KFRI Research Report 12

PROTECTION OF FIBROUS RAW MATERIAL IN STORAGE AGAINST DETERIORATION BY BIOLOGICAL ORGANISMS

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PEECHI, THRISSUR

June 1982

Pages:24

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ABSTRACT

Raw materials for pulp end paper industry stored outdoors are subject to deterioration by insects or decay or both. The objectives of this study were to understand the nature and causes of deterioration of cashew wood ***(Anacardium occidentale)*** and reed ***(Ochlandra*** spp.) and to develop suitable control methods.

The study was conducted in the timber depot of M/s Gwalior Rayons at Nilambur, Kerala. Cashew wood was stored for nine months and reed for six months, both under outdoor conditions.

The effect of prophylactic treatment with borax-boric acid and BHC was studied In addition, the effect of debarking before stacking in the case of ~~reed~~ casew wood was studied.

Cashew wood was damaged mainly by insect borers Three species of beetles were invulved, viz., ***Batocera rufomaculata*** (Cerambycidae), ***Sinoxylon anale*** (Bostrychidae) and ***Xyleborus similis*** (Scolytidae). Debarked billets suffered less damage than billets stored with bark. Monthly spraying of BHC or borax-boric acid did not give effective protection. The results suggest that more frequent application of chemicals is necessary to prevent establishment of the borers. Debarking the material before stacking and application of BHC at fortnightly intervals is suggested.

Reed was damaged by fungi; no insect attack occurred in the experimental site although ***Dinoaerus*** beetles are known to cause damage. Vertically stacked reeds suffered less fungal dImage than horizontally stacked material due to better drainage of water, although vertical stacking is more cumbersome. Treatment with borax-boric acid at monthly intervals resulted in substantial gain in pulp yield.

The cost of the suggested chemicals for prophylactic treatment for a 6-monthstorage period will be about **Rs.** 1.20 per tonne for cashew wood and about Rs. 1.75 per tonne for reed. The total cost including labour, equipment, etc. will be small compared to the considerable saving in wood substance and gain in pulp yield.

Key words: ***Batocera,*** cashew wood, pulp and paper, reed, ***Sinoxylon,*** wood deterioration, ***Xylsborus***

INTRODUCTION

In a tropical country like India, with a large number of wood species and multitude of wood deteriorating organisms, problem of protecting wood under outdoor storage conditions are quite complex and difficult to resolve. Some species of insects are able to attack freshly felled trees with high starch and moisture content and continue even after the wood is dry whereas, others attack after the wood is dry. The presence of bark is necessary for inducing egg laying by some wood borers. At the same time, bark will have a retarding effect for the attacks of certain other insects. So removal or retention of bark bv itself will not solve the insect problem completely. Added to the insect problem, we have fungal problem also.

In India, raw materials for pulp and paper industry which mainly comprise of bamboo, reed and wood species, are generally stored outdoors for periods ranging anywhere from one week to six months. In some cases the storage period may even extend to 9 to 12 months During this period, they are exposed to sun and rain, and fungal and insect attack. Under the weather conditions in Kerala, generally, there is high incidence of fungal attack during monsoon and high incidence of insect attack during non-monsoon season A major portion of the stored material usually gets seriously damaged by insects or decay or both.

Fresh wood grinds easily and produces brighter pulp than the pulp produced from stored wood. But storage of raw material is inevitable becduse the forests cannot normaly be worked round the year. Also effective material management requires raw material storage for at least six months. Moreover, raw material supply may be interrupted due to transport bottlenecks and other unforeseen circumstances.

The deterioration of raw material during storage outdoors can be checked to a great extent by adopting good yard management practices like systematic storage on a first come first off basis, storing the material on raised structutes and keeping the storage yard tidy with proper drainage. Besides the above practices the most effective method is to give a prophylactic treatment with a preservative solution. Because of the huge quantities of raw materials utilised and increasing shortfalls in availability, it is important to effect saving of raw material through scientific management of storage.

The main raw material for rayon grade pulp are eucalypts, bamboos and reeds. Besides these, cashew wood ***(Anacardium occidentale),*** murukku ***(Erythrina*** spp.) and other mixed hardwood species are used when available. Eucalypt wood stored outdoors does not suffer much deterioration. However, bamboo and reed are damaged by ***Dinoderus*** beetle (ghoon borer) and fungi. Cashew wood is also subject to damage by insects during storage.

In this project the deterioration of cashew wood and reed ***(Ochlandra*** spp.) under outdoor storage conditions was studied. The objectives were, (1) to determine the nature and causes of deterioration under storage and (2) to develop suitable control methods.

This report is organised into two parts. Part I deals with protection of cashew wood and Part II with protection of reed, both under outdoor storage conditions.

LITERATURE REVIEW

In developed countries, continuous water sprays or treatment with fungicides- and insecticides is a common practice for protection of raw material stored outdoors. However, many of the preservatives performing very well in temperate climates have failed totally when tested in the tropics due to climatic conditions, resulting in leaching and evaporation of preservatives (Fougerousse 1969). Several reports have appeared in Indian literature recommending various chemicals and their combinations for protection of timber (Purushotham 1970; Purushotham *et al.* 1965), but with no adequate qudntitative data to support the effectiveness of the sugeested treatments.

Guha *et al.* (1975) studied the effect of storage of ***Eucalyptus hybrid*** [sic] wood on pulping quality. It has not been mentioned how long the material was stored but they arrived at the obvious conclusion that when fresh wood is used, power consumption is reduced and a brighter and easily bleachable pulp is produced.

Guha and Chandra (1979) tried three different preservatives (1% sodium pentachlorophenate; 2% borax-boric acid (1:I) and 5% acid cupric chromate) for protection of bamboo stored under outdoor conditions. The treatment involved spraying and brushing the chemical solution **on** all the surfaces of individual pieces. About six litres of water solution of the chemicals were used to treat 20 pieces, 250 cm long. They observed that wood-destroying fungi attacked bamboo only after the first four months of storage. They found that chemical treatment reduced the deterioration loss. Over a period of eight months, the wood substance loss was 17% in untreated bamboo; 13% in sodium pentachlorophenate treated bamboo and 14% each in borax-boric acid treated and acid cupric chromate treated bamboo. Based on an economic analysis Guha *et al.* (1980) claimed that treatment with sodium pentachlorophenate proved very economical. But the validity of this conclusion is doubtful as the data were not statistically analysed.

Based on the same study, Chandra and Guha (1979) observed that the degree of polymerisation of α-cellulose decreased as decay progressed both in untreated and treated bamboo. The loss of cellulose in sodium pentachlorophenate treated bamboo was about 24% after a 12-month storage period, while in untreated control it was about 31%. Lignin content also progressively decreased as the storage period, increased due to white rot type of fungal decay (Chandra and Guha 1981).

Kumar *et al.* (1979) studied the effect of preservatives on chemical constituents and pulping quality of ***Eucalyptus camaldulensis*** bolts during storage under outdoor conditions. In addition to the preservatives tried by Guha and Chandra (1979), they tried 2% solution of 2:l:l sodium pentachlorophenante-borax-boric acid mixture in water. The acid cupric chromate concentration was reduced from **5%** to 2%. For each treatment, there was only one lot of bolts, without any replication. Six bolts from each lot were examined for wood substance loss, pulp yield, etc. They observed that treatments with sodium pentachlorophenate and sodium pentachlorophenate-borax-boric acid cut down the wood substance loss by about 30% over a period of 12 months. These treatments improved the yield of unbleached pulp by **3** to 4%.

In a similar study with poplar ***(Populus de/toides)*** Beri ***et*** a/. (1979) found that sodium pentachlorophenate cut down the losses due to decay and insect attack by about 17% over a period of 12 months and improved the pulp yield by 5.6%. Borax–boric acid treatment which was not very effective with eucalypts (Kumar *et a/.* 1979) was able to cut down wood substance loss by about 24% and improve the pulp yield by 3.4%.

Based on the above two studies, Kumar *et a/.* (1980 a) made an economic analysis of chemical protection of stored pulpwood. Various investigations pertaining to protection of different raw materials fo; pulp industry have been summarised by Kumar ***et*** a/. (1980 b). These studies indicate that during unprotected storage the following defects occur in varying degrees:

1. Decrease in pulp yield depending on the extent of decay or borer attack and increase in screening rejects.
2. Decrease in strength properties of pulp sheets.
3. Increase in bleach consumption per unit weight of pulp.
4. Decrease in brightness of pulp sheet which necessitates blending with higher percentage of more expensive chemical pulp.
5 Decrease in digester capacity, as less weight of chips per charge may be fed due to decrease in packing density of wood caused by fungal or borer attack.

No information is available in literature regarding the protection of reed or cashew wood under outdoor storage conditions against biological organisms. So a systematic study was undertaken.

PARTI: CASHEW WOOD

The experiment involved storing cashew billets for nine months under outdoor conditions. Different treatments were given and data on weight loss and insect/fungal damage were collected at the end of three, six and nine months. Since only debarked material is used for pulping, the effect of debarking was studied in addition to the effect of some chemical treatments.

Materials and Methods

The experiments were laid out at Nilambur in the Gwalior Rayons timber depot in August 1980, using freshly cut cashew wood billets received from places within a radius of about 25 km around Nilambur. The billets were 1.0m long with girth ranging from 15 to 90cm.

The effect of debarking and chemical treatments with (1) borax-boric acid solution (2% boric acid equivalent), abbreviated as B-B for convenience, and (2) BHC (hexachlorocyclohexane) emulsion (0.5%) were studied.

There were three main experimental factors, namely, presence or absence of bark, chemical treatment (B-B, RHC and untreated control) and storage period (three, six and nine months) constituting 18 treatment combinations. In ail, there were 18 stacks, Each stack (Fig. 1) was 4 x 2 x 2 m in size. This size was chosen to

Fig. 1. Stacks of cashew wood

simulate the actual storage condition to the extent possible and at the same time to make easy observation. The stacks were arranged in three rows with six stacks per row and a gap of 3m between the stacks and between the rows. Also the stacks were arranged in a staggered manner to minimise spray drift from one stack to another while spraying. In each stack, there were 24 marked and weighed billets positioned in different places to represent the entire stack. These billets were considered as replicates for quantitative assessment of the weight loss and insect damage.

A 2% boric acid equivalent (BAE) solution was prepared by dissolving 100 g of boric acid and 150 g of borax in 10 litres of water. Both boric acid and borax were of technical grade.

A 0.5% BHC emulsion was prepared by mixing 100 g of BHC **50%** wettable dust in 10 litres of water.

A rocker sprayer was used to spray the chemical solutions at the rate of 10 litres per stack (about 0.3 litres/kq. m area). The entire exposed surface (surface area of 32 sq. m) af the stacks was sprayed with the respective spray solution after the stacks were made. Subsequent sprayings weredone at monthly intervals. Before each spraying, visual observations on the incidence and intensity of fungal/ insect attack were recorded.

At the end of three months, one stack from each treatment was dismantled, the marked billets were removed, weighed and scored for insect attack. Similar procedure was repeated at the end of six and nine months.

The method of scoring for insect attack was as follows. Each billet was divided into eight zones and a 5 x 5 cm area was sampled from each zone. The entire area of the billet was represented by systematic distribution of sampling sites among the different zones. Within the selected zone, the sampling site was identified by placing a 5 x 5 cm square wire frame over the billet surface and the number of holes within this frame was counted.

In addition to the above, another experiment was laid out in January 1981, mainly to gather further information on the biology of the borers. Here the stack size was reduced to 2 x 1 x 1 rn. Freshly cut material was used. Because of the smaller stack size only 10 pre-marked billets were used for damage assessment. There were 24 stacks consisting of four replication of six treatment combinations (B-B, BHC and untreated control, with and without bark). In this experiment the chemicals were sprayed at fortnightly intervals for the first two months and monthly thereafter for a total period of six months. To gather information on the development of insects, one replicate of each treatment combination was dismantled and observations made at the end of one month, as well as at the and of three months. The remaining stacks were dismantled at the end of six months for observation.

Results and Discussion

Weight loss

At the end of every 3-month storage period, six stacks representing different treatments were dismantled. The marked billets were weighed and loss in weight was determined. The change in weight is due to loss/gain of moisture and loss of wood material due to insect/fungal attack.

It may be seen from Table 1, that the percentage weight loss ranged between 44 and 43 at three months, 50 and 56 at six months and 33 and 38 at nine months. This shows progressive loss up to six months, mainly due to loss of moisture. There was gain in weight between six and nine months, evidently due to moisture absorption during the rainy period.

Table 1. Loss in weight of freshly cut cashew billlets stored outdoors [1]

Storage period and month of demolition	Percentage weight loss under specified treatments					
	Billets with bark			Biliets without bark		
	B-B	BHC	Control	B-B	BHC	Control
3 mos. (Dec 1980)	43.9	44.0	44.3	438	44.7	49.2
6 mos. (Mar. 1981)	54.8	55 7	53.6	52.7	50.8	50 1
9 mos. (Jun. 1981)	34.0	35.7	38.0	35.7	33.4	34.0

1 Stacks set up between 20-25 August 1980 and first treatmet given on 30 August 1980.

The weight loss data was statistically analysed (Table 2). The presence or absence of bark significantly ($P \leq 0.05$) affected weight loss. At the end of three months, weight loss was more or less similar (Table 1). This weight loss was mostly due to loss of moisture. At the end of six months material with bark had lost more weight than materiai without bark. Since moisture loss should be equal or more in debarked billets as compared to billets with bark, the comparatively lower oss of weight of debarked billets suggests that it is due to prevention of borer damage ***(videinfra)***

There was no significant difference in weight loss among chemical treatments,

Damage caused by fungi

Some fungal growth was seen in the first month, mostly in BHC treated and untreated control stacks. No further growth of fungi was noticed in the subsequent months. Apparently fungal damage was not a major factor.

***Table 2** Analysis of weight loss data of cashew billets stored outdoors*

Source of variation	Degree of freedom	SS	MS	F
Bark (B)	1	153.69	153.69	4.26"
Chemical treatment (C)	2	36.57	18.29	0.51
Storage period (S)	2	22035.05	11017.53	305.24**
B x C	2	80.22	40.11	1.11
B X S	2	469.02	234.51	6.50**
C X S	4	305.79	76.45	2.12
B X C X S	4	331.56	82.89	2.30
Error	397 †	14329.50	36.09	
Total	414	37741.40		

• significant at $P \leq 0.05$

** significant ot $P \leq 0.01$

† 17 billets were missing

Damage caused by insects

Stacked cashew billets were attacked by three species of insects - ***Batocera rufomaculata, Sinoxylon anale*** and ***Xyloborus similis,*** all belonging to the order Coleoptera (beetles). Visual observations on the occurrence of these insects and intensity of attack were recorded every month, in addition to quantitative estimation of damage at 3-month intervals on dismantled stacks. Observations for each insect are detailed below.

Batocera rufomaculata **De Geer (Family Cerambycidae)**

This large beetle, about 5 cm long and with antennae longer than the body (Fig. 2) is well known in Kerala as the mango tree borer. It is polyphagous, attacking over 30 species of timber .(Beeson 1941). The damage is caused by larval feeding. Larvae make extensive excavations in the sapwood which are packed with coarse wood and bark fibres (Fig. 3). Heaps of frass may be seen near points of attack.

Table 3 shows the incidence and progression of attack in the experimental stacks. No infestation occurred in the first month. After two months (early November) most stacks in which bark was retained were found attacked. The attack was heaviest in untreated control with an average of eight infestation points per stack. After January no fresh frass was noticed, indicating cessation of feeding of existing larvae (prior to pupation) and absence of new infestations.

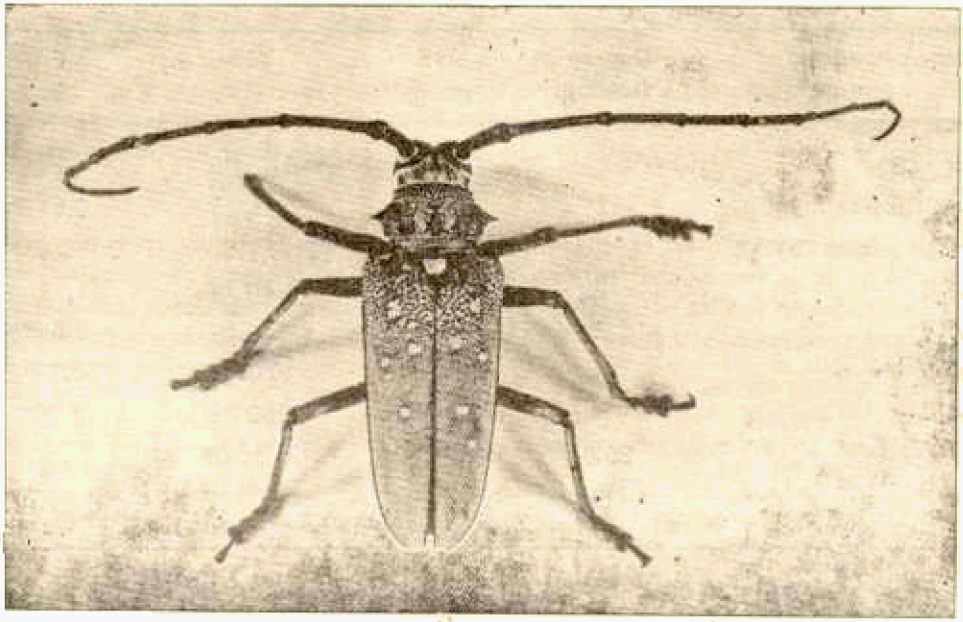

Fig. 2. Batocera rufomaculata *beetle*

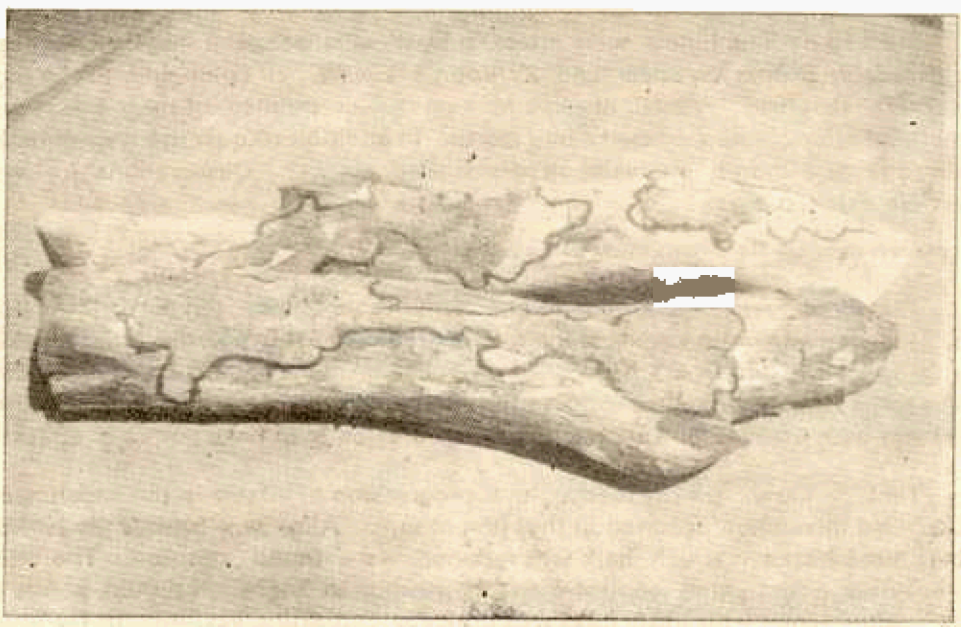

Fig. 3. Extensive attack by larvae of Batocera rufomaculata *as seen after removal of bark. Frass packed with coarse wood and bark fibres may be seen.*

***Table* 3.** Incidence of Batocera rufomaculata infestation on the marked cahew billets stored outdoors 1

Date of observation	No. of active infestation sites as indicated by accumulation' of fresh frsss in each stack under specified treatments																	
	Biliets with bark									Billets without hark								
	B-B			BHC			Control			B-B			BHC			Control		
	@																	
	6	7	**3**	**5**	11	**17**	**16**	**16**	**2**	**14**	**10**	**8**	**4**	**13**	**18**	**12**	**9**	1
3 Oct. **1980**	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Nov. **1980**	1	0	0	1	1	4	2	3	7	0	0	0	0	0	0 .	0	0	0
16 Dec. **1980**	1	0	3	6	2	13	9	8	7	0	1	0	0	2	0	0	0	1
12 Jan. **1981**		0	6		3	12		0	8		0	0		2	0		0	0
18 Feb **1981**		0	0'		0	0		0	0		0	0		0	o		0	0
18 Mar. **1981**		0	0		0	0		0	0		0	0		0	0		0	0
20 Apr. **1981**			0			0			0			0			0			0
20 May **1981**			0			0			0			0			0			0
23 Jun. **1981**			0			0			0			0			0			0

1 Stacks set up between 20-25 August **1980** and first treatment gived on **30** August **1980**

@ Serial number of stack

Stacks **6, 5, 16, 14,** 4 and **12** - dismantled in December 1980

Stacks 7, **11, 15, 10, 13** and **9** - dismantled in March 1981

Stacks **3,17, 2, 8, 18** and 1 - dismantled in June I981

From an infested billet collected from the control stack in December 1980, an adult beetle emerged on **27** February 1981. Since the stacks were put up in late August, this shows that the life cycle is completed within six months. Available literature also indicate that the life cycle is annual (Beeson 1941). The adults are known to live for several months.

In our experiments, no fresh activity of the insect wES noticed duriug February to June. However, since freshly cut billets which the adult insect may prefer tor egg laying were not available during this period, this period cannot be considered safe from attack. Year round experiments in which freshly cut material are stacked at monthly intervals would probably suggest a safe period for cutting and stacking. It is possible that material cut in December-January may not be attacked because most insects will be in the pupal stage at this time, and by the time the adult beetles emerge, the billets would have lost their attractiveness to elicit egg laying. This was also suggested by the fact that no attack occurred in the secondset of experiments laid out In January 1981.

Our experiments have clearly shown that debarked billets suffered little damage from this borer. This is apparently because egg laying and survival of early stage larvae are dependent on the presence of bark. Monthly sprays of BHC on the stack surface had little affect in protecting the billets from attack. Some larvae survived on borax-boric acid treated material also. Thus debarking is the best method of protection against this insect.

The damage caused by this insect is substantial. In our experiments the incidence of attack was low-an average of eight larvae per stack in the untreated control. Since only one of tho marked billets was attacked in this stack, the damage is not reflected in the weight loss data. A larger population of these insects could cause heavy damage.

Sinoxylon anale **Les. (Family Bostrychidae)**

Belonging to the group popularly known as powder-post beetles, *S anale* is a small (about 5 mm in length), dark brown to black beetle. It is reported to be the commonest bostrychid in India, known to attack, over 65 species of timber (Beeson 1941). Both the adult beetle and larva bore into the wood and cause damage. In cashew, the borer holes extend deep into the wood (Fig. 4).

Fig. 4 ***Cashew woad attacked by*** Sinoxylon anale ***beetle.***

Fig. 5. Cashew wood attacked by Xyleborus similis ***beetle.***

Attack by this insect was first noticed three months after stacking in December 1980 (Table 4). Infestation is characterised by accumulation of fine wood dust coming out from borer holes. No fresh dust accumulated after January 1981. No further attack was noticed until June 1981 when the observations were dicontinued.

Table 4 also shows the average number of borer holes per marked billet at the end of each 3-month storage period. The average number varied from 0 to 3.2 per 200 sq. cm surface of the marked billet. The number of marked billets attacked varied from 0 to 8 out of 24 per stack. It may be seen that, in general, the incidence of attack by these borers was low. Because of the generally low incidence of attack no conclusions could be drawn on the effectiveness of chemical treatments and bark removal.

In this experiment, since the attack was confined to the period between December and January and since only a small number of borer holes were present in general, the damage caused by *S. anale* was insignificant in terms of material loss.

In the second set of experiments laid out in January 1981, incidence OF *S. anale* attack was noticed within a fortnight of stacking the billets. Borer activity as indicated by accumulation of fresh frass continued for about four months, until May 1981 (Table 5). The intensity of attack was considerably greater than in the first set of experiments, with the average number of borer holes per billet ranging from 0 to 65.2 per 200 sq. cm surface of marked billet. No definite conclusion could be drawn on the effectiveness of the various treatments although there is indication that BHC was more effective than borax-boric acid for control of *S. anale* attack. Apparently the sample size was not large enough to yield statistically significant results.

Observations on field-collected infested billets kept under laboratory conditions showed that the life cycle of *S. anale* is completed in 30 to 45 days, Repeated generations were able to develop on the same infested billets, completely riddling it and converting the wood into fine dust in course of time

It is interesting to note that although continuous generations occurred under laboratory conditions, attack was confined to certain periods under outdoor conditions. In addition, although the smaller stacks were attacked during February to May 1981, no borer activity was noticed in the bigger stacks during the same period- Further investigations are required to elucidate the causes of such differences.

This insect must be recognised as a serious pest of stored cashew wood, potentially capable of causing much economic loss.

Xyleborus similis **Ferr. (Family Scolytidae)**

This insect belongs to the group generally known as pin-hole borers or ambrosia beetles. The adult beetle is brownish in colour and about 2.5 mm long. It is polyphagous and attacks a large variety of timbers (Beeson 1941).-

Table 4. Incidence of Sinoxylon anale *Infestation as indicated by visible accumulation of fresh frass and number of borer holes on tbe marked cashew billets stored outdoors* [1]

Date of observation	Incidence of attack under specified treatments																	
	Billets with bark									Billets without bark								
	B-B			BHC			Control			B-B			BHC			Control		
	6*	7	3	5	11	17	16	15	2	14	10	8	4	13	18	12	9	1
3 Oct. 1980	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5 Nov. 1980	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16 Dec. 1980	+ (0.1)δ	–	–	+ (0.9)	–	–	– (0.3)	++	+	+++ (1.1)	++	++	– (0.0)	++	+	+++ (3 2)	++	++
12 Jan. 1981		+	+		+	–		–	–		+++	++		++	+		++	–
18 Feb. 1981		–	–		–	–		–	–		–	–		–	–		–	–
18 Mar. 1981		– (0.6)	–		– (0.5)	–		– (0,1)	–		– (3 0)	–		– (0.2)	–		– (2.1)	–
20 Apr. 1981			–			–			–			–			–			–
20 May 1981			–			–			–			–			–			–
23 Jun. 1981			– (0.7)			– (0.1)			– (0.2)			– (0.3)			– (0.0)			– (0.2)

1 Stacks set up between 20-25 August 1980 and first treatment given on 30 August 1980

* Serial number of stack

δ Average number of borer holes per billet (200 sq. cm area)

Intensity of incidence of attack : + slight; ++ moderate; +++ heavy; — no visible attack

Stacks 6, 5, 16, 14, 4 and 12 - dismantled in December 1980

Stacks 7, 11, 15, 10, 13 and 9 - dismantled in March 1981

Stacks 3, 17, 2, 8, 18 and 1 - dismantled in June 1981

Table 5. Incidence of Sinoxylon anale *infestation as indicated by visible accumulation of fresh frass and number of borer holes on the marked cashew billets stored outdoors*[1]

Date of observation	Incidence of attack under specified treatments																							
	Billets with bark												Billets without bark											
	B-B				BHC				Control				B-B				BHC				Control			
	10*	24	6	12	4	21	1	15	11	20	2	8	18	9	7	16	22	14	5	19	13	17	3	23
19 Feb. 1981	– (0.0)δ	+	+	+	+ (1.1)	–	+	–	– (0.0)	+ +	+	+	+ (1.6)	+	+ +	+ +	+ (0.9)	–	–	–	+ (0.2)	+ +	+ +	+ +
18 Mar. 1981		+ +	+	+ + +		+ +	+	–		+ + +	+ +	+ +		+ +	+ + +	+ + +		+ +	+	+ +		+ +	+ + +	+ + +
22 Apr. 1981		– (20.0)	+	+ +		– (9.2)	+	–		– (65.2)	+ +	+ +		– (38.8)	+ +	+ +		– (12.6)	+	+ +		– (8.9)	+ +	+ +
21 May 1981			–	–			–	–			+ +	+ +			+ +	+ +			+	+ +			+ +	+ +
23 Jun. 1981			–	–			–	–			–	–			–	–			–	–			–	–
14 Jul. 1981			– (16.9)	–			– (4.1)	–			– (49.9)	–			– (61.6)	–			– (1.6)	–			– (23.3)	–

1 Stacks set up and first treatment given on 19 January 1981

* Serial number of stack

δ Average number of borer holes per billet (200 sq. cm area)

Intensity of incidence of attack: + slight; + + moderate; + + + heavy; – no visible attack

Stacks 10, 4, 11, 18, 22, and 13 – dismantled in February 1981

Stacks 24, 21, 20, 9, 14 and 17 - dismanted in April 1981

Remaining stacks dismantled in July 1981

Table 6. Incidence of Xyleborus similis *infestation as indicated by visible accumulation of fresh frass and number of borer holes on the marked cashew billets stored outdoors*[1]

Date of observation	Incidence of attack under specified treatments																	
	Billets with bark									Billets without bark								
	B-B			BHC			Control			B-B		BHC			Control			
	6*	7	3	5	11	17	16	15	2	14	10	8	4	13	18	12	9	1
3 Oct. 1980	++	+	+++	+++	+++	++	++	++	+++	+++	-	-	+	++	+	++	++	++
5 Nov. 1980	++	+	+++	+++	+++	++	++	++	+++	+++	+	+	+	++	+	++	++	++
16 Dec. 1980	- (14.4)δ	-	-	+++ (25.9)	+++	-	- (18.6)	-	-	- (6.8)	-	-	+ (5.5)	-	-	- (7.7)	++	-
12 Jan. 1981		-	-		-	-		-	-		-	-		-	-		-	-
18 Feb. 1981		-	-		-	-		-	-		-	-		-	-		-	-
18 Mar. 1981		- (12.0)	-		- (12.7)	-		- (10.1)	-		- (7.2)	-		- (7.3)	-		- (2.6)	-
20 Apr. 1981			-			-			-			-			-			-
20 May 1981			-			-			-			-			-			-
23 Jun. 1981			- (5.0)			- (2.5)			- (17.4)			- (1.9)			- (3.0)			- (3.0)

1 Stacks set up between 20-25 August 1980 and first treatment given on 30 August 1980

* Serial number of stack

δ Average number of borer holes per billet (200 sq. cm area)

Intensity of incidence of attack : + slight; ++ moderate; +++ heavy; - no visible attack

Stacks 6, 5, 16, 14, 4 and 12 - dismantled in December 1980

Stacks 7, 11, 15, 10, 13 and 9 - dismantled in March 1981

Stacks 3, 17, 2, 8, 18 and 1 - dismantled in June 1981

Table 7. Incidence of Xyleborus similis *infestation as indicated by visible accumulation of fresh frass and number of borer holes on the marked cashew billets stored outdoors*[1]

Date of observation	Incidence of attack under specified treatments																							
	Billets with bark												Billets without bark											
	B–B				BHC				Control				B–B				BHC				Control			
	10*	24	6	12	4	21	1	15	11	20	2	8	18	9	7	16	22	14	5	19	13	17	3	23
19 Feb. 1981	+ (1.3)δ	–	–	–	++ (6.9)	–	–	–	– (0.0)	–	–	–	– (0.0)	–	–	–	– (0.0)	–	–	–	– (0 0)	–	–	–
18 Mar. 1981		–	–	–		–	–	–		–	–	–		–	–	–		–	–	–		–	–	–
22 Apr. 1981		– (0.0)	–	–		– (0.0)	–	–		– (0·0)	–	–		– (0.0)	–	–		– (0.0)	–	–		– (0.0)	–	–
18 May 1981			–	–			–	–			–	–			–	–			–	–			–	–
23 Jun. 1981			–	–			–	–			–	–			–	–			–	–			–	–
14 Jul. 1981			– (0 0)	–			– (0.0)	–			– (0.0)	–			– (0.0)	–			– (0.0)	–			– (0.0)	–

1 Stacks set up and first treatment given on 19 January 1981
* Serial number of stack
δ Average number of borer holes per billet (200 sq. cm area)
Intencity of incidence of attack: + slight; + + moderate; – no visible attack
Stacks 10, 4, 11, 18, 22, and 13 - dismantled in February 1981
Stacks 24, 21, 20, 9, 14 and 17 - dismantled in April 1981
Remaining stacks dismantled in July 1981

In the first set of experiments, attack by this insect was noticed in the first month itself. Damage is characterised by small pin holes, and narrow branching tunnels mostly confined to the superficial layer of the billet, although some tunnels run deeper (Fig. 5). No borer activity was noticed after the initial three months period (Table 6). Billets with bark sustained more damage than debarked billets.

At the end of 3-, 8- and 9-month storage period, marked billets from the demolished stacks were scored for insect attack. Average number of borer holes in 200 sq. cm surface area of each billet ranged from 1. 9 to 25.9 (Table 6).

The scoring data was analysed (Table 8). There was highly significant difference ($P \leq 0.01$) between billets with bark and billets without bark, those with bark suffering greater damage. No significant difference was noticed between chemical treatments.

In the second set of experiments infestation was confined to the initial month only and intensity of attack was also lower than in the first set (Table 7). Apparently this insect attacks only comparatively fresher wood. While in the first set of experiments attack occurred over the initial three months, in the second set it was confined to the first one month. No satisfactory explanation is available. Billets with bark were more affected comparatively confirming earlier observations made on the first set of stacks.

Since the attack is more or less superficial and the incidence confined to short periods - damage caused is low. Particularly for pulp industry, this will not have much economic significance.

Table 8. Analysis of variance of scoring of Xyleborus ***attack*** on cashew *billets* ***stored outdoor8***

Source of variation	Degrees of freedom	SS	MS	F
Bark (B)	**1**	**6795.50**	**6795.50**	**60.28****
Chemical treatment (C)	**2**	**241.47**	**120.73**	**1.07**
Storage period (S)	**2**	**4322.94**	**2161.47**	**19.17****
B x C	**2**	**607.31**	**303.66**	**2.69**
BXS	**2**	**1148.41**	**574.20**	**5.09****
C X S	**4**	**1802.77**	**450.69**	**4.00****
B x C x S	**4**	**1951.83**	**487.96**	**4.33****
Error	**394 †**	**44420.09**	**112.74**	
Total	**441**	**61290.30**		

** significant at $P \leq$ 0.01
† 20 billets were missing

PART II : 'REED'

The experiment involved storing reed for six months under outdoor conditions. in general practice, reed is stored horizontally. When material is stacked to considerable height, the reed culms at the bottom get crushed facilitating easy entry of insects. If material is stored vertically, this problem can be avoided but stacks will occupy more space and will be cumbersome to make and to maintain the stacks. The experiment was designed to evaluate the effect of different method of stacking and different prophylactic chemical treatments on deterioration of reed.

Materials and Methods

Bundles of fresh reed were collected and the experiments laid out in the Gwalior Rayons' depot at Nilambur on 20 February 1981. Each bundle had 10 to 15 reed, 4 to 5 m long.

There were two main experiment variables—stacking method (vertical/ horizontal) and chemical treatments (B-B, BHC and untreated control as in Part I). This constituted six treatment combinations and each treatment combination was replicated thrice. Thus, there were 18 stacks, nine vertical and nine horizontal.

Before the stacks were set up, the yard was prepared as follows. An area of about 30 x 10 rn was selected. This area was treated with aldrin to prevent termite attack (ISI 1971). Then it was covered with gravel. In one half of this area, low walls 30 cm high and 2.5 m apart were built lengthwise and used for horizontal stacking of reeds. This was done to facilitate air circulation and water drainage. In the other half of the area, bamboo poles were erected 3 m apart with cross-arms and reed bundles were stacked vertically.

Each stack, about 4 x 1 x 1 m in size, consisted of 16 bundles of reed arranged in four rows. A gap of 2.5 to 3.0 m was left between the stacks. One reed in each bundle was pre-marked for damage assessment.

Preparation of the chemical solution was as in Part I except that a 3% BAE solution was used instead of 2% BAE.

All the exposed surface (about 15 sq. m) of the stacks was sprayed with the respective chemical solution at the rate of five litres per stack. Spraying was carried out fortnightly for the first two months and monthly thereafter. Before -Spraying, visual observations on the incidence of fungal and insect attack were .decorded.

At the end of 3-month storage period, one replicate of each treatment combination was dismantled, The marked reeds were assessed for damage.

At the end of six months, all the remaining stacks were dismantled and .observation made. To ascertain the overall damage, pulp yield was determined from the marked reeds of each treatment combination using 25 kg material. Pulp yield was determined by the Research and Development Department of Gwalior Rayons.

Results and Discussion

No insect attack was observed in the experimental stacks throughout the 6-month storage period, although stored reed is known to be damaged by ***Dinoderus*** beetles (Beeson 1941). However, black fungal growth was noticed.

At the end of three months, the marked reeds from the dismantled stacks were critically examined and found to be in sound condition without any apparent damage.

By the end of four months (June 1981), there had been monsoon rain and black fungal growth appeared. The overall incidence and progression of fungal attack are recorded in Table 9. By the end of five months, reeds in horizontally stacked untreated control were Comparatively soft, indicating the activity of decay fungi.

Table 9. Overall incidence of fungal attack on reeds stored outdoors[1]

Date of observation	Incidence of attack under specified treatments					
	Vertically stacked reeds			Horizontally stacked reeds		
	B-B	BHC	Control	B-B	BHC	Control
18 Mar. 1981	-	-	-	-	-	-
20 Apr. 1981	-	-	-	-	-	-
20 May 1981	-	-	-	-	-	-
23 Jun. 1981	—	+	+	-	+	++
14 Jul. 1981	-	+	++	+	++	++
31 Aug. 1081	+	++	++	++	+	+++

1 Stack set up and first treatment given on 20 February 1981
Intensity of incidence of attack : + slight; ++ moderate;
+++ heavy; - no visible attack

At the end of 6-month storage period, general observation showed that reeds in vertical stacks were less affected by fungi than reeds in horizontal stacks. Fungal damage was particularly heavy in horizontal stacks wherever there was water accumulation. When the stacks were dismantled and the marked reeds assessed, it was found that reeds from borax-boric acid treated stacks were more or less sound whereas reeds from BHC treated and untreated control stacks were comparatively soft.

Pulp yield determined from marked reeds pooled from the two stacks for each treatment combination is given in Table 10. These figures could be subjected to statistical analysis because they were based on pooled samples. Although there was no difference in the pulp yield between vertically and horizontally stacked material with BHC treatment. in both control and borax–boric acid treatment, vertically stacked material yielded more pulp. This supports the visual observation that horizontally stacked material is more susceptible to fungal damage.

Table 10. Yield of unbleached pulp* from reeds stored outdoors for six months

Percentage pulp yield under specified treatments					
Vertically stacked reeds			Horizontally stacked reeds		
B-B	BHC	Control	B- B	BHC	Control
45.0	41.0	41.6	43.5	41.0	38.4

* Determined by Research and Development Dept. of Gwalior Rayons.

Borax-boric acid treated material yielded more pulp compared to untreated control in both vertical and horizontal stackings. The gain in pulp yield over control amounted to 8% in vertical stacking and 13% in horizontal stacking.

It must be mentioned here that pulp yield determination was based on unit weight (oven dry) of material. Possible differences in weight loss among treatments due to different degrees of damage were not accounted for in the above assay.

GENERAL DISCUSSION

The investigations have shown that both cashew wood and reed are subject to deterioration when they are stored outdoors over a long period.

Damage to cashew wood was caused primarily by insects. Fungal attack was of minor nature and did not appear to result in loss of material. In general, debarked material lost less weight than material with bark.

The stored cashew billets lost weight progressively and by six months, about half the initial weight was lost. However, with the onset of monsoon, the weight of billets increased again. Since the billet weight thus fluctuated with the ambient moisture conditions, it cannot be used as a satisfactory index of deterioration. However, the weight loss of billets with bark exceeded the weight loss of billets without bark (Table 1) which suggests that billets with bark suffered more damage by insects. That material with bark is more susceptible to damage by ***Batocera*** and ***Xyleborus*** was also shown by visual scoring of damage (Tables 3 and 6).

Monthly spraying of BHC or borax - boric acid did not lead to effective protection from insects. It may be noted that only the exposed surface of the stacks was treated. Surface treatment prevents only establishment of insects and cannot reach the insects which have already become established. Once established, the insects are capable of continuing the damage in spite ot outside treatment. It was also found that the bostrychid, ***S. anale*** could undergo repeated generations inside the billets. Apparently, more frequent application of chemicals is necessary to ensure protection from establishment of the borers Also, it should be noted that application of chemicals is only a prophylactic treatment and not a remedial treatment.

Of the two chemicals tried, BHC is an insecticide and borax - boric acid, a fungicide with some insecticidal action. Since insects were mainly responsible for damage, and since the results gave indications of better protection with BHC, application of BHC spray at more frequent intervals should prove effective.

It could therefore be concluded from this study that debarking the cashew billets and applying prophylactic treatment with BHC (0.5%) at fortnightly intervals will result in saving of wood substance.

As regards reed, though it is known to be damaged by ghoon borer, no insect attack was observed. The primary cause of damage was fungal attack. Fungal damage did not become evident for about three months, but from then on it progressed steadily and by six months, there was considerable damage.

On the average, vertical stacking resulted in about 4%gain in pulp yield over horizontal stacking. This was because vertically stacked materical suffered less fungal damage due to better drainage of water in the stacks.

Since there was no insect damage, treatment with BHC was not advantageous. Treatment with borax - boric acid resulted in a substantial gain in pulp yield over untreated control. This gain amounted to about 8% in vertical stacking and 13% in horizontal stacking.

Based on this study, the best method of protection of reed is vertical stacking combined with monthly application of borax - boric acid. If horizontal stacking is followed in view of practical difficulties in vertical stacking, the material may be stored over raised walls to facilitate water drainage and air circulation. Although a 3% BAE solution used in the present trial was found effective, a 2% solution should be equally effective as shown by Guha and Chandra (1979), and Kumar *et al.* (1979).

To summarise, the present investigations suggest that deterioration during storage can be minimised as follows. Cashew wood may be debarked and given prophylactic treatment with BHC (0.50%) at fortnightly intervals. Reed may be stored horizontally on raised walls and sprayed with borax - boric acid (2% BAE) at monthly intervals.

Cost of Chemical treatment

In our experiments the stack size of cashew was 4 x 2 x 2 m. In general practice, the stack size is much larger and variable. The cost of treatment is worked out here for a stack, 10 x 2 x 3 m, which will hold about 30 tonnes of material. At the rate of 0.3 litres of spray solution per sq. m surface area as used in this study, one application will require 30 litres of 0.5% BHC (300 g of 50% dust). This would cost Rs.3/- per application (at the rate of Rs. 10/-per kg of BHC 50% dust). For a six months storage, with fortnightly treatment, the cost would be Rs.36/- and for nine months Rs. 54/-. This works out to Rs. 1.20 per tonne for 6-month storage period and Rs. 1.80 per tonne for nine months, if the above stack size is used.

At the same rate of application per unit area, one applicatton of borax - boric acid (2% BAE) to a reed stack, say, 5 x 5 x 3 m which will hold about 25 tonnes material, will require 30 litres of spray solution (300 g of boric acid and 450 g of borax). This would cost Rs. 7.20 per application (at the rate of Rs. 12/- per kg of boric acid and Rs. 3/- per of borax, both technical grade). Monthly application for a period of six months will cost Rs.43.20 and for nine months, Rs. 64.80. This works out to Rs. 1.75 per tonne for 6-month storage period and Rs. 2.60 per tonne for nine months, if the above stack size is used.

The cost of the suggested chemicals for prophylactic treatment for both cashew and reed is negligible, The total cost including labour, equipment, etc. will be small compared to the gain in pulp yield.

CONCLUSIONS AND RECOMMENDATIONS

The present study has shown that both cashew wood and reed are subject to. deterioration when they are stcred outdoors over a long period. Cashew is damaged mainly by insect borers and reed by fungi.

To minimise the deterioration of cashew wood, the billets may be debarked before stacking and the exposed surface of the stacks, sprayed with 0 5% BHC emulsion at the rate of about 0.3 litreslsq.m at fortnightly intervals. This treatment is a prophylactic measure. Once established, the insects are capable of continuing- the damage in spite of outside treatment.

In the case of reed, vertical stacking combained with monthly application of, borax.boric acid solution resulted in least deterioration. In view of practical difficulties involved in vertical stacking, the material may be stored horizontally over raised walls (to facilitate water drainage and air circulation) and exposed surface of the stacks sprayed with borax-boric acid (2% boric acid equivalent) at the rate of about 0.3 litres/sq. m at monthly intervals,

The cost of the suggested chemicals for prophylactic treatment for a 6-month storage period will be Rs. 1.20 per tonne for cashew wood for a stack size of 10 x 2 x 3 m and Rs. 1.75 per tonne for reed for a stack size of 5 x 5 x 3 m. The total cost including labour, equipment, etc will be small compared to the considerable saving in wood substance and gain in pulp yield ,

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