GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES, VOL.7, NO. 1, SEPTEMBER 2001: 613-619

EFFECTS OF HEAT-TREATED COWPEA ON *CALLOSOBRUCHUS MACULATUS* INFESTATION.

D. T. GUNGULA, M. Y. JADA and K. M. KAYANDACHA

(Received 25 July 2000; Revision accepted 13 June 2001)

ABSTRACT

Callosobruchus maculatus F. (bruchid) is one of the major insect pests of cowpea and constitutes a major problem of cowpea storage. The only successful methods of controlling the insects are chemical methods. In this experiment, a non-chemical means of controlling the insects on stored cowpea that is meant for both consumption and planting was sought. Cowpea seeds were treated to higher temperatures ranging from 80°C to 130°C for durations ranging from 5 minutes to 6 hours. Bruchid infestation was significantly reduced in the heat treated cowpea ($P<0.01$) compared to the control. There were significant interaction effects between temperature and heating time for number of perforations on cowpea seeds, number of adults emerged and germination percentage at 80 and 90°C ($P<0.01$). While at temperatures from 100°C, there were significant interaction effects for number of eggs laid, number of perforations and germination percentage ($P<0.01$). Higher temperatures and longer heating time gave better bruchid control, however, less than 50% germination percentage was obtained. Thus suggesting that higher temperature treatments at shorter periods are better for bruchid control than longer heating which may require more energy. At 120°C and 5 minutes' heating, 98% germination percentage was obtained while seed weight loss was 0.47. This temperature can therefore be used for storing cowpea seeds for planting. However, cowpea meant for consumption can be heated at 120°C for 10 minutes or more.

Key words: Bruchid, control, heat-treatment, cowpea, germination

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is an important food legume and a versatile crop cultivated between 35°N and 30°S of the equator, covering Asia and Oceania, the middle East, Southern Europe, Africa, Southern USA, and Central and South America (Fery 1990, Hadjichristodoulou 1991 and Perrino *et al.* 1993). Singh *et al.* (1997) estimated that 12.5 million hectares are used for cowpea cultivation annually with annual production of over 3 million tonnes. Cowpea is distributed throughout the tropics but Central and West Africa account for over 64% of the area. Nigeria is the leading producer of cowpea with the bulk of cowpea production coming from the drier regions of Northern Nigeria (Singh *et al.* 1997).

Cowpea is of major importance as a cheap source of protein to millions of relatively poor people in less developed countries of the tropics (Quin 1997). Cowpea serves as a source of food, animal feed and revenue generation to the rural families. The crop has additional benefits to farmlands in terms of in situ decay of root and leaf residues, use as manure, ground cover and improvement in soil fertility.

Quin (1997) reported that all the aerial parts of cowpea are used for food and they provide protein, vitamins and minerals. The author further stated that cowpea on the average contains 23-25% protein and 50-67% starch. Thus it is a cheap source of protein for people in the major producing areas (Alghali 1991). This makes it a good supplement of the locally available diets based on cereals and root crops, which are usually very low in protein and high in carbohydrates.

Although, most cowpea varieties grown in West Africa have grain yield potentials of 1.5-3.0 t/ha with insecticidal sprays, the actual farm yields obtained are usually low (0.47 t/ha) due to severe attack from an extensive pest complex (Rachie 1985 and Quin 1997). In addition to yield losses in the field, cowpea also suffers considerable damage in storage due to bruchids. The most important bruchid on cowpea is *C. maculatus* F. which is known to cause loss in stored cowpea grains by more than 80% (Anon. 1982). The initial infestation occurs in the field and from there, it is carried over to the store (Caswell 1973), where the population rapidly builds up. Howe and Currie (1964) recognised that *C. maculatus* F. develops at temperatures between 17°C and 37°C. Furthermore,

D. T. GUNGULA, Dept of Crop Production and Horticulture, Federal University of Technology, Yola, Nigeria
M.Y. YADA, Department of Crop Production and Horticulture, Federal University of Technology, Yola, Nigeria
K. M. KAYANDACHA, Department of Crop Production and Horticulture, Federal University of Technology, Yola, Nigeria

below this temperature range, hatching is deterred while at higher temperatures the eggs, larvae and pupae are killed. The adults can survive temperatures up to 51.5°C for 15 minutes (Koba and Osuji 1986). Some local farmers in Nigeria roast their cowpea in hot ash at uncontrolled temperatures before storage to control the insect pest but such seeds loose their viability. It is therefore thought that higher temperatures can be used to control the insect pest.

The objective of this work was therefore to investigate the storability and germination capacity of cowpea seeds heated at varying temperatures and durations.

MATERIALS AND METHODS

Insect culture

Male and female *C. maculatus F.* were reared on 1 kg of clean dry weevil susceptible cowpea in the laboratory. Freshly emerged adults were used for the experiments.

Experiment 1: Comparison of heat-treated cowpea with the control

Clean cowpea seeds of a local variety (Kananado) were sorted out and 16.1 g were weighed into glass petridishes and oven heated at 80 and 90°C for 6 hours. The experimental design was a completely randomised design with four replicates. The treatments consisted of heat-treated cowpea at 80°C, 90°C and the control where the seeds were not subjected to heat treatment. Each petridish constituted a treatment.

Experiment 2: Heat treatment of cowpea seeds at 80 and 90°C for varying time periods.

Split-plot in randomised complete block design with four replications was used. The main plots were the temperatures while the sub-plots were the duration of heating. This was to look at the interaction of heating and the duration on the storability and germination capacity of cowpea seeds. About 16.1 g of clean cowpea seeds were weighed into each petridish and oven heated at 80°C and 90°C for 1, 2, 4 and 6 hours.

Experiment 3: Roasting cowpea at 100, 110, 120 and 130°C for varying time periods.

Split-plot in randomised complete block design was used for the experiment where the main plots were the temperatures while the sub-plots consisted of the duration. Each treatment was replicated four times. This was to investigate the effects of heating cowpea seeds at higher temperatures but for shorter periods on the storability and viability of the seeds. About 16.1 g of cowpea seeds were heated at 100, 110, 120 and 130°C for 5, 10 and 15 minutes for each of these temperatures.

Inoculation of insects

After roasting, the seeds were brought out and placed on the laboratory table for at least four hours to cool. Thereafter, three pairs of young male and female *C. maculatus* F. that were reared were introduced into each petridish and covered. These were monitored each day and data were collected.

Germination test

Twenty five cowpea seeds heated at various temperatures as described in experiments 2 and 3 were put in petridishes lined with moistened filter paper and replicated four times. This was to determine the temperature at which maximum insect control and seed germination can be obtained. The filter paper was constantly kept moist by adding small quantity of water (2-3 ml) daily. The petridishes were covered and left 5 to 6 days to observed seed germination. The number of seeds that germinated were expressed as percentage.

Data collection

The number of eggs that were laid by the *C. maculatus* were counted during the first week of inoculation on a daily basis. The number of perforations on seeds, adults emerged, and final seed weight were taken at the time of termination of the experiments.

Statistical analysis

The data collected were subjected to analysis of variance using Generalised Linear Model (GLM) procedure of the Statistical Analysis System Institute Inc. (SAS 1996) and least square means that were significantly different were compared using Least Significant Different (LSD) computed for the particular level of probability.

RESULTS

The comparisons of the effects of increasing temperature from 80 to 90°C against the control shows highly significant differences ($P<0.01$) between the two temperatures and the control for all the parameters measured (Table 1). There were however, no significant differences observed between the two temperatures for all the parameters measured except for percentage grain weight loss where there was a highly significant difference between 80 and 90°C (Table 2). In the control, 82% grain weight loss due to bruchid infestation was recorded as against 0.2% recorded at 90°C.

Means squares for some parameters determining the influence of temperature on bruchid infestation of cowpea grains tested at 80 and 90°C are presented in Table 3. The number of eggs of bruchids

Table 1. Analysis of variance showing means squares for some parameters determining the influence of temperature on bruchid infestation of cowpea grains tested at 0, 80 and 90°C.

Source	df	Egg No.	PF No.	Adults No.	Grain weight loss
Temp	2	187002.77**	140211.58**	139691.31**	8264.45**
Error	9	529.66	908.44	899.13	5.38

Temp = Temperature, df = degree of freedom and PF No. = number of perforations on grains and ** = significantly different at P<0.01.

Table 2. The least square means of some parameters showing the effects of temperature on the control of bruchid infestation of cowpea seeds.

Temperature	Egg No.	PF No.	Adults No.	Seed weight loss (%)
Control	530.5	336.0	335.5	82.11
80°C	164.2	21.5	21.9	7.01
90°C	148.3	2.8	2.6	0.19
Mean	281.0	120.1	120.0	29.77
S.E.	11.51	15.07	14.99	1.16
LSD (0.01)	49.42	78.86	78.69	5.073

PF No. = number of perforations on grains

Table 3. Analysis of variance showing mean squares for some parameters determining the influence of temperature on bruchid infestation of cowpea grains tested at 80 and 90°C.

Source	df	Egg No.	PF No.	Adults No.	Grain weight loss	¶GER%
Temp	1	2016.13ns	2812.50**	2964.50**	375.95**	2964.50**
Error a	3	416.88	5.25	5.08	7.80	5.08
Time	3	1500.58**	458.75**	461.42**	93.26**	461.42**
Temp x Time	3	398.21ns	369.58**	347.08**	88.61**	347.08**
Error b	9	89.07	35.56	34.67	6.28	35.94

Temp = Temperature, df = degree of freedom and PF No. = number of perforations on grains, GER% = germination percentage, ns = not significantly different at P=0.05, ** = significantly different at P<0.01 and ¶ = transformed values were used for the computation.

Table 4. Analysis of variance for some parameters determining the influence of temperature on bruchid infestation of cowpea grains tested at 100, 110, 120 and 130°C.

Source	df	Egg No.	PF No.	Adults No.	Grain weight loss (%)	¶GER%
Temp	3	20106.24**	13686.52**	6052.58**	3043.88**	286.59**
Error a	9	178.89	18.28	7.46	4.52	32.12
Time	2	3966.02**	427.58**	55.19ns	86.08**	18945.69**
Temp x Time	6	801.99**	289.58**	20.33ns	58.12**	346.59**
Error b	18	95.39	58.67	41.08	12.24	54.95

Temp = Temperature, df = degree of freedom and PF No. = number of perforations on grains, GER% = germination percentage, ns = not significantly different at P=0.05, ** = significantly different at P<0.01 and ¶ = values used for computation are transformed data.

significantly differed between the different time periods the cowpea grains were exposed to heat at P<0.01. However, there was no significant effect of temperature (80 and 90°C) on number of eggs. Similarly, there was no interaction between temperature and time of exposure to heat. The number of perforations on the cowpea grains, number of adults that emerged, grain weight loss and germination percentage were significantly affected by temperature and time of exposure to heat at P<0.01. There were significant interactions between temperature and the time of exposure to heat at P<0.01 for the number of perorations on the cowpea seeds, number of adults that emerged, grain weight loss and germination percentage.

All the parameters measured were significantly affected (P<0.01) when the cowpea grains were exposed to temperatures of 100, 110, 120 and 130°C (Table 4). Apart from number of adults emerged which was not affected by the time the grains were exposed to heat, the rest of the variables were significantly affected by the time of exposure to heat. Similarly, apart from the number of adults emerged, there were significant interactions between temperature and time of roasting for the rest of the parameters measured (P<0.01).

Table 5. The interactions of temperatures of 80 and 90°C and varying duration of heat treatment of cowpea seeds on the control of cowpea bruchid.

Parameter	Temperature	Duration of heat treatment of cowpea				Mean
		1 hour	2 hours	4 hours	6 hours	
Egg No.	80°C	188.00	159.50	161.75	147.50	164.19
	90°C	154.00	158.00	153.00	128.25	148.31
	Mean	171.00	158.75	157.38	137.88	
	LSD(0.05) for comparing temperature means = 22.97					
	LSD(0.01) for comparing duration means = 15.02					
	LSD(0.05) for comparing temperature x duration means = 24.43					
PF No.	80°C	36.75	29.25	15.50	4.50	21.50
	90°C	4.00	2.25	3.25	1.50	2.75
	Mean	20.38	15.75	9.38	3.00	
	LSD(0.01) for comparing temperature means = 2.58					
	LSD(0.01) for comparing duration means = 6.29					
	LSD(0.01) for comparing temperature x duration means = 7.85					
Adults No.	80°C	36.75	29.25	2.70	8.90	21.88
	90°C	4.00	2.25	3.25	1.00	2.63
	Mean	20.38	15.75	10.13	2.75	
	LSD(0.01) for comparing temperature means = 2.54					
	LSD(0.01) for comparing duration means = 6.24					
	LSD(0.01) for comparing temperature x duration means = 7.78					
Grain weight loss (%)	80°C	10.02	2.58	0.42	1.77	3.70
	90°C	0.28	0.16	0.12	0.06	0.16
	Mean	5.15	1.37	0.27	0.92	
	LSD(0.01) for comparing temperature means = 3.14					
	LSD(0.01) for comparing duration means = 2.63					
	LSD(0.01) for comparing temperature x duration means = 3.84					
Germination percentage	80°C	40.00	1.01	0.01	0.01	10.26
	90°C	6.00	2.01	0.01	0.01	2.01
	Mean	23.00	1.51	0.01	0.01	
	LSD(0.01) for comparing temperature means = 4.382					
	LSD(0.01) for comparing duration means = 3.063					
	LSD(0.01) for comparing temperature x duration means = 4.33					

PF No. = number of perforations on grains, and ¶ = original values before transformation.

The interactions between temperature (80 and 90°C) and the time period of exposure of the cowpea grains to heat for the number of perforations on the cowpea grains, number of adults that emerged, grain weight loss and germination percentage is presented in Table 5. There were fewer number of perforations on the seeds as the time of roasting was increased with the best results at roasting for 6 hours at 80°C. However, at 90°C, there were no significant differences between the time of roasting even though the trend showed fewer perforations with longer time of roasting. Similarly, the number of adults that emerged decreased with time of roasting at both temperatures with the lowest number of adults at 6 hours roasting period. There were no differences between the roasting periods at 90°C. The same trend was observed for grain weight loss. At 80°C, the highest germination percentage of 40% was obtained at the roasting period of 1 hour. Exposure of the seeds to heat for more than 1 hour resulted in germination percentage of not more than 2% for both temperatures.

The interaction table (Table 6) shows that there were fewer number of eggs found on the seeds as heating temperature and the duration of heating were increased. The highest number of eggs were found on grains roasted for 5 minutes at 100°C while the least number of eggs were found on grains roasted for 15 minutes at 130°C. The 15 minutes' time of roasting had the lowest number of eggs at all the temperatures. However, there were no differences between 10 and 15 minutes' time of roasting at temperatures higher than 100°C ($P<0.01$). The number of perforations were least at the roasting time of 15 minutes at 100°C ($P<0.01$).

The same trend was observed for 110°C although, there were no significant differences between the roasting periods. At 120 and 130°C, there little or no perforations observed.

Grain weight loss was lower with increased temperature and roasting period. The lowest weight loss was obtained from 15 minutes roasting time at 100°C. At higher temperatures, there were no differences between the roasting periods. The best germination percentage of 99 and 98% were obtained from the roasting period of 5 minutes at 100 and 110°C, respectively. With increased temperature, germination was lower. Similarly, germination percentage decreased with increased

Table 6. The interactions of temperatures of 100°C and above and varying duration of heat treatment on the control of cowpea bruchid.

Parameter	Temperature	Duration of heating in minutes			Mean
		5	10	15	
Egg No.	100 °C	184.00	172.75	117.25	158.00
	110 °C	112.75	98.50	85.25	98.83
	120 °C	87.75	79.75	77.50	81.67
	130 °C	73.75	63.00	54.00	63.58
	Mean	114.56	103.50	83.50	4.88
	LSD(0.01) for comparing temperature means = 12.35				
	LSD(0.01) for comparing duration means = 8.47				
	LSD(0.01) for comparing temperature x duration means = 17.64				
Number of perforations on grains	100 °C	83.25	78.50	50.50	70.75
	110 °C	9.50	11.75	5.25	8.83
	120 °C	1.00	10.00	1.00	1.00
	130 °C	1.00	1.00	1.00	1.00
	Mean	23.69	23.06	14.44	
	LSD(0.01) for comparing temperature means = 3.95				
	LSD(0.01) for comparing duration means = 5.65				
	LSD(0.01) for comparing temperature x duration means = 9.80				
Adults No.	100 °C	50.50	50.25	43.00	47.92
	110 °C	9.50	11.75	5.25	8.83
	120 °C	1.00	1.00	1.00	1.00
	130 °C	1.00	1.00	1.00	1.00
	Mean	15.50	16.00	12.56	
	LSD(0.01) for comparing temperature means = 2.52				
	LSD(0.01) for comparing duration means = 4.47				
	LSD(0.01) for comparing temperature x duration means = 7.60				
Grain weight loss (%)	100 °C	37.99	36.67	23.65	32.77
	110 °C	2.90	4.11	1.10	2.71
	120 °C	0.16	0.16	0.17	0.16
	130 °C	0.16	0.17	0.16	0.16
	Mean	10.30	10.27	6.27	
	LSD(0.01) for comparing temperature means = 1.96				
	LSD(0.01) for comparing duration means = 2.53				
	LSD(0.01) for comparing temperature x duration means = 4.45				
¶Germination percentage	100 °C	99.0	19.0	2.0	40.0
	110 °C	98.0	21.0	2.0	40.3
	120 °C	54.0	18.0	3.0	25.0
	130 °C	59.0	22.0	1.0	27.3
	Mean	77.5	20.0	2.0	
	LSD(0.01) for comparing temperature means = 4.78				
	LSD(0.01) for comparing duration means = 4.00				
	LSD(0.01) for comparing temperature x duration means = 7.99				

¶ = values presented are original values before transformation.

time of roasting. Roasting for 15 minutes at any of the temperatures gave the highest germination percentage of not more than 3%.

DISCUSSION

The significant differences observed between the control and the two temperatures for all the parameters measured is an indication that heat treatment of cowpea can be employed to control the cowpea bruchid. There was at least 69% reduction in egg number by roasting the cowpea seeds. Similarly, other parameters (number of perforations, number of adult emerged and seed weight) were greatly improved by the roasting when compared to the control thus indicating that bruchid can be controlled by the use of heat treatment of cowpea. The use of the number of eggs laid on seeds as index of bruchid control had earlier been advocated by Barde (1992) and Mensah (1991) who also used a non-chemical means (neem ash and ground pepper) to control bruchid. The reduction in the number of adults emerged is an indication that the roasting cowpea had effects on the earlier developmental stages of bruchid thus making it impossible for the insects to complete their life cycle.

One of the effects of bruchid infestation is the reduction in grain weight since the insects reduce the grains to powder. However, with the heating of the grains at 90°C (for any of the durations), the reduction in grain weight was less than 1%. This is an indication that heating actually prevents the insects from feeding on and damaging the cowpea grains.

Except for number of eggs, there were significant interaction effects ($P<0.01$) between temperature and time of heating for the 80 and 90°C in all the traits measured indicating that both temperature and time of heating significantly contributed to the control of bruchid on cowpea as measured by those parameters. This agrees with the report of Murdock *et al.* (1997) who stated that heating cowpea for several hours at 80°C did control bruchid. Increasing the heating period from 1 hour to 6 hours at 80°C, greatly reduced the number of perforations from 36.8 to 4.5 indicating that the heating period is effective in controlling the bruchid. Murdock *et al.* (1997) reported that seed coat texture (smooth and glossy) and thickness are associated with pre-establishment mortality of bruchids. They found that cowpea with smooth seed coat were not preferred by bruchid for laying eggs. The heating at 80°C for 6 hours was not different from the heating at 90°C for 1 hour for all the parameters measured except for germination percentage. This shows that at higher temperature, a shorter heating time is required to control the insect. This reinforces earlier report (Murdock *et al.* 1997) that increasing the heating temperature will reduce the duration of heating to control the insects. The reduction in germination percent by both increased temperature and time shows that heating the cowpea at 80°C for up to 1 hour reduces seed viability even though, bruchid may be controlled.

The significant interactions between heating temperature and time for most of the parameters measured at temperatures of 100°C and above, shows that both factors were important in controlling the bruchid infestation. The results further show that at higher temperature, heating is required just for a short period to give effective control of the insects. This confirms the report of Koba and Osuji (1986) that the adults can survive temperatures up to 51.5°C for 15 minutes There were no differences observed between the heating time for number of perforations and adults emerged when the temperature was increased to 120°C. This shows that at this temperature, only 5 minutes heating was required to control the insects. At such temperature, the larvae could not survive hence only few adults emerged.

Roasting the cowpea seeds at 120°C for 5 minutes gave a high germination percentage of 98% in addition to controlling bruchids. Beyond this temperature and heating interval, there was a decline in seed germination. Since at this temperature and time, all the other parameters measured had low values, it is an indication that if cowpea seeds are to be used for planting, they should be heated at 120°C for 5 minutes before storage. However, if they are to be used for consumption, heated at a temperature of 120°C for 10 minutes is recommended.

CONCLUSION

Comparisons between the heated seeds and the control showed that bruchid infestation and cowpea damage were significant reduced by heating the seeds. Heating the cowpea seeds for longer than four hours at 80°C was not better than heating the seeds for just one hour at 90°C. Thus suggesting that higher temperatures at shorter periods are better for heating cowpea to control bruchid than longer heating. At higher temperatures, the germination percentage was very low. Therefore, for storage of cowpea for planting, the temperature of 120°C at 5 minutes should be used for heating while for consumption, the temperature of 120°C at 10 minutes or more is suggested.

REFERENCES

Alghali, A. M. 1991. Studies on cowpea farming practices in Nigeria, with emphasis on insect pest control. Tropical Pest Management. 37:71-74.

Anonymous 1982. Storage of Cowpea. A paper presented during the general inservice training for state extension staff of agriculture. Extension, Research and Liaison Services. Ahmadu Bello University , Zaria.

Barde, A. A. 1992. Comparative susceptibilty of stored cowpea varieties (*Vigna unguiculata* (L) Walp) to attack by *Callosobrochus maculatus* and their control using synthetic and neem products. An MSc. thesis submitted to the Department of Crop Protection. Ahmadu Bello University, Zaria, Nigeria. (Unpblished).

Caswell. G. H. (1973). The storage of cowpea. Samaru Agricultural Newsletter. Vol. 15 (2):72-75. A.B.U. Zaria.

Ferry, R. L. 1990. The cowpea: Production, utilization, and research in the United States. Horticultural Reviews. 12:197-222.

Hadjichristodoulou. A. 1991. Evaluation of cowpea (*V. unguiculata*) lines for dry seeds. Technology Bulletin No. 143. Cypres Agricultural Institute, Nicosia, Cyprus. 8pp.

Howe, R. W. and Currie, J. E. (1964). Some laboratory observations on the rate of development, mortality and oviposition of several species of bruchid breeding in stored pulses. Bull. Ent. Res. 44 (3): 456-468. Ibadan.

Koba, B. N. and Osuji, F. N. C. (1986). The thermal death point of *Callosobruchus maculatus* (Fabricius). Nigerian Journal of Entomology. 7(1):18-23.

Mensah, G. W. K. 1991. Farm products storage techniques. A paper presented at a seminar for storage techniques for Adamawa and Taraba States on 22-23 Nov 1991, Yola.

Murdock, L. L., Shade, R. E , Kitch, L. W., Ntoukam, G., Lowenberg-DeBoer, J., Huesing, J. E., Moar, W., Chambliss, O. L. Endondo, C. and Wolfson, J. L. (1997). Postharvest storage of cowpea in sub-Saharan Africa. In Advances in Cowpea Research. B. B. Sing, D. R. Mohan Raj, K. E. Dashiell, and L. E. N. Jackai (eds). Copublication of International Institute of Tropical Agriculture IITA and Japan International Research Centre for Agricultural Sciences(JIRCAS). IITA, Ibadan, Nigeria. P302-312.

Perrino, P., G. Laghetti, P. L. S. Zeuli, and L. M. Monti. 1993. Diversification of cowpea in the Mediterranean and other centres of cultivation. Genetic Resources and Crop Evolution. 40:121-132.

Quin, F. M. 1997. Introduction. P ix – xv. In Advances in Cowpea Research. B. B. Sing, D. R. Mohan Raj, K. E. Dashiell. and L. E. N. Jackai (eds). Copublication of International Institute of Tropical Agriculture IITA and Japan International Research Centre for Agricultural Sciences(JIRCAS). IITA, Ibadan, Nigeria.

Rachie. K. O. 1985. Introduction xxi – xxviii. In Cowpea Research, Production and Utilization, edited by S. R. Singh and K. O. Rachie. John Wiley and Sons, Chichester, U.K.

Statistical Analysis System Institute Inc. (SAS) (1996). Release 6.12. SAS Institute Inc., Cary, NC, USA.

Singh, B. B., O. L. Chambliss, and B. Sharma. 1997. Recent advances in cowpea breeding. P 30 – 49. In Advances in Cowpea Research.

B. B. Sing, D. R. Mohan Raj, K. E. Dashiell. and L. E. N. Jackai (eds). Copublication of International Institute of Tropical Agriculture IITA and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA. Ibadan. Nigeria.