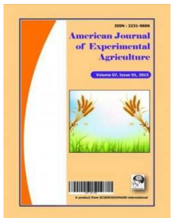

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Performance of Hand-pollinated Maize Genotypes at Different Daytimes in a Nigeria Forest Agro-ecosystem

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Weather condition prevailing during pollination could have some effect on seed set and yield in maize. A controlled pollination experiment was conducted at the Teaching and Research Farm, Ekiti State University, Ado-Ekiti, Nigeria during the early seasons of 2007 and 2008 to investigate the effect of daytime on the performance and seed yield of five maize genotypes viz. two open pollinated, two inbred lines and one hybrid. Hand-pollination was done on an hourly basis between 09.00 to 18.00 hours which constituted the treatments. The ten treatments were laid out in a Randomized Complete Block Design with three replicates. In all the experimental units, five plants were bulk pollinated for each of the time treatment. Results indicated differential responses of the genotypes to time of pollination. When averaged across the five genotypes, there were significant ($p<0.05$) differences in cob length, weight of 100 seeds weight, and seed yield per cob for the two years whilst cob diameter and number of kernels per row were only significant in 2008. Hand-pollination of maize can be done between 09.00 and 18.00 hours, however, the optimum performance was obtained for cob and seed traits when pollination was done between 10.00 and

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12.00 hours, There was 36.65% reduction in seed yield per cob when pollination was delayed till 16.00 hours compared with when done at 10.00 in 2007 and 32.94% reduction between 11.00 and 17.00 hours in 2008. The rate of decline can be minimized when pollination is delayed till 18.00 hours when temperatures are relatively low, which implies that perhaps the most determining factor that precludes pollination is temperature which is comparatively high between 13.00 and 17.00 hours. Furthermore, suboptimum performance was observed when pollination was done at 09.00 hours possibly due to the dampness of the pollen which may impair pollen shedding.

Keywords: Maize; hand pollination; optimal time of pollination; forest ecology.

1. INTRODUCTION

Maize (*Zea mays* L.) is highly amenable to genetic manipulation due to its floral structure and responds well to genetic improvement through hybridization and or selection. Controlled pollination is a prerequisite for successful breeding work and it is done for two main reasons viz. prevent cross pollination and resultant unwanted hybrids both in breeding nurseries and in the production of pure seed for commercial purposes and secondly it is essential to making the particular types of matings required in several breeding programme. In maize, controlled pollination is achieved through the transfer of pollen from the tassel (male gamete) to the silk (female gamete) in a hand pollination process which leads to hybridization when the sources of pollen and silk are different genetically or selfing when both are from the same plant [1].

The performance of hand pollinated crops is often influenced by environmental factors prevailing around the plant during pollination. Important climatic factors such as temperature, humidity and light intensity are known to fluctuate from one location to the other and even from time to time in the same location. These fluctuations could dictate the limit within which controlled pollination can be successfully conducted in any given location for a given crop. The findings of [2] on maize showed that temperature increase of 4.5℃ around the ear leads to reduced kernel number by as much as 73% compared with those exposed to ambient temperature. At temperatures above 38℃, poor seed set in maize has been attributed to both a direct effect of high temperature [3] and pollen desiccation [4]. Conversely, [5] found that during five growing seasons in North America, maize yield was unaffected by temperature, which ranged from 25.41 to 31.6℃ during periods of pollination. Several empirical analyses have also demonstrated sensitivity during portions of maize, for example, moderate sensitivity to high temperatures prior to silking, exceptional sensitivity during silking, and increased yields with elevated temperatures after the silking period were demonstrated for maize yields in sub-Saharan Africa [6]. Similarly, sensitivity to high temperatures during early reproductive stages has been demonstrated for US maize [7]. Heat stress decreases the number and weight of grains, thereby reducing yield. The effects of heat stress at an early grain development stage have been found to be severe. However the findings of [8] suggests that heat stress decreases fresh grain yield and accelerates grain filling rate; it increases starch content and starch granule size. Water stress associated with high temperature is often considered to be a limiting factor in maize production in dry regions. Water deficit [9], low light level [10], or nutrient deficiency and large anthesis-silking intervals [11] contribute to slower ear growth culminating in small cob size and weight. An optimum level of these conditions is required during pollination for good ear performance. It is necessary to determine the time when these optimum conditions are available to conduct successful hand pollination for maize in a forest ecological zone like Ado-Ekiti. This information is not only important in understanding the floral biology of maize and its implication on seed production, but also critical in gaining more insight into the relationship between weather and floral biology of maize for its improvement. Therefore experiments were conducted in 2007 and 2008 to ascertain the effects of daytime on pollination and yield traits of five maize genotypes in Ado-Ekiti.

2. MATERIALS AND METHODS

The experiments were conducted in the first seasons of 2007 and 2008 at the Teaching and Research Farm of the Ekiti State University, Ado-Ekiti is located between Longitude 4° 45'E to 5° 45' and Latitude 7° 15' to 8° 5' N. Five maize genotypes were used consisting of two open pollinated varieties TZEE Comp4C_4F_2 and TZEE-

$WSRBC_5$; two inbred lines KU1414SR/SR and 4001STR and one hybrid variety Obasuper1. These genotypes were obtained from the Maize Improvement Programme of the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. Genotypes were planted in a Randomized Complete Block Design with three replications. Each genotype was assigned to a row plot of 15 m long with a spacing of 0.75 m between the rows and 0.25 m within the row to give a standard planting density of 53,333 plant ha^{-1}. At planting, each plot was hand sown with three seeds per hill and later thinned to one. Weeds were controlled with a pre-emergence application of Atrazine and Paraquat. This was subsequently supplemented by two manual weeding at 7 and 10 weeks after planting (WAP). Supplemental irrigation was done to check the effect of drought particularly at early stage of growth and during flowering. Fertilizer application of NPK 15:15:15 was done in two equal splits of 150 kg ha^{-1} equivalence at 2 and 7 WAP to ensure nutrient adequacy throughout the plant life cycle.

At flowering, ears were covered with shoot bags upon emergence and before the appearance of silk, when silks appeared pollen was collected from at least three plants from each row and mixed thoroughly. Plants designated as pollen donors were bagged a day before pollination to minimize contamination. The composited pollen was then used to pollinate five plants for each of the time treatments. Pollen bags were then used to cover the pollinated plants and secured using staplers to avoid contamination. The time of pollination was noted on the pollination bags. In all there were ten pollination times spanning from 09.00 hours to 18.00 hours which constituted the treatments. Air temperature was recorded on an hourly basis during the period of pollination. Data were collected at harvest for the following traits: cob length, cob diameter, number of kernel rows, weight of seeds per cob and weight of 100 seeds. The data were subjected to analysis of variance using the PROC GLM procedure of the SAS Statistical Software Package for Windows [12]. Means were separated using Duncan's Multiple Range Test at 5% level of probability. The linear statistical model assumed for the ANOVA was as follows:

$$Y_{ij} = \mu + t_i + r_j + e_{ij}$$

where Y_{ij} = Effect of the ith time of pollination in the jth replication; μ = overall mean performance of all the times of pollination; t_i = effect of the ith time of pollination (1, 2, 3…10); r_j= effect of the jth replication (1, 2, 3); and e_{ij}= residual error as a result of the ith time of pollination in the jth replication.

3. RESULTS AND DISCUSSION

Mean temperatures increased steadily from 09.00 hours reaching its peak at 15.00 hours and thereafter declined (Fig. 1). Average temperatures in 2008 were slightly higher than those in 2007 particularly before 16.00 hours. Temperatures at the beginning and at the end of pollination time were comparable in 2007 and similar in 2008.

The effect of time of pollination on the cob length of five maize genotypes during the 2007 and 2008 cropping seasons is presented in Table 1. There were significant differences in cob length due to time of pollination in 2007 for all the five genotypes except TZEE WSRBC5, an open pollinated early maturing variety. Highest cob length was observed at 10.00 hours in all the fives genotypes except in the hybrid variety where it was highest at 11.00 hours. Averaged across the genotypes the highest cob length was observed at 10.00 hours whilst the lowest cob length was at 17.00 hours. The 8.5℃ and 8.0℃ differences in temperature between 10.00 and 14.00 hours during the 2007 and 2008 seasons, respectively could have influenced the cob length of maize. The anatomical explanation for this can be linked to the kernel size which could have exerted some force for expansion and or elongation of the ear rather than direct increase of the ear per se. Favorable temperatures in the early hours of pollination may have enhanced larger kernels; this finding was corroborated by [13] in which high temperature after pollination was found to change the dynamics of grain filling of maize resulting in lower grain filling. The low performance at 18.00 hours compared with that done in the early hours of maize pollination could have been accounted for by the level of desiccation of the pollens which may have minimized its viability [14-16]. Cob lengths were generally longer in 2008 than in 2007 despite the fact that temperatures during pollination where slightly higher in 2008. This, therefore, demonstrates that though temperature is an important factor it can only be inclusive of other factors in determining the cob length. It could, therefore, have been due to a complex interaction of weather variables including relative humidity, moisture and light intensity. The results of [17] demonstrated through multiple regression model the possible effect of climatic changes. It was found that lower yields of maize were found to be associated with increase in daytime temperature during the month of pollination in the southeastern United States. The Inbred lines (Ku 1414 SR/SR and 4001 STR) were generally shorter than the open pollinated varieties (TZEE Comp 4 C_2 F_2 and TZEE $WSRBC_5$) and the hybrid was consistently longer than the others in both years of the experiment (data not shown). This underscores the importance of inbreeding and heterosis in maize. Cob diameter averaged across the genotypes was indifferent to the time of pollination during the 2007 season (Table 2).

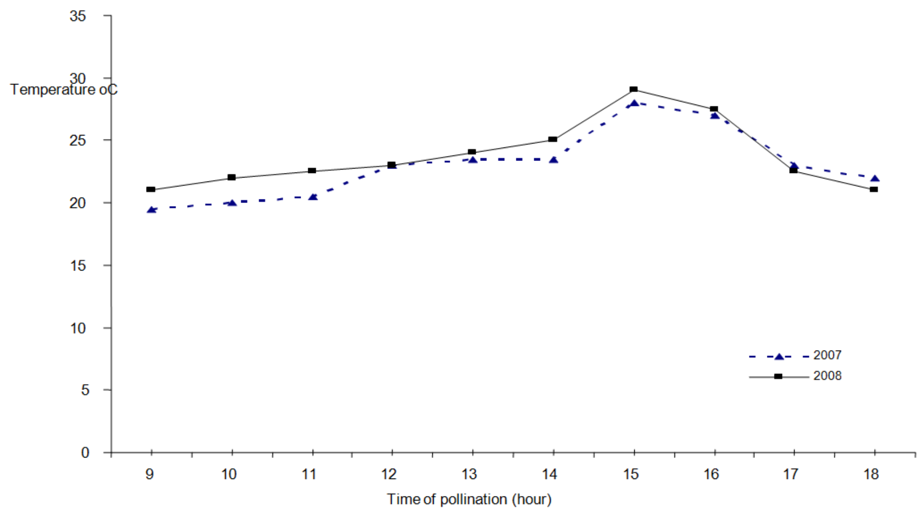

Fig. 1. Mean air temperature during the period of pollination in 2007 and 2008

Table 1. The effect of time of pollination on the cob length (cm) of maize five genotypes during the 2007 and 2008 cropping seasons

Pollination time (Hour)	Genotype					Mean
	TZEE $Comp4C_2F_2$	TZEE-$WSRBC_5$	Ku1414 SR/SR	4001STR	Obasuper1	
			2007			
09.00	15.11ab	12.11a	13.75ab	14.06b	16.81ab	14.37ab
10.00	15.76a	13.00a	16.06a	16.50a	17.75a	15.81a
11.00	14.33b	12.61a	14.41ab	14.17b	18.28a	14.76ab
12.00	14.56b	12.33a	13.00ab	14.81ab	16.81ab	14.30ab
13.00	14.58b	11.72a	12.58ab	14.92ab	17.61a	14.28ab
14.00	13.72b	11.47a	11.92ab	13.34c	17.78a	13.65b
15.00	13.84b	11.31a	12.42ab	13.31c	17.92a	13.76b
16.00	14.08b	11.69a	13.40ab	14.17b	16.50b	13.97b
17.00	14.05b	11.44a	10.78b	14.67b	16.78ab	13.54b
18.00	14.56b	12.92a	13.81ab	16.03ab	17.67a	15.00ab
			2008			
09.00	11.97b	11.50ab	10.90b	12.69ab	15.00a	12.41b
10.00	15.50a	13.90a	13.27a	12.57ab	15.65a	14.18a
11.00	15.90a	13.73a	14.17a	15.80a	16.27a	15.17a
12.00	15.60a	12.00ab	13.40a	14.97a	16.60a	14.51a
13.00	13.60ab	12.13ab	12.20ab	13.90a	14.27ab	13.22ab
14.00	14.40ab	10.50b	11.53ab	11.50b	14.80ab	12.55b
15.00	10.30b	10.35b	11.37ab	10.50c	14.67ab	11.44c
16.00	12.80ab	10.05b	10.85b	10.30c	13.43b	11.49c
17.00	12.90ab	10.20b	10.80b	12.00ab	13.83b	11.95ab
18.00	15.63 a	11.67ab	12.50ab	13.50a	14.97ab	13.65ab

Means with the same letter(s) in each column for each year are not significantly different at p<0.05 by Duncans Multiple Range Test (DMRT)

Table 2. The effect of time of pollination on the cob diameter (cm) of five maize genotypes during the 2007 and 2008 cropping seasons

Pollination time (Hour)	Genotype					Mean
	TZEE $Comp4C_2F_2$	TZEE-$WSRBC_5$	Ku1414 SR/SR	4001STR	Obasuper1	
			2007			
09.00	5.63a	4.78a	5.33a	4.24b	5.70a	5.14a
10.00	5.65a	5.04a	5.28a	5.48a	5.92a	5.47a
11.00	5.55a	5.06a	5.22a	5.32a	5.81a	5.39a
12.00	5.63a	5.03a	4.98b	5.42a	5.89a	5.39a
13.00	5.59a	4.96a	5.15a	5.26ab	5.70a	5.33a
14.00	5.58a	4.90a	4.98b	5.28ab	5.65a	5.28a
15.00	5.99a	4.77a	5.20a	5.28ab	5.63a	5.37a
16.00	5.44a	4.70a	5.20a	5.25ab	5.63a	5.24a
17.00	5.75a	4.67a	4.92b	5.15ab	5.50a	5.20a
18.00	5.55a	4.83a	5.12ab	5.32a	5.73a	5.31a
			2008			
09.00	5.40a	4.27a	4.03ab	4.53a	4.94a	4.63a
10.00	5.75a	4.60a	4.73a	4.40a	5.00a	4.90a
11.00	5.20a	4.20a	4.10ab	4.37a	4.73a	4.52a
12.00	5.10a	4.08ab	4.53a	4.30a	4.73a	4.55a
13.00	5.13a	3.90b	4.23a	4.20a	4.37ab	4.37a
14.00	4.60ab	3.80b	4.00ab	4.00ab	4.37ab	4.15ab
15.00	4.97ab	3.10c	3.90ab	3.93ab	4.70a	4.12ab
16.00	4.57b	3.05c	3.75b	3.85b	4.77a	4.00ab
17.00	3.98c	3.60b	3.60c	3.65b	4.77a	3.92c
18.00	4.50b	4.05ab	3.95b	4.25a	4.63a	4.28a

Means with the same letter(s) in each column for each year are not significantly different at p<0.05 by DMRT

During the 2008 season, cob diameter showed no consistent trend with the time of pollination among the genotypes, however, when averaged across the five genotypes cob diameter of maize pollinated between 09.00 and 13.00 hours were not significantly different. However, cob diameter of maize pollinated between 14.00 hours and 17.00 was lower and significantly different from that pollinated earlier. The least cob diameter was observed for maize pollinated at 17.00 hours. High temperatures during this period can be implicated in the reduction in diameter. The cob diameter of maize is a function of the kernel size which in itself is dependent on the condition prevailing at the time of pollination. Cob diameters were generally higher in 2007 experiment compared with 2008. There were no significant (p>0.05) differences in number of kernel rows for the time of pollination for the two years except for number of kernel rows at 17.00 in 2008 when averaged across the five genotypes (Table 3). However, in 2008, open pollinated varieties and inbred line Ku1414 SR/SR indicated significant differences for the time of pollination in which higher numbers of kernel rows appeared to occur between 10.00 and 12.00 hours, while time extending beyond 12.00 hours but before 18.00 had the least number of kernel rows. The effect of time of pollination on the weight of 100 seeds of the five maize genotypes during 2007 and 2008 cropping seasons is presented in Table 4. Apart from genotypes 4001STR and TZEE-$WSRBC_2$ in 2007 and 2008, respectively, the rest were significantly different (P<0.05) for the time of pollination. The trend observed for cob length and cob diameter appeared to have been repeated with the highest weight of 100 seeds being consistently highest at 10.00 and 11.00 hours for the two years while the least weight was at 14.00 in 2007 and 15.00 in 2008 hours. The study by [18] showed a 7% reduction in kernel growth rate per heat unit when exposed to heat stress after pollination of maize inbred lines. Furthermore, reduction occurred for starch, protein and oil content. Similar results were also been observed earlier by [19]. The five genotypes indicated statistical differences (p<0.05) for seed yield per cob for the two years of observations (Table 5). The seed yields of hybrid were better than that of open pollinated variety whilst those of inbred lines were least; the differences seem accentuated with increasing temperature at pollination. Studies by [20] showed that differences in grain yield between hybrids and inbreds (i.e., heterosis) increased with the intensity of drought stress. When averaged across the genotypes, the highest seed yield per cob occurred at 10.00 hours in 2007 and 11.00 hours during the 2008 season. There was 36.65% reduction in seed yield per cob when pollination was delayed till 16.00 hours compared to when it was done at 10.00 hours in 2007 and 32.94% reduction between 11.00 hours and 17.00 hours in 2008. Furthermore, these reductions were minimized to 7.87% and 11.88% in 2007 and 2008, respectively when pollination took place at 18.00 hours compared to the time which gave the highest seed yield per cob. When the performance of the five genotypes were ranked across the ten pollination times to determine the time that will support optimum maize cob and seed traits, the performance were in the order of 10.00> 11.00 >12.00 hours in both 2007 and 2008 (data not shown) whilst the least performance occurred between 14.00 and 17.00 hours. This suggests that hand-pollination of maize beyond 12.00 noon in the forest ecosystem in Nigeria is not likely to give optimum performance. Pollinating earlier than 10.00 hours is also not desirable, possibly due to the dampness of the pollen which is caused by mist which often settles on the pollination bags as well as the tassels overnight. Some level of exposure to sunlight is, therefore, desirable to facilitate pollen shedding. The 4th and 5th in rank of performance in 2007 and 2008, respectively, for maize pollinated at 18.00 implies that perhaps the most determining factor that precludes pollination is temperature which is comparatively high between 13.00 and 17.00 hours. Therefore for maize breeding programmes involving large numbers of plants for which hand-pollination is necessary to be done, if daily batches cannot be completely handled between 10.00 and 12.00 hours it is better to delay pollination and complete it at 18.00 hours when the temperatures would have dropped considerably.

Table 3. The effect of time of pollination on number of kernel row per cob of five maize genotypes during the 2007 and 2008 cropping seasons

Pollination time (Hour)	Genotype					Mean
	TZEE Comp4C_2F_2	TZEE-WSRBC_5	Ku1414 SR/SR	4001STR	Obasuper1	
			2007			
09.00	13.67a	12.00a	12.00a	13.00a	13.11a	12.76a
10.00	14.67a	13.56a	12.33a	13.22a	14.22a	13.60a
11.00	13.33a	13.33a	12.22a	14.00a	14.33a	13.44a
12.00	14.11a	14.00a	12.00a	13.89a	14.33a	13.67a
13.00	13.00b	13.11a	11.67a	13.11a	13.78a	12.93a
14.00	13.67a	14.67a	11.44a	12.89a	13.11a	13.16a
15.00	12.56c	11.56a	11.33b	12.11a	13.33a	12.18a
16.00	13.00b	11.11a	11.33b	12.00a	13.33a	12.15a
17.00	13.33a	12.00a	11.00b	13.22a	12.89a	12.49a
18.00	14.50a	13.67a	12.22a	13.55a	13.00a	13.39a
			2008			
09.00	14.00a	12.67ab	12.67a	12.33a	13.33a	13.00a
10.00	16.50a	14.67a	13.33a	13.67a	14.50a	14.53a
11.00	16.50a	15.00a	11.33a	12.67a	14.00a	13.90a
12.00	14.67a	14.00a	12.33a	12.67a	14.00a	13.53a
13.00	13.67b	12.00ab	11.33a	12.50a	13.33a	12.57a
14.00	13.67b	13.00ab	10.67b	11.33a	12.33a	12.20a
15.00	13.33b	12.33ab	11.00b	12.50a	12.33a	12.30a
16.00	14.33a	11.00c	10.00b	11.50a	14.00a	12.17a
17.00	12.00c	11.00c	10.33b	12.67a	14.00a	12.00b
18.00	14.33a	14.00a	11.33a	13.00a	14.67a	13.47a

Means with the same letter(s) in each column for each year are not significantly different at p<0.05 by DMRT

Table 4. The effect of time of pollination on the weight of 100 seeds (g) of five maize genotypes during 2007 and 2008 cropping seasons

Pollination time (Hour)	Genotype					Mean
	TZEE Comp4C_2F_2	TZEE-WSRBC_5	Ku1414 SR/SR	4001STR	Obasuper1	
			2007			
09.00	40.73ab	28.35a	37.83a	34.15a	40.87ab	36.39ab
10.00	45.10a	28.33a	40.22a	36.56a	52.91a	40.62a
11.00	41.39ab	27.71a	36.89a	37.77a	46.38a	38.03a
12.00	41.77ab	28.08a	36.45a	33.35a	43.42a	36.61ab
13.00	40.84ab	27.10a	34.88ab	34.91a	42.91ab	36.13ab
14.00	37.89b	22.20c	34.46ab	31.10a	38.51c	32.23b
15.00	37.64b	26.02ab	34.43ab	34.63a	47.50a	36.04ab
16.00	37.05b	25.02b	29.63b	31.07a	41.47ab	32.85b
17.00	36.05b	26.90ab	33.49ab	34.85a	45.47a	35.35ab
18.00	41.98ab	27.53ab	38.61a	34.27a	46.49a	37.78a
			2008			
09.00	40.67ab	29.33a	36.50a	38.33a	37.00ab	36.37ab
10.00	45.75a	33.00a	37.67a	38.55a	40.00a	38.99a
11.00	42.00a	35.00a	38.00 a	37.67a	38.00a	38.13a
12.00	40.00ab	31.00a	38.33a	36.67a	34.67ab	36.13ab
13.00	41.00a	29.33a	34.67a	30.67a	33.00ab	33.73ab
14.00	38.67b	30.56a	32.00a	32.00ab	33.50ab	33.35ab
15.00	34.00 b	26.00a	24.00b	24.00b	34.00ab	28.40b
16.00	31.33c	24.00a	28.00ab	25.50b	35.33ab	28.83b
17.00	36.00b	22.00a	30.25a	28.00ab	32.00b	29.65ab
18.00	40.67ab	31.50a	36.70a	32.00ab	36.67ab	35.51ab

Means with the same letter(s) in each column for each year are not significantly different at p<0.05 by DMRT

Table 5. The effect of time of pollination on the seed yield per cob (g) of five maize genotypes grown during 2007 and 2008 cropping seasons

Pollination time (Hour)	Genotype					Mean
	TZEE Comp4C_2F_2	TZEE-WSRBC_5	Ku1414 SR/SR	4001STR	Obasuper1	
			2007			
9.00	138.91ab	86.17a	112.72a	91.23ab	167.67ab	119.34ab
10.00	155.76a	93.36a	108.42a	111.17a	202.32a	134.21a
11.00	120.35ab	90.50a	112.20a	118.08a	186.83a	125.59a
12.00	159.48a	86.41a	75.53c	105.01a	186.56 a	122.60a
13.00	120.49ab	93.15a	75.61c	90.44ab	150.70ab	106.08b
14.00	125.40ab	77.97ab	78.17c	81.49c	149.79ab	102.56b
15.00	83.54d	57.15c	75.04c	78.3c	145.55b	87.92c
16.00	106.42c	48.70c	74.43c	91.76ab	103.77 c	85.02c
17.00	94.85d	76.69ab	64.69c	101.13a	143.42b	96.16c
18.00	159.86a	90.80a	101.26ab	103.74a	162.54ab	123.64a
			2008			
9.00	110.22ab	90.98a	119.83a	109.48a	141.65c	114.43ab
10.00	145.67a	78.19ab	113.33ab	102.07a	166.68a	121.19a
11.00	136.81a	88.85a	125.54a	105.24a	184.13a	128.11a
12.00	136.83a	79.55ab	100.55ab	100.02a	170.21a	117.43a
13.00	126.62a	73.72b	103.54ab	87.96ab	158.68ab	110.10ab
14.00	133.38a	65.43c	63.72c	85.71ab	118.71d	99.39c
15.00	73.61c	79.83ab	74.18c	73.59c	146.42c	89.53c
16.00	90.44c	67.07c	64.45c	67.52d	145.15c	86.93c
17.00	81.84c	52.98d	51.86c	97.36ab	145.51c	85.91c
18.00	107.27ab	82.85ab	102.53ab	111.69a	160.50ab	112.97ab

Means with the same letter(s) in each column for each year are not significantly different at p<0.05 by DMRT

4. CONCLUSION

In the forest agro-ecosystem of Nigeria hand-pollination of maize can be done between 09.00 and 18.00 hours. However, this study showed that optimum performance was obtained for cob and seed traits when pollination was done between 10.00 and 12.00 hours. Beyond 12.00 hours and earlier than 18.00 there was a decline in performance. The rate of decline can be minimized when pollination is delayed till 18.00 hours when temperatures are relatively low. This implies that perhaps the most determining factor that precludes pollination is temperature which is comparatively high between 13.00 and 17.00 hours. Furthermore, suboptimum performance was observed when pollination was done at 09.00 hours possibly due to the dampness of the pollen which may impair pollen shedding.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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