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EFFECT OF TIME INTERVAL BETWEEN POD SET AND HARVESTING ON THE MATURITY AND SEED QUALITY OF FLUTED PUMPKIN

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SUMMARY

A two-year study considered the effect of pod harvesting intervals of 3, 5, 7, 9, 11 or 20 weeks after pod set (WAPS) on the relationship between the physical condition of the pods, seed maturation and quality in fluted pumpkin (*Telfairia occidentalis*). Pod characteristics, such as the intensity of bloom wax on the pod and stiffness of the pod ridges, showed perfect linearity and correlation with the age of the pod, whereas changes in seed quality factors – germination, dry matter, oil and protein concentrations were curvilinearly associated with the time of pod harvest. Thus, seed quality factors increased steadily up to nine WAPS then declined. The point at nine WAPS defined as physiological maturity for fluted pumpkin seed and approximate visible indications of this point in the field were fairly stiff pod ridge condition and fading of bloom wax.

INTRODUCTION

Fluted pumpkin (*Telfairia occidentalis*), a native of tropical Africa (Grubben, 1977), is generally known and cultivated for its succulent foliage which is relished as a vegetable in many African countries. The seed, which contains 30% protein (Terra, 1973) and 45% oil (Girgis and Turner, 1972), is also edible but has not been used extensively as food or feed. This may have been due to the difficulty of obtaining a steady supply of good quality seeds despite the fact that the seed yield of fluted pumpkin has been reported as 2.08 t ha^{-1} (Oyolu, 1978) – an output that is superior to that of most other oilseeds now being exploited for seed oil and cake in Nigeria.

In the few cases where fluted pumpkin was cultivated for seed, farmers' lack of adequate knowledge of appropriate harvesting time resulted in the production of poor quality seed. For good quality seed, harvesting should be when the moisture content of the seed is sufficiently low as to permit easy handling and, in the absence of artificial drying, when storage presents minimal risk of damage to the seed by pest attack at physiological maturity (Harrington, 1972). This has been found to be true in several orthodox seed crops such as sunflower (*Helianthus annuus*

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L.) (Adetunji, 1991) and soyabeans (*Glycine max*) (Delouche, 1974; Tekrony *et al.*, 1980). Recently, Ellis *et al.* (1987; 1993) propounded the potential longevity hypothesis which suggests that maximum seed quality may not be attained until some time after physiological maturity in orthodox seed. In spite of the abundance of evidence in support of these two hypotheses in orthodox seeds, there is almost a total lack of information on their application to unorthodox seeds such as recalcitrant fluted pumpkin seed (Akoroda, 1986).

Furthermore, the tendency for fluted pumpkin to develop perennial growth under favourable conditions further complicated the choice of the appropriate time of pod harvest for seed production. Consequently, the seeds are frequently not fully mature or are overmature when pods are harvested.

This problem arises because there is no documented information on either physical or internal features to indicate physiological maturity of seeds inside the pods of fluted pumpkin. Unlike other seed crops, such as maize and sorghum, where seeds mature almost at the same time and therefore can be examined easily for maturity, pod formation, development and maturity in individual plants of fluted pumpkin in the field are very variable and the opening of pods to test for seed maturity leads to seed wastage. The aim of this research was to define adequate criteria for describing the 'physiological' maturity of fluted pumpkin seed.

MATERIALS AND METHODS

Two field trials were carried out under the moist savanna conditions of Ogbomoso (lat 8°N, long 04°E), Nigeria during the 1993 and 1994 cropping seasons. Each year in May seeds from mature fruits of fluted pumpkin were sown in trays containing sawdust and two-weeks-old seedlings were transplanted in the field at a spacing of 1 × 1 m in a complete randomized block design with four replications. In each of the planting seasons, there were 24 plots each measuring 4 × 4 m and consisting of five rows and five stands of fluted pumpkin per row. The treatments were six harvesting dates at 3, 5, 7, 9 or 11 weeks after pod set (WAPS) and at complete foliage dryness (20 WAPS). These treatments were randomized according to the experimental design. Plants were staked to a height of 1.5 m with bush sticks. Supplementary irrigation and mulching (Adetunji, 1989) were used to sustain plants during the dry months (October–March) of the planting seasons. Fields were weeded and fallen plants restaked as necessary. Weather conditions during the experimental period in both planting seasons were recorded and the edible foliage was not harvested. At anthesis, female flowers were tagged with the date of anthesis for easy identification of pod age.

Since fluted pumpkin is dieocious, at anthesis an average of 13–15 of the 25 stands planted per plot were fruit-bearing females. Therefore, for each age category, pods were harvested at sampling time from two fruit-bearing female plants in each plot. Before opening, the stiffness of the ridges on the pods were measured using a scale of 1–5, where 1 = easily breakable, 2 = breakable, 3 = fairly stiff, 4 = stiff and 5 = very stiff. The stiffness was tested by pressing two adjacent ridges on the pod between the thumb and forefinger. The intensity of bloom (white wax) on the surface of pods was also assessed visually using a scale of 1–4, where 1 = less intense, 2 = fairly intense, 3 = intense, 4 = very intense. Thereafter, the pods were opened to extract the seeds and measure the pH of the mesocarpic pulp. The pH was determined with a digital pH meter, model DIGIMED PM 600, each determination taking about 25 s. Dry weights of the empty pods and of 50 seeds were measured from each plot. At each harvesting time the number of mature, immature and partly-filled seeds were counted and their dry weights recorded. Partly-filled seeds was identified through their half-empty testae, while immature seeds were soft to the touch. The number of seeds that either germinated or rotted inside the pods was also recorded. Subsamples of 100 g intact seeds were taken randomly from each harvest category and sun-dried to a constant weight. Testae were removed from these seeds and clean cotyledons were then ground and analysed for crude protein, fibre and oil contents (AOAC, 1980).

Duplicate samples of 50 intact seeds randomly selected from each harvest category were used for germination tests. The seeds were sown at a depth of 8 cm in wooden boxes (40 × 100 × 15 cm) filled with sterile sand, moistened to approximately 50% of field capacity. There were two boxes per treatment and each treatment was replicated four times according to the original experimental design. A total of 96 boxes were used. The boxes were held under laboratory conditions for 14 days with temperatures fluctuating between 23 and 32 °C and relative humidity between 54 and 86%. Seeds from which healthy hypocotyls had protruded above the sand surface were considered to have germinated and emerged. The ungerminated seeds were examined further after 14 days by opening their testae to check the condition of the cotyledons. The cotyledons of all the ungerminated seeds were found to be at various stages of decay. Data from the two planting seasons were analysed in accordance with the experimental design. Data were also subjected to simple linear and curvilinear regression models and correlation analysis to determine the relationship between harvest dates, seed quality factors and pod physical conditions. Data were analysed after angular transformation.

RESULTS

Weather conditions at the experimental site in 1993 and 1994 are summarized in Table 1. Although the weather in 1994 was as expected, a slight drought was experienced in 1993. In this year, the growing season was characterized by a hot dry late season which coincided with anthesis and the seed-filling period of the crop. For example, the total monthly rainfall for August prior to anthesis was only 49.2 mm and this shortage of moisture continued throughout the anthesis and harvesting periods. Mean monthly maximum air tempertures during the seed-filling period from anthesis to constant 50-seed dry weight (physiological maturity) were also high, ranging from 29.5 to 34.2 °C. By comparison, the weather conditions in the 1994 planting season were more favourable during the seed-filling period from anthesis to physiological maturity.

Table 1. *Monthly rainfall, mean monthly maximum and minimum temperatures at Ogbomoso, Nigeria in 1993 and 1994*

	Rainfall (mm)		Temperature (°C)			
			1993		1994	
	1993	1994	Maximum	Minimum	Maximum	Minimum
January	0.0	0.0	32.8	18.2	33.9	22.1
February	0.0	3.6	38.7	21.3	35.0	22.7
March	0.0	51.6	37.0	25.3	35.8	24.1
April	0.0	29.8	36.8	25.5	34.5	24.0
May	140.0	141.4	35.0	35.0	31.0	22.8
June	72.5	142.6	30.4	24.9	29.9	22.3
July	116.3	146.6	20.0	24.3	28.0	21.6
August	49.2	203.3	29.5	24.1	27.9	21.4
September	189.7	234.3	30.1	24.7	29.5	21.7
October	166.4	202.3	33.2	24.3	30.4	21.7
November	30.6	55.5	34.2	22.5	32.3	21.2
December	0.0	0.0	33.3	19.4	32.0	19.1

Pod physical characteristics and seed condition

In both seasons, dry weight of empty pods increased with delayed pod harvest up to 11 WAPS and declined significantly thereafter (Table 2). The slight increase in pulp acidity which became noticeable in week 7 continued up to week 20 when

Table 2. *Effect of date of pod harvest on pod physical characteristics and seed condition for fluted pumpkin grown at Ogbomoso, Nigeria*

Date of harvest (WAPS)†	Dry weight per empty pod (g)	Stiffness of pod ridges (1–5 score)	pH of pulp	Bloom (wax) intensity (1–4 score)	No. of mature healthy seeds per pod	No. of rotten seeds per pod	No. of seeds germinated within pod	No. of immature and partly-filled seeds
				1993 Planting season				
3	26.5	1.4	6.31	3.7	23.3	0.0	0.0	75.1
5	33.6	1.7	6.12	3.3	68.9	0.0	0.0	63.3
7	41.2	2.9	6.04	2.9	78.2	0.0	0.0	31.6
9	65.7	3.5	5.72	2.5	98.7	0.0	0.0	7.8
11	62.2	3.8	5.68	2.2	96.0	4.7	3.1	6.6
20	39.1	5.0	5.52	0.7	100.8	11.3	18.4	8.4
s.e.	3.97	1.22	0.55	1.02	5.38	2.12	2.79	5.50
				1994 Planting season				
3	59.2	1.4	6.20	3.8	40.7	0.0	0.0	48.7
5	75.8	1.9	6.08	3.7	77.9	0.0	0.0	20.0
7	89.5	2.9	6.06	2.7	86.0	0.0	0.0	10.2
9	130.7	3.6	5.81	2.3	101.6	0.0	0.0	3.9
11	126.5	3.8	5.73	0.7	106.5	1.2	3.7	2.8
20	81.2	5.0	5.86	0.6	109.2	6.8	12.1	3.1
s.e.	5.36	1.15	0.42	1.17	5.07	1.67	2.20	4.23

WAPS = weeks after pod set.

Table 3. *Regression equations and correlation coefficients between harvesting time and seed dry matter (DM) concentration, percentage seed germination, seed oil and protein concentrations, stiffness of pod ridges and bloom (wax) intensity*

Character	Regression equations	R	R^2	r	r^2
Seed DM concentration ($g\ kg^{-1}$ fresh seed)	$Y = -61.048 + 65.635x - 2.424x^2$	0.958	0.918	–	–
Seed germination (%)	$Y = -63.595 + 24.742x - 0.968x^2$	0.990	0.981	–	–
Seed oil concentration ($g\ kg^{-1}$ DM)	$Y = -202.242 + 115.983x - 4.576x^2$	0.985	0.972	–	–
Seed protein concentration ($g\ kg^{-1}$ DM)	$Y = 46.976 + 50.566x - 2.104x^2$	0.981	0.963	–	–
Stiffness of pod ridge (1–5 score)	$Y = 0.98 + 0.23x$	–	–	0.888	0.791
Bloom (wax) intensity (1–4 score)	$Y = 4.14 - 0.18x$	–	–	0.914	0.835

the experiment was terminated. Whilst severity of ridge stiffness increased with pod age, the bloom intensity decreased with pod age. The levels of these two parameters (which serve as physical indicators of seed maturity) reached noticeable turning points when pods reached 9 WAPS at which stage they stagnated without further change until 20 WAPS. Linear relationships with significant positive and negative correlations were observed between harvesting time and stiffness of pod ridges, and harvesting time and bloom (wax) intensity respectively (Table 3). However, there was no significant difference in the conditions of pods harvested at both 9 and 11 WAPS.

In both planting seasons, numbers of mature healthy seeds, rotten seeds and seeds at different stages of germination per pod increased with increasing delay in harvest, reaching maximum levels in pods harvested at complete foliage dryness (20 WAPS) (Table 2). There was a close relationship between the number of rotten and germinated seeds within a pod at different stages of harvest in both planting seasons. Between 3 and 9 WAPS there were no rotten or germinated seeds in the harvested pods. Seed rotting and germination within the pod became apparent from 11 WAPS to complete foliage dryness (20 WAPS). The number of immature and partly-filled seeds per pod decreased with increasing delay in pod harvest. Pods harvested at 9 WAPS contained a negligible number of immature and partly-filled seeds. Compared with the 1994 season, substantially greater numbers of seeds were either immature or partly filled in the 1993 planting season.

Seed quality factors

Seeds at every stage of pod harvest were heavier and accumulated more dry matter (DM) under the favourable weather conditions of the 1994 season than in

Table 4. *Effect of date of pod harvest on some seed quality factors in fluted pumpkin grown at Ogbomoso, Nigeria*

Date of harvest (WAPS)	Seed fresh weight (g)	Seed dry weight (g)	Seed dry matter concentration ($g\,kg^{-1}$ fresh weight)	Seed germination (%)	Seed oil concentration ($g\,kg^{-1}$ dry matter)	Seed protein concentration ($g\,kg^{-1}$ dry matter)
			1993 Planting season			
3	154.7	20.2	130.3	0.0	91.1	151.3
5	215.1	40.1	185.8	28.1	282.1	242.5
7	254.9	60.4	236.6	52.6	368.0	298.1
9	339.6	130.1	383.2	78.3	508.6	332.5
11	324.7	115.2	353.6	78.8	487.7	315.0
20	295.3	90.0	305.1	36.6	289.1	213.6
s.e.	8.14	6.56	9.48	5.53	12.41	8.32
			1994 Planting season			
3	220.4	35.1	158.7	0.0	232.1	187.5
5	324.8	65.3	200.0	45.7	316.7	268.8
7	369.5	90.1	243.1	70.6	409.1	306.3
9	460.2	170.2	368.8	96.2	551.3	358.8
11	434.8	155.4	356.2	90.8	516.9	341.3
20	389.6	100.1	258.1	51.6	382.2	223.6
s.e.	9.28	7.20	8.74	5.94	10.95	8.19

WAPS = week after pod set.

the droughty 1993 season. Seed DM accumulation increased significantly with delay in pod harvesting up to 9 WAPS after which it declined (Table 4). Seed DM concentrations were highest in pods harvested at 9 WAPS but not significantly different from those harvested at 11 WAPS. Maximum seed crude oil and protein concentrations were attained in both seasons at between 9 and 11 WAPS (Table 4). This period corresponded with the time when maximum DM accumulation and germination were attained. It was during this same period that the bloom became fairly intense and pod ridges became stiff. The optimum time of pod harvest for high quality seed production in fluted pumpkin was between 9 and 11 WAPS.

Whilst seed quality factors showed positive correlations and significant curvilinear relationships with harvesting time, pod physical characteristics, such as stiffness of the pod ridge and bloom intensity, showed linearity with significant positive and negative correlations with harvesting time respectively (Table 3). The relationships between different seed quality factors and pod physical characteristics are presented in Table 5. All the seed quality factors (seed DM accumulation, seed germination, seed oil and protein concentrations) were significantly and positively correlated with each other. Seed quality characteristics such as dry matter accumulation, germination and oil concentration showed significant positive relationships with stiffness of pod ridges but their relationships with bloom (wax) intensity were weak and negative.

Table 5. *Correlation coefficients between different components of seed maturity in fluted pumpkin grown at Ogbomoso, Nigeria in 1993 and 1994*

Components of seed maturity	Seed dry matter concentration (g kg^{-1} fresh weight)	Seed germination (%)	Seed oil concentration (g kg^{-1} dry weight)	Seed protein concentration (g kg^{-1} dry weight)	Stiffness of pod ridges (1–5 score)	Bloom intensity (1–4 score)	pH of pulp
Seed dry matter concentration (g kg^{-1} fresh weight)		0.920**	0.985**	0.809*	0.838*	−0.832*	−0.426
Seed germination (%)			0.988**	0.998**	0.889*	−0.102	0.635
Seed oil concentration (g kg^{-1} dry weight)				0.989**	0.755	−0.264	0.822*
Seed protein concentration (g kg^{-1} dry weight)					0.221	−0.417	−0.226
Stiffness of pod ridges (1–5 score)						−0.450	−0.524
Bloom intensity (1–4 score)							−0.509

*Significant at $p = 0.05$; **significant at $p = 0.01$.

DISCUSSION

Observations in this study showed that fluted pumpkin has a relatively long optimum pod harvest period within which high quality seed can be harvested provided there is enough moisture in the soil to sustain the plant to maturity. Thus seed of high quality was obtained in the 1994 planting season when environmental conditions were favourable and relatively humid during pod maturation in contrast to the hot and dry weather conditions recorded during the same period in the 1993 planting season. Being a recalcitrant seed (Akoroda, 1986), located in an abundance of moisture in the mesocarpic pulp, the hot weather of the 1993 season not only reduced plant vigour but also created a suffocating environment for the seeds inside pods before and after maturity.

This study also suggests that there is little advantage in allowing pods to ripen beyond 9 WAPS. Seed quality increased with delayed pod harvest up to 9 WAPS, stabilized up to 11 WAPS and declined thereafter in a curvilinear relationship. This decline may be attributed to the rotting process which became apparent immediately after 9 WAPS. However, perfect linearity and correlation was recorded between pod physical characteristics and harvesting time. Whilst the stiffness of pod ridges increased with delayed harvest, the intensity of bloom on the pods declined with delayed pod harvest.

Maximum seed dry matter, oil and protein concentrations and seed germination occurred at 9 WAPS. Thus the reduction of assimilate translocation to the seed inside the pods and the appearance of conditions favourable for rotting such as high pulp pH appear to occur at this time. Approximate visible signs of this point in the field were the fading of bloom on the pods and the stiffness of pod ridges. The sudden escalation of pulp acidity at 9 WAPS may be attributed to biodeterioration of mesocarpic pulp instigated by increased seed respiration and high temperature at physiological maturity. Germination and growth of seeds within overmature pods reduced the number of seeds useable for consumption and for seed-related studies due to differing levels of growth. Poor seed germination recorded in pods harvested at 3 and 5 WAPS may be attributed to the high proportion of partly-filled and immature seeds in the pods. When such seeds were sown in the germination study, they rotted before germination could take place.

The crude oil and protein concentrations of fluted pumpkin seeds at 9 WAPS compared favourably with the seed oil and protein contents of 45 and 30% respectively as recorded by Girgis and Turner (1972) and Terra (1973). The general reduction in seed oil and protein concentrations after 9 WAPS might be expected on physiological grounds, because respiration after physiological maturity could reduce oil and protein concentrations (and hence seed weight) especially with the higher pH of mesocarpic pulp and the high temperatures that existed after 9 WAPS.

Harvesting of pods at 9 WAPS rather than at complete foliage dryness as practised by farmers will not only lengthen the period of foliage production but will also enhance the yields of succulent leaves and vines for consumption as vegetables. This is because the assimilates that might have been directed towards further pod development are now channelled into production of more foliage and sustenance of leaf area further into the season. Finally, harvesting pods at 9 WAPS (physiological maturity) will also minimize storage problems. The major problem of fluted pumpkin pod storage is the absence of an after-ripening period for seeds inside the pods. Thus the Ellis *et al.* (1993) hypothesis of potential longevity may not be applicable to fluted pumpkin fruit where the seed is maintained at a moisture content approaching full imbibition and the free flow of oxygen in the seed is hampered. This permits either germination or rapid deterioration of seeds within the fruit. Outside the fruit, seeds easily desiccate under room conditions and rapidly loose viability (Akoroda, 1986). Therefore, seeds harvested late in the season would have undergone a series of degradation processes inside the pod, such that putting them away for further storage would lead to total wastage of the seed. Since a seed begins storage from the moment it matures on the plant and remains in storage until it is sown (Harrington, 1973), prompt harvest of fluted pumpkin pods at physiological maturity will allow the farmer to store pods for some time in a cool place without much degradation before seeds are utilized.

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