower reproductive systems differ considerably among insect species, but two mechanisms are significant for sexual reproduction in all flowering plants: firstly the transfer of pollen from the anthers of a stamen to the stigma of a pistil (Fig. 4), secondly the fertilization, the blending of the sperm nuclei from

Fig. 4. Raspberry flowers and sexual reproduction (Photo A S Tanda)

pollen grains with the egg nucleus in the ovary to produce an embryo. Many crop plants self-pollinate, implies that pollen transfer occurs within the same flower or among the flowers on a single plant, usually because the anthers touch the adjacent stigma. However, majority of the flowering plants, depend on the transfer of pollen from other individuals known as cross-pollination. Over 200,000 species of insect pollinators to various extents to meet their reproductive necessities. More than three-fourths of the planet's angiosperms depend on wind and water for pollen transfer. The fossil records are the evidences, angiosperms underwent a remarkable diversification between 130 million and 90 million years ago.

Self-seed fertilization barricades

In different taxa, adaptations that decrease the likelihood of selfing is found. Dioecy and monoecy promote outcrossing, and that they achieved ecological dominance 100 million to 70 million years ago (Davies et al., 2004). For the dispersal of pollen dust, main among the various explanations provided for their spectacular ascendancy is the evolution of mutualistic associations among animal species (Labandeira et al., 1994) and seed formation (Herrera, 1989; Kevan, 1984). Mutualistic associations among creatures provide mobility of gametes to otherwise predominantly sessile terrestrial plants, which allows for greater genetic variation in crop plants as well as access to a wider range of bioecological opportunities through seed dispersal mechanism. For flowering plants, use of an insect partner to transport pollen increases the area in which potential mates can be found and promotes outcrossing, the merger of gametes from genetically distinct individuals. By increasing genetic variability through recombination associated with outcrossing is key although monoecious plants can receive self-pollen from male flowers on the same plant. Monoecious plants give rise to male and female flowers at different stages, and thus the chances of selfing is reduced. When the male and female flower parts mature at different times in hermaphrodite flowers, self-pollination within flowers is failed. Because the male and female parts of the same flowers are isolated, the probability of self-pollination in some plants, is minimized. Allowing self-pollination before the flower is too old to set fruit, the male and female parts of the flower come closer together as the flower ages in those species. Several angiosperms are self-incompatible, means pollen that is transferred on a stigma within the same flower (or another flower on the same plant) deterrent to selfing, is unable to succeed fertilization. Self-incompatibility is under jurisdiction in complex and variable ways, and it involves the interplay of incompatibility alleles (of which there may be many) and their effects in the two parent plants (Matton et al., 1994).

Mechanisms to stop up self-fertilization can suddenly cease to function as a result of aging or environmental factors, especially temperature, the efficacy of self-incompatibility processes ranges from absolute to weak. Even when cross-pollination is not possible, shattering barricades down assures sexual reproduction in plants. Several species persevere exclusively and successfully live with self-pollinating and self-fertile flowers in spite of the omnipresence of outbreeding. In agriculture, few self-fertile species that can self-pollinate are of great significance. Where their native bee pollinators are not present many can set-up themselves in non-indigenous crop regions. In detail, the nature and evolutionary biology of crop-breeding systems are demonstrated by Richards (1997). Genetic variability in crop populations could ease the resistance to pathogens and herbivores, by permitting animals to adjust spatially and temporally in variable environments. It may contain hundreds of ovules and give rise to a fruit bearing hundreds of seeds as in tomato, kiwi fruit, cucumber, watermelon, or squash, or an ovary may have a single ovule and produce a fruit that bears only a single seed as in almond, avocado, coconut, plum, or cherry fruit plants. Some plants need many hundreds of pollen grains to fertilize all the egg cells to form seed as each seed results from the union of a sperm cell from a pollen grain and an egg cell. Some of the egg cells will not be fertilized and seeds will not set if a flower gets insufficient amount of pollen grains. Undersized fruits which have less value in the market are developed due to the result of incomplete pollination and fertilization. Individual flowers be foraged by several pollinators or that one too many pollinators make multiple visits to the same flower, the sufficient pollination often requires this. That would not be sustainable in natural environment, as few fruits are generally the outcome of selective breeding or genetic manipulations (Schery,1972). Seedless bananas are the results of clean triploid plants emerging either suddenly or because of hybridization of diploid and tetraploid people and are proliferated vegetatively. Parthenocarpic natural products, for example, seedless tangerines, are those in which organic products create without effective fertilization treatment could fall flat in light of the fact that these self- incompatible cultivars are developed in monoculture plantations. Seedless grapes, interestingly, are stenospermocarpic; fertilization happens, however the subsequent natural product is seedless because the immature embryo fails to develop (Schery, 1972).

Bioenvironment and crop foragers

Deguines et al., (2016) indicated that benefits from agricultural intensification may be offset by depletion in pollination services, and supports the need for an ecological intensification of agriculture through optimization of ecosystem. Flower foragers and plant interactions have been approximated to 400,000 species, exceptionally the nature of relationship between plant and pollinators differs. Though some foragers visit flowers for nectar or pollen, but all pollinators never help in pollination as they do not touch the male parts. Efficient bee pollinators often have behavioral and anatomical traits that greatly enhance the effectiveness and precision of pollen transfer (Barth 1991; Proctor et al., 1996; Lewinsohn et al., 2006). Crop pollination, in general, is a beneficial relationship for each other pollinating insects get some form of nutritional food and transfer pollen. For some flies, butterflies, birds, and bats, pollen itself is a gift, helping as the primary food necessity for bee larvae and as a rich source of protein (Roulston and Cane, 2000). Many plants offer nectar, oils, resins, fragrances, pheromone precursors, and other assets to prompt foraging and pollen dissemination (Barth, 1991; Dafni et al., 2005; Roulston and Cane, 2000; Roulston et al., 2000). Degree of interdependence differ in pollinators and flowers. Some crops rely on a single species or genus of insect pollinator, which in turn has limited sources of pollen or nectar.

The mutualism between plants in the genus *Yucca* (Agavaceae) and their pollinators, the aptly named yucca moths of the genus *Tegeticula*, is an important example of a close relationship (Pellmyr, 2003). In developing yucca seeds, adult yucca moth is the main pollinator as the main food source for the caterpillar, this relationship is 40 million years old. To gather and compact big amount of pollen grains even up to 10% of the moth's weight from yucca blossoms, female moths have tentacles, utilized for this activity. After collecting a pollen load, the moth flies off and forage at other plant, in which eggs are laid by female moth. Female transfer part of the pollen on the stigma for cross pollination and fertilization, also as a nutritious food for the offsprings, showing a unique biofloral behavioural activity. In plant-pollinator mutulism, such sterotyped associations are unusual. Similar relationships exploiting immediate opportunities are found in many cases, if not most. At least, 45 species of insects in 5 orders foraged on *Geranium thunbergii* Sieb. et Zucc.plants in a natural environment; of these, 11 species in 3 orders worked as key pollinators (Kandori, 2002). In its native Rocky Mountains is fertilized mainly by bumble bees at heights and by flies at low altitudes (Galen et al., 1987). Plants need pollen deposit on receptive stigma to set seed and develop fruits, it is well known now in the agricultural industry for pollination process. Till the seventeenth century and even after that mechanism was recognized slowly, that the seeds are developed from the transfer of pollen on stigmatic surfaces, was not well eloquent. Sexual organs of plants are significant components of classification. The natural niche associations design a platform for the plant hybridization among closely associated crop plants. By evolving a new methodology of artificial pollination and developed the first cross-hybrid from two flower species for seed development in many economic fruits, vegetables, and ornamental flowers (Mayr, 1986). A new era of experimental bee pollination biology was documented in 'The origin of species by means of natural selection or the preservation of favoured races in the struggle for life' in 1859.

Crop pollinators' management

Prasifka et al. (2018) reported related difference in bee foraging with specific floral traits, measured advantages of pollinators to hybrid crops, and used genetic assets in sunflower and other plants to find markers connected with principal floral characteristics. A model for using nectar-related traits to increase flower pollinator interactions, future work to enhance pollinator rewards should enable sunflower. Management of bee pollinator species allowed for increasing crop yield and for financial gain of crops exhibition of biotic pollination techniques showed direction to significant agricultural technology, with extensive economic results (Fig. 5). Worldwide the western honey bee, *Apis mellifera* L., is the leading domesticated pollinator, for its great efficiency as a pollinator, and wax, honey producer (Delaplane and Mayer, 2000; Free, 1993;

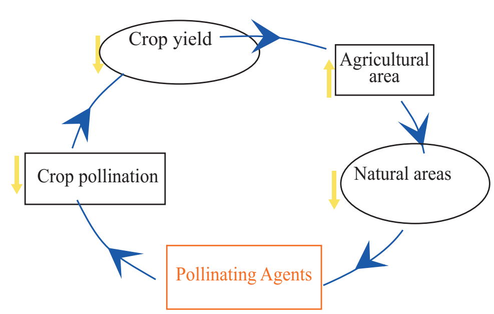

Fig. 5. Pollinating agent's role in agricultural crop entpollinatological system (drawn A S Tanda)

Kearns et al., 1998; McGregor, 1976).

In the 1600s, first in North America with European colonists, *A. mellifera* rapidly became the key pollinator for advance agro industry, and managed hives were transferred worldwide (Sheppard, 1989). Flower pollinators for which effective management process have been evolved constitute many bumble bee species (*Bombus*), for tomato pollination in greenhouses mostly (de Ruijter, 1997; Hughes 1996; Kevan et al., 1991; Macfarlane et al., 1994; Plowright, 1996; van Heemert et al., 1990), and leafcutting bees (Megachile rotundata) (Bohart, 1972a; Frank, 2003), and in arid Pacific Northwest for alfalfa crop pollination. For alfalfa pollination, Alkali bees (*Nomia melanderi*) (Bohart, 1972a) are also used (Stephen, 2003). In the eastern United States, the Japanese horn-faced bee, Osmia cornifrons, mostly Mason bees, are domesticated in apple orchards for pollination (Batra, 1982; Bohart, 1972b), though in Japan these bees are utilized for pollinating the entire apple crop on a larger area. In the northwestern United States, *O. lignaria* is employed to pollinate apple plantations (Bosch et al., 2000; Bosch and Kemp 2002) and in eastern Canada (Sheffield, 2006) and for cherry fruit fertilization (Bosch and Kemp, 1999, 2000, 2001). For breeding this species advance procedures are available (Griffin, 1993; Torchio, 2003). For multiplication and management of various crop pollinators methods are accessible (Batra, 1994a, b; Bosch and Kemp, 2001; Free, 1970; Kevan et al., 1990; Shepherd et al., 2003; Torchio,1990, 2003). Except honey bees, for many crop pollination, more effective pollinators such as bumble bees, megachilids, and other wild bees are available (Cane, 2002; Javorek et al., 2002; Tepedino 1997). As an alternative flower pollinators *Osmia* spp. work in almond orchards (Bosch et al., 2000; Bosch and Kemp, 2000; Torchio, 2003), red raspberries and blackberries (Cane, 2005), pears (Maeta et al., 1993), blueberries (MacKenzie et al., 1997) and for sweet clover fields (Richards, 2003).

Commercial and ecological significance

Agroindustry comprises one of the most important economic sectors. The yield of most crop species is boosted by bee pollination services. Pollination has both commercial and ecological importance in crop production. In the context of agriculture, pollination supplies a wide range of benefits to a broad diversity of commodities across the world. Production of the fruit itself brings about directly from the bee pollination action for fruit formation in some cases. In other cases, although pollination does not result in productivity of the produce itself, the procedures contribute production of seeds used to grow a root crop such as carrots or quality, as size of tomatoes has been linked to repeated pollination (da Silva, 2018; Tanda, 2019) (Fig. 4).

Through food chain associations there are indirect advantages there as well. Directly, an annual value of $109 million, alfalfa seed crop is produced, along with hay valued at $4.6 billion per year for livestock forage indirectly by bee-pollination services (Morse and Calderone, 2000). Though indirect results overemphasize the economic value of crop pollination, the findings have been utilized in many research programs. To the U.S. agriculture, annual value of honey bee pollination has been estimated at $150 million (Rucker et al., 2005), $1.6-5.7 billion (Southwick and Southwick, 1992), $9 billion (Robinson et al., 1989a, b), $14.6 billion (Morse and Calderone, 2000), and $18.9 billion (Levin 1983). In Canada, honey bee pollination annual profits had been reported as $443 million (Scott-Dupree et al., 1995). As alfalfa leaf cutting bees and bumble bees also pollinate crops, the role of *A. mellifera* is not distinctive. In annual bee pollination, about $2 billion to $3 billion benefits can be ascribed to the role of wild bees and other insect species (Losey and Vaughan, 2006; Prescott-Allen and Prescott-Allen, 1986; Southwick and Southwick, 1992).

As plant pollinators of economically significant crops, many vertebrates also work. Species utilized for timber, silk, cotton, balsa wood, and other products, depend mainly on bats for pollen transfer in tropical trees of Bombacaceae family (Bawa, 1990; Watson and Dallwitz, 1992). Also rely on bats and birds for seed fertilization-related activities which are main origin of alcoholic beverages (tequila, mescal) cacti and agaves, and several other valuable products such as sisal fibers (Arizaga and Ezcurra, 2002; Arizaga et al., 2002; Fleming et al., 2001a, b; Grant and Grant, 1979; Rocha et al., 2005; Valiente-Banuet et al., 1996; Slauson, 2000, 2001). Than estimating their economic significance in agriculture sector, the contribution of bees and natural pollinators, and forecasting the results of their deprivation are more demanding. Both the number of species engrossed and the scarcity of details obtainable for most of those species, such approximates are more intricate. Losey and Vaughan (2006) did not try to calculate a dollar value of the plant pollinators in their role to estimate the economic importance of their eco-services given by pollinators. Further for maintenance of natural crop ecosystems, it is practicable to presume that an important number of flowers in uncultivated terrestrial environment rely on bee pollinators. Valuable to humans, for example water filtration, carbon sequestration, floods and soil erosion control, all these cropping systems offer a lot of environmental jobs (Daily et al., 1997). Other than flower pollination in their immature stages, the difficulty is that crop pollinators may contribute many environmental services. The significance of these jobs is equally complicated to estimate, especially without a full understanding of all aspects of pollinators' biological systems. Honey bee (*A. mellifera*) is the main pollinator that applies a strong effect on its population through their enlarged phenotypes that connects to disease resistance traits (Easton-Calabria et al., 2019). Honey bees confirm resistance to pathogens and pests in its enlarged phenotypes such as honey, propolis, venom, beeswax, bee bread and royal jelly etc. To show antipathogenic properties and to play as a hive level defensive tool against diseases, each of these enlarged phenotypes have proved.

Crop pollination catastrophes

About one million species now face extinction, according to a major new UN report. Scientists warn that this is not only a crisis for nature, but for humanity all over the world (Howard and Johnson, 2019). Why they so feared are and what does it mean for our life systems? Localized bee population diminishing and a global decrease in the number and survival of insect pollinating agent, the concept of a pollinator crisis contributing to trophic collapse (Dobson et al., 2006) was noted in 1990s. About this crucial crop pollinator, big losses in honey bee colonies were found in the United States (Watanabe, 1994). As a fundamental ecoservice system a stress on insect pollination (Daily et al., 1997) brought about an outburst of interest in the international policy arena (Allen-Wardell et al., 1998; Costanza et al., 1997; Eardley et al., 2006). In conservation of biodiversity, the science of insect pollination ecology and floral biology has now been well established. Worldwide scientists and agriculturists were worried about a decline of bee pollinators and ill effects on biodiversity globally occurring in the mid-1990s. In 2000, at the Fifth Meeting of the Conference of Parties (COP) of the Convention on Biological Diversity (CBD) to establish an International Initiative for the Conservation and Sustainable use of pollinators (also referred to as the International Pollinators Initiative, or IPI), concerned policymakers. Within the program of work on agricultural biodiversity to encourage coordinated program globally Fifth Meeting of the Conference of Parties (COP) contemplated this to be an alternate initiative, and appealed for the development of an Action Plan for the IPI. In 2002, Action Plan developed on the São Paulo Declaration on Pollinators recommendations was embraced at COP 6 (decision VI/5). All the conservationists, growers, landscape architects, town planners and other stakeholders are required to follow policy designers and perform for the significance of crop pollinators and sustainability of biodiversity around the world (Eardley et al., 2006; Howard and Johnson, 2019).

Conclusions: Challenges and threats

To conclude, bees are well established as efficient crop pollinators, domesticated bumble bees and solitary bees are also important for the prosperous fertilization of many crop plants, while native bees offer a voluntary service. For the conservation of wild flora, insect pollination is significant for natural ecosystem sustainability. It is very complicated to understand the history of insect pollination or entpollinatology, bee behaviour and their management for crop pollination services. Bees perform a big job in the agro-ecosystem resilience, though they are little in size. Of a big mutual connection between humans and the natural environment, the relationship between bees and humankind is figurative. The role of insect pollinator's attempt;

- To fill the gap by offering the evaluative analysis of different management strategies in agriculture sustainability and environment protection
- Pollination needs of various field crops in enhancing quality and quantity
- Why insect pollinators or entpollinatology important in crop improvement programs?
- Global agro industry in the absence of bee pollinators
- Insect pollination in hybrid seed production system of entomophilous crops
- Sustainability of natural bio-ecosystem
- Improvement in pollinators density and diversity boosting crop yields
- Current threats to pollinator populations and sustainable food productivity
- Overuse of insecticides and safety to flower foragers
- Crop pollinators, conservation and strategies
- Importance of non-insect pollinators in crop improvement
- Important issues and future of entpollinatology

- New advances in pollination materially engineered artificial pollinators
- Assessment of pollinators, bee management and crop services
- Adaptive management of crop plants and wildlife
- How pollination biotechnology may be main-streamed into policy decisions for global food sustainability.

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