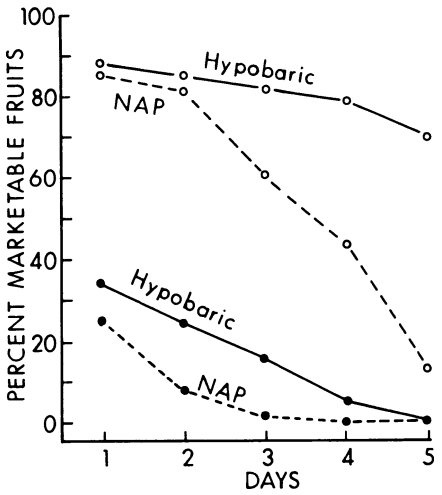

Fig. 1. Marketability of papaya fruits after shipment from Hawaii to New York in a refrigerated (10°C) hypobaric container. Control fruits were stored in a refrigerated container (10°C) under normal atmospheric pressure (NAP) in Hawaii. All fruits were graded at ambient temperature (20-26°C) for 5 days after removal from the container. Closed circles = Packer 1; Open circles = Packer 2.

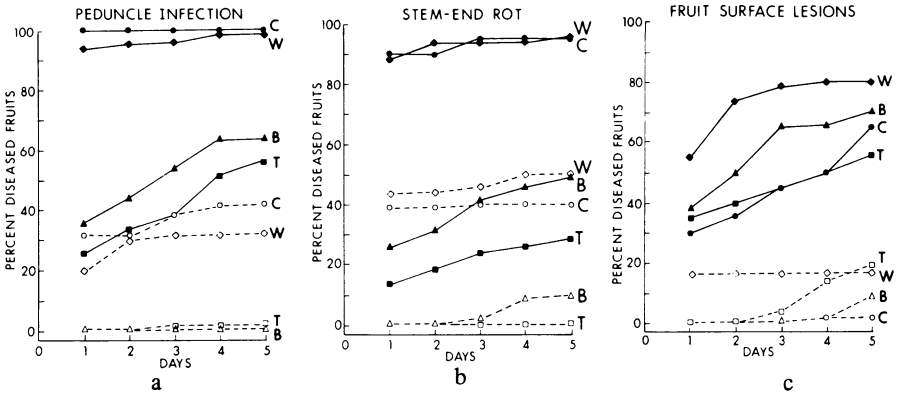

Fig. 2. Comparison of wax and fungicide treatments on postharvest disease incidence in papaya fruits shipped from Hawaii to New York City in a refrigerated (10°C) hypobaric container (broken lines) and fruits refrigerated (10°C) for the same period under normal atmospheric pessure in Hawaii (solid lines). In both cases the interval from harvest to the first day of grading was 21 days. W = wax alone; B = benomyl plus wax; T = TBZ plus wax; C = untreated control.

treated with wax alone had the disease.

In the second test shipment LP-shipped fruits also had significantly less disease than those stored under NAP. Three days after removal from the containers, untreated fruits of Packer 1 had 63% (percentage points) less peduncle infection (Fig. 2a), 55% less stem-end rot (Fig. 2b) and 45% less anthracnose (Fig. 2c) in LP-shipped fruits than those stored at NAP. In fruits of Packer 1 peduncle infection was further reduced ca. 36% by benomyl-wax and 38% by TBZ-wax applications (Fig. 2a). Likewise in the NAP- container, peduncle infection was reduced ca. 47% and 63% by benomyl-wax and TBZ-wax applications, respectively. Similar reductions of stem-end rot were achieved by the fungicide applications. On the third day of ripening incidence of anthracnose was too low (less than 5%) to determine the effects of fungicides on disease control in the LP-shipment.

Prior to the second shipment, harvesting practices for Packer 2 had been improved, so that fewer losses occurred due to bruising; 72% of the fruits were still marketable after 5 days of ripening. While LP-shipped fruits of this packer also had significantly less disease than those stored under NAP, differences were not pronounced because overall disease levels were lower, and data are not shown.

These tests were done following commercial practices as closely as possible. Some problems could not be avoided; ambient temperature during ripening were variable and the NAP-control remained in Honolulu during the second test. Although grading errors were avoided by standardizing methods before travel, ripening conditions did vary. Nevertheless, the purpose of this paper is to present preliminary findings which show the potential of LP storage in extending shelf life of papaya.

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Seed Treatment of Hairy Indigo (*Indigofera hirsuta L.*) to Overcome Hard Seed Dormancy[1]

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Additional index words. germination

Abstract. **Seeds of hairy indigo, a tropical legume cover crop, are dormant due to hard seed coats. Immersion of the seed in concentrated H_2SO_4 for 20 or 30 minutes or hot water at 70° to 80°C for 2 minutes, significantly increased the germination percentage and rate. H_2SO_4 was more effective than hot water. Redrying the seed after treatment improved the effectiveness of the treatments slightly.**

Hairy indigo is a native annual, frost sensitive leguminous plant of tropical Africa and Asia (5). There has been considerable interest in this species as a cover crop on vegetable land in southeastern U.S., especially in Florida, because it is rootknot nematode resistant and is a legume. Hairy indigo grows well on dry sandy soils without irrigation.

One major drawback to the increased usage of hairy indigo as a cover crop is that at least 60% of the seed are "hard." Consequently, stands are not uniform

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Table 1. Germination of hairy indigo seeds in Petri dishes at 25°C for 14 days after H_2SO_4 or hot water immersion for various periods of time.

Treatment	Duration (min)	Germination (%)	Growth rate index (GRI)
H_2SO_4	0	0 a[z]	--[y]
	1	1 a	0.4 a
	2	6 a	0.9 a
	5	35 b	4.4 b
	10	73 c	10.1 cd
	20	90 d	13.5 d
	30	86 d	12.7 d
Hot water			
Control	0	2.0 a	0.1 a
55°C	1	2.9 a	0.3 a
55°	2	2.0 a	0.5 ab
55°	5	4.5 a	0.6 ab
55°	10	15.8 ab	1.7 ab
55°	20	19.0 ab	1.8 ab
55°	30	30.0 ab	3.6 abc
80°	1	43.7 b	5.6 bc
80°	2	70.5 c	9.1 c
80°	5	35.7 b	3.0 ab
80°	10	5.3 ab	0.7 ab
80°	20	--[y]	--[y]
80°	30	--[y]	--[y]

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

[y]No germination.

Table 2. Effect of hot water treatment for 2 min at various temperatures on germination of hairy indigo at 25°C after 14 days.

Temperature (°C)	Germination (%)	GRI[y]
Control	2 a[z]	0.1 a
70	56 b	6.9 b
75	66 b	6.9 b
80	59 b	7.6 b
90	7	0.8 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

[y]Germination rate index (4).

Table 3. Germination after 14 days of hairy indigo seeds after immersion in hot water at 75°C for 2 min or H_2SO_4 for 20 min.

Seed	Control	Hot Water	H_2SO_4
	Germination (%)		
Not hard[z]	13.4	51.0	90.4
Hard	2.9	60.1	81.5
	**[y]	NS	**
Mean	7.3 a[x]	55.6 b	86.3 c
	Germination rate index (GRI)		
Not hard	1.7	6.3	12.3
Hard	0.2	7.6	10.9
	**	**	**
Mean	0.9 a	7.0 b	11.6 c

[z]Seed imbibed 24 hr, then classified as not hard (imbibed) or hard.

[y]**Significant at the 1% level.

[x]Mean separation in rows by Duncan's multiple range test, 5% level.

and, in many cases, it becomes a weed when vegetable species are planted after incorporation of the cover crop.

Many similar tropical legume species with hard seed dormancy have been investigated in order to find methods to improve germination. Phipps (3) increased germination percentages of *Stylosanthes gracilis* and *Centrosema pubescens* by freezing or immersing in boiling water. These treatments, however, were ineffective in promoting germination in *Pueraria kudzu* and *Phaseolus atropurpureus,* but concentrated H_2SO_4 increased their germination. Hanna (2) found that scarification improved germination of *Heschynomene americana.*

Percentage germination was not increased above the control in our previous experiments (unpublished) when hairy indigo seeds were primed in polyethylene glycol, KNO_3 or K_3PO_4; soaked in 95% ethanol for 2 to 30 minutes; or frozen at −20°C for 24 hr. Mechanical scarification did increased germination, but a high percentage of the resultant seedlings were abnormal. Thus, other methods such as immersion in H_2SO_4 and hot water were investigated.

Hairy indigo seeds were treated by various methods and the percentage and rate of germination were determined. Four replications of 50 seeds each were treated, then germinated at 25° for 14 days in Petri dishes. Germination rate index (GRI) was determined according to the methods of Schmueli and Goldberg (4). In the first experiment, seeds were heated in distilled water at 55° or 80°C for 0, 1, 2, 5, 10, 20, or 30 min, and placed in concentrated H_2SO_4 for 1, 2, 4, 10, 20 or 30 min. After treatment the seeds were washed, redryed, then germinated. In the second experiment, seeds were heated for 2 min in distilled water at 70°, 75°, 80°, and 90°, then handled as in experiment 1. In a 3rd experiment, seeds were imbibed at 25° for 24 hr, then separated into hard and not hard (normal) seed, redryed and placed in concentrated H_2SO_4 for 20 min, or hot distilled water at 75° for 2 min. The treated seeds and a control were washed and germinated as before. In the 4th and 5th experiments, seeds were treated with concentrated H_2SO_4 or hot water as in experiment 3, washed, and germinated or redryed for 1 and 7 days. In experiment 4 the seeds were germinated in Petri dishes at 28°, while in experiment 5 the seeds were planted in flats containing vermiculite and peatmoss (1:1) in the greenhouse. In the latter experiment, the temperature was 20° night and 30° day.

Immersion in H_2SO_4 for 5 to 30 min increased the germination percentage and rate of hairy indigo seeds (Table 1). A 20 or 30 min soak led to the highest germination percentages. The hot water treatment was generally ineffective at 55°C regardless of the duration of the soak. At 80° the germination percentage was significantly increased above all other hot water treatments when the seeds remained at the temperature for 2 minutes. Thus there appeared to be a rather strict temperature duration interaction. No germination occurred when seeds were left at 80° for 5 min or more.

Hot water treatments of 70°, 75°, and 80°C for 2 min improved germination percentage and rate of hairy indigo seeds over the control but were generally no different from one another (Table 2). At 90° the percentage germination was no different than the control. Most of the seeds of this treatment rotted after 14 days.

In order to determine the maximum effect of the treatment without a high risk of killing the seeds, the 20 min acid and 2 min 75°C hot water treatments were compared in laboratory and greenhouse tests. Hairy indigo seeds which were classified as "not hard" germinated more than "hard" seeds, but only 13.4% of the "not hard" germinated (Table 3). The H_2SO_4 treatment increased the rate of germination over 11 times that of the control, while the hot water treatment increased germination rate 7 times. This meant that water was rapidly taken up to initiate earlier germination in the treated seeds. Hot water improved germination regardless of the "hardness" of the seed. H_2SO_4 was more effective than hot water in increasing germination in both classes of seeds although the treatment was slightly more effective on "not hard" than "hard" seeds. The dormancy problem is clearly only solved after the seed coat structure has been sufficiently altered. This may explain why H_2SO_4 was more effective than the hot water treatment.

In Petri dishes, seeds which were redryed 1 day after treatment germinated slightly more than seeds which were not redryed after treatment or which were dryed and stored for 7 days (Table 4). The hot water and H_2SO_4 treatments were similar in effectiveness when averaged over all storage times except that germination rate was faster in H_2SO_4 treated seeds. When the seeds were germinated in the greenhouse, redrying and storage improved the germination of seeds which had been treated in hot water or H_2SO_4 (Table 5). The overall percentage germination resulting from the hot water and H_2SO_4 treatments were similar while germination rate was again improved more by H_2SO_4.

Soaking hairy indigo seeds for 20 min in H_2SO_4 or hot water for 2 min at 75°C significantly increased their germination percentage and rate. The H_2SO_4 treatment was generally more

Table 4. Effect of hot water (75°C for 2 min) and concentrated H_2SO_4 (20 min) seed treatments and storage time after treatment on germination of hairy indigo in a laboratory test.

Storage (days)	Control	Hot Water	H_2SO_4	Storage Mean
		Germination (%)		
0	15.0 a[z]	63.0 ab	64.0 a	46.2 ab
1	13.0 a	66.1 b	76.0 b	50.7 b
7	16.9 a	59.1 a	61.0 a	44.7 a
Mean	14.9 l[y]	62.7 m	67.3 m	
		Germination rate index (GRI)		
0	1.6 a	8.1 ab	8.7 a	6.1 a
1	1.7 a	8.6 b	10.3 b	6.9 b
7	2.0 a	7.9 a	8.5 a	6.1 a
Mean	1.8 l[y]	8.2 m	9.2 n	

[z]Mean separation in columns within groups by Duncan's multiple range test, 5% level.
[y]Mean separation in rows by Duncan's multiple range test, 5% level.

Table 5. Effect of hot water (75°C for 2 min) and concentrated H_2SO_4 (20 min) seed treatments and storage time after treatment on germination of hairy indigo seeds in a green house test.

Storage (days)	Control	Hot Water	H_2SO_4	Storage Mean
		Germination (%)		
0	6.6 a[z]	38.9 a	40.3 a	26.5 a
1	8.9 a	51.5 b	48.9 b	34.3 ab
7	3.4 a	51.5 b	63.6 c	35.3 b
Mean	6.1 l[y]	47.3 m	51.0 m	
		Germination rate index (GRI)		
0	0.7 a	4.4 a	4.9 a	3.3 a
1	0.9 a	5.9 b	6.0 a	4.3 a
7	0.5 a	5.7 ab	7.5 b	4.5 a
Mean	0.7 l	5.3 m	6.1 n	

[z]Mean separation in columns within groups by Duncan's multiple range test, 5% level.
[y]Mean separation in rows by Duncan's multiple range test, 5% level.

effective than hot water especially when germination rate was considered. Other researchers have found that hot water and H_2SO_4 treatments effectively overcome hard seed dormancy in legumes. Phipps (3) and Gray (1) found that boiling water for short periods of time overcame hard seed dormancy, while Phipps (3) also found that germination increased in some species in 55° water. In our experiments, temperatures <55° were ineffective and >80° killed hairy indigo seeds. The temperature and time of the hot water treatment must be fairly precise. Although H_2SO_4 soak was successful, strict safety precautions are necessary when using the acid, and it is expensive to treat large quantities of seed. Also, the seeds may be damaged by overheating in the acid or by acid penetrating the seed. Thus, it appears that hard seed dormancy in hairy indigo can be overcome effectively and safely by proper seed treatment.

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Effect of Style Removal on Fruit Set in Macadamia

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Abstract. **It takes over 48 hours after anthesis for the egg cell to be fertilized by the male gamete in macadamia (*Macadamia integrifolia* Maiden & Betcha). Fertilization occurs up to 4 days after anthesis.**

Nut set and yield are important problems wherever macadamia is grown (3). There are about 200-300 perfect flowers per raceme and a 15-year old tree can produce about 10,000 racemes during a season (7). An average mature tree yields about 45 kg of in-shell nuts during a season (1) or about 6,500 nuts. This is less than 1 nut/raceme or only 0.3% of over 2 million flowers produced on a tree.

Earlier studies on pollen germination (7) indicated that pollen begins to germinate after 24 hr on the style and that most pollen germinates with 48 hr. In this study we determined the time necessary for a pollen tube to grow down the style and into the ovule to provide the male gamete for fertilization.

The duration it takes for fertilization to occur is important since rain can easily wash the pollen away before pollen germination. A limited stigmatic area for the pollen to grow on also lessens the chances of fertilization (7). Other factors such as compatibility of existing cultivars (1, 7) and insect pollination (4, 6) affect nut set and yield. In regard to controlled pollination, macadamia flowers have a unique way of having the stigmatic area pushing through the anthers to assure abundance of pollen on the stigma.

We determined the time for the male gamete to fertilize the egg using the technique of Richardson and Currence developed in tomato (5). Racemes of four 12-year-old trees each of 'Ikaika', 'Kau' and 'Keaau' macadamia were tagged in the late afternoon about 14 hr before anthesis. The next morning all closed buds were stripped from the racemes and all open flowers retained – about 150-250 flowers per raceme.

Styles were left uncut or cut at 4-hr intervals after anthesis during a 48-hr period in the first trial. Only the control racemes with intact styles had nut set in the first trial. These results suggest that fertilization of the egg had not occurred, although the pollen grains when tested germinated during the 48-hr period after anthesis. Consequently, styles were cut 24, 48, 72, and 96 hr after anthesis in a second trial and after 48, 72, and 96 hr in a third trial using 5 racemes per tree for each time interval. Nut set data indicates that fertilization occurs between 48 and 72 hr after anthesis (Table 1). There was a significantly greater number of nuts set per raceme from flowers with intact styles as compared to flowers with styles decapitated after 96 hr. The number of nut set increased on 'Keaau' and 'Kau' with the number of days after anthesis. It is possible that disease could have infected the flowers more readily from physical damage to the style accounting for the low nut set.

The number of nut set per raceme was significantly greater with 'Ikaika' than the other cultivars for controls as well as for the treatment where styles were cut after 72 hr but not where styles were cut after 96 hr.

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