Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 55 (2013) 12878-12883

ISSN: 2229-712X

Studies on Entomophil pollination towards sustainable production and increased profitability in the oil Palm: a review

Appiah, S. O. and Agyei-Dwarko, D

CSIR - Oil Palm Research Institute, Post Office Box 74, Kade, Ghana.

ARTICLE INFO

Article history:

Received: 6 December 2012;

Received in revised form:

2 February 2013;

Accepted: 4 February 2013;

Keywords

Oil Palm,

Pollen,

Anemophily,

Entomophily,

Zoomophily,

Pollination.

ABSTRACT

The paper reviews pollination studies in oil palm in West Africa, the Far East and South and Central America. The main types of pollination in the oil palm, anemophily and entomophily, and other forms of pollination are discussed. The floral characters of the oil palm that promote anemophily and entomophily are: abundant smooth dry pollen grains, enlarged stigmatic surfaces, reduced perianth, coloured perianth and a raised female inflorescence. The critical role played by insects and the resulting increases in yield of fresh fruit bunches (ffb) and oil following introductions of pollinator insects into the plantations in the Far East and Central and South America are mentioned. The introduction of insect pollinators into areas in the Far East with poor fruit set rates led to the cessation of assisted pollination and increased profitability. The introduction of the insect pollinators led to as much as 36 – 80 % improvement in fruit set, a 12 % increase in fruit-to-bunch ratio and a 28 – 54 % increase in mean bunch weight. The oil-to-bunch ratio increased by 9 % and a 43 % improvement recorded in the kernel-to-bunch ratio. Insects belonging to the *Elaeidobius* spp. *(Coleoptera: Curculiondae; Derelominae*) are the main insects involved in pollination of the oil palm. Other insects listed are the *Prosoestus* spp., *Microporium* spp. *(Coleoptera: Nitidilidae*) and *Atheta spp. (Coleoptera: Staphylinidae). Mystrops* spp. are of economic importance in South and Central America. The insects generally carry pollen on their hairy bodies and wings. The bigger and more hairy insects are more efficient pollinators and contribute to adequate fruit set and increased yield. Pollinator insect populations may be conserved through the selective use of insecticides, the proper timing of application, and the mode of application to achieve sustainable production.

Introduction

The oil palm, *Elaeis guineensis* is a monocotyledonous tree belonging to the family Palmaceae, sub family *Coccoidea*e and genus *Elaeis*. The productive commercial life of the crop is between 20 and 30 years after which harvesting becomes increasingly difficult and yields decline slowly.

The oil palm has assumed an increasing importance in the non-traditional export sector of the Ghanaian economy, becoming next to cocoa in the agricultural tree crop sector of the economy (Anon., 2004).

The palm produces two distinct oils: palm oil and palm kernel oil, which have both culinary and industrial uses. The oils have a wide variety of applications in the food and detergent industries.

There is fossil, historical and linguistic evidence for an African origin of the oil palm (Hartley, 1988). Zeven (1964) reported fossil pollen from Miocene and younger layers in the Niger delta as being similar to pollen of the oil palm as it grows today. That such pollen is found throughout these layers is strong evidence that the palm has been maintaining an existence in West Africa from very early times.

In its natural habitat in Africa, natural pollination in the oil palm is considered adequate largely due to a combination of climatic factors and the presence of pollinator insects. (The drought period of 3-6 months assists anemophily and also induces the production of a lot of male inflorescences and hence more pollen). Outside the palm's natural environment, pollination and fruit set problems may arise especially where rainfall is persistent and humidity high throughout the year.

The increasing importance of the oil palm in the economies of Nigeria, Cote d'Ivoire, Cameroon and Ghana where the cultivation of the crop is to be expanded and processed to serve as one of the key pillars in driving the economy makes it even more imperative to draw attention to the importance of pollination and the agents involved to ensure adequate fruit set and high yields with the view to suggesting agro-management practices that will conserve and enhance the effects of the biotic agents of pollination to ensure sustainable production.

The purpose of this paper is to review the types of pollination generally and to highlight the critical role insects play in pollination and fruit set towards increased yields and profitability in the oil palm which will contribute to food security and also lead to economic gains to alleviate poverty and spread incomes especially in the rural areas where oil palm is produced and processed.

Types of pollination

1. Anemophily:

This is the transfer of pollen from the anthers to the stigma by wind. Anemophily is influenced by climate (rainfall influences pollen density as damp or wet pollen will not disperse) and the number of male inflorescences.

The floral characters of the oil palm which include abundant production of pollen, an enlarged stigmatic surface, reduced perianth and small pollen grains with smooth dry exine point to

Tele:

E-mail addresses: dandwarko@yahoo.co.uk

the role played by wind in pollination of the crop (Jyoti and Saradamani, 1994).

In anemophilous plants, the pollen is light and non-sticky and can be transported by air currents. The anthesising male flowers are also well exposed so that the pollen is exposed to wind currents. The female flowers which develop into individual fruits are abundant and easily trap airborne pollen grains (Anonymous, 2006)

2. Entomophily:

This is the transfer of pollen by insects from the anthers to the stigma. Insects get dusted with pollen through their foraging activities and transfer or deposit such pollen onto other flowers they visit. Bigger and more hairy insects have a higher pollen carrying capacity and are more efficient as pollinators (Abraham, 1994; Syed, 1979; 1994). Entomophily often occurs in plants that have developed coloured petals and a strong scent to attract insects such as bees, wasps and occasionally ants (Hymenoptera) and beetles and weevils (Coleoptera).

The floral features facilitating entomophily in the oil palm include the odour of aniseed produced particularly by the male flower and to a lesser extent by the female inflorescence (Turner, 1978).

Temperature changes in the female inflorescence are also linked to pollination as observed in the sapromyophilous Arum (Turner, 1978). A marked temperature rise at the time of male flower opening and female flower receptivity induces volatilization of substances to produce a strong smell, which is believed to attract small beetles, which might previously have visited a male flower in anthesis (Meeuse, 1977).

In the oil palm, a temperature rise of 5-10^{o}C above ambient with accompanying strong aniseed odour was recorded in Sumatra (Henry, 1947; Heusser, 1922 cited in Turner, 1978). The rise in temperature could have an indirect effect on pollen dispersal through bringing about a lowering of atmospheric humidity and drying out of the male inflorescences (Turner and Gillbanks, 1982). There is thus a general correlation between temperature rise and atmospheric concentrations of pollen grains which could result in improved pollination of the oil palm.

3. Zoomophily:

This is pollination effected through the agency of animals such as birds, bats etc. Floral features indicating zoomophily include the presence of brightly coloured flower parts, abundant nectar and the emission of strong odour which is a characteristic found in the oil palm (Turner, 1978).

Rodents which feed on the ripened fresh fruit bunch are also likely agents of pollen spread. This is a typical plant-animal relationship which is mutually beneficial as the rodent in search of food acts as a pollinator.

4. Artificial pollination:

This refers to the transfer of pollen to the stigma of the flower by an agent other than the naturally occurring ones mentioned above. It is performed by man and is mainly for purposes of breeding and seed production. . The oil palm is considered a good pollinizer as it provides compatible, viable and plentiful pollen. A pollinizer is a plant that serves as the pollen source for other plants.

Pollination in the oil palm

The oil palm is monoecious, producing separate male and female inflorescences on the same palm. Male and female inflorescences follow each other in cycles. The female flowers usually anthesise before the male flowers shed their pollen thus facilitating cross-pollination.

Pollination in the oil palm was originally believed to be mainly wind assisted (Jagoe, 1934) but the invariably good pollination and high fruit set even in periods of incessant rainfall and high humidities suggest the involvement of other agents in addition to wind in the pollination of the oil palm (Appiah, 1999).

A wet inflorescence does not disperse pollen. Turner and Gillbanks (1982) reported a strong correlation between rainfall and the concentration of pollen in the atmosphere. Rain has a depressing effect on the density of airborne pollen, thus affecting the amount of natural pollination taking place during rainy weather. Hardon and Turner (1967) found that the onset of rains caused an immediate reduction in atmospheric pollen density and that pollen density was influenced more by the number of days on which rain falls.

Even low rainfall levels of about 2.5 mm/day are reported to reduce pollen density in the air remarkably to affect adequate pollination (Hardon, 1973; Turner and Gillbanks, 1982; Syed, 1979).

Role of Insects

In the oil palm, insects have also been observed to be involved in pollination (Syed, 1979; Abraham, 1994) but their efficiency varies with the height of the canopy (Jyoti and Saradamani, 1994). Generally in aged tall plants, pollination is successfully done by airborne pollen, whereas in the young palms, insects could enhance the pollination to a larger extent especially in deeply borne flowers within the female inflorescences.

Several species of insects are associated with the male and female inflorescences of the oil palm (Syed, 1979) and these insects are believed to assist in transferring pollen to the lower parts of the female inflorescence, which is protected by persistent bracts, and are as such not easily accessible to air borne pollen.

Syed (1979) reported that a large number of insects visited female inflorescences throughout the period of their receptivity mainly during the daytime. These insects were observed to arrive in intermittent storms. The main insects observed by Syed (1979) on both male and female inflorescences were *Elaeidobius* spp. and *Atheta* spp.

Studies in Cameroon

Investigations in Cameroon started from July 1977. The studies were carried out at Plantations Pamol du Cameroon, Lobi Estate in the South-West Province of Cameroon. The results demonstrated very convincingly that oil palm is pollinated by an array of insects attracted to the aroma given off by the flowers (Syed, 1979).

Prior to Syed's (1979) work there was little published evidence to suggest that insects play any significant role in the pollination of oil palm. He found large numbers of insects present on the male inflorescence during anthesis and on the female flowers during the first few days of receptivity. He further observed that all the species that were found on male inflorescences also visited female inflorescences. A large number of insects were found on the male inflorescences, and he reported that some of these continuously left the flowers and were usually laden with pollen grains. To investigate whether the pollen was actually carried to the female flowers, he captured insects on the female inflorescences and examined them under the microscope. He found that the species of *Elaeidobius* carried the largest number of viable pollen. Syed reported that 68.5% of pollen was viable and concluded that most of the pollen was fresh (Caudwell *et al.*, 2003).

It was further reported that weevils of the genus *Elaeidobius* were the principal pollinators. Under coastal climatic conditions the most numerous species is *Elaeidobius kamerunicus* (Table 1). Its capacity to transfer pollen is much greater than the others since it was found well adapted to the wet season, and could cope reasonably well with dry seasons. It has good searching ability and above all it is extremely host specific (Syed, unpublished; Kang and Zam, 1982). The studies in Cameroon indicated that *E. kamerunicus* is a more efficient pollinator. Owing to this, *E. kamerunicus* was introduced into Malaysia (Syed, 1981).

Mariau and Genty (1988) observed that when same numbers of *E. kamerunicus* and *E. subvittatus* were artificially introduced into caged anthesising female flowers, the fruit set rate was higher (twice) in the cages with *E. kamerunicus* than in the cages with *E. subvittatus*.

Malaysian Experience

The variation in natural pollination and the poor fruit set observed in South East Asia where the oil palm is grown on commercial basis necessitated artificial and assisted pollination to obtain satisfactory yields (Hardon, 1978; Donough and Law, 1987). This led certain Malaysian planters who had had previous planting experiences in West Africa to question the then prevailing thinking that pollination was solely anemophilous (Syed, 1979). Studies by Syed (1979) demonstrated that insects play an active and essential role in pollen transfer in the oil palm in contrast to the earlier belief that pollination was solely by wind.

The introduction of the insect, *Elaeidobius kamerunicus* into Malaysia led to cessation of the practice of assisted pollination, saving the plantations millions of dollars (Abraham, 1994). Higher bunch weight and greater yield of fruits were also observed with the introduction of the pollinator insects as shown in Table 2 (Syed, 1994). Similarly, Donough and Law (1987) reported an increase in yield and profitability with the introduction of pollinator insects in Johore and Sabah. Basri (1984) had earlier reported that the introduction of *E. kamerunicus* into Malaysia led to a 36 % improvement in fruit set, a 12 % increase in fruit to bunch ratio and a 28 % increase in the mean bunch weight. He further reported a 9 % increase in the oil to bunch ratio and an improvement of 43 % in the kernel to bunch ratio.

Generally the impact of the introduction of *E. kamerunicus* in South East Asia was highly favourable, dispensing with the need for assisted pollination and contributed significantly to improving fruit set and profitability (Chinchilla and Richardson, 1991).

E. kamerunicus was selected as the preferred choice for introduction to effect pollination in the Far East owing to its relative efficiency as a result of its relatively large size and hairy body which facilitate a higher pollen carrying capacity. Moreover, their activity seem to be little or non-affected by rain even when it is heavy and can cope reasonably well with dry seasons (Mariau and Genty, 1988; Syed, 1994). *E. kamerunicus* has good searching ability and is extremely host specific (Kang and Zam, 1982).

Pollination in Indonesia

Inadequate natural pollination and low pollinating capacity of the native *Thrips hawaiensis* led to the introduction of *E. kamerunicus* into Indonesia in 1983. Mariau and Genty (1988) reported an increase in fruit-set rates from a low average of 36 % to 56, 59 and 69 % in the three years immediately following the introduction of *E. kamerunicus*.

They further reported an increase in the mean bunch weight from 9.6 kg in 1985 to 11.9, 13.9 and 14.8 kg on average during the three years after the introduction. These results further buttress the active role played by insects in the pollination of the oil palm and the increased production attributable to the insect pollinators.

Pollination in Papua New Guinea

E. kamerunicus was introduced into Papua New Guinea (PNG) in 1982. This led to significant improvement to oil palm pollination similar to those in Malaysia (Caudwell *et al*., 2003). The introductions resulted in improved fruit set levels; increased fresh fruit bunch yields and increased oil extraction ratios. Caudwell *et al*. (2003) further observed that the introduction of the pollinating weevil made a significant contribution to the economic viability of the oil palm industry in PNG. This was particularly helpful to the smallholder farmers because yields were significantly increased with no direct cost to the farmers.

Pollination in Central and South America

Oil palm pollination in South America was basically ensured by two species of pollinators, *Mystrops costaricensis* (Nitidulidae) and *E. subvittatus* (Mariau and Genty, 1988). The presence of these two pollinators is attributed to the presence of *Elaeis oleifera*, which is native to South America (Wood, 1968). The genus *Mystrops* is exclusive to South America and is found along the edge of America and throughout Central America up to Southern Mexico (Caudwell *et al*. 2003).

Evers (1977), observed large numbers (about 27,000 – 38,000) of *Mystrops* spp. per inflorescence around the male inflorescence of *E. guineensis*, *E. oleifera* and their interspecific hybrids. The same species of insects were observed on the female inflorescence. A sizeable percentage (28 % – 41 %) carried viable pollen in their abdominal hairs and on their wings (Evers, 1977). The peak period of activity of these insects on *E. guineensis* palms occurred between 4.00 pm – 6.00 pm when there is still some light in the sky (Chinchilla and Richardson, 1991).

It was also observed along the Atlantic coast up to the extreme west of Venezuela. It is further found within the Andes along the Magdalena valley in Colombia. *E. subvittatus* is the sole *Elaeidobius* species observed in South America. It seems to have come from West Africa via the east coast of Brazil (Mariau and Genty, 1988). It then went on to colonize the whole of Neotropical America. The presence of these two pollinators could however not ensure adequate pollination and fruit set in America which though generally better than in Asia was still not satisfactory.

The low fruit set levels therefore generated interest in the introductions of other pollinators into South America to improve oil yields (Caudwell *et. al*., 2003). In 1986, other *Elaeidobius* species were introduced into South America; *E. kamerunicus* in Columbia, *E. singularis* in Brazil and a mixture of four *Elaeidobius* species in other plantations in the Manaus region. *E. kamerunicus* was also introduced into Ecuador and Costa Rica.

Syed (1986 b.) recommended the introduction of *E. kamerunicus* to Malaysia and the Americas owing to its high capacity to transport pollen. The author estimated that the adult male *E. kamerunicus* carried on average 235 pollen grains per individual and the female 56 per individual.

Table 1: Population (per spikelet) of Elaeidobius spp., rainfall and male inflorescence density at Lobe Estate, Cameroon (June 1979-May 1980)

Months	Population						
	E. Kamerunicus	E. plagiatus	E. singularis	E. subvittatus	Population total	Rain-fall (mm)	Male inflorescences/ 100 palms
Adults:							
June	25	10	6	15	56	335	12
July	56	9	5	6	76	477	15
August	38	2	1	7	48	865	18
September	64	7	0	5	76	435	16
October	118	18	1	31	168	276	19
November	98	15	1	18	132	106	12
December	81	18	3	21	123	6	13
January	69	27	10	51	157	24	10
February	66	16	5	36	123	52	8
March	124	22	9	48	203	185	8
April	32	4	0	7	43	242	7
May	35	6	1	13	55	155	7
Progeny							
June	38	7	2	0	47	-	-
July	41	3	2	2	48	-	-
August	14	3	1	0	18	-	-
September	23	2	0	1	26	-	-
October	23	5	0	1	29	-	-
November	25	1	0	1	27	-	-
December	33	7	2	2	44	-	-
January	29	10	3	3	45	-	-
February	26	6	3	3	37	-	-
March	26	6	1	1	36	-	-
April	53	8	3	3	64	-	-
May	36	7	2	2	46	-	-

Source: Syed, (1994)

Table 2: Bunch composition before and after the release of *Elaeidobius kamerunicus* in Malaysia

Plantings	**1973 – 1976 MAMOR ESTATE**			**1959 – 1966 PAMOL ESTATE**		
Period	**Pre-release Apr. – June 1981**	**Post-release Dec '81 – Mar '82**	**% Increase**	**Pre-release Mar – Jun '81**	**Post-release Dec '81 – Mar '82**	**% Increase**
Mean bunch weight (kg)	10.7	13.6	27	23.5	26.9	15
Fruit set (%)	47.8	76.0	59	53.4	71.2	36
Mean fruit weight (g)	-	-	-	11.2	7.7	-31
Mesocarp to fruit (%)	76.5	74.8	- 2	74.8	70.6	- 6
Shell to fruit (%)	15.7	15.0	- 5	16.1	17.8	11
Kernel to fruit (%)	7.8	10.2	31	9.1	11.5	26
Oil to mesocarp (%)	49.1	48.7	-1	48.7	47.4	- 3
Fruit to bunch (%)	60.4	68.3	13	60.4	64.4	7
Mesocarp to bunch (%)	46.2	51.1	11	45.2	45.5	1
Kernel to bunch (%)	4.7	7.0	47	5.5	7.4	36
Oil to bunch (%)	22.7	24.9	10	22.0	21.5	- 2

Source: Syed, 1994

Table 3: Mean numbers of insect species collected on one male and one receptive female inflorescence

Insect species	Mean number	
	Male inflorescence	Female inflorescence
Elaeidobius plagiatus	60.1	160.4
Elaeidobius singularis	42.7	100.0
Elaeidobius kamerunicus	28.4	938.5
Elaeidobius bilineatus	29.3	137.5
Elaeidobius subvittatus	70.5	120.7
Prosoestus sculptilis	1.6	864.6
Prosoestus minor	3.0	1688.5
Microporum congolense	3.1	17.0
Microporum dispar	8.4	20.9
Atheta	16.1	200.0
Others	-	283.9

Source: Appiah, (1999)

Table 4: Number of insect species arriving on one female flower in anthesis during the day

Insect species	Time (a.m.)							
	8.00	9.00	10.00	11.00	12.00	1.00	2.00	Total
E. plagiatus	1	2	2	4	4	4	4	21
E. singularis	1	2	3	4	3	2	2	17
E. kamerunicus	2	5	5	8	6	7	4	37
E. bilineatus	2	2	2	3	3	3	3	18
E. subvittatus	2	2	2	5	3	3	2	19
P. sculptilis	1	1	1	1	1	1	1	7
Prosoestus minor	9	9	17	21	24	1	11	92
M. congolense	2	1	2	3	5	2	2	17
M. dispar	1	1	1	2	2	1	1	9
Total	21	25	35	51	51	24	30	237

Source: Appiah, (1999)

Generally, the introductions led to marked improvements in the previous low and fluctuating fruit set levels of 30-49 % to between 70 and 80 % (Mariau and Genty, 1988).

Ghanaian Study

Studies into entomophil pollination of the oil palm in Ghana by Appiah (1999) revealed remarkably uniform fruit set rates within the year showing that natural pollination during both wet and dry seasons was adequate.

The presence of the same or similar species of insects on both the male and female flowers and the powerful aniseed odour produced by the male and to a lesser extent the female flowers is suggestive of an insect attractant as noted by Jagoe (1934) and Wood (1968), indicating the role of insects in pollination in the oil palm.

The main insect pollinators observed in the study in Ghana were the *Elaeidobius spp* (*Coleoptera: Curculionndae; Derelominae*). Mariau *et al*., (1995) and Syed (1979, 1981) made similar observations on the insect complex on the male and female flowers in Cote d'Ivoire and Cameroun. *E. kamerunicus* was the predominant specie on the female inflorescence Table 3). *Prosoestus minor* observed in relatively large numbers on the female inflorescences is believed to aid in pollen distribution within the inflorescences (Syed, 1981).

Discussion

The uniform fruit set rates within the years as observed in Ghana (Appiah, 1999), Cote d'Ivoire (Mariau and Genty, 1988) and Cameroon (Syed, 1979) show that natural pollination during both the wet and dry seasons was adequate. The floral characters of the oil palm which include abundant smooth dry pollen grains, enlarged stigmatic surfaces, reduced perianth and a raised position of the female inflorescence (Hardon and Corley, 1976; Syed, 1979) are characters that promote both anemophily and entomophily.

The observations in Ghana (Appiah, 1999) and Cameroun (Syed, 1979) during the wet months when wind borne pollen grains are relatively scarce as a result of the depressing effect of rainfall reveal the activity of an agent in addition to wind in oil palm pollination. The role of insects as important pollinators in the oil palm is further underscored by observations in Peninsular Malaysia where an increase occurred in bunch weight with the introduction of insect pollinators (Appiah, 1999; Donough and Law, 1987; Syed *et. al*., 1982). Similar increases in yield of the oil palm were observed in Papua New Guinea and in Central and South America (Evers, 1977; Mariau and Genty, 1988; Caudwell *et. al*., 2003).

The populations of the various pollinators in oil palm may be conserved through the selective use of insecticides for sustainable production. This form of selectivity, which may be termed ecological selectivity, involves the proper timing of application of any chemical treatment and the mode of application of the chemical treatment, which will be based on the biology of the target species and the pollinators. Widespread and indiscriminate blanket applications of pesticides leave no islands of safety for native pollinator species to repopulate and recolonize leading eventually to a pollinator decline. In the Ghanaian study (Appiah, 1999), it was observed that the peak period of activity/movement towards an anthesising female inflorescence by the pollinators was between the hours of 10.00 am and 1.00 pm (Table 4). Bees are also generally known to forage on opened flowers from late morning to early afternoon (Dent, 1991). This behaviour suggests that insecticide treatment could be judiciously applied late in the evening or at dusk as a conservatory measure to protect the pollinators and ensure sustainable production.

In the oil palm, methods involving the use of systemic insecticides by either trunk injection or absorption through the root system have been devised to ensure ecological selectivity and sustainable production. In these methods only the target species are affected by any insecticides applied.

In the extreme event of the application of a blanket spray to bring a serious insect pest infestation under control, it may be prudent to phase out the treatment in blocks over time to give the opportunity of recolonisation of the earlier treated blocks by the pollinators.

Conclusion

Wind and pollinator insects play complementary roles in the pollination of the oil palm. The efficiency of the two agents in pollination however varies with the height of the canopy. Wind pollination is of importance during the dry periods when atmospheric humidity is low and there is a large production of male flowers with an attendant increase in pollen availability.

Insect pollination is particularly crucial during the wet periods when atmospheric humidity is high and pollen density in the atmosphere is low as well as in flowers that are embedded deep within the female inflorescences. The role of insects and their contribution to sustainable production and increased profitability were clearly established by the studies undertaken. The increased profitability included money saved as a result of the cessation of the practice of assisted pollination.

To ensure a sustainable production of the oil palm and the conservation of the pollinator insect population, chemical treatments on the plantations, when necessary, should be based on the biology of the target species and the pollinators

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