



A review on: Effectiveness of insect pollinators on qualitative and quantitative parameters of fruits and vegetables

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Abstract

Pollination is the transfer of pollen grains from the male parts to the female parts. About 90% food obtained from plants and 77% plants are depend upon bee pollination, globally. Pollination is the ecosystem services which provided through insects in agricultural and natural areas worldwide. The main pollinating agents are insect, birds, animals and wind. Among them insect orders like Diptera and Hymenoptera are the important pollinators that play key role in plants pollination. The quality and quantity of fruits and vegetables improved through pollination which considered highly important. The entomo-pollinated crops are mango, strawberry, onion, carrot etc. These all are significant and provide food, fiber, oils and nutrients. The fruits and vegetables relay on insects for increasing their fruits set and physiological properties. The pollinated fruits and vegetables showed greater fruit weight, size and longer shelf life as compared to non-pollinated. Through improper pollination and fertilization, the fruits weight, development reduce even abscission occur. The shape of fruits and vegetables also deformed, quality decrease even fruits remain on their plants. Honey and Bumble bees are the competent pollinators, which visit fruits and vegetables flowers many times in a day and helpful for crop production worldwide.

1. Introduction

1.1. Importance of pollination:

According to an estimate, human population will increase up to 9 billion in 2050 around the globe (Godfray et al., 2010). Because of increasing population, food demand will substantially increase leading to food security (Lautenbach et al., 2012). The well pollinated crops received more pollens and bears large number of fruits. In 2011, more than 1.5 million tons of fruits and vegetables were consumed by the humans (Faostat et al., 2013). Thus, due to the increasing population with low resources malnutrition is an increasing problem in underdeveloped countries. Godfray et al. (2010) was performed a survey reported that many people are facing the problems of food security (Godfray et al., 2010). Beside the low resources of people, the produce grown is also

wasted and handled improperly which result in poor quality of the produce (Gustavsson et al., 2011).

Alongside the problems mentioned above, poor pollination by insects also results in low production of crops (Zhang et al., 2007). Thus, the natural ecosystem is maintained (Kevan, 1999; Kevan & Phillips, 2001; Eardley et al., 2006). Pollinators are the main source to support and maintain the recreation, erosion control, climate regulation, raw materials production and cultural services. Pollination depends on the species symbiosis. A few studies have been reported that crops yield as well as the shelf life of fruits and vegetables are influenced by the insect pollination. The crops like tomato, onion, carrot, reddish, brinjal, apple, mango, guava and strawberry have economic value in Pakistan, their shelf life is affected due to deficient pollinators (Al-Attal et al., 2003; Shin YS

et al., 2007; Gajc-Wolska et al., 2011 and Klatt et al., 2014).

1.2. Importance of pollinators

The following insects are known to pollinate the plants effectively. These are [honeybees](#), solitary bees, bumble bees, wasps, [ants](#), [flies](#), hoverflies, [butterflies](#), [moth s](#) and flower [beetles](#) which play role in pollination of fruits and vegetables.

Pollinators play significant part in the economy of agriculture as reported by (Gallai et al., 2009 and Morse & Calderone, 2001). In Bangladesh, Bhutan, China, India, and Pakistan insect pollinators contribute 2.69 US dollars to agricultural economy and maintain the biodiversity (Partapet et al., 2012). It has been reported that 90% plants and 3 quarter food crops depend on pollinators such as insects, birds and mammals (Chivian, 2002). Insect pollinators are also play key role in artificial managing system (Collette, 2008 and Gallai et al., 2009). Many countries such as Asia, India, China, Africa, America, Japan and Europe depend on natural pollinator such as birds and insects for crop pollination that provide vitamins minerals and carbohydrates etc. (Ken et al 2012).

Pollinators are the animals or vectors which carry pollen from the male parts to the female parts for fertilization. The studies have been reported that pollinators play important role in fruits and vegetables production (Aebi et al., 2012; Breeze et al., 2011; Ollerton et al., 2012). Most of the crops are important for human food depend on pollinators (Klein et al., 2007; Eilers et al., 2011 and Ollerton et al., 2011). The pollinators have been reported to enhance the tropical fruits, vegetable and seed setting (Kremen et al., 2001).

Large number of pollinators such as beetles, wasps, butterfly, moths, ants and midges play important role in pollination. About 80% pollination of fruits, vegetable and crops carried out by insects (Akhter et al., 2016). More than 90% yield of fruits and vegetables decrease due to less pollinator's availability. Like insects some birds such as humming birds, honeyeaters, sunbirds and roosting birds are efficient pollinators. Human and monkey both also play important role in pollination. In Pakistan four species of honey bee present like *Apis dorsata*, *Apis florea*, *Apis cerana* and *Apis mellifera* while last species imported from Russia and Australia in 1979. Honeybees are important pollinator (Thapa, 2006 and Klein et al., 2007) worldwide. During nectar collection honey bees

pollinate the fruits, nuts, vegetables, pulses, oilseeds, spices, fibers and forage crops to enhance the quality and yield (Partap & Verma, 1994; Singh et al., 2000; Sekita, 2001; Mattu et al., 2012). Now a days domesticated bee becoming the important pollinator.

Many studies have been focused on the importance of honey bee for several fruits and vegetables yields like Assam lemon *Citrus limon* Burm. Japanese plum *Prunus salicina* Lundl. (Stern et al., 2007), Pear *Pyrus communis*, Apple *Malus domestica* Borkh, rabbiteye blueberry *Vaccinium ashei* Reade. Several types of fruit crops such as apple, mango, strawberries, guava and many other require insect pollinator for their pollination. At the time of bloom many pollinators are available as a result there is production of sustainable crops. The fruit and vegetable are in good size, shape and weight with well pollination. Pollination proves to be helpful in pests, diseases reduction and water saving (Anonymous, 2010).

2. Review of Literature:

2.1. Fruits:

2.1.2. Strawberry:

In greenhouse, *Bombus lucorum* and *Apis mellifera* are the main pollinators which pollinate the strawberry (Li Ji-Lian et al., 2006). Strawberries are sensitive to fungal attack and quickly degrade due to fast metabolic process and short shelf life (Hernandez-Munoz et al., 2006). After four days of storage losses occur in strawberries (Hernandez-Munoz et al., 2006). The shelf life is very important factor in determining the quality of strawberries (Ariza et al., 2010). Fruit quality parameters are fruit size and weight that determined the shelf life of fruits. Shelf life affected by reduction in weight and size of fruits. Twisting occurs due to lack of pollination, as result fruits remain unfertilized (Ariza et al., 2010) and no physiological functions occur (Pipattanawong et al., 2009). Deformation occurs due to pollination limitation and absence of pollinators (Zebrowska et al., 1998). The important pollinators are *Apis mellifera*, *Halictus ligatus* Say, and *Eristalis* spp. Honey bee is an efficient pollinator and increase production 19-22% while next important is Syrphidae.

2.1.3. Apple

Apple (*Malus domestica* Borkh.) belong to Rosaceae family (Hancock et al., 2008) and need cross pollination for fruit setting (Delaplane & Mayer 2000). It is a self-incompatible fruit (Sheffield, et al., 2016). Apple is an important fruit

in temperate areas of the world and cultivated in Europe and Asia (Janick et al., 1996).

In enhancing the apple production, pollination is playing the key role which is carried out by insect pollinators especially honey bees and bumblebees (Michener 2007). Other studies have been reported that solitary bees and bumblebees are efficient pollinators of fruits and vegetables (Vicens & Bosch 2000; Ladurner et al., 2004; Matsumoto et al., 2009 and Thomson & Goodell, 2001). With good pollination the fruit and seed size increase which ultimately influence the quality and quantity (Ward et al., 2001 and Garratt et al., 2013).

Honey bees are the most important pollinators of apple orchard (Jackson, 2003; Dag et al., 2005 and Delaplane and Mayer, 2000). The main pollinator of apple is the honey bees (Stern et al., 2001) which managed in the apple orchard and through these fruit quality increase (Gupta et al., 1993). Foraging behavior is the key role of insects and it has been recorded in honey bee. The pollination services which provided by bees have important value in improving the quality and quantity of fruits (Sharma et al., 2012). The hoverflies and bees are the main pollinators of this fruit, which improved the production (Klein et al., 2007). The seed number and nutrients concentration like calcium also increase through pollinators (Buccheri and Di Vaio, 2004 and Matsumoto et al., 2012). Artificial pollination (Hand pollination) which performed through labor's, by doing this fruits quality such as size, weight and shape badly affected.

Due to poor pollination many fruits start falling before reaching the maturity and seed size reduce while proper pollination fruit set increase and dropping of fruits stops in apple orchards (Sharma and Gupta 2001 and Sharma et al., 2004). These free of cost pollination services provided by insect pollinators worldwide for various fruits like apple (Delaplane & Mayer, 2000 and Sharma et al., 2012). Pollination enhance through the repeated visitation of pollinators such as insects which pollinate the flowers and dropping of fruits reduce and fruits size and shape improve.

2.1.4. Mango

The mango (*Mangifera indica*) is dicotyledonous plant, known as the "King of Fruits" and grown worldwide especially in the tropical and

subtropical areas (Litz, 2009b). There are large number of *Mangifera* species (Dillon et al., 2013). It is grown in more than 80 countries (Sauco, 2004; Tharanathan et al., 2006). It is the 5th largest fruit crop in production with respect to globe. It is very nutritious fruit, rich in sweet taste vitamins and minerals (Masibo and He, 2008). *Apis dorsata*, *Apis florea*, *Episyrphus balteatus*, *Ischiodonts cutellaris*, *Lucilia* spp., *Chrysomyamegacephala* and *Chrysomyapinguis* are the effective pollinators and increase the yield of mango (Bashir et al., 2013; Mingjian, Zi & Jianguo, 2003 and Sung et al., 2006). Stingless bees, calliphorids, *Melipona* sp., *Syrphus* sp. *Rhynchaenus mangiferae* Marsh and honeybees are efficient primary pollinators of mango (Fajardo et al., 2008).

More than 550 species of plants pollinate by dipteran (Larson et al., 2001). The honey bee, bumble bee and stingless bee are efficient pollinators of mango and play key role in human economy (Oldroyd et al., 2006 and Velthuis et al., 2006). It has been reported that Dipteran, aphides and Hymenopteran insects are good mango pollinators (Dag et al., 2000). Among the mentioned insects blow flies are also known as an efficient pollinator (Losey & Vaughan, 2006; Klein et al., 2007 and Heath, 2015). It helps in increasing the yield of mango production (Kumari et al., 2014; Ssymank et al., 2008; Munawar et al., 2011 and Abrol, 2012).

2.1.5. Guava:

Guava, *Psidium guajava* family: Myrtaceae and cultivated in tropical and subtropical regions (Pathak et al., 2007). Fruit quality like fruit weight and size are in good condition in winter than rainy season (Aulakh, 2004). It is distributed in Pakistan, India, Bangladesh, USA, Thailand, Mexico, Brazil, and many other countries of the globe (Watson & Dallwitz, 2007). It is enriched with delicious taste and highly nutritional value. The various nutrients like minerals and vitamins are present in higher amount (Rahman et al., 2003; Adrees et al., 2012). It is the 4th most important fruit crop with annual 0.55 million tons production in Pakistan (Usman et al., 2013).

The flowers of the guava are most attractive to various pollinators especially the honeybees. The flowers of guava produce large concentration of pollen and nectar which are the attractive agents of pollinators. Due to cross pollination pollinators attract towards the guava for

nectar collection and become the cause of increasing yield (Kumar et al., 1996).

2.1.6. Litchi:

Litchi (*Litchi chinensis*) belongs to family Sapindaceae. It is a large plant, lasting throughout the year and cultivated in subtropical regions of the world. Firstly, grown in china. Both type of pollination like self and cross carried out in litchi. The cross pollination carried out by pollinating agent especially insects. The insects which take part in pollination belongs to order; Coleopterans, Hemipterans and Lepidopterans. The main visitors of litchi are flies, wasps and honey bees. The study carried by (Menzel and Waite, 2005) that production enhance through honey bees. In the open field, quality and quantity like fruit size, weight and shelf life improved (Kumar, 2014) by honey bees as compared to closed or caged field where honey bees' access is impossible.

2.1.7. Coconut:

The coconut palm (*Cocos nucifera* L.) depends on insects for cross pollination. It is monoecious plant carry both male and female flowers. It has medicinal properties and its oil used for treatment of many diseases like heart diseases. European and Asian honey bees are main pollinators of coconut (Castro and Viana, 1997). About 30 % of the coconut fruit is dependent on insect pollinators (Melendez-Ramirez et al., 2004). During visiting the flowers pollen grain stick the legs or wings of pollinators and when the pollinators move to other flowers for nectar collection. Both these pollinators prove to be helpful in enhancing the fruits quality as reported by Melendez-Ramirez et al., 2004). Honey bees insert their tongue in flowers for nectar sucking and pollinate those flowers.

3. Vegetables:

3.1. Onion

Onion is popular vegetable, cultivated worldwide especially in temperate region. It is cross pollinating vegetable but cross pollination become very difficult due to hermaphrodite nature. Large number of insects like honey bees, halictid bees, bumble bees, syrphid flies, drone flies, butterflies are main visitors of onion (Sajjad et al., 2008) that are attracted toward the onion flowers for nectar collection. Insects are the main pollinating agents which enhance the quality and quantity of onion production. Onion seed quality and quantity also affected by the absence of insect pollinators as reported by (Chandel et al., 2004). Onion seed size, weight and germination increase by pollinators

especially red mason bees, which have potential to pollinate the onion (Wilkaniec et al., 2004). Honey bees, bumble bees and syrphids (Chandel et al., 2004) are frequently visitors of onion flowers. In open field honey bees are efficient pollinators but in closed condition drone flies are good pollinators. Syrphid flies are others efficient pollinators of onion as reported by (Chaudhary, 2004). The pollinators are increasing about fruit setting (73%) while 17% production reduced without pollinators during the flowering period of onion (Rao and Sunyanarayana, 1989). Insect pollinators continue to decline by many factors such as pesticides usage (Saeed et al., 2008), due to this yield of onion decrease gradually (Witter and Blochtein, 2003).

3.2. Tomato

The tomato belongs to family Solanaceae. The tomatoes originated from the Andean regions. Now a days is grown worldwide (Olmstead & Palmer 1997). Tomato has well and closely relation with insect pollinators for the fruit and production (Chetelat et al., 2009). The pollination of tomatoes in greenhouses is performed by different ways among them using of bumblebees is one of them (Doorn, 2006). Native bees are the main pollinators which play role in buzz pollination (Greenleaf & Kremen, 2006a; Macias-Macias et al., 2009; Vergara & Fonseca-Buendía, 2012). When bees visit the flowers for nectar collection then pollen traps on their wings, legs and drop to next flower or plant when bees set on flowers for nectar (Morandin et al., 2001a and Teppner, 2005). Exomalopsis analis, Augochloropsis spp. and Centristarsata frequently visit the tomato for nectar collection in Brazil (Santos & Nascimento, 2011). The genus Bombus have significance role in open pollination (Macias-Macias et al., 2009 and Silva-Neto et al., 2016). Both quality and quantity improved by using bumblebees. It has been observed that yield improved about 15% in greenhouses where *Melipona quadrifasciata* bees managed (Bispo dos Santos et al., 2009). The number of seed and fruit production enhance up to 50% as reported by (Morandin et al., 2001b). The similar results have been recorded by (Hogendoorn et al., 2006; Palma et al., 2008; and Vergara & Fonseca Buendía, 2012). Due to high speed and visitation of bumble bees increase fruit weight (41.5%), diameter (15%) and seed production (30%) reported by (Hatami et al., 2013). The reduction in yield of tomato is occurred due to non-availability of bees especially bumble bees (Bonda and Paxton, 2008).

3.3. Carrot:

Carrot (*Daucus carota*), belongs to Apiaceae family, is important vegetable (Bose and Som 1990) cultivated throughout the year in tropical and subtropical regions. It is cultivated two times in a year as vegetables and seed production. Self-pollination doesn't occur in carrot. Due to lack of self-pollination, carrot depends on cross pollination. Poor pollination result the poor seed size and pollen viability as reported by (Spurr, 2003a and Spurr et al., 200b). Due to flowers arrangement carrots attract insect pollinators (Koul et al., 1993). Insect pollinators are the main pollinating agents that pollinate the carrots and transmit the pollen grains from plants to plants, enhance the yield of carrots (Anonymous, 2014). Honey bees are the best and efficient pollinators of carrots and carried more pollen than other pollinators (Eaton & Murray, 1997).

About 85% yield increase by honey bees, visitation affects the quality and quantity of carrot nectar (Johannsmeier and Mostert, 2001). Those flowers which are visited by honey bees carried more nectars and quality also enhance by doing this as reported by (Delaplane & Mayer, 2000).

3.4. Brinjal

Brinjal (*Solanum melongena*) belongs to family Solanaceae and very delicious vegetables of tropical and subtropical areas. It is cultivated in temperate regions such as Pakistan, China, Turkey, Italy, France and USA. It is self-pollinated but 90% vegetables depend on pollinators for pollination. The honey bees (Ricketts et al., 2008 and Delaplane and Mayer, 2000) and bumble bees (Velthuis and van Doorn, 2006) are efficient pollinator of eggplant. The fruit weight and size increase by both bees (honey bees and stingless bees) pollination as reported by (Nunes, 2013). It has been reported by many authors that eggplant production enhances by insect pollinators like honey bees (Gemmill-Herren and Ochieng, 2008; Venturieri et al., 2009; Montemor and Malerbo-Souza, 2009; Abak et al., 2000 and Kowalska, 2008). Another study was showed that the yield and fruit size increase with increasing pollinators like honey bees and bumble bees. The yield (23%) percentage was improved through bumble bees. The solitary bees like *Xylocopa caffra*, *Macronomia rufipes* were efficient pollinators and proved to be helpful in seed production (Gemmill and Ochieng, 2008). Other bees like stingless bees, *M. fasciculata*, have potential to pollinate the eggplant in in greenhouses.

The fruit set about (29.5%) of brinjal increase through sting bee visitation (Patrícia et al., 2013).

3.5. Radish

The radish, (*Raphanus sativus*) belongs to family Brassicaceae is very important vegetable, cultivated worldwide. It is cultivated in winter season and very short duration crop (Mahmood and Mehmood, 2015). There are various varieties of reddish mostly are cross pollinated. The cross pollination is very important for seed production. The cross pollination is carried out by insects (Kercher and Conner, 1996). Honey bees are the good pollinators of reddish as reported by (Partap and Verma, 1994). The seed yield and quality like appearance, size and weight increase by honey bees.

3.6. Cauliflower

Cauliflower (*Brassica oleracea*) belongs to family Brassicaceae and is very nutritious winter vegetable worldwide (Rashid, 1999). As cross pollinated, require some pollinating agents like Insects especially honey bees (Singh et al., 2005). The various type of insect - pollinators visit the cauliflowers, play key role in pollination but honey bees and bumble bees are the potential pollinators which enhance the yield. During collection of nectar from flowers, pollen sticks at the legs of honey bees and pollination occur when bees move to other flowers the pollens transfer to another flower. Honey bee pollinates six flowers in a minute. About 85.23% pollination carried by honey bees as reported by (Selvakumar, 2003). It has been observed that weight of seeds was more which pollinated through insect pollinators as compared to those which are self-pollinated (Singh et al., 2005).

Due to good pollination fruit size, weight and number of seeds per flowers increase than poor pollination (Sihag, 2001). Very few seeds produce in next season due to poor pollen grain fertilization (Sushil et al., 2013). The seed set, and weight increase (Rouf et al., 2016). It has been recorded by (Sharmah et al., 2015) that *Aphis cerana* increase fruits yield. Among the factors which influence the production of cauliflower lack of insect pollinators is one of them (Sushil et al., 2013).

3.7. Okra

Okra (*Abelmoschus esculentus*) belongs to family Malvaceae and cultivated worldwide throughout the year (Baidoo et al, 2014). Mostly grown in highly irrigated areas (Pushpalatha 2008). It used as vegetables due to presence of various factors like calcium, vitamins A, B, C, high protein and fiber (Sona et al, 2000). Due to the presence of

fiber, stem and fruits of okra used in paper industries for manufacturing of paper (Sharma, 1993). Large number of fruits and vegetables depend upon the pollination agents like insects. The selfing in crops does not promote the seed production (Greenleaf 2006) but with the help of cross-pollinating agents like insects, fruits size, yield and spores number enhance (Herrera, 2000). Among the insect's pollinators honey bees are efficient and potential pollinators of fruits and vegetables (Klein et al., 2007).

The fruits quality and quantity enhance with insects' pollinators. The fruits shelf life also improved and seed production increase. Insects pollination increase the weight, capsule length and number of seed present in pod (Angbanyere, 2014). About 19% yield and production of okra enhance due to pollinators in India (Angbanyere, 2014). Due to the absence of pollinators the yield and weight of fruits and vegetables reduce (Partap, 2001). It has been reported that the flowers of okra which are bagged carried a smaller number of seeds, capsule size and length reduced without open pollination (Azo'o et al., 2011). The okra yield and number of seeds in pods improved with the help of insect - pollinators as studied carried out by (Baidoo et al., 2014).

Conclusion

In this review, we highlight the importance of pollinators for fruits and vegetables. The physicochemical properties of both fruits and vegetables can be enhanced by effectiveness of insect pollinators that are necessary for these crops. Pollinators stay time and visitation rate are the important parameters to determine the effectiveness of any pollinator. The yield of both self- and cross-pollinated crops can be increased by the presence of more numbers of insect pollinators that are necessary for these crops. We should conserve the important insect pollinators of fruits and vegetables crops by providing them natural conservation landscape and soil nesting habitats in the fields. The use of insecticides which are harmful and cause of declining the pollinators should be minimized.

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