Effect of different methods of pollination on fruiting and yield of wet season date palm (*Phoenix dactylifera*) in Jigawa State, Nigeria

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Abstract

The study was carried out to determine the effect of pollination methods on fruiting and yield of wet season Date palm. The experiment was set up as a complete randomized block design with three treatments, each replicated four times. The three treatments are; T1 (unpollinated), T2 (Pollination twice without protection) and T3 (Pollination twice with protection). Data were collected on fruit set, fruit drop, percentage of seedless fruits, fruit weight, pulp weight, seed weight, fruit size and bunch weight. The results indicated that pollination methods significantly affected fruit set, fruit drop, fruit weight, percentage of seedless fruits, seed weight, fruit size and bunch weight. Maximum fruit set was observed from pollination twice without protection (T2). Bunch weight was also higher in pollination without protection (T2) but it is not significantly different with T3 (pollination with protection). On the other hand, pollination with protection gives high quality fruits in terms of fruit weight, pulp weight, and less number of seedless fruits. The significant lowest yield per bunch was achieved by natural pollination (T1). The results suggested that pollination with protection of wet season inflorescences can substitute for natural pollination thus improving the quality of the wet season fruit and also reducing the need for further fruit thinning.

Keywords: Date palm, Fruiting, Pollination strategies, Yield, Wet season

INTRODUCTION

Date palm, *Phoenix dactylifera* L., is a perennial long-lived dioecious monocotyledon fruit tree of great socio-economic importance (Abdulqadir *et al*., 2011). Grown in arid and semi-arid regions on 1.34 million hectares and produced 8.17 million tons of fruit across the globe (FAOSTAT, 2017). Date trees are cultivated not only for their valuable fruits, but also for producing fuel, fibre and as shelter for ground crops (Adamu *et al*., 2011). There are more than 120 million date palm trees worldwide yielding several million tons of dates annually, besides its secondary products (Abdel-Sattar *et al*., 2017).

The Arab world has more than 84 million date palm trees with the majority in Egypt, Iraq, Saudi Arabia, Algeria, Morocco, Tunisia, United Arab Emirates and Iran (Abdel-Sattar *et al*., 2017). About 70% of the world's date palm trees are found in Arab countries and contribute 67% of the global production. Kingdom of Saudi Arabia has more than 23 million date palm trees, which produce about one million tons of dates annually (Al-Abdoulhadi *et al*.,2011).

Nigerian annual production of dates was over 21,000 MT with Kano, Jigawa, Yobe, Borno, Gombe, Bauchi and Adamawa States as the major producers of date palm (Abdulqadir *et al*., 2011). Jigawa State is famous for date palm farming and its production dates back to over 400 years (Abdulqadir *et al*., 2011).

Date palm is a cross-pollinated fruit tree, due to its dioecious nature, where pollen grains from male palm are applied on to fruit buds bearing female palm (Bekheet and Hanafy, 2011). Pollen tube formation is precisely guided by female cues (Higashiyama and Takeuchi, 2015). Several female secreted peptides are identified that specifically control the direction of pollen tube growth (Takeuchi and Higashiyama, 2012).

The molecular mechanism of pollination and fertilization indicated the importance of fruit setting and yield attributes, particularly for a dioecious species like date palm. The date palm is naturally wind or insect-pollinated but this method has proven inefficient and economically unfeasible (El-Mardi *et al*., 1998).

Failure of effective pollination leads to the formation of triple parthenocarpic fruits of no economic value (Zaid and de Wet, 2002). To tackle this problem, artificial pollination is considered to be important to improve crop productivity and quality, which is commonly practiced in commercial date palm plantations (Gupta *et al*., 2017). Pollination of 60-80% of the female flowers is considered satisfactory and will usually lead to a good fruit set and yield (Gupta *et al*., 2017). The pollination efficiency is affected by several factors and consequently fruit set is highly dependent on these factors such as pollen sources, pollination time, pollination methods, male flowering time, pollens viability, amount and quality, and the female flowers receptivity (Zaid and de Wet, 2002; Ahmed *et al*., 2016; Abdel-Sattar and Mohamed, 2017). Therefore, a number of date palm pollination methods have been adopted to attain maximum fruit set and yield benefits such as male strands (spikes) placement, pollen dusting and pollen suspension methods (Haffar *et al*., 1997; Hajian, 2005; El Dengawy, 2017; Munir, 2019). The date palm growers, according to their

experience and pollen source availability, approve these pollination methods. However, adopting an appropriate and improved pollination method could save pollen grains and enhance fruit yield (Awad, 2010). Moreover, due to the substantial increase in date palm numbers across the world, the growers and researchers are prompted to adopt alternative unconventional methods of pollination, which minimize labor-cost and improve crop production (Awad, 2010).

Failure of effective pollination leads to formation of triple parthenocarpic fruits of no economic value (Zaid and de Wet, 2002; Samouni *et al*., 2016). Although fertilization and fruit set are the two major results of pollination, there is still another interesting but uncommon effect called 'Metaxenia': the direct influence of pollen on the maternal tissues of the fruit (Shaaban *et al*., 2019). It has been observed that some date cultivars had better yield when pollinated with selected males rather than with others (Shafique *et al*., 2011). To make pollination effective, it is better if 2 to 3 strands of male flowers are inserted between strands of female spathe. To meet with this problem of artificial pollination is considered to be the most important factor affecting fruit set and yield (Samouni *et al*., 2016).

Floral spike branches arise from the axils of leaves that emerged in the previous year. Pollination relies essentially on wind. However, to guarantee high productivity, artificial pollination is commonly practiced in commercial plantations. It consists of placing a portion of a male flower spike on the female inflorescence. Pollen source has been reported to affect fruit set, ripening and quality (Iqbal *et al*., 2010). The direct influence of pollen on the maternal tissues of the fruits was recorded in many cultivars of date palms (Shafique *et al*., 2011). Most of the male palms available are of seedling origin with great variations in their pollen quality (Shafique *et al*., 2011). Pollen can change some fruit morphological properties and fruit texture which affect the endosperm (embryo and albumen). It affects fruit size, shape, weight and time of ripening. These effects on tissue of purely maternal origin, rather than on parts resulting from syngamy have been described as 'Metaxenia' (Iqbal *et al*., 2010).

Owing to the xenia and metaxenia, a wide variation is observed in terms of morphological as well as various biochemical attributes of date palm fruit. It directly influences the fruit size, fruit development rate and most importantly, the time of fruit ripening (Iqbal *et al*., 2010).

The time of fruit ripening is important for date palm, particularly in Northern Nigeria, because when the ripening time coincides with rainy days, a huge loss in yield and fruit quality is observed. Hence, selection of pollen parent carries immense significance in date, in which artificial pollination is commercially practised. The present research aims to evaluate the effect of different methods of pollination on fruiting and yield of wet season date palm fruits (*Phoenix dactylifera* L.) in Dutse, Jigawa State Nigeria.

MATERIAL AND METHODS

Experimental site

The research was conducted at the Nigerian Institute for Oil Palm Research (NIFOR), Date Palm Substation at Dutse, Jigawa state. NIFOR Dutse Substation is located within Sudan savannah zone of Nigeria. The climate of the location is characterized by two seasons: The wet season which spans from May/June to September/October and the dry season from October to April/May. The monthly average mean temperature ranges from 21°C in coldest month and 31°C in the hottest month with annual mean rainfall ranging from 650 to 750 mm (JARDA, 2012).

Experimental materials

The experimental materials consisted of four flowering female palms, one flowering male palm, pollination bags, knife and cutlass, labels, water, log book, hand gloves and pen.

Treatments and experimental design

The experiment consisted of three treatments; Control (the female inflorescences will be left unpollinated (T1)), the female inflorescences was pollinated twice during pollination period (T2) and the female inflorescence was pollinated twice and protected with pollination bag to prevent external pollination (T3). Four female flowering palms serving as blocks containing at least three inflorescences each were identified from NIFOR/FUD field. One promising male flowering palm was used for the pollination of the four female flowering palms. The spathe of the matured male inflorescence was removed, opened, dried and kept in a dry place. The dried male pollen collected was used to pollinate the female inflorescence according to the design of the experiment. Each female inflorescence serves as experimental plot, while each female palm represents block (containing three plots). The treatments were randomized within the block and replicated four times. The design of the experiment was a randomized complete block design (RCBD), containing twelve plots and four replications.

Pollination

Pollination was carried out immediately after the tagged female inflorescences cracked. Pollen application to the female flower was done manually by ensuring that pollen grain reached the center of the inflorescences. Inflorescence that will not be pollinated was firmly wrapped in a plastic bag to avoid contamination and latter opened when pollination was completed. Pollination bag was used to cover the protected treatment to avoid wind pollination. Second pollination was carried out three days after the first pollination.

Data Measurements

Fruit set

Fruit set is the percentage of retained ovary under the stimulus of pollination (Strivastava, 2002). Data on Fruit set percentage was collected at three different periods

(week 2, 4 and 6). Ten spikelets per bunch were randomly selected, from which the number of attached fruits and the total number of fruit position were counted. Fruit set percentage was calculated using following formula as given by (Strivastava, 2002):

Fruit set percentage = (Total fruit set)/(Total fruit positions) ×100

Fruit drop

This refers to the percentage of formed fruit that drop in each spikelet. Fruit drop at an early stage occurs due to incomplete pollination or physiological abnormalities of the fertilization (Haffer *et al.,*1997). Ten spikelets per bunch were randomly selected from which the number of drop fruits and the total fruit position were counted. Fruit drop percentage was calculated using the following formula as given by (Strivastava, 2002):

Fruit drop percentage = (Number of fruit drop)/(Total fruit position) ×100

Fresh fruit weight

This refers to weight of fresh fruit containing seed and pulp. Thirty fruits were randomly selected from each bunch and the weight was determined using digital weighing scale. The average fruit weight was then recorded.

Seed weight

This refers to the weight of the seed when the mesocarp has been removed. Thirty fruits from each bunch were randomly selected, the mesocarp was removed and the weight of the seed was determined using digital weighing scale. The average seed weight was calculated and recorded.

Pulp weight

Pulp weight is the weight of the mesocarp after the seed has been removed. Thirty fruits from each bunch were randomly selected, the seeds were removed and the weight of the mesocarp was determined using digital weighing scale. The average weight of the mesocarp was then calculated and recorded.

Presence or absence of seed in fruits

This is the assessment of parthenocarpic character of the fruits and was assessed by selecting thirty fruits from each bunch. The presence or absence of seed inside the fruit was then recorded.

Fruit size

This refers to the diameter and the length of the fruits. Length and diameter of the fruit were measured when the fruit reached its maximum size (Khalal Stage). The diameter was taken at maximum circumference of the fruit using vernier caliper while the length was measured using a ruler. Thirty fruits were randomly selected from each bunch, the average diameter and length were calculated and recorded.

Bunch weight

Total bunch weight of all the treatments were measured at Khalal stage using a weighing balance.

Statistical analysis

Data collected was subjected to Analysis of Variance to determine significant differences between means. Statistical Analysis Software SAS (2007) was used for the analysis. Comparison of means was done according to the least significant difference, which provides a test of differences of data pairs between groups of means used.

RESULTS

Effect of pollination method on fruit set

Data on fruit set percentage indicates that different pollination methods had significant effect on fruit set percentage. Maximum fruit set was obtained in both treatments at the second week (Harbabook stage) with a slight superiority for pollination twice without protection (88.2%) (Table 1). At fourth week, there was a remarkable reduction in fruit set for both treatments. At sixth week, fruit set is significantly high in pollinated bunches T2 and T3, 50.9 % and 47.1% respectively. The lowest fruit set of 39.7 % was observed in natural pollination (control treatment).

Effect of pollination method on fruit drop

The percent fruit drop data are presented in table 2. The data reveal that different pollination techniques significantly affected fruit drop at second, fourth and sixth week. The significantly highest fruit drop (60.3%) occurred in control at week six. There was a progressive increase in fruit drop for both treatments from second to sixth week. Minimum fruit drop was observed in T2 (pollination without protection) at week two, four and six.

Table 1: Fruit set percentage

Treatments	Sampling period		
	Second week	Fourth week	Sixth week
Natural pollination (T1)	78.3 b	47.3 b	39.7 b
Pollination without protection (T2)	88.2 a	58.2 a	50.9 a
Pollination with protection (T3)	87.9 a	56.4 a	47.1 a
LSD≤0.005	8.52	4.52	7.48
CV (%)	13.4	5.66	12.9

Table 2: Fruit drop percentage

Treatments	Sampling period		
	Second week	Fourth week	Sixth week
Natural pollination (T1)	21.7 a	52.9 a	60.3 a
Pollination without protection (T2)	12.1 b	42.0 b	49.1 b
Pollination with protection (T3)	12.1 b	43.6 b	52.8 b
LSD≤0.005	8.52	4.66	7.41
CV (%)	12.4	6.31	17.4

Means within each column having different letters are significantly different according to LSD at 5 % level

Effect of pollination methods on fruit weight

Significant differences in average weight of fruit were observed due to different pollination methods as shown in table 3. The maximum fruit weight of 9.2 g was recorded in fruits developed from pollination with protection (T3). It was followed by T2 pollination without protection with average fruit weight of 8.7 g. The minimum fruit weight of 7.9 g was recorded in fruits developed from natural pollination (Control).

Effect of pollination methods on pulp weight

Result revealed that there was no significant difference in average weight of pulp due to different pollination methods (Table 4). However, the maximum pulp weight of 7.2 g was recorded in fruits developed from pollination with protection (T3) It was followed by T2 (pollination without protection). The minimum pulp weight of 6.7 g was recorded in fruits developed from natural pollination (Control).

Effect of pollination methods on seed weight

Significant difference in average weight of seed was observed due to different pollination methods (Table 5). The maximum seed weight of 1.5 g was recorded in fruits developed from pollination without protection (T3) and pollination with protection (T3) with average seed weight of 1.5 g and 1.5 g respectively. The minimum seed weight of 1.3 g was recorded in fruits developed from natural pollination (Control).

Effect of pollination methods on seedless fruits

Different pollination techniques exhibited significant effect on percentage of seedless fruits (Table 6). The highest number of seedless fruit is recorded in natural pollination 25.8 %. The minimum percentage of seedless fruit was observed in pollination with protection (T3), however pollination without protection was not significantly different from it in term of percentage of seedless fruit.

Effect of pollination methods on fruit size

Data on fruit size (Table 7) indicates that different pollination methods showed significant effect on fruit size. The significant lengthiest fruit was obtained from T3 (pollination with protection), while shortest fruit was obtained from natural pollination. Fruit diameter was significantly higher in pollination without protection (T2) than in all other treatments.

Table 3: Fruit weight

Treatments	Fruit weight (g)
Natural pollination (T1)	7.87 b
Pollination without protection (T2)	8.66 a
Pollination with protection (T3)	9.17 a
LSD≤0.005	0.61
CV (%)	5.25

Table 4: Pulp weight

Treatments	Pulp weight (g)
Natural pollination (T1)	6.71 a
Pollination without protection (T2)	6.94 a
Pollination with protection (T3)	7.18 a
LSD≤0.005	NS
CV (%)	13.7

Table 5: Seed weight

Treatments	Seed weight (g)
Natural pollination (T1)	1.29 b
Pollination without protection (T2)	1.52 a
Pollination with protection (T3)	1.52 a
LSD≤0.005	0.17
CV (%)	13.0

Table 6: Percentage of seedless fruit (%)

Treatments	Percentage of seedless fruit (%)
Natural pollination (T1)	25.8 a
Pollination without protection (T2)	16.7 b
Pollination with protection (T3)	16.6 b
LSD≤0.005	0.17
CV (%)	9.66

Table 7: Seed size

Treatments	Fruit Length (cm)	Fruit diameter (cm)
Natural pollination (T1)	3.56 b	1.84 b
Pollination without protection (T2)	3.87 a	1.84 b
Pollination with protection (T3)	3.91 a	1.95 a
LSD≤0.005	0.14	0.09
CV (%)	11.6	5.78

Means within each column having different letters are significantly different according to LSD at 5 % level

Pollination methods effect on fruit yield per bunch

Different pollination methods exhibited significant effect on fruit yield per bunch. The significantly highest fruit yield per bunch was recorded by pollination without protection (4.9 kg/ bunch), although not significantly different with T3 (pollination with protection), with an average bunch weight of 4.8 kg. The significantly lowest fruit yield of 4.4 kg/bunch was achieved by natural pollination (Control), in comparison with T2 and T3.

DISCUSSION

The results of this study showed that different pollination methods affect fruit set percentage, fruit drop percentage, fruit weight, pulp weight, fruit size and total fruit yield per bunch.

Fruit set percentage

The highest fruit set percentage was obtained from pollinated bunches T3 and T2 with slight superiority for pollination twice without protection (47.1 %). The lowest fruit set of 39.7 % was observed in natural pollination. This result of the study corresponds with the finding of Attalla *et al*., (1998) who stated that pollination of female spathe with 10% pollen powder, or with 5 and 15% pollen powder, significantly increased the average fruit set percentage compared to natural pollination. Similar finding was also reported by Iqbal *et al. (*2005) who stated that different methods of pollination significantly affected the fruit set percentage. The highest fruit set (89.3% and 88.8 %) was recorded in placement method, while the lowest fruit set was observed in the control.

Fruit drop percentage

Data on fruit drop percentage revealed that different pollination methods significantly affected the fruit drop at second, fourth and sixth week. The significantly highest fruit drop (60.3 %) occurred in control at sixth week. There is progressive increase in fruit drop for both treatments from the second week to sixth week. Similar finding was reported by Iqbal *et al*. (2005) who reported that the maximum fruit drop of 61.2 % was recorded in control bunches where no artificial pollination was done. Haffer *et al.* (1997) also reported that different pollination techniques helped in increasing the yield and lowering the fruit drop.

Percentage of seedless fruit

Result from this study showed that different pollination techniques exhibited significant effect on percentage of seedless fruits. The highest number of seedless fruit is recorded from un-pollinated bunch (25.8 %) whileT2 was not significantly different with T3. Similar result was obtained by Arzani (1999) who reported that in the absence of pollination all or one of the three carpels will develop into parthenocarpic fruits.

Weight of fruit

Significant difference in average weight of fruit was observed due to different pollination methods. The maximum fruit weight of 9.2 g was recorded in fruits developed from pollination with protection (T3), followed by T2 (pollination without protection) with average fruit weight of 8.7 g. The minimum fruit weight of 7.9 g was recorded in fruits developed from natural pollination (Control). Farag *et al.* (2012) revealed that fruit weight of "Zaghloul" date cultivar was significantly influenced by the methods of pollination. Mizuno *et al.* (2002) also reported that average fruit weight obtained from four different methods of pollination shows that the maximum fruit weight was obtained in bunch pollinated artificially.

Pulp weight

Result obtained from this study revealed that there was no significant difference in average weight of pulp due to different pollination methods. The maximum pulp weight of 7.2 g was recorded in fruits developed from pollination with protection (T3), followed by T2 (pollination without protection). The minimum pulp weight of 6.7 g was recorded in fruits developed from natural pollination (Control). This result correspond with the finding of Iqbal *et al. (*2005) who reported that weight of pulp is non-significant in all pollination techniques used.

Seed weight

Significant difference in average weight of seed was observed due to different pollination methods. The maximum seed weight of 1.5 g was recorded in fruits developed from pollination without protection (T2) and pollination with protection (T3) with average seed weight of 1.5 g and 1.5 g respectively. The minimum seed weight of 1.3 g was recorded in fruits developed from natural pollination (Control). The result of the study contradict with the finding of Iqbal *et al.* (2005) who reported that there is no significant variation in seed weight due to different pollination methods.

Fruit size

Data on fruit size indicates that different pollination methods showed significant effect on fruit size. the significant lengthiest fruit was obtained from T3 (pollination with protection), while shortest fruit was obtained from natural pollination. Fruit diameter was significantly higher in pollination without protection (T2) than in all other treatments. Similar result was obtained by

Table 8: Bunch weight

Treatments	Bunch weight (Kg)
Natural pollination (T1)	4.39 b
Pollination without protection (T2)	4.90 a
Pollination with protection (T3)	4.76 a
LSD≤0.005	0.27
CV (%)	3.39

Means within each column having different letters are significantly different according to LSD at 5 % level

Attalla *et al.*(1998), Ghnaim and Al-Muhtaseb (2006), and Rahnama and Rahkhodaei (2014) who reported that there were significant differences in fruit length due to pollination methods.

Yield per bunch

Different pollination techniques exhibited significant effect on yield of fruit per bunch. The significantly highest fruit yield per bunch was recorded by pollination without protection (T2) (4.90 kg/ bunch), but it was not significantly different with T3 (pollination with protection) having an average bunch weight of 4.76 kg. The significantly lowest fruit yield of 4.39 kg/bunch was achieved by natural pollination (Control), which differed significantly from all other treatments. Similar results were obtained by Ibrahim (1994) who reported that different pollination techniques exhibited significant effect on yield of fruit per bunch. The significantly highest fruit yield per bunch was recorded by male spathe placement while the significantly lowest fruit yield of 3.02 kg/bunch was achieved by natural pollination (Control), which differed significantly from all other methods. Attalla *et al.* (1998) also reported an increase in fruit yield due to various pollination methods compared to control.

CONCLUSION

The results of this study suggested that artificial pollination of wet season female date flowers increased total yield and quality of wet season date fruits. However, among the methods of artificial pollination, pollination without protection (T2) produced the highest yield. Pollination without protection caused significant increase in fruit set and total bunch weight compared to natural pollination. On the other hand, pollination with protection (T3) increased the quality of wet season fruit by increasing total fruit weight, pulp weight with minimum percentage of seedless fruits.

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