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RESEARCH ARTICLE

Evaluation of Potentiality of Different Adjuvants for Date Palm Pollination and Fruit Set

Kapil Mohan Sharma[1] · C. M. Muralidharan[1] · D. A. Baidiyavadra[1] · Kirti Bardhan[2] · C. N. Panchal[3]

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Abstract In commercial date palm cultivation, artificial pollination is an expensive necessary agronomic practice. For effective pollination, timely availability of pollen is a requisite; however, in time of pollen scarcity and/or in need of higher amount of pollen for mechanical pollination, dilution of pollen with adjuvant is an effective approach. We tested efficiency of pollination by mixing pollen with different low cost and easily available adjuvants, viz. *Maida* flour, wheat flour, talcum powder, *bajra* flour, ash and marble dust in 1:9 and 1:19 ratio, over control (no adjuvant) and evaluate their efficacy in sustaining the fruit set and yield. Our results suggest that all of the experimented adjuvants can be diluted up to 1:9 ratio; however, talcum powder can be diluted up to 1:19 without reducing fruit yield.

✉ Kapil Mohan Sharma
k.m.sharma456@sdau.edu.in

C. M. Muralidharan
muralidharancm@yahoo.com

D. A. Baidiyavadra
shreedev1968@gmail.com

Kirti Bardhan
kirtivardhan@nau.in

C. N. Panchal
chetanpanchal1265@gmail.com

[1] Date Palm Research Station, Sardarkrushinagar Dantiwada Agricultural University, Mundra-Kachchh, Gujarat 370421, India

[2] ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat 396450, India

[3] Polytechnic in Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Amirgadh-Banaskantha, Gujarat 385130, India

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Introduction

Date palm is one of the oldest cultivated crops in the world originated around 6000 years ago in the region of present-day Iraq, while in India, its presence is estimated to be around 500 years old (Johnson et al. 2013; Muralidharan et al. 2008). More than 90 percent of the total cultivated area of date palm in India is concentrated in Kachchh District of Gujarat (Anonymous 2018; Singh 2018). However, in the last two decades (2000–2020) with the availability of high productive tissue cultured plants, there has been a rapid expansion of cultivated area not only in the area adjoining Kachchh but different states of the country, viz. Rajasthan, Punjab, Maharashtra, Tamil Nadu, Andhra Pradesh and Telangana (Muralidharan et al. 2008, Baidiyavadra et al. 2019).

Since date palm is a dioecious crop, male and female flowers are borne in separate plants, and naturally, they are wind pollinated, but chances of their natural pollination are very meager in commercial orchards, where the females are in the main block while male plants are planted either in the border planting or in a limited section of the orchard, restricting the pollen movement and availability to the whole orchard. However, artificial pollination by hand is followed since time immemorial (Zaid and de Wet 2002). Two methods of practicing pollination are very popular among the growers globally: The first is the placement of the male flowers' spikelet in the freshly opened female inflorescence, and the second is dusting and swapping the collected pollen using cotton (Muralidharan et al. 2008;

Baidiyavadra et al. 2019). Since the canopy of the date palm keeps on growing vertically and after around 5–6 years of plant growth, the growers need to climb to the tree for various operations including pollination. Moreover, all the spathe of the date palm inflorescence does not emerge and opens simultaneously and their need to get pollinated within 2–3 days of spathe opening becomes highly laborious and expensive operation (Barfod et al. 2011; Muralidharan et al. 2020). To overcome the problem in over last 30 years, a large number of mechanical duster or pollinator have emerged (Ibrahim 1988; Attalla et al. 1998; Awad 2006, 2010, 2011). However, all of them need a higher quantity of pollen than the traditional method as a large section of pollen spreads away from the inflorescence, mostly due to wind and pressure exerted by the pollinator (El-Mardi et al. 1998; Shabana et al. 1988). Moreover, in many cases, late emergence of the male inflorescence has also resulted in the pollen scarcity. Thus, pollen is a limited precious resource in dates production and its usage needs to be done efficiently. Many earlier experiments suggest that pollen can be diluted with different adjuvants without hampering the fruit set and yield. Khalil and Al-Shawaan (1983), El-Mardi et al. (1995, 1998), Nasir et al. (1997) suggested usage of wheat flour, Zaid and de Wet (2002) suggested usage of talcum powder, Bashir et al. (2012) used combination of wheat flour and saw dust, El-Refaey and Al-Dengawy (2017) used a stimulative solution of pollen germination, while Abu-Zahra and Shatnawi (2019) reported that pure pollen is better than any dilution with water. Based on the literature surveyed and need of our region, we tested efficacy of local materials as adjuvants, viz. *Maida* flour (wheat flour without husk), wheat flour, talcum powder, *bajra* flour (pearl millet flour), ash and marble dust, and diluted them in the ratio of 1: 9 and 1:19 to evaluate the amount of adjuvant that can be added to the pollen without affecting the fruit set and yield.

Materials and Methods

The experiment was conducted at Date Palm Research Station, Sardarkrushinagar Dantiwada Agricultural University, Mundra-Kachchh, Gujarat (22° 49′ 25.1″ N & 69° 43′ 13.6″ E), during the production season of 2016–2018 (3 years) with date palm plants cv. *Hallawy* of the same age (9 years old on first year of experimentation), transplanted from the same origin in the year 2007 at 8 m × 8 m spacing and received similar management and cultural practices. Five flower bunches were allowed to grow on each tree and among them to maintain uniformity. The experiment was conducted as randomized block design with the factorial concept. Each treatment was replicated three times (one tree per replication). The plants were pollinated with pollen mixed with six different adjuvants (Factor A), viz. a_1 = *maida* flour (wheat flour without husk), a_2 = wheat flour, a_3 = talcum powder, a_4 = *bajra* flour (pearl millet flour), a_5 = ash and a_6 = marble dust in two different ratios (Factor R) (pollen: adjuvant), viz. r_1 = 1:9 and r_2 = 1:19, measured in weight by weight (w/w) basis presented in Table 1. The treatments were compared with control, i.e., fresh pollen with no mixture.

The pollens were collected from the mature male inflorescence of the same male plant in all the three flowering season. The male inflorescences were harvested from the plant when cracking in their spathe was observed by cutting from the base of the spathe. The spadix covers over the inflorescence were removed soon after the harvest to avoid moisture gain inside the spathe followed by shade drying (25–30 °C) for 3–4 days. The male inflorescence was then dusted to extract out the pollen and was tested for pollen viability which were then sieved using 40-µm sieve and were collected in a glass bottle and kept at − 4 °C till further usage. The pollen viability was tested for their viability using acetocarmine test by staining the pollen in slide with 1–2 drops of 1% acetocarmine and viewing them under 200 X as described by Shaheen (2004). The pollens were showing more than 95% viability. The collected pollen was then mixed uniformly with adjuvant just before pollination. Small pouches weighing 2 g were made of pollen mixtures with and without adjuvants as per the treatments for each bunch that were pollinated in the experimentation. Pollinations were done in the morning between 8 am and 10 am in every plant based on their treatments by dusting pollen utilizing the amount present in each pouch on the female inflorescence on the day of spathe opening. The inflorescence is covered just after pollination with a brown paper bag to avoid pollination from other sources, and the cover was removed after 15 days of pollination. No fruit thinning of the selected plants was done during experimental periods to avoid its influence on the outcome of the experiment. Observations for percent fruit set were taken by recording initial flower count at the time of pollination from five strands of each of three bunches from each replicated tree and recording the proportionate number of fruits at the time of harvest (*Khalal* stage). Number of fruits per bunch and yield (kg/plant) were recorded at the time of harvest.

In the experiment, treatment comparison was done for all the adjuvants with control; pollen dilution ratio with control; and interaction of adjuvants and pollen dilution ratio with control by pooling the data for all the 3 years of observations (2016–2018). Statistical analysis was done using "R" with "agricolae" package, and treatments' significance was measured at $p = 0.05$, while graphical representation was made using "ggplot2," "ggthemes" and

Table 1 Dilution materials and ratios used for experimentation

Factor A: adjuvant		Factor R: pollen dilution ratio (w/w)	
a_1	Pollen powder + maida	r_1	1:9
a_2	Pollen powder + wheat flour	r_2	1:19
a_3	Pollen powder + talcum powder		Control (no adjuvant)
a_4	Pollen powder + bajra flour		
a_5	Pollen powder + ash		
a_6	Pollen powder + marble dust		
	Control (no adjuvant)		

"tidyverse" packages of "R" (R Core Team 2019; Mendiburu 2019; Wickam 2016, 2017; Arnold 2019).

Results and Discussions

The successful development of fruits is dependent on successful pollination followed by fertilization; however, the amount of pollen dusted on the inflorescence is only a fraction of the pollen stick to the stigma, where the pollen germinated among them only single pollen tube reaches the ovary and sets the fruits (Lord and Russell 2002). It represents that even the diluted pollen can also set the fruits based on which our experimental results are discussed below.

Percentage Fruit Set

The effect of usage of all adjuvants on percent fruit set pooled for 3 years (2016–2018) is presented in Fig. 1a. The percent fruit set was observed in control with 52.59% which was at par with the results of *maida* and talcum powder with 47.39 and 49.69%, respectively, while the lowest fruit set was observed with *bajra* flour with 41.40%. Among different ratios of the adjuvants, dilution up to 1: 9 is at par with the control with 48.20% and 52.59%, respectively, while dilution up to 1:19 shows lower fruit set than control with 41.60% as presented in Fig. 1b. However, each adjuvant was responding differently in different ratios and the interaction effect was found to be significant as presented in Fig. 1c. All the adjuvants diluted up to 1: 9 were showing at par percent fruit set with that of control; however, the treatments (adjuvants) diluted to 1:19 only talcum powder (47.72%) were showing at par results with control, while the lowest fruit set was observed with pollen diluted with marble dust with 36.35%. The average reduction in fruit set (of all three years) in comparison with control is presented in Fig. 2a which shows that lowest reduction in fruit set was with talcum powder at 1: 9 ratio (− 1.74%) which on diluting to 1:19 shows − 9.26%, whereas in case of *maida*, ash and marble dust the reduction in percentage fruit at 1:19 ratio was approximately three times higher than that of 1:9 while in case of wheat it was two times and in *bajra* it is 1.5 times.

Number of Fruits per Bunch

The number of fruits influenced by different adjuvants is presented in Fig. 1d. The highest number of fruits per bunch was recorded in control (1467.51) which was found to be at par only with that of talcum powder (1365.64), while the lowest number of fruits per bunch was observed in *bajra* flour (1153.94). On comparison of different ratios, control was having the highest number of fruits which was at par with the ratio of 1:9 (1390.07), while the ratio of 1:19 was showing 1148.39 number of fruits/bunches as presented in Fig. 1e. When both the characters were studied together, the highest number of fruits in control was at par with all the adjuvants diluted at 1:9 ratio while none of the adjuvants diluted at 1:19 was at par with control. However, talcum powder at a ratio of 1:19 (1286.18) was at par with its dilution at 1:9 ratio (1445.09), while the lowest number of fruits was observed with *bajra* as adjuvant at 1:19 ratio (1052.83). On comparison of reduction in a number of fruits in comparison with control in the ratio of 1:9, a range of − 1.52% in talcum powder to − 14.47% *bajra* flour was observed while in the ratio 1:19 range of − 14.47% in talcum powder to − 28.25% in *bajra* flour was observed. The reduction in the number of fruits was approximately seven to eight times higher in pollen mixture with the ratio of 1:19 compared to that of 1:9 as presented in Fig. 2b.

Yield

The highest yield among different adjuvants was observed in control (59.88 kg/tree) which was at par with talcum powder (56.57 kg/tree) while the lowest was observed with

bajra flour (49.39 kg/tree) as presented in Fig. 1g. Among different ratios of dilution, the highest was recorded with control which was at par with dilution up to 1:9 (57.61 kg/tree) as presented in Fig. 1h. In the interaction effect of adjuvant and the ratios, the results are in line with percentage fruit set with control giving the highest yield which was at par with all the adjuvants mixed in the ratio of 1:9; however, only talcum powder was showing at par results with the control at the ratio of 1:19 (54.23 kg/tree) as presented in Fig. 1i. On comparison in reduction in yield in reference to control, it is observed that in pollen mixture at ratio of 1:9 the reduction ranges from − 1.23% in marble dust to − 7.58% in *bajra* flour, while at the ratio of 1:19 the reduction ranges from − 9.43% in talcum powder to − 27.46% in *bajra* flour. On comparison of the adjuvants for reduction percentage among their ratios at 1:9 and 1:19, it was almost four to five times higher in *maida* flour, wheat flour and *bajra* flour while it is seven times in talcum powder and more than twelve times in ash and marble dust as presented in Fig. 2c.

Fruit set percentage was dependent on the success of fertilization which also impacts the number of fruits per bunch and overall yield of the plant. One of the major contributing factors in success or failure of fertilization is pistillate receptibility which may be based on four factors, viz. (i) days after spathe opening, (ii) time of pollination, (iii) temperature of inflorescence at the time of pollination, (iv) pistillate moisture content (Muralidharan et al. 2020;

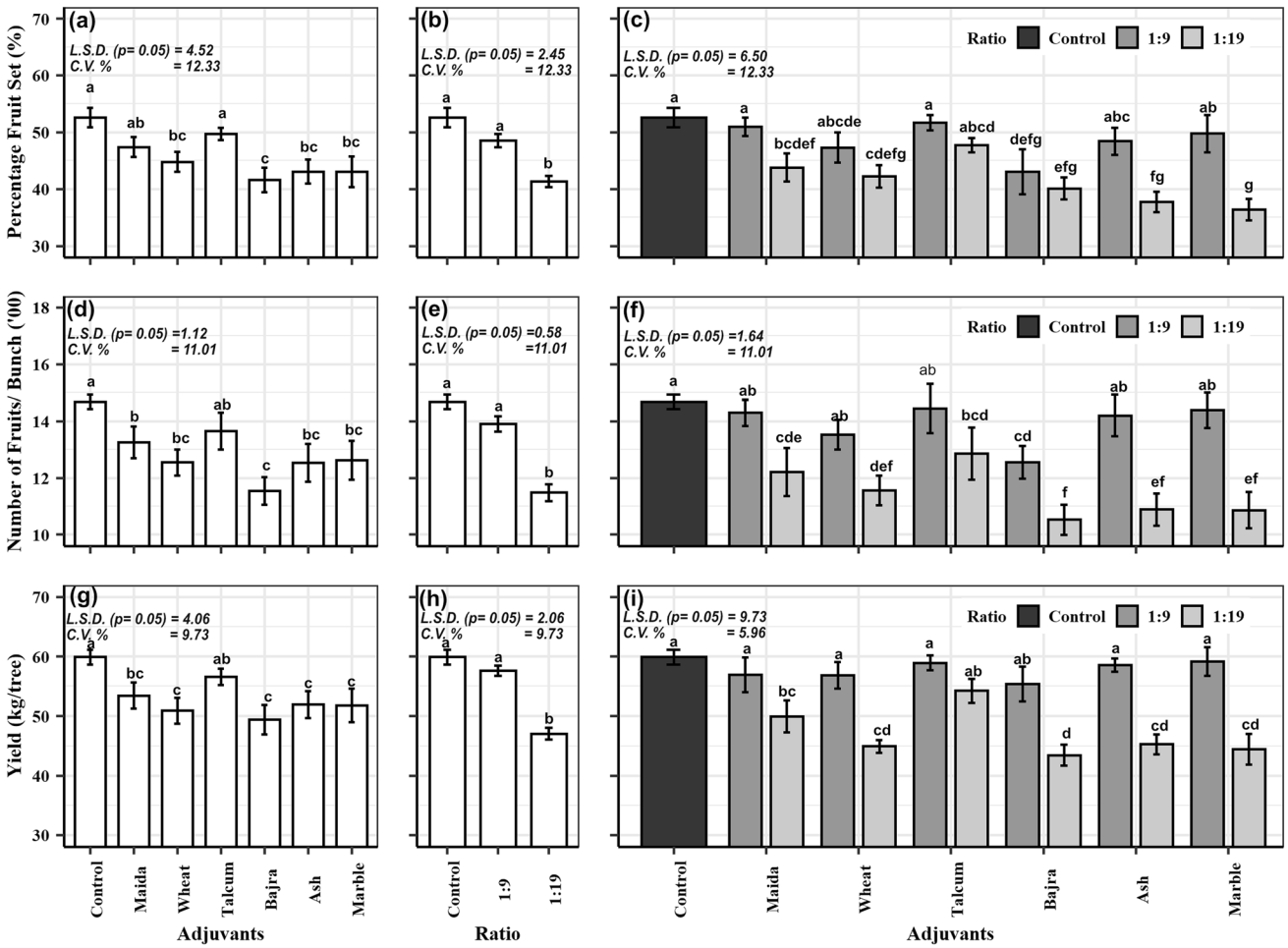

Fig. 1 **a** Effect of different adjuvants mixed with pollen on percentage fruit set of date palm; **b** effect of different proportions of pollen mixed on percentage fruit set of date palm; **c** effect of different adjuvants mixed in different ratios with pollen on percentage fruit set of date palm; **d** effect of different adjuvants mixed with pollen on number of fruits per bunch of date palm; **e** effect of different proportions of pollen mixed on number of fruits per bunch of date palm; **f** effect of different adjuvants mixed in different ratios with pollen on number of fruits per bunch of date palm; **g** effect of different adjuvants mixed with pollen on yield of date palm; **h** effect of different proportions of pollen mixed on yield of date palm; **i** effect of different adjuvants mixed in different ratios with pollen on yield of date palm. The data are pooled for the year (2016–2018); values marked with same alphabets are at par with each other; bar in the figure represents standard error of mean; *L.S. D.* ($p = 0.05$) = least significant difference at 5% level of significance; *C.V.* % = coefficient of variation in percentage

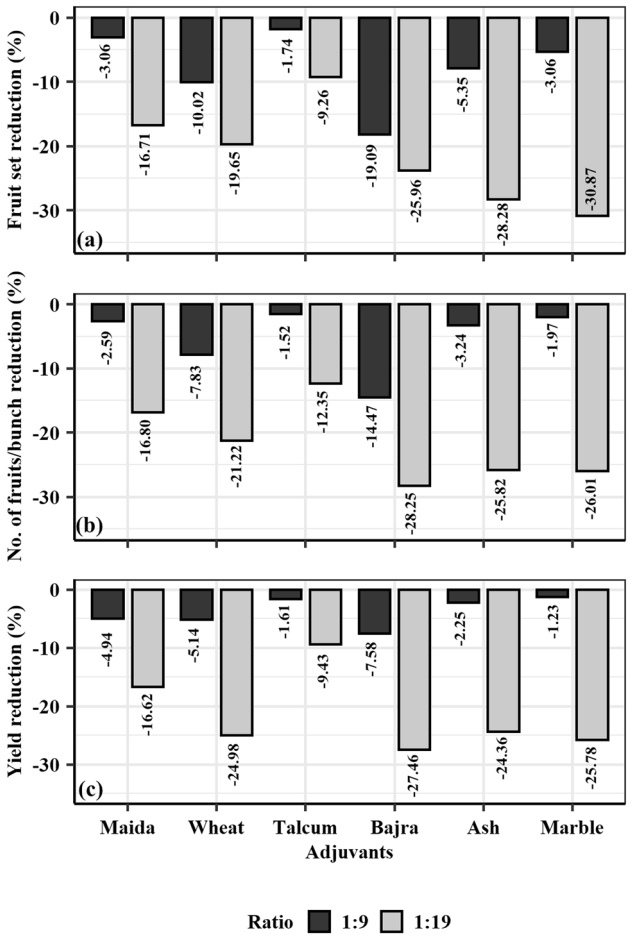

Fig. 2 **a** Percentage reduction in percentage fruit set with reference to control; **b** percentage reduction in number of fruits/bunches with reference to control; **c** percentage reduction in yield with reference to control. Note: The data are pooled for three years (2016–2018)

Sharma et al. 2019; Cohen et al. 2016; Zheng et al. 2018). Since the pollination was done within 2 days of spathe opening, the first criteria are taken care of. The time of pollination and temperature of inflorescence are interrelated to each other, and based on our earlier experimentation, pollination was done when it was highly receptive (Sharma et al. 2019). However, moisture content of pistil might get influenced with the usage of dilution materials. Since the wheat flour, *bajra* flour, *maida* flour are edible products, they are also used for dough making and might absorb the moisture content of the pistil which might increase at higher level of flour (more dilution ratio). Formation of sticky dough was also observed in a bunch where pollination was followed by foggy weather in the next morning and that might influence the fruit set percentage at higher level of dilution (Fig. 1c). Moreover, in a few bunches the presence of ants was also observed collecting the flour dusted on the inflorescence. The amount of flour might increase when pollen mixture is dusted in larger amount and may invite insects which feed on edible materials like flour and create additional problems. While, stone powder, ash and talcum powder were having no such property; however, stone powder and ash at higher concentration found to be reducing fruit set, number of fruits and yield in date palm, while talcum powder was found to be a suitable option which unlike others talcum powder only showed reduction in yield approximately up to 9.5% while other adjuvants were showing as high as 27.5% in yield on dilution up to 1:19 and can be used as an adjuvant for the pollen. Talcum powder superiority may be attributed to its smaller particle sized which helps in uniform covering of pollen surface area and have more hydrophobic nature so has less desiccation power (Vaknin et al. 1999). It is also reflected when talcum powder is used in higher proportion too.

It is to note that for success of pollination followed by fertilization, pistil needed a fraction of pollen quantity compared to what we dust in our traditional method. During the time of pollen scarcity or low availability of pollen, dilution of pollen up to 1:19 with talcum powder can be a best approach as it will multiply the available pollen to twenty times of its capacity, i.e., the 2 g of pure pollen which was used to pollinate a single inflorescence can be mixed with 38 g of talcum powder to pollinate 20 inflorescence. The same method is also applicable for mechanical dusters which generally uses higher amount of pollen as discussed earlier. In many of the earlier literatures based on the research conducted at different institutions, various dilution ranges are suggested based on the adjuvant used. Haffar et al. (1997) recommended usage of 1:10 ratio with wheat flour, while Al-Wusaibai et al. (2012), Bashir et al. (2012), El-Mardi et al. (1998) recommended 1:15, 1:1 and 1:9 ratio of wheat flour. Zaid and de Wet (2002) suggested usage of 1:9 ratio of talcum powder; however, Abu-Zahra and Shatnawi (2019) found the best yield results with usage of fresh pollen only. However, the current experiment will allow to further dilute the pollen up to 1:19 with talcum powder for wider usage.

Conclusion

In date palm, timely availability of pollen in required quantity for both hand and mechanical pollination is one of the major concerns among the date growers of the world. We evaluate low-cost, easily available adjuvant and their different proportions for increasing uniform distribution of date pollination for fruit setting and yield. Our study advocates to use of talcum powder, which is easily available to date growers and has come as a potential and

suitable adjuvant which could be mixed with pollen up to 1:19 ratio without impacting fruit set and yield.

Author's Contributions KMS, CMM, DAB and CNP conceptualized the experiment and determined methodology and investigated the experimented and curated the data. KMS, CMM and DAB administered the project and did the formal analysis. KMS and KB validated the data and did visualization. KMS, CMM and KB written the original draft and did review and editing. All authors discussed the results and commented on the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Consent for Publication The experiment was conducted at Date palm Research Station, Mundra, under the jurisdiction of Sardarkrushinagar Dantiwada Agricultural University, and the authors have consent to publish the outcome of the experiment.

Human and Animal Rights Statement The experiment does not involve any humans or animals, and thus, no such consent was taken. No commercial interest of any author or institution is involved

References

Abu-Zahra, T.R., and M.A. Shatnawai. 2019. New pollination technique in date palm (*Phoenix dactylifera* L.) cv. "Barhee" and "Medjol" under Jordan Valley Conditions. *American-Eurasian Journal of Agriculture and Environmental Sciences* 19 (1): 37–42.

Al-Wusaibai, N.A., A.B. Abdallah, M.S. Al-Husainai, H. Al-Salman, and M. Elballaj. 2012. A comparative study between mechanical and manual pollination in two premier Saudi Arabian date palm cultivars. *Indian Journal of Science and Technology* 5 (4): 2487–2490.

Anonymous. 2018. *Horticultural cultivation of crops, area and production*. Director of Horticulture, Agriculture, Farmer's Welfare and Co-operation Department, Government of Gujarat. Retrieved from https://doh.gujarat.gov.in/horticulture-census.htm on 25th March, 2019.

Arnold, J. B. 2019. *ggthemes: Extra Themes, Scales and Geos for 'ggplot2'*. R package version 4.2.0. https://CRAN.R-project.org/package=ggthemes.

Attalla, A.M., M.O. Warring, and F.A. Sharaan. 1998. Suitable time of two Saudi date palm cultivars. *Alexandria Journal of Agricultural Research* 43 (3): 203–208.

Awad, M.A. 2006. Water spray as a potential thinning agent for date palm flowers (*Phoenix dactylifera* L.) cv. Lulu. *Scientia Horticulturae* 111: 44–48.

Awad, M.A. 2010. Pollination of date palm (*Phoenix dactylifera* L) cv Khenazy by pollen grain-water suspension spray. *Journal of Food, Agriculture and Environment* 8 (3 & 4): 313–317.

Awad, M.A. 2011. Pollination of date palm (*Phoenix dactylifera* L.) cv. "Lulu" with pollen grains-water suspension. *Meteorology, Environment and Arid Land Agriculture* 22 (1): 91–101.

Baidiyavadra, D.A., C.M. Muralidharan, and K.M. Sharma. 2019. Fresh date production in Kachchh (India): Challenges and future prospects. *Medicinal Plants* 11 (3): 218–227.

Barfod, A.S., M. Hagen, and F. Borchsenius. 2011. Twenty-five years of progress in understanding pollination mechanisms in palms (Arecaceae). *Annals of Botany* 108: 1503–1516.

Bashir, M.A., M. Ahmada, M.I. Khan, and F. Altaf. 2012. To economize date palm pollens through different diluting materials, in Aseel CV. *Sarhad Journal of Agriculture* 28 (2): 197–200.

Cohen, Y., F. Slavkovic, D. Birger, A. Greenberg, A. Sadowsky, M. Ish-Shalom, M. Benita, T. Ticuchinski, Y. Avnat, and R. Kamenetsky. 2016. Fertilization and fruit setting in date palm: biological and technological challenges. *Acta Horticulturae* 1130: 351–358. https://doi.org/10.17660/ActaHortic.2016.1130.53.

El-Mardi, M. O., E. C. Consolacion, K. M. Abdelbasit, M. Al-Marozouqi, and O. S. Al-Mantheri. 1998. Evaluation of the pollination method and pollen concentration on chemical characteristics of date fruit from Fard cultivar. *First international conference on date palms*, Al-Ain, UAE, March 8–10. Retrieved on 29th March, 2020 from pubhort.org/datepalm.

El-Mardi, M.O., S.N. Labiad, E. Consolacion, and K.M. Addelbasitm. 1995. Effect of pollination methods and pollen dilution on some chemical constituents of Fard dates at different stages of fruit development. *Emirates Journal of Agricultural Sciences* 7: 1–19. https://doi.org/10.9755/ejfa.v7i1.5351.

El-Refaey, F., and A. El-Dengawy. 2017. Improvement of the pollination technique in date palm. *Journal of Plant Production* 8 (2): 307–314.

Haffar, I., A. Juburi, and M.H. Ahmed. 1997. Effect of pollination frequency and pollen concentration on yield and fruit characteristics of mechanically pollinated date palm trees (*Phoenix dactylifera* var. Khalas). *Journal of Agricultural Engineering Research* 68: 11–14.

Ibrahim, A.A. 1988. Field performance evaluation of different types of mechanical pollination systems of date palm. *Journal of Agricultural Water Resources Research* 7 (1): 61–82.

Johnson, D.V., J.M. Al-Khayri, and S.M. Jain. 2013. Seedling date palm (*Phoenix dactylifera* L) as genetic resources. *Emeritus Journal of Food and Agriculture* 25 (11): 809–830. https://doi.org/10.9755/ejfa.v25i11.16497.

Khalil, A. R. and A. M. Al-Shawaan. 1983. Wheat flour and sugar solution media as carrier for date palm pollen grains. In *Proceedings of first symposium on the date palm*. King Faisal University, Al-Hassa, Saudi Arabia, pp 120–125.

Lord, E.M., and S.D. Russell. 2002. The mechanisms of pollination and fertilization in plants. *Annual Review of Cell and Developmental Biology* 18: 81–105. https://doi.org/10.1146/annurev.cellbio.18.012502.083438.

Mendiburu, F. 2019. *Agricolae: Statistical procedures for Agricultural Research*. R package version 1.3-1. https://CRAN.R-project.org/package=agricolae.

Muralidharan, C. M., C. N. Panchal, D. A. Baidiyavadra, K. M. Sharma, and P. Verma. 2020. Pistillate receptivity of date palm (*Phoenix dactylifera* L.) cv. Barhee. *Sugar Tech*. https://doi.org/10.1007/s12355-020-00859-2.

Muralidharan, C. M., S. B. S. Tikka, and P. Verma. 2008. *Date palm cultivation in Kachchh. Technical Bulletin No. 8*, Date palm Research Station, S. D. Agricultural University, Mundra-Kachchh.

Nasir, M.A., I.H. Mian, and M. Asghar. 1997. Effect of date pollen mixed with wheat flour and tap water on date yield. *Journal of Agricultural Research* 35 (1–2): 63–67.

R Core Team. 2019. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Shabana, R.H., E.A. Mawlood, and Th Khalil. 1988. *Date palm mechanical pollination Report*. Baghdad, Iraq: Agric. Res. Water Resources Center. Scientific Research Council.

Shaheen, M.A. 2004. Evaluation of date palm males using pollen viability and ultrastructure. *Acta Horticulturae* 632: 37–43.

Sharma, K.M., C.M. Muralidharan, D.A. Baidiyavadra, and C.N. Panchal. 2019. Effect of different time of pollination in date palm (*Phoenix dactylifera* L.) cv. Barhee. *Environment and Ecology* 37 (4B): 1568–1570.

Singh, R.N. 2018. Date palm: An ideal fruit for health and wealth. *Indian Horticulture* 63 (5): 17–21.

Vaknin, Y., S. Gan-Mor, A. Bechnar, B. Ronen, and D. Eisikowitch. 1999. Effects of desiccation and dilution on germinability of almond pollen. *Journal of Horticultural Science & Biotechnology* 74 (3): 321–327.

Wickam, H. 2016. *ggplot2: Elegant graphics for data analysis*. New York: Springer.

Wickam, H. 2017. *tidyverse: Easily Install and Load the 'Tidyverse'*. R package version 1.2.1. https://CRAN.R-project.org/package=tidyverse.

Zaid, A., and P. F. de Wet. 2002. Pollination and bunch management. (In) Zaid, A. and E. J. Arias-Jimenez (eds). *Date palm Cultivation, FAO plant production and protection paper 156, Rev.1*. FAO of the United Nations, Rome. Retrieved from http://www.fao.org/3/Y4360E/y4360e0c.htm#bm12 on 29th March, 2020.

Zheng, Y.Y., X.J. Lin, H.M. Liang, F.F. Wang, and L.Y. Chen. 2018. The long journey of pollen tube in the pistil. *International Journal of Molecular Science* 19: 3529. https://doi.org/10.3390/ijms19113529.