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D. Nangju

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Effect of harvest frequency on yield, quality and viability of indeterminate cowpea seed

BY D. NANGJU

International Institute of Tropical Agriculture, PMB. 5320, Ibadan, Nigeria

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SUMMARY

Field experiments were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, for four seasons to evaluate the effect of harvest interval on yield, quality and viability of indeterminate cowpea (*Vigna unguiculata* (L.) Walp.) seeds. Decreasing harvest frequency from every week to every 4 weeks reduced seed yield, quality and viability. Rate of yield losses was highest at close spacing and intermediate at wide spacing during the first rainy season, and lowest at wide spacing with supplementary irrigation during second rainy season. Time of harvest study conducted with six cultivars indicated that these yield losses were attributable to reduced seed weight and increased pod losses after mature pods were exposed to weathering for more than 1 week. The reduction in seed quality and viability was associated with a high degree of fungal and bacterial infection in the seed. Varietal differences in resistance to weathering were noted among the cultivars tested. TVu 2616 P-O1D, that has thick, leathery pods and smooth, tan seed coat was the most resistant to weathering.

INTRODUCTION

Harvesting cereals at optimum maturity is necessary for obtaining high grain yield and quality (Nangju & De Datta, 1970; Morse *et al.* 1968), but in most grain legumes including cowpeas, the problem is not when to harvest but how often to harvest ripe pods to obtain high yield of high quality. Cowpea cultivars can be divided into two major groups: (*a*) determinate cultivars that flower and produce pods within a short time, and (*b*) indeterminate cultivars that flower and produce pods over a long period. Most cowpea cultivars belong to the latter category. Out of 6837 accessions described in the IITA Cowpea Germplasm Catalog (IITA, 1974*b*), 98·2% are indeterminate.

During a favourable, long growing season, indeterminate, day-length-insensitive cultivars generally outyield determinate cultivars (IITA, 1974*a*, 1975). But to obtain high yields, indeterminate cultivars should be harvested several times in contrast to one or two harvests for determinate cultivars. This paper reports the effect of harvest frequency on seed yield, quality and viability of indeterminate cowpeas.

MATERIALS AND METHODS

The experimental site and crop management

Field experiments were conducted at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Ibadan is located at latitude 7° 34′ N and altitude 220 m with an average maximum temperature of 31 °C and minimum temperature of 21 °C. Average relative humidity ranges from 78% in the dry season to 89% in the wet season. Total rainfall during the year is about 120 cm. The rainfall pattern is generally bimodal. The first (early) rainy season is from April to August while the second (late) rainy season is short, starting late August and ending in late October. In all the experiments, fertilizers were applied at planting at the rate of 30 kg N and 30 kg P/ha in the form of urea and superphosphate, respectively. Plots were hand-weeded at 10 and 25 days after planting (DAP). Insect pests were controlled with weekly applications of dimethoate and Gardona mixture or monocrotophos alone.

Experiment 1

To study the effect of interaction between spacing and harvest frequency, indeterminate cultivars of

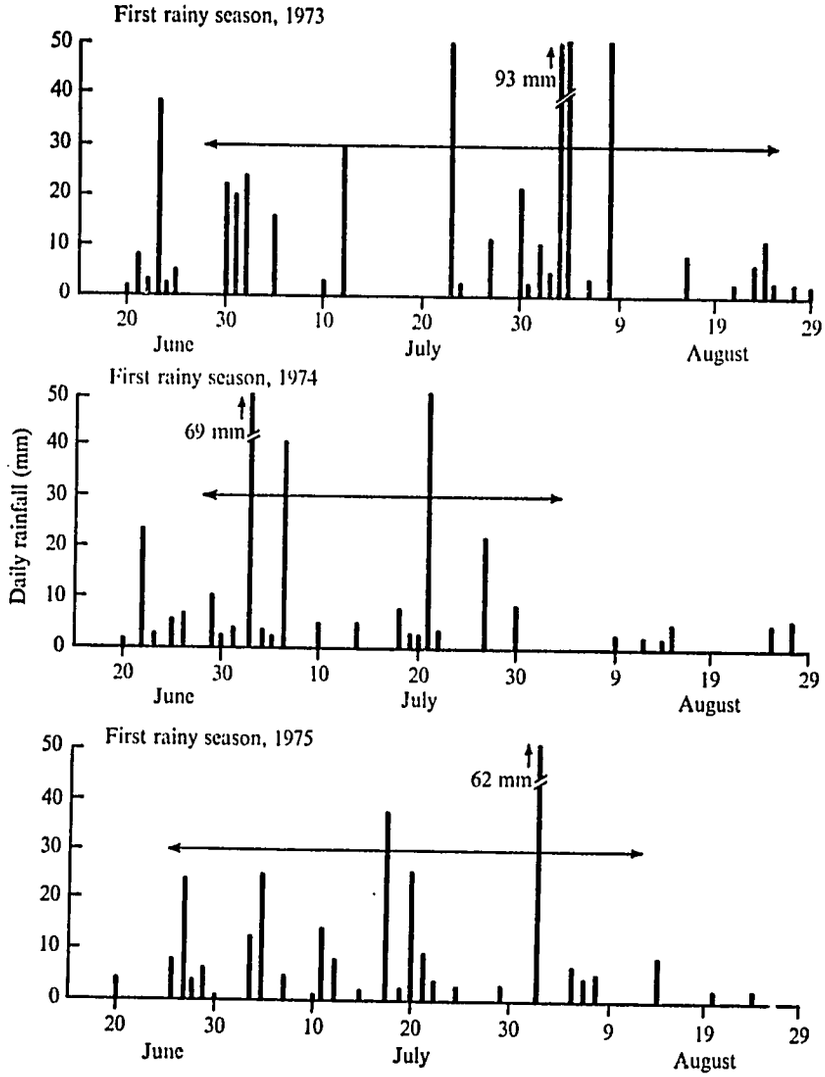

Fig. 1. Rainfall pattern during the harvesting period in 1973, 1974 and 1975. Arrows indicate harvesting period.

Pale Green and Iran Grey were planted at two spacings, 15 by 60 cm and 15 by 120 cm, on 28 April 1973. Pale Green is insensitive while Iran Grey is moderately sensitive to daylength. Both cultivars have tan, smooth seed coats but the pods and seeds of Iran Grey are larger than those of Pale Green. The plants were harvested at 1-, 2-, 3- and 4-week intervals starting when 50% of the plants had produced their first ripe pods. A total of 9, 5, 4 and 3 harvests were made from each interval respectively. The experiment was laid out as a split plot design with cultivars in main plots, spacing in subplots and harvest interval in sub-subplots. There were four replicates arranged in blocks. The sub-subplot size was 3·6 by 4·0 m and area sampled was 2·4 by 3·0 m. The first harvest was on 29 June and the last harvest was on 24 August. The rainfall pattern during the harvesting period is depicted in Fig. 1.

Experiment 2

The objective of this experiment was to study the effect of harvest frequency on seed yield, quality and viability of cowpea grown with supplementary irrigation in the second season. The experiment was planted on 7 September 1973. Five indeter-

minate cultivars of Pale Green, Iran Grey, New Era, Hanbru and TVx 33-5C were planted at a spacing of 15 × 125 m and were again harvested at four intervals as in Expt 1. Harvesting began on 7 November when 50 % of the plants had produced their first ripe pods and continued up to 19 December. This allowed 7, 4, 3 and 2 harvests to be made from the 1-, 2-, 3- and 4-week intervals respectively. Cultivars were in the main plots and harvest frequency in the subplots of a split-plot design with four replications arranged in blocks. The main-plot size was six rows 5 m long and the subplot size was one row 5 m long. The two border rows of each plot were discarded. The sample area was 6 m². There was no rain after 29 October and the experiment was sprinkler irrigated with about 20 mm of water every week.

Experiment 3

The indeterminate cultivars of Pale Green and Iran Grey were chosen to study the factors responsible for seed yield losses at different harvest periods. Because it was difficult to determine what happened to mature pods when they were not harvested on time since the pods were hidden beneath the dense canopy at close spacing, both cultivars were planted at wide spacing (100 × 125 cm). Ten plants from each treatment were harvested at intervals of 1, 3 and 6 weeks after 50 % of the plants had ripe pods. Harvest duration was only 6 weeks because of a heavy attack by anthracnose. A split-plot design with cultivars in main plots and harvest interval in subplots was used. There were five replications arranged in blocks. The numbers of shattered and rotted pods were recorded every week from individual plants. Pods were considered shattered when they had dehisced, and rotten when the colour was dark and the seeds were mouldy.

Experiment 4

Further study was made in the first season of 1975 to determine whether there are varietal differences in the susceptibility of cowpeas to weathering, and to assess the time that cowpea pods start to deteriorate in the field. For this study, six elite cultivars were selected from among the promising lines of cowpeas (IITA, 1975). These cultivars were VITA-1 (TVu 201-1D), VITA-3 (TVu 1190), TVu 1977-OD, TVu 2616P-O1D, TVu 4557 and TVu 3629 (Ife Brown). The pod walls of the first four cultivars are thick, while those of the last two cultivars are thin. The seed coats of TVu 4557 and TVu 3629 are rough, while the rest of the cultivars have smooth seed coat. The seed coat colours were as follows: VITA-1, brown; VITA-3, red; TVu 1977-OD, creamy white; TVu 2616P-O1D, tan; TVu 4557, white; and TVu 3629, brown. The pods of these cultivars were tagged at optimum maturity, i.e. when the pods had just matured. Many pods from each cultivar were tagged so that triplicate samples of 50 pods each could be harvested each week for a period of 5 weeks. The six cultivars were harvested at the same time starting from 24 June to 12 August. The rainfall pattern during this period is shown in Fig. 1.

Both pods and seeds were analysed soon after they were harvested. Pod damage by fungi was scored from 1 (most resistant) to 5 (most susceptible). The main fungi associated with cowpea pods were identified by the grain legume pathologist, R. J. Williams, as *Cercospora* sp., *Corynespora* sp., *Fusarium* sp., and *Choanephora infundibulifera* (Currey) Sacc., the first two fungi being more prevalent in the first season causing black discoloration on the pods. Holes observed in each pod as a result of the entry of *Maruca testulalis* and *Laspeyresia ptychora* larvae were counted in each sample. The threshed seeds were counted and weighed, and then classified into four groups: (*a*) smooth, clean seed, (*b*) discoloured seed, (*c*) shrivelled seed, and (*d*) seed with holes or damaged by pod borers. Each type of seed was counted and expressed as a percentage of the total seed in 50 pods. Between 25 and 50 seeds of each group were tested for germination at 30 °C. The number of seeds germinated, and infected by fungi and bacteria was recorded at the end of 6 days. The germination test was carried out in sterile petri dishes.

Harvesting process

Except for Expt 4, only mature pods were picked by hand at each harvest. Pods were considered mature when they turned brown. Pods were oven dried at 40–50 °C for 3–4 days. After drying, pods were weighed and the threshed seeds were again weighed to obtain threshing percentage, i.e. the ratio between seed and pod weight. A random sample of 50–100 g seeds was taken from seed yield samples to evaluate the percentage of bad seeds (the proportion of seeds which are different from the normal appearance, shape and size). Emergence tests from the samples were also made in the glasshouse by planting 100 seeds at 2·5 cm depth. The temperature in the glasshouse ranged from 25 °C in the morning to about 39 °C in the afternoon. The soil was kept moist throughout the test and counts were made after 10 days.

RESULTS AND DISCUSSION

Seed yield

In Expt 1, the harvest duration lasted nearly 2 months for both Pale Green and Iran Grey. In contrast, the period from planting to the

appearance of the first flowers ranged from 35 days for Pale Green to 41 days for Iran Grey. Irrespective of harvesting interval, accumulative seed yield increased with time until the plants died (Fig. 2). Yield increase per unit time was highest during the early part of pod ripening and lowest as plants were senescing. In both cultivars 50% of the total possible yield was achieved within the first 20 days of harvest. Harvest interval had a highly significant effect on yield, the effect being more pronounced when the cowpeas were planted at 15 × 60 cm than at 15 × 120 cm, and more consistent with Pale

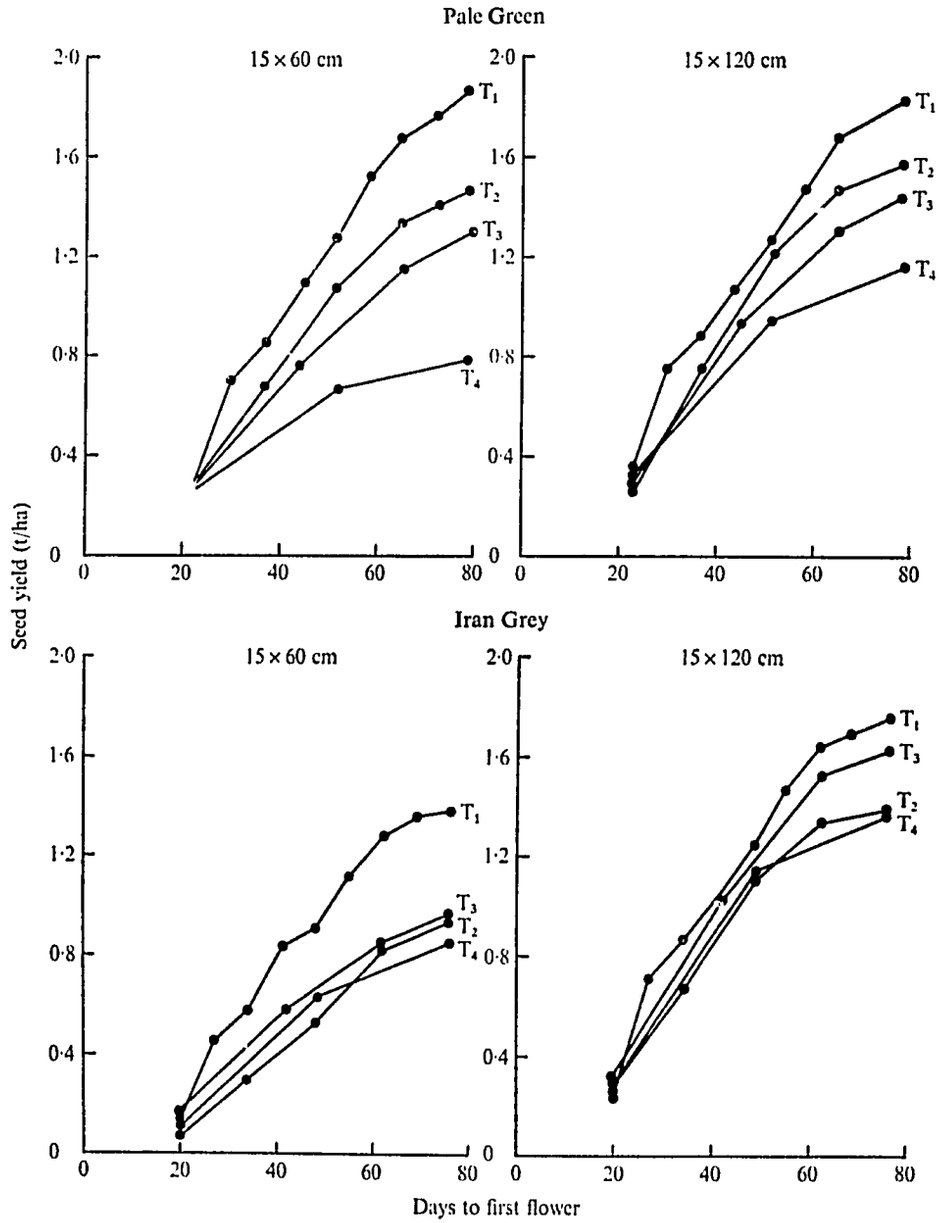

Fig. 2. Seed yield of Pale Green and Iran Grey at four harvest intervals and two spacings during the first rainy season, 1973 T_1, 1 week; T_2, 2 weeks, T_3, 3 weeks, T_4, 4 weeks. L.S.D. ($P = 0{\cdot}05$) for comparing the final accumulated yield is 0·22 t/ha.

Green than with Iran Grey. The interaction between harvest interval and spacing was significant but the interaction between harvest interval and cultivar was not. In general, increasing harvest interval from 1 to 4 weeks progressively reduced total seed yields of Pale Green and Iran Grey. With weekly harvest, increasing row spacing from 60 to 120 cm did not significantly affect total seed yield of Pale Green but increased total seed yield of the moderately daylength-sensitive and leafy cultivar Iran Grey. Harvesting at 4-week intervals, wider row-spacing increased total seed yield of both cultivars indicating that yield losses resulting from delayed harvest were greater at close spacing than at wide spacing perhaps as a consequence of rapid deterioration of pods under dense canopy conditions.

Table 1. *Effect of harvest interval on seed yield of five indeterminate cultivars, second season* 1973

Harvest interval (weeks)	Cultivars: Pale Green	Iran Grey	New Era	Hanbru	TVx 33-5C	Mean
	Seed yield (t/ha)					
1	1·49	1·30	1·17	1·17	1·14	1·25
2	1·43	1·28	1·27	1·18	1·21	1·27
3	1·22	1·14	0·99	0·88	1·07	1·06
4	1·22	1·08	0·85	0·91	0·99	1·01

For comparison of harvest interval means: S.E. = 0·06.
For comparison of harvest interval within the same cultivar: S.E. = 0·11.
For comparison of cultivars at the same or different harvest intervals: S.E. = 0·14.

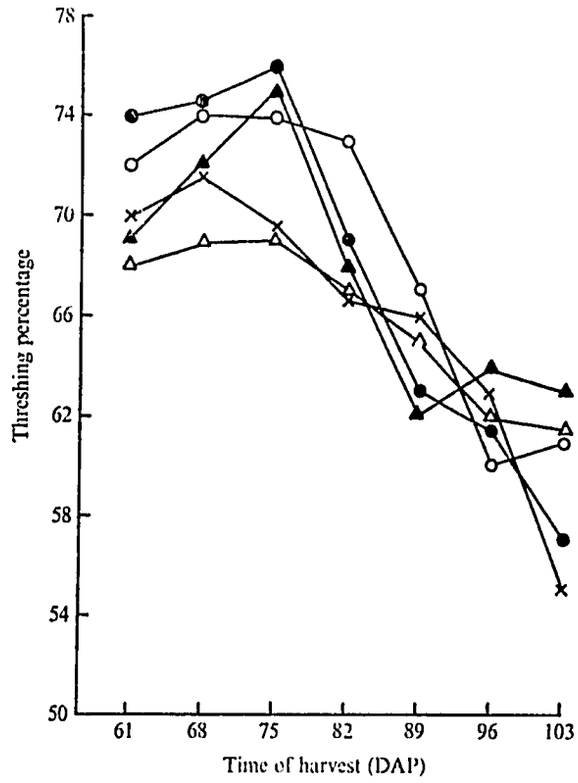

Fig. 3. Effect of time of harvest on threshing percentage of five indeterminate cultivars in the second rainy season, 1973. ○, Pale Green; △, Iran Grey; ●, New Era; ▲, Hanbru; ×, TVx 33-5C.

Table 2. *Effect of harvest interval on percentage of bad seed in Pale Green and Iran Grey cowpea*

Harvest interval (weeks)	First season, 1973		Second season, 1973		First season, 1974	
	Pale Green	Iran Grey	Pale Green	Iran Grey	Pale Green	Iran Grey
	Bad seed (%)					
1	30·0	40·3	19·2	18·4	14·9	19·6
2	30·5	44·1	28·8	22·8	—	—
3	42·2	46·4	22·5	27·3	29·0	31·7
4	42·7	47·4	23·0	26·5	—	—
6	- -	—	—	—	39·1	37·5
S.E.	2·3		2·5		2·7	

Table 3. *Percentage of emergence of smooth, clean and bad seeds harvested at different harvest intervals*

Harvest interval	First season, 1973		Second season, 1973		First season, 1974	
	Pale Green	Iran Grey	Pale Green	Iran Grey	Pale Green	Iran Grey
	Emergence of smooth, clean seeds (%)					
1	85·6	89·8	89·5	80·3	87·9	86·2
2	83·3	72·9	83·6	81·3	—	—
3	80·0	68·8	78·3	81·7	65·2	69·6
4	80·3	65·9	74·7	76·2	—	—
6	—	—	—	—	60·2	61·0
S.E.	3·0		4·2		3·3	
	Emergence of bad seeds (%)					
1	30·0	34·4	45·4	40·0	30·0	33·6
2	17·5	21·7	24·9	37·0	—	—
3	15·8	16·3	26·4	35·0	13·9	17·5
4	20·6	11·3	26·0	25·3	—	—
6	—	—	—	—	7·6	14·0
S.E.	4·7		4·7		2·9	

Relative humidity around the pods was probably higher at close spacings than at wide spacings.

In Expt 2, yield patterns at different harvest frequencies were similar for the five indeterminate cultivars (Table 1). Increasing harvest interval from 1 to 4 weeks generally reduced yield; however, the total yields obtained at weekly intervals were not significantly different from those obtained at 2-week intervals.

The rate of yield loss for every week delay in harvest was calculated from the two experiments and the results show that yield losses were highest (249·4 kg/ha/week) when cowpeas were planted during the first season at close spacing, intermediate (144·2 kg/ha/week) when planted during the first season at wide spacing, and lowest (69·4 kg/ha/week) when planted at wide spacing in the second season with supplementary irrigation. These results indicate that the extent of yield reduction depended on rainfall intensity and distribution, and on the density of leaf canopy. Apparently, high rainfall and high relative humidity were conducive to rapid deterioration of ripe pods in the field. Yield reduction resulting from delayed harvest would have been negligible in the second season if supplementary irrigation was not used because relative humidities would be lower and the plants would be induced to ripen by lack of soil moisture. Total seed yield was lower in the second season than in the first season probably because of the shorter growing season. Some indeterminate cultivars could yield up to 2·5 t/ha in the first

season but only about half of this in the second season in Ibadan, Nigeria (IITA, 1974*a*, 1975).

Seed quality

In both Expts 1 and 2, threshing percentage declined with time irrespective of harvest interval. Figure 3 shows the magnitude of reduction of threshing percentage in the five indeterminate cultivars grown in the second season and harvested weekly. The decline in threshing percentage started at about 75 DAP. According to Booker (1963), insect damage can cause a large reduction in threshing percentage because pods are often partly filled and abnormally short, and seeds are smaller. However, this cannot be the whole explanation in the present experiments since the crop was repeatedly sprayed with insecticides. The decline of threshing percentage is attributed to frequent handling of plants during harvest, leaf senescence, increased incidence of *Cercospora* leaf spots and anthracnose in the susceptible cultivars, and in the case of delayed harvest, pod rotting and shattering.

The effect of harvest interval on percentage of bad seed was significant in all the experiments. The percentage of bad seeds increased with an increase in harvest interval, although the trend was not obvious between 3- and 4-week intervals (Table 2). In the first season, the percentage of bad seed was high (30–40 %) even when the pods were harvested weekly. It was even higher than the highest percentage of bad seeds (23–27 %) obtained in the second season when the pods were harvested every 4 weeks under

Table 4. *Effect of harvest interval on seed yield, pod quality and threshing percentage: first season*, 1974

Harvest interval (weeks)	Seed yield (g/plant)	No. of pods/plant	No. of shattered pods/plant	No. of rotted pods/plant	Threshing percentage
			Pale Green		
1	344·6	102·7	1·2	7·8	74·0
3	155·3	88·7	3·2	14·5	69·7
6	81·6	75·3	3·5	27·9	63·2
			Iran Grey		
1	305·4	82·0	1·1	4·9	70·9
3	184·6	75·8	2·4	11·3	65·3
6	75·9	69·1	5·2	23·9	65·3
S.E.	3·2	5·6	0·8	4·5	1·3

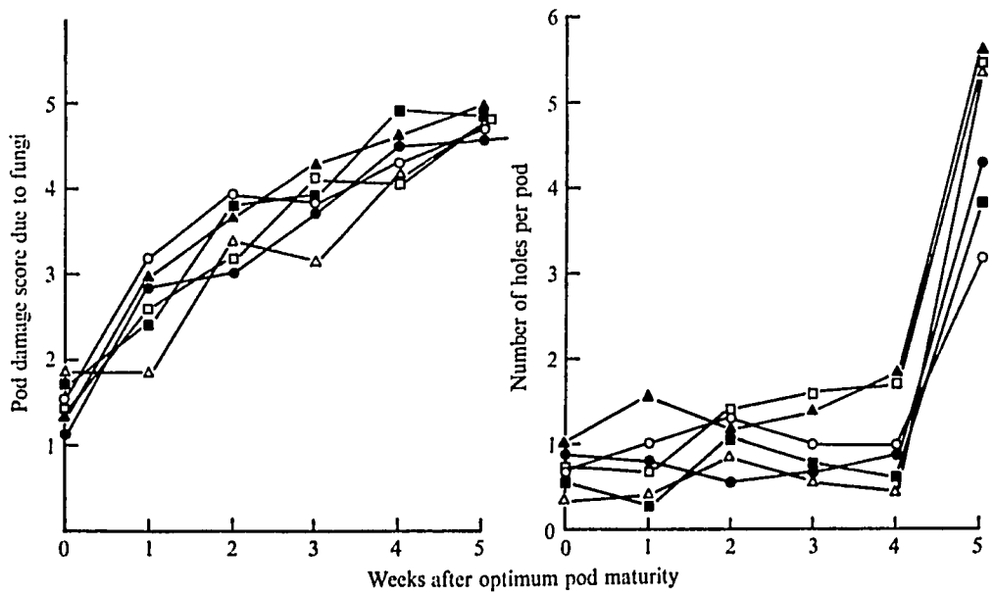

Fig. 4. Effect of time of harvest on pod damage by fungi and pod borers in six cowpea cultivars in the first rainy season, 1975. ●, VITA-1; ▲, VITA-3; ■, TVu 1977-OD; ○, TVu 2616P-O1D; △, TVu 4557; □, TVu 3629.

irrigation. This suggests that seed quality can be a serious problem if cowpea matures during the rainy season.

The percentage of emergence of both smooth, clean seed and bad seed was analysed separately and the results are presented in Table 3. In all three experiments there was a trend in the reduction of percentage of emergence in both types of seeds with an increase in harvest interval suggesting that prolonged exposure of seeds to rainfall fluctuation, microbiological attack and insect pests not only reduces its quality but also its viability. The apparently healthy-looking seeds of Pale Green and Iran Grey harvested at 3- to 4-week intervals showed 5–25% lower emergence than seeds harvested at 1- to 2-week intervals. This trend was also observed with bad seeds. The percentage of emergence of bad seeds was significantly lower than that of smooth, clean seeds. This emphasizes the importance of cleaning and treating seeds before planting. Bad seeds normally produced stunted seedlings which had split or absent primary leaves, and damaged cotyledons.

Factors affecting yield losses

Experiment 3 conducted in the first season 1974 was primarily designed to observe ripe pods when they were left in the field at different periods. Results indicated that yield losses at longer harvest intervals (3–6 weeks) resulted from fewer pods per plant and more rotted pods per plant (Table 4). Pod shattering did not play a major role in yield losses as shown by the low number of pods shattered per plant even after the pods had ripened for more than 6 weeks. Threshing percentage was inversely correlated with the number of rotted and shattered pods per plant. Pod rotting and shattering generally decreased the ratio of seed weight to pod weight. The total number of pods per plant decreased with an increase in harvest interval. Pods rotted when left in the field for more than 2 weeks. These rotten pods eventually fell down and were not harvested, thereby reducing seed yield.

Varietal differences in weathering susceptibility

Results obtained from Expt 4 confirmed the observations made in the earlier experiments (Figs. 4–7). Fungal attack on cowpea pods generally increased as pods were exposed to weathering from 1 to 5 weeks (Fig. 4). After 4 weeks the pods became black and soft instead of the normal brown and hard appearance at the time of optimum ripening. Pod damage by pod borers was significant only at 5 weeks after optimum pod maturity possibly due to the build-up of these insect pests during late maturity (Fig. 4). Increasing exposure of pods to weathering decreased seed weight and increased pod losses particularly after 2–3 weeks (Fig. 5). These two factors were responsible for the seed yield losses obtained at different harvesting

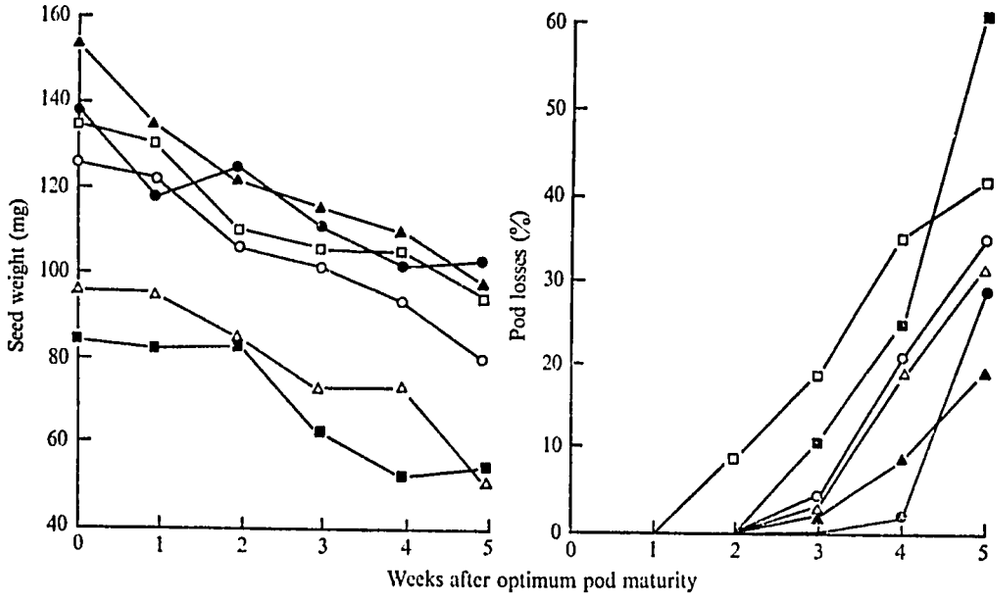

Fig. 5. Effect of time of harvest on seed weight and pod losses (%) in six cowpea cultivars in the first rainy season, 1975. ●, VITA-1; ▲, VITA-3; ■, TVu 1977-OD; ○, TVu 2616P-01D; △, TVu 4557; □, TVu 3629.

intervals (Expts 1–3). However, among the six cultivars, VITA-1, VITA-3 and TVu 2616P-O1D showed the least seed weight and pod losses.

The effect of time of harvest on seed quality is shown in Figs. 6 and 7. Increasing the exposure of the pods to weathering reduced the percentage of smooth, clean seed primarily as a result in the increase of the percentage of discoloured seed (Fig. 6). Percentage of wrinkled or shrivelled seed was not associated with weathering of the pods, while seed damage by insect pests was significant only in 5-week-old pods. Percentage of seed infected by fungi and bacteria generally increased with age of the pods in both smooth, clean seed and discoloured seed, the latter type of seed being more severely attacked by fungi and bacteria as would be expected (Fig. 7). No attempt was made to identify the different species of fungi and bacteria found in the seeds. Esuruoso (1975) has identified 22 fungal species associated with cowpea seeds

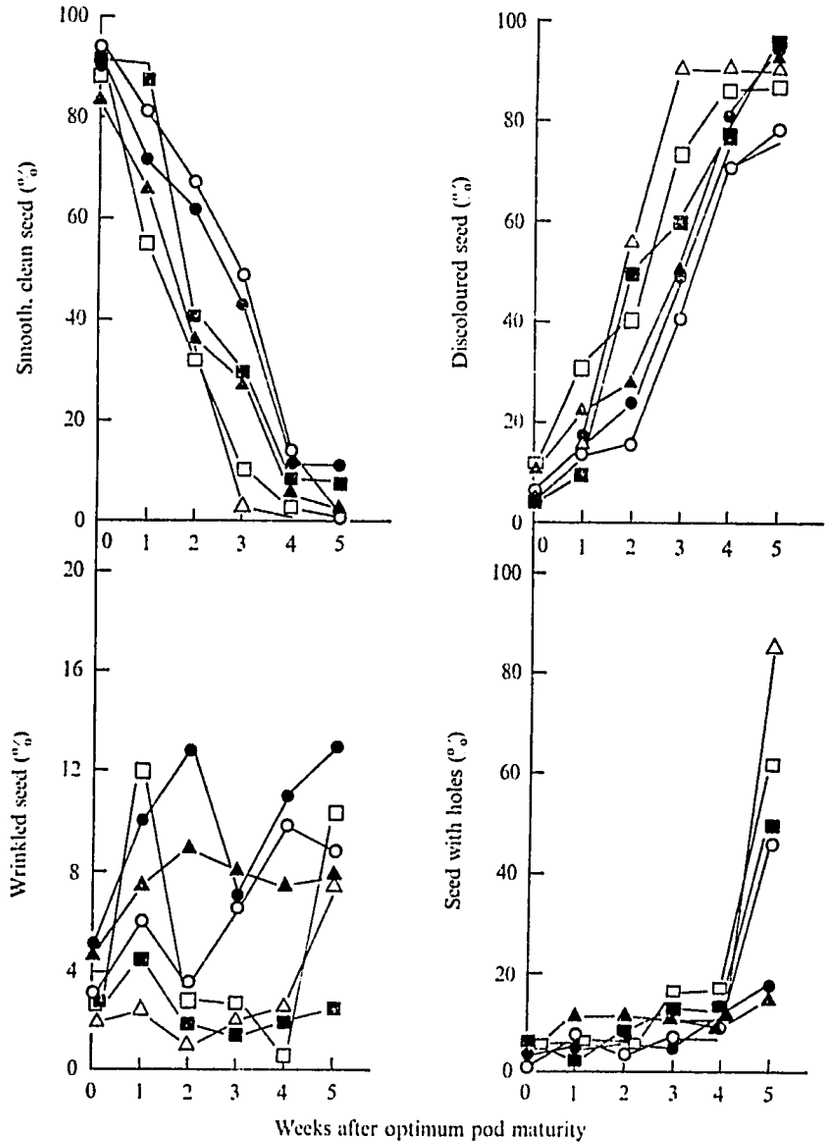

Fig. 6. Effect of time of harvest on seed quality of six cowpea cultivars in the first rainy season, 1975. ●, VITA-1; ▲, VITA-3; ■, TVu 1977-OD; ○, TVu 2616P-O1D; △, TVu 4557; □, TVu 3629.

obtained from the research farms, local farmers and markets in Western Nigeria. Two of the species, *Aspergillus flavus* Link ex. Fr and *Phoma* spp., were the most common.

Percentage of germination and emergence of seed declined with age of the pods possibly due to the increase in the fungal and bacterial infection in the seed (Fig. 8). Seed viability was extremely low when mature pods were left in the field for more than 3 weeks. However, varietal differences did exist. Figures 6–8 consistently show that TVu 2616P-O1D was more resistant to weathering than the rest of the cultivars. The seed of this cultivar has a tan, smooth seed coat. This type of seed was also found by R. A. Luse to be resistant to weathering in an earlier experiment conducted at IITA (IITA,

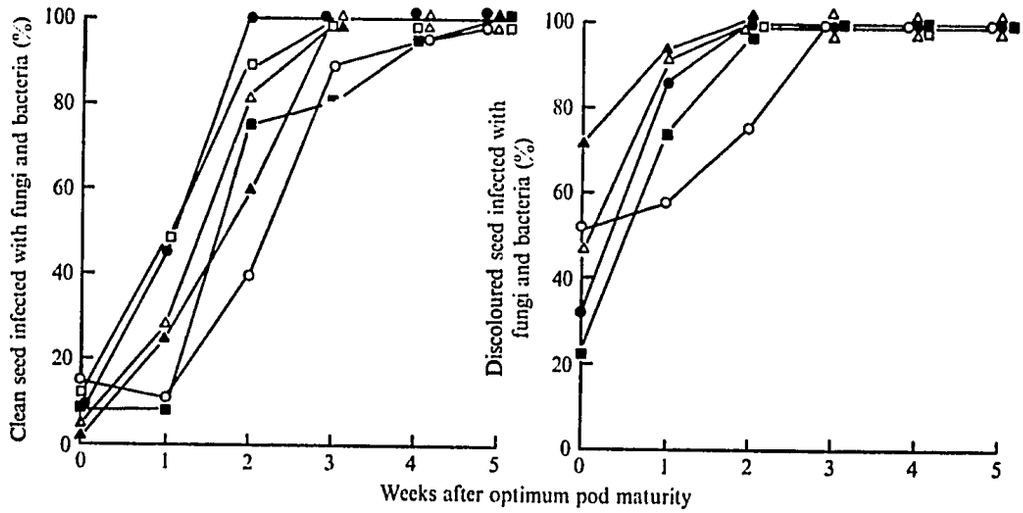

Fig. 7. Effect of time of harvest on fungal and bacterial infection in both smooth, clean seed and discoloured seed in six cowpea cultivars in the first rainy season, 1975. ●, VITA-1; ▲, VITA-3; ■, TVu 1977-OD; ○, TVu 2616P-O1D; △, TVu 4557; □, TVu 3629.

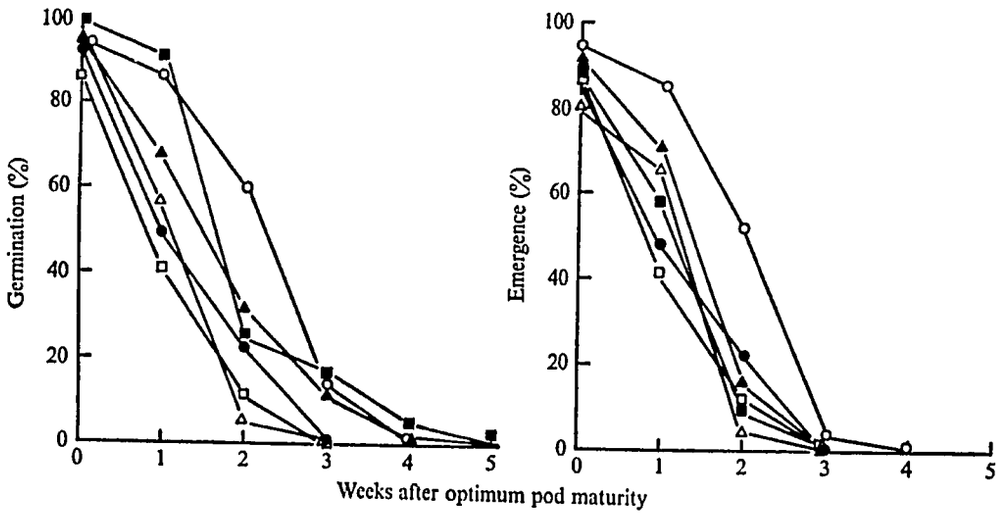

Fig. 8. Effect of time of harvest on percentage germination and emergence of six cowpea cultivars in the first rainy season, 1975. ●, VITA-1; ▲, VITA-3; ■, TVu 1977-OD; ○, TVu 2616P-O1D; △, TVu 4557; □, TVu 3629.

1975). These results suggest that there may be a range of resistance to weathering among pod and seed types within the broad range of genetic diversity in cowpea.

Prospect for growing cowpea in the lowland, humid tropics

Cowpea is more adapted to the semi-arid regions than humid regions (Sellschop, 1962). In Nigeria, this grain legume is more widely grown in the north where rainfall is lower than in southern Nigeria. Introducing cowpea to the lowland, humid tropics not only presents harvesting and drying problems but also increases the incidence of diseases as rainfall and relative humidity are high. Disease problems can be solved by incorporating multiple disease resistance into the high-yielding cultivars. Many multiple disease resistant cultivars have been identified at IITA (IITA, 1974, 1975). The harvesting and seed quality problem may be more difficult to solve unless farmers are willing to accept low yield of high-quality seed by planting cowpea in the second season when rainfall is low and unpredictable.

The other possibilities of overcoming the harvesting problems in cowpea are (*a*) to develop high-yielding, determinate cultivars that can ripen uniformly, particularly for commercial production where labour can be a limiting factor (Ebong, 1971), (*b*) to develop dual-purpose cultivars which can be grown as a vegetable in the long rainy season, and as a pulse during the short rainy season (pods harvested green are less sensitive to weathering although frequent and timely harvests would still be necessary), (*c*) to breed for pods and seeds of pulse types which are resistant to weathering.

Of the three approaches, the first two are probably more realistic. The third approach will involve a laborious examination of pods and seeds. Even if we do find resistant material, it may only delay the weathering process. All ripe pods eventually deteriorate completely when left in the field for more than 3 weeks. Furthermore, there might be incompatibility between weathering resistance and cooking quality and consumer's preference.

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