UBC Social, Ecological Economic Development Studies (SEEDS) Student Report

The Effectiveness of an Infra-red Weeder Applied at Varying Speeds and Time Intervals in Controlling Weeds at Two Sites on the UBC Campus

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Abstract

As part of the initiative by the UBC Campus Sustainability Office to reduce the use of herbicides in the UBC Campus, an infra-red weeder was tested to analyze its effectiveness as a herbicide alternative. An infra-red weeder is a tool which burns propane gas in order to generate infra-red heat, which is concentrated and controlled to kill weeds. The purpose of this experiment was to determine whether it is viable replacement for herbicides. Using 12 experimental plots at both the MacMillan building (cracks in between paving stones) and the Asian Centre (open gravel) at UBC, we treated them twice with the IR weeder, at speeds of 0.33 m/s or 0.16 m/s, and at either 15 minute, 3 day, or 1 week intervals between treatments. Observations were taken over the seven days after the final application, and used to generate survivorship charts for the different treatments. A clear percentage explaining the efficiency of the weeder could not be generated, but it was clear from the graphs that it was far more effective at the Asian Centre than MacMillan (probably because of the terrain), and that the slow treatment speed of 0.15 m/s was far more effective at killing the weeds than the fast was. Looking at both areas combined, the weed most susceptible to the treatment was the Mouse-Eared Chickweed (*Cerastium fontanum*) with an average death rate across all treatment plots of 44%. According to our findings the IR weeder does work well but would require areas to be treated approximately once a week to maintain results.

Introduction

Control of weedy plants is a multimillion dollar industry in North America and throughout the world. One of the most common methods used in weed control is herbicidal chemicals. Concern exists over the use of chemicals for a number of reasons such as health issues and ecological side effects both affect on non-target organisms and selection for herbicide-resistant species. Figure 1, below, shows the accumulation over time of species resistant to four classes of herbicides (Tranel and Wright 2002). This project was initiated by the UBC Campus Sustainability Office; the vision of the sustainability office is to promote campus initiative so as to “earn the respect of future generations for the ecological, social, and economic legacy we create" (SEEDS pamphlet, UBC Campus Sustainability Office). To this end the CSO has begun a series of projects to evaluate alternatives to herbicide use on campus. The purpose of this experiment is to test the efficacy of an Infra-Red (IR) weeder at controlling weeds as an alternative to pesticide use on the UBC campus.

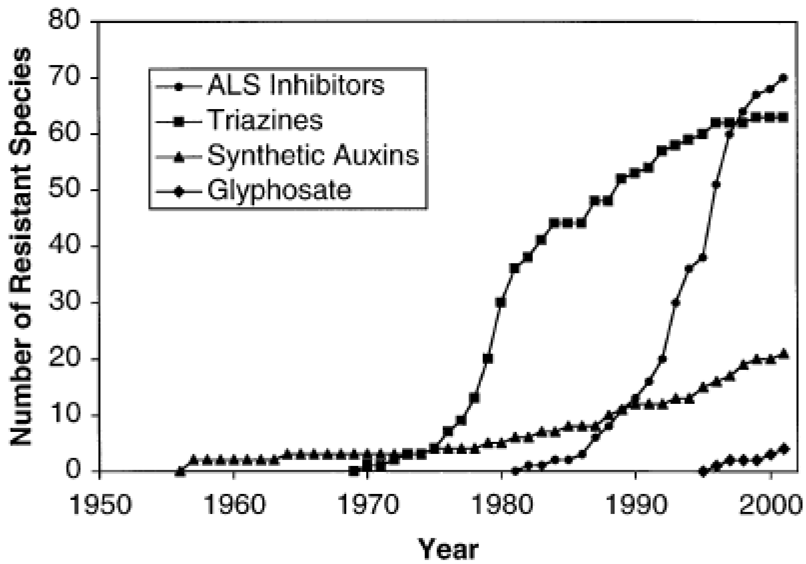

Figure 1. Global tally for the appearance of herbicide-resistant weed species for selected herbicides/herbicide groups. (From Tranel and Wright 2002)

The integrity of membranes is vital to all cell processes, high temperatures cause excess fluidity and can disrupt of hydrogen bonds and electrostatic interactions within membranes resulting in ion leakage, disruption of electron transport chains and loss of cellular integrity. The other important effect that the high temperatures is the denaturing of proteins, this in effect destroys the machinery of the cell so even if it survives the loss of membrane integrity the ability of the plant to repair itself or to continue day by day activity is greatly reduced if not destroyed (Taiz and Zeiger 2002). These types of damage occur at temperatures outside of the optimum for the plant but well below the temperatures produced by the IR weeder (~40-60°C). The IR weeder burns propane to heat ceramic tiles to temperatures as high as 1800° C (Forevergreen 2004); at this temperature the moisture in exposed cells evaporates and cells are ruptured, theoretically killing the plant.

Methods

Two sites were chosen for experimental plots, one located in the courtyard on the west side of the MacMillan building and one at the eastern entrance to the Asian Center. These two locations were chosen as they were deemed to be representative of conditions under which the IR weeder may be used by Plant Operations at the University. The MacMillan site is a courtyard with largely open western exposure, paved with large concrete slabs bordered with smaller bricks (see Figure 2a). This site was intended to test the effectiveness of the weeder at eliminating weeds in the cracks between paving stones. The Asian Center site is a sheltered site, bordered by large trees on the east, north and to some extent south sides, and the Asian Center itself on the west. The ground at this site is unpaved and covered with a thin layer of pea gravel (see Figure 2b). This site was chosen to provide a comparison of effectiveness of the weeder in different environments.

The treatments for this experiment were chosen to attempt to determine the optimum usage of the IR weeder and determine its level of effectiveness. The factors under consideration were frequency and intensity of treatment, as the temperature of the weeder was not easily controlled the speed at which the weeder was pushed was used as a measure of the intensity of the treatment. Two speeds and three frequencies of application were chosen; the applied treatments consisted of the six possible combinations of these factors. The two speeds used were 0.33 and 0.16 ms^{-1}; these speeds are a slow and very slow walking speed respectively. All plots received two applications at a given speed with one of, 15min, 4 days, or 7 days between treatments. These treatments were designed to representative of methods, which may be used in landscaping maintenance.

At each site 12 plots were chosen and randomly assigned one of the six possible treatments with two replicates of each per site. Due to differences in the sites the size and shape of the plots differed between them. At MacMillan the plots were limited to the areas between pavers and were simply straight sections 3 sets of pavers long (approximately 4.5m). At the Asian Center there were no limitations of the kind experienced at MacMillan and so rectangular plots 0.66m x 3m were used. Before beginning the experiment the weeds at each site were identified and the percent cover overall and by species was recorded.

Treatments were applied on March 12, March 16 and March 20; before beginning application the weeder was allowed to heat up for ten minutes to ensure that it was at full temperature for every treatment. Observations were taken one day, and three days after the second application to determine the overall health of the weeds on each plot. A more thorough set of observations was taken eight days after the second weeder application. Each species that was on the plot and initially identified was assessed and placed into three health categories: Healthy - no apparent signs of stress; Intermediate - showing obvious signs of stress (yellowing, wilt etc.) but still alive; Dead - very strong discolouration and wilt, showing no signs of growth or recovery (see Appendix 2). Percent covers were used rather than counts as the number of plants per plot was very large in many instances and because for some species such as *Poa annua* and *Stellaria media* distinguishing individuals was difficult.

Van der Waerden analysis of the treatments was used to determine if there was a difference in mean mortality between them. This non-parametric test was used because of a lack of normality in the data. Separate one-way analyses were done on speed and frequency (see Appendix 3).

A) B)

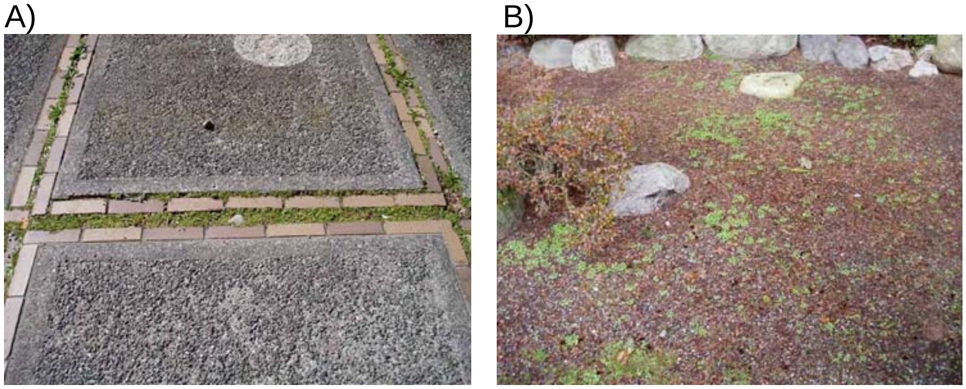

Figure 2: Typical growing environments at A) Macmillan and B)Asian Center

Species Name	Common Name	Abbreviation	Location
Poa Annua	Annual Blue Grass	ABG	B
Cerastium arvense	Mouse-Eared Chickweed	MCh	B
Stellaria media	Common Chickweed	CCh	AC
Lamium amplexicaule	Henbit, Dead nettle	Lam	M
Cardamine oligosperma	Cress	Car	AC
Capeslla bursa-pastoris	Shepherd's Purse	SP	B
Senecio vulgaris	Common Groundsel	Grn	M
Hypochaeris radicata	Spotted Cat's Ear	SCE	B
Sonchus arvensis	Sow Thistle	ST	B
Taraxacum officinale	Dandelion	Dan	M
Matricaria matricardioies	Pinapple Weed	PW	AC

Table 1: Species found in plots in the experimental sites (AC - Asian Center, M – MacMillan, B – Both)

Results

There were eleven species of weed and one moss found in the two experimental sites, five of them common between the sites (see Table 1). Appendix 1 shows the total percent cover and percent cover by species. The percent cover of the plots ranged from 30% -90% at the MacMillan site and from 10% - 70% at the Asian Center with averages of 55% and 32% respectively.

Figure 2 shows the average mortality of each of the six treatments, expressed in proportion of total weeds killed for the two sites. There was a marked difference in response between sites, with a significantly higher mortality seen at the Asian Center. As the sites differ greatly in their conditions this variation is not overly surprising. Because of the differences between the sites analysis of their respective results was done separately.

For both sites there was no significant difference in mean mortality between frequency treatments (P=0.84 for the Asian Center and P=0.81 for MacMillan). The Asian Center did not show a statistically significant difference in the means between speed treatments at a significance level of 0.05 but did at a significance level of S=0.10 (P=0.096). There was however more significant difference in mean mortality between speed treatment at MacMillan with P=0.0416. Due to the low sample number there is difficulty with Type II error but these results seem to be confirmed with a visual inspection of the data. Particularly for the Asian Center, but slightly less so at MacMillan there seems to be little difference in mortality between the three frequencies of application. A more consistent difference appears between the fast and slow treatments; at each frequency the slower application speed had a greater average mortality than did the fast treatment.

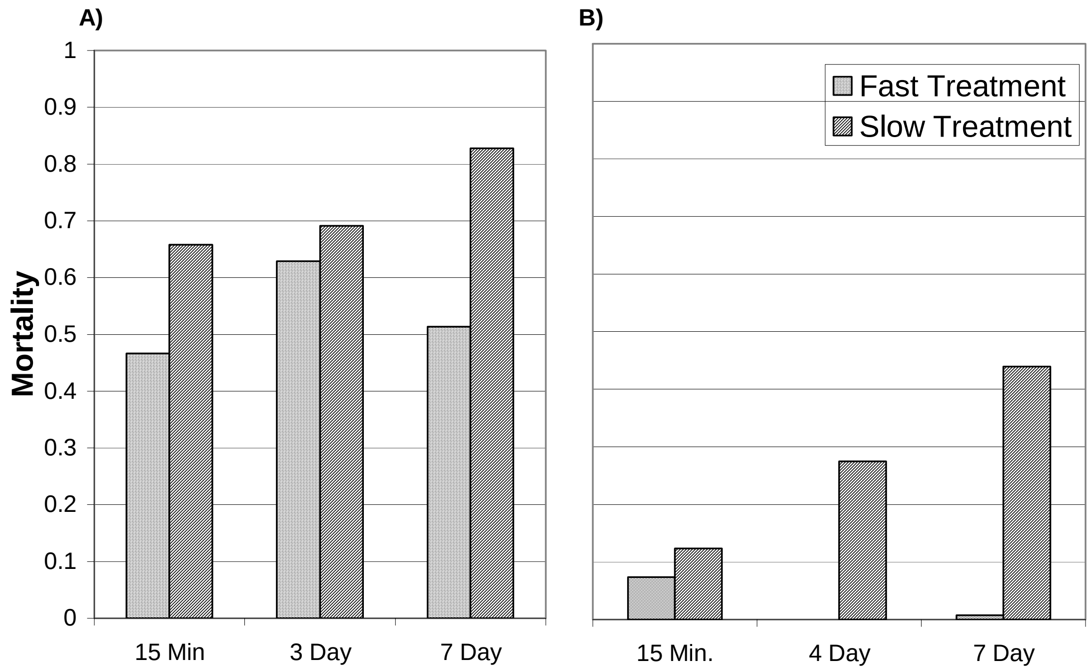

Figure 3: Mortality expressed in proportion of total weeds for the two speed treatments across the three frequencies for A) the Asian Center and B) MacMillan

In addition to differences in response between treatments there was also significant difference in the responses between species, Figure 4 shows the mortality rates of the more common species found at each site. The effect of the weeder varied drastically, showing little or no effect on the more robust, taprooted plants such as dandelion and spotted cat's ear, and average mortality near 100% for species such as mouse-eared and common chickweed and dead-nettle.

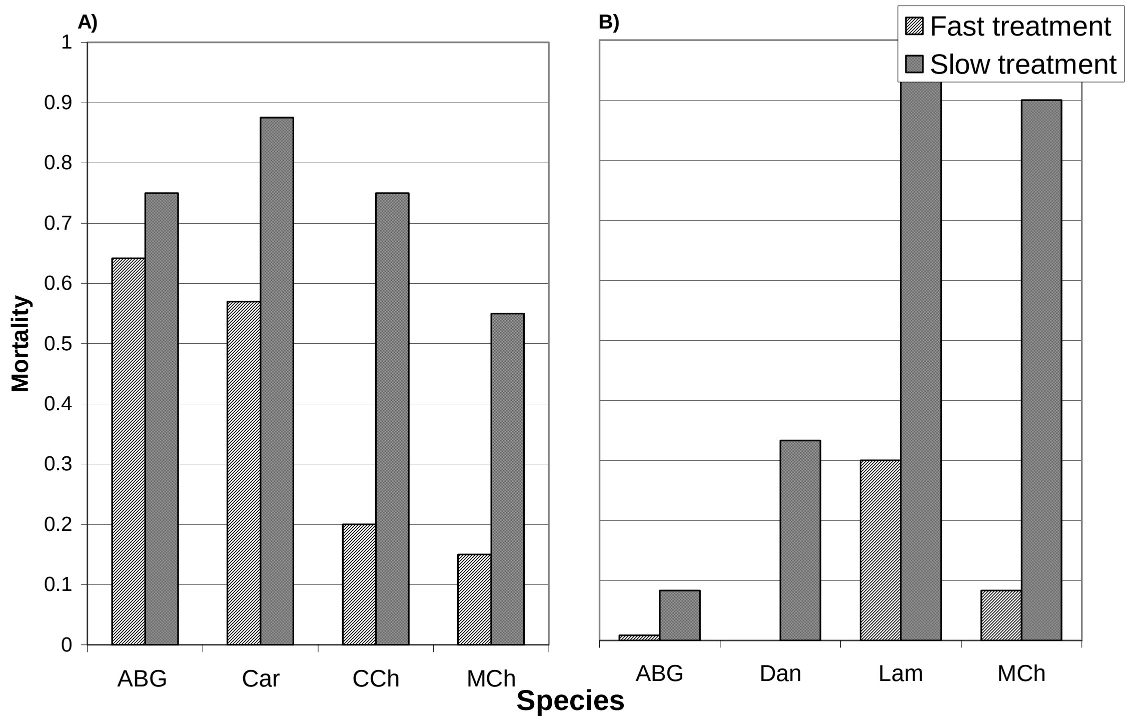

Figure 4: The effect of fast and slow treatments on common species at A) Asian Center, and B) MacMillan (ABG - Annual Blue Grass, DAN - Dandelion, Lam – Lamium, MCh- Mouse-eared Chickweed, CCh – Common Chickweed, Car – Cardamine)

Discussion

The IR weeder showed a very large range in its effectiveness, weeds killed in any given plot varying from nearly 0 to 93%. The effectiveness seemed to be determined in large part by three factors, growth setting, type of weed, and intensity of application. Immediately following weeder application signs of wilting and discolouration could be seen, these signs tended to be more pronounced at the four day point but within a week plants that were not killed showed signs of recovery. Some plants, particularly those with taproots did not show any sign of damage 8 days after treatment.

As can be seen from Figure 3 the effectiveness of the weeder varied greatly between MacMillan and the Asian Center. One reason for the difference may be variation in species composition between the two sites. This however does not fully explain the difference between the two sites largely because of the major discrepancy in the effect on *P. annua,* which is abundant at both sites but shows significant mortality only at the Asian Center site; also many species were common between the two sites. This discrepancy is one of the more interesting results of the experiment but cannot be conclusively resolved from this data, as there does not seem to be a trend in mortality difference that crosses all species. At the MacMillan site the weeds grow between paving bricks while at the Asian Center the weeds grow directly in the ground. It is seems likely that the bricks act as a physical barrier to heat produced by the weeder, sheltering the roots and preventing root damage. This would be critical in regrowth after damage to the aboveground portions and offers a possible explanation for the discrepancy in results between sites. Why this effect is stronger for the grass species and not others (see Figure 4) is not clear but it may be that root damage is not the determining factor in the mortality of other species while it is in the *P. annua*. Another possibility is that the root systems of some of the other annuals are more sensitive to heat damage and any level of damage is fatal.

One of the more dramatic, although not unexpected, results was the difference in response by different species. As can be seen in figure 4 and appendix 2 the effectiveness of the weeder varied greatly depending upon species. Shallow rooted species such as *P. annua, L. amplexicaule, S.media,* and *C. oligosperma* had high mortality, while taprooted species such as *T. officinale, H. radicata* and *C. bursa-pastoris* showed little or no mortality. This difference is undoubtedly due to the greater quantity of stored nutrients found in their large taproots. Plants with taproots are able to mobilize stored nutrients after being defoliated; allocating them to production of new shoots and leaves. This has primarily been demonstrated in alfalfa but would apply to other taprooted species. Boyce *et al*. (1992) showed that upon defoliation alfalfa (*Medicago sativa*) showed an increase in amylase activity in the roots, accompanied by a decrease in the quantity of starch. Storage material other than starch has also been shown to mobilize following defoliation. In *M. sativa* three proteins of 15, 19, and 35 kDa have been identified in the root system that act as storage molecules and undergo rapid mobilization following defoliation (Avice *et al*. 1996, Hendershot and Volenec, 1993).

One of the positive aspects of using the Infra Red Weeder is that only a few seconds of exposure is required to damage plants since the weeder reaches temperatures of $1800^{\circ c}$ which is hundreds of times greater than what would normally kill plants which under normal circumstances of extended exposure is approximately $45^{\circ c}$ (Taiz and Zeiger 2002; Forevergreen 2004). Some dry seeds are able to withstand temperatures up to $120^{\circ c}$ and also some plants can tolerate lethal temperatures if exposed to sub lethal levels of temperature; however, the Infra Red Weeder heats the ceramic plates several magnitudes greater than any plant or most living organism can tolerate (Taiz and Zeiger 2002). But once again due to the fact that the Infra Red Weeder is unable to destroy all portions of the plant because the root system may be beyond the proximity of application of the weeder. Therefore it was shown that over longer periods of time between treatments caused a higher mortality amongst roots which may be due to the fact that when the plants put in a greater amount of nutrients to repair the damaged tissues and transcribe more proteins in the process when the plant is hit again with the high heat treatment there becomes less and less amount of nutrients to draw from since the photosynthetic organs have been damaged to such critical conditions. Plants that were exposed to shorter time between treatments thus have not utilized as much reserve materials and therefore have more reserves left to regenerate the plant.

The other factor involved is the speed at which applications were utilized which yielded unsurprising results. The longer time taken to move the Infra Red Weeder over the plot meant that the weeds were exposed to greater period of lethal temperatures therefore from the results we can see that the slower treatments, especially at the Asian Center had relatively more weed mortality than the fast treatments which showed less distinction between sites and frequency of application.

Most of the weeds gave similar reactions to the Infra Red Weeder but the most striking reaction was found in the Common Chickweed, *Stellaria media*, which is a winter annual weed that grows to the height of turf or lawn grass with a shallow root system, all features that may contribute to the poor response after treatments (Virginia Tech 2004). Other larger weeds such as the Dandelion, *Taraxacum Officinale*, a perennial weed all responded by total recovery and this could be due to the growing year round in many cycles as compared to many of the annuals, which only have one cycle within the year. Dandelions also have a deep tap root that may become half an inch thick in diameter which will contribute to nutrient storage allowing greater chances of recovery as compared to other weeds such as the Chickweed which does not (Virginia Tech 2004). The annual Blue Grass surprisingly had recovered at the MacMillan site with 75-100% recovery but not as well at the Asian Center where most of the grass had been destroyed. This may be due to the environment because the roots may be protected in a way by the cement that had compacted and surrounded the roots whereas the roots in the Asian Center may have been more exposed since it is open grounds with only a thin layer of pebbles overtop.

The final conclusion seems that many weeds have recovered at MacMillan building while at the Asian Center most of the weeds had been eradicated. Slower treatments combined with longer time between treatments provided better results and it should be noted that smaller weeds such as the Common Chickweed and Lamium were more susceptible than larger weeds such as the Dandelions or Sow Thistles.

Conclusions

The primary goal of this experiment was to determine the conditions under which the IR weeder shows optimal performance. This experiment showed that the frequency of weeder use is less important than the intensity/speed of application. This has implications for more widespread use of the IR weeder by University Plant Operations and Botanical Gardens staff. This suggests that repeated application may not enhance the effectiveness against certain weeds provided that the weeder is pushed at an appropriate speed; this makes it a more feasible option than if many applications were required. It was also shown that while some the weeder may not provide effective control for some species it is a very effective option on certain weeds, specifically *S. media, L. amplexicaule, C. arvense,* and in some conditions *P. annua*.

This study provided valuable information on some of the methods which can be used to increase effectiveness of the IR weeder but there is still plenty of work required to properly quantify its effectiveness. This experiment took place during the spring and conditions were more or less ideal for regrowth of the plants, the temperature was moderate with some sunny days but the several days of rain kept the ground moisture and humidity high. An interesting study would be to test whether use of the weeder during the summer, when stress on the plants would be high, changes its effectiveness. Another issue worth considering is the long-term efficiency of the IR weeder at suppressing weeds by slowing their reproduction and through effects on the seed bank. Also of interest would be the number of treatments required to eliminate hardy taprooted plants.

The IR weeder has not shown itself to be as effective as current herbicides but it has shown that under certain circumstances it can drastically lower weed number. Perhaps further study will reveal applications that will be considered effective enough to offset any economic advantage of herbicide use. An important factor in this will be a change in attitude that allows us to accept a certain level of weeds in a landscaped setting.

Acknowledgments:

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Appendix 1: Percent cover at each site before experiment

MacMillan

Plot #	Total %	% Cover by Species		Plot #	Total %	% Cover by Species	
	Cover	Species	% Cover		Cover	Species	% Cover
1	90	ABG	30	6	30	ABG	30
		MCh	30				
		Lam	10			SP	1
		SCE	5			Dan	1
		Dan	5				
		ST	2	8	80	Moss	50
						MCh	10
2	75	ABG	50			Lam	10
		Car	10			ABG	5
		MCh	10			Dan	2
		Dan	2			Grn	1
		CP	2				
				9	35	ABG	35
3	30	Bras	15				
		ABG	10	10	35	MCh	5
		SCE	2			ABG	30
		MCh	1			Moss	30
		Lam	1	11	40	Lam	5
		Dan	1			ABG	35
4	40	ABG	40	12	70	Moss	30
						MCh	15
5	60	ABG	60			ABG	25
						Lam	<5

Asian Center

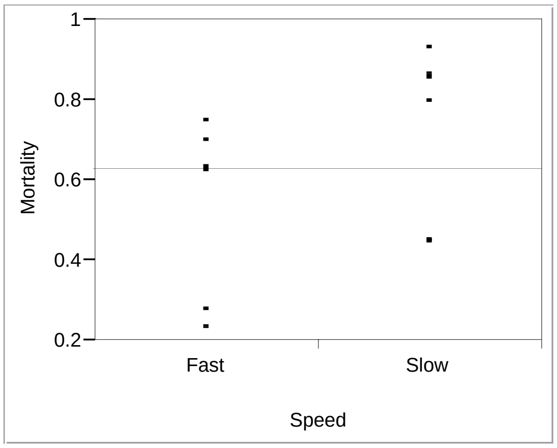
Plot #	Total % Cover	% Cover by Species: Species	% Cover	Plot #	Total % Cover	% Cover by Species: Species	% Cover
1	70	ABG	10	6	40	ABG	30
		SP	<1			MCh	7
		CCh	15			Car	3
		MCh	10				
		ST	<1	7	55	ABG	40
		SCE	<1			MCh	15
		PW	<1			Car	<1
						SP	<1
2	40	ABG	20				
		Car	10	8	25	MCh	15
		MCh	10			ABG	5
		ST	<1			SP	5
3	30	MCh	15	9	20	ABG	20
		ABG	10				
		CCh	5	10	30	ABG	30
		PW	<1				
				11	15	Car	5
4	30	Car	20			ABG	10
		ABG	5	12	10	ABG	5
		MCh	5			Car	5
5	25	Car	15				
		ABG	5				
		CCh	5				
		MCh	<1				

Appendix 3: Statistical Analysis

Analysis done using JMPin 4.0.4

Asian Center

Oneway Analysis of Mortality By Speed



Van der Waerden Test (Normal Quantiles)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Fast	6	-2.44615	-0.40769	-1.664
Slow	6	2.44615	0.40769	1.664

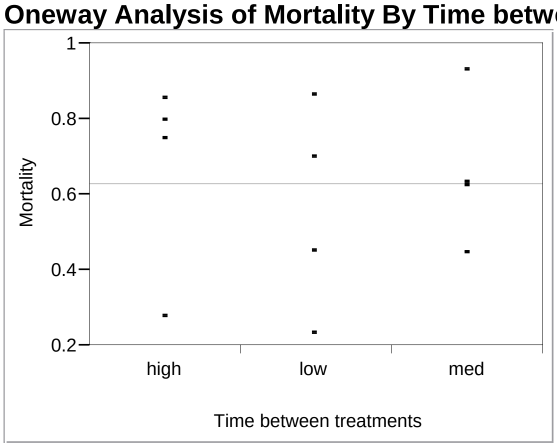
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
2.4461531	1.66351	0.0962

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.7673	1	0.0962

Oneway Analysis of Mortality By Time between treatments



Van der Waerden Test (Normal Quantiles)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
high	4	0.512023	0.12801	0.369
low	4	-0.811844	-0.20296	-0.586
med	4	0.299821	0.07496	0.216

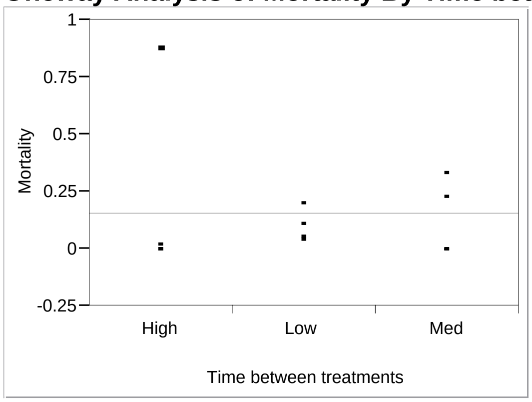
1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.3507	2	0.8392

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

MacMillan

Oneway Analysis of Mortality By Time between treatments



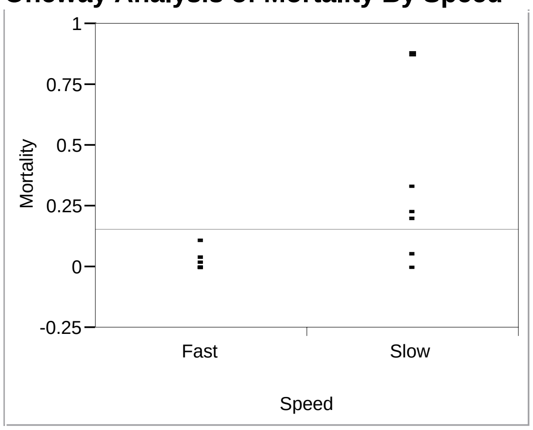
Van der Waerden Test (Normal Quantiles)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
High	4	-0.709740	-0.17743	-0.528
Low	4	0.795783	0.19895	0.592
Med	4	-0.086043	-0.02151	-0.064

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.4222	2	0.8097

Oneway Analysis of Mortality By Speed



Van der Waerden Test (Normal Quantiles)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Fast	6	-2.86021	-0.47670	-2.006
Slow	6	2.86021	0.47670	2.006

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
2.860212	2.00601	0.0449

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.0241	1	0.0449