CHAPTER 4

EPIDEMIOLOGICAL STUDIES OF CASHEW POWDERY MILDEW (*OIDIUM ANACARDII* NOACK) IN SOUTHERN MOZAMBIQUE

ABSTRACT

Regional and seasonal variations of climatic conditions are frequently reflected in differences of powdery mildew disease patterns over time. In this study, we evaluated the effect of climatic conditions on cashew powdery mildew (caused by *Oidium anacardii* Noack) progress on inflorescence tissue. The experiment was conducted at Ricatla Cashew Research Station (Maputo). Labelled shoots were assessed using a standard scale at seven day intervals from mid-July 1999 to August 2000 with interruption only during the non-flowering period. Meteorological data including air temperatures, relative humidity and dew points were collected from within the tree canopy using computer programmed sensors. Results showed that the powdery mildew epidemic progressed as a bi-modal epidemic; the first main epidemic built up from the end of June towards the end of September, while the second minor peak was reached in November. The onset of the epidemic did not start until the maximum average temperature was below 30°C and the average temperature equalled 20°C. Similarly, the prevailing average relative humidity had to be equal or above 80% and average dew point below 15.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) originated and dispersed from north-east Brazil (Lopes *et al.*, 1993; Milheiro & Evaristo, 1994; Ferrão, 1995). During the sixteenth century, the Portuguese disseminated the species throughout Africa and Asia, i.e. Mozambique, Tanzania and India, while Spanish sailors introduced cashew to Panama and Central America (Ferrão, 1995; Behrens, 1996). Today, cashew is cultivated throughout the tropical world at low altitude and commonly near the Atlantic and Indian oceans (Milheiro & Evaristo, 1994; Ferrão, 1995). Besides the importance of its status as earner of valued foreign exchange, cashew also provides employment, thereby stimulating the economy of developing countries particularly Asia, Africa and South and Central America (Rickson & Rickson, 1998). However, significant losses have been recorded in east Africa due to powdery mildew (*Oidium anacardii* Noack) (Castellani & Casulii, 1981; Milheiro & Evaristo, 1994; Nathaniels, 1996; Topper *et al.*, 2000).

In Mozambique, cashew powdery mildew remained negligible until the early 1970's (Milheiro & Evaristo, 1994), when its severity increased, causing a serious decline in production (Anon, 1999). It is suggested that climatic changes may have favoured dispersal and infection (Uaciquete, 1997). Inappropriate cultural practices motivated by difficulties in nut marketing, possible emergence of a new and virulent pathotype and the narrow genetic base of the present cashew populations are the major causes for the continuous recurrence of the disease (Milheiro & Evaristo, 1994; Prasad *et al.*, 2000).

Earlier studies (Shomari & Kennedy, 1998) demonstrated that *O. anacardii* conidial germination and cashew tissue infection by this pathogen occured over a wide range of temperature and humidity. Powdery mildew development is therefore influenced by environmental conditions that affect the viability of the pathogen (Shomari & Kennedy, 1999). In general, epidemic development is favoured by dry, cold conditions (Waller *et al.*, 1992; Milheiro & Evaristo, 1994).

Differences in weather conditions are common over time and between various cashew production areas (Nathaniels & Kennedy, 1996). Therefore, distinct patterns of epidemic development have been observed in different regions of Tanzania (Nathaniels *et al.*, 1993) and Mozambique (Nathaniels, 1994; Topper *et al.*, 2000). The above observations have led to the hypothesis that chemical applications for disease control would probably require more frequency in some regions than others as a consequence of climatic differences. In this context, the present study was aimed at understanding the progress of the disease on inflorescence tissue and its relationships with climatic parameters in the southern part of Mozambique.

MATERIALS AND METHODS

The experiment was conducted at Ricatla Cashew Research Station, 25 km north of Maputo, during the 1999/2000 and 2000/2001 crop seasons on 25-30 year old trees. The plantation was originally established by grafting for the purpose of germplasm preservation. Therefore, the trees selected represented various cloned land-types.

The methodology followed is essentially based on the work of Shomari and Kennedy (1999) but with an increased number of sampling points. Ten replicate plants were randomly selected within a block of 144 trees. Ten shoots per tree were labelled prior to the onset of growth. Thus, a total of 100 randomly distributed buds on both shady and sunny peripheral sides of the tree were targeted. Labelled shoots were assessed at seven-day intervals from mid July 1999 to August 2000 with interruption during the non-flowering periods.

At each assessment date, the severity of powdery mildew on panicles was evaluated using the cashew blossom scale of Nathaniels (1996). The scale assesses the percentage of diseased blossom components (florets and buds) out of the total number of florets and buds. It consists of a visual severity rating of 0-6; where 0 = no active disease, 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-99% and 6 = 100% diseased blossom (Appendix.1). The overall mildew score for a given observation date on a tree was calculated using the following procedure of Masawe *et al.* (1997): The median of the disease severity scale was: 0 (for 0%); 5.5 (for 1-10%); 18 (11-25%); 38 (26-50%); 63 (51-75%); 87 (76-99%) and 100 (100%). The frequency of panicles scored was tabulated showing the date of observation and scores on a 0-6 scale. The formula multiplied each median by the frequency of panicles scored in that scale, summed and divided by the total sample value (Masawe *et al.*, 1997).

Meteorological data included air temperature, relative humidity and dew point and were collected using sensor devices (model HOBO H8, RH/Temp.) obtained from Onset Computer Corporation, Massachusetts, USA. The sensors were placed at a height of 6 m within the tree canopy. They were protected from direct sunlight and rain through special metallic funnels (Michael *et al.*, 1996). The devices were computer programmed to record data at 15 min intervals in order to assess changes in the above parameters.

RESULTS

Detailed meteorological data including standard deviations are presented in Table 4.1. The pattern of disease severity during the late 1999/2000 season is given in Fig. 4.1a. The post-terminal stage of the epidemic in 1999 indicates that a decline in severity was observed from week 44 to the end of the flowering season (November, week 48). No data was recorded between week 48/1999 (end of flowering season) and week 23/2000 (beginning of new flowering season). The actual epidemic (Fig. 4.1b) progressed rapidly from June (week 25/2000) to August (week 30/2000), when 100% inflorescence florets and buds had been infected.

No direct relationship between powdery mildew severity and dew point could be made. However, weekly dew point equal to or below 15 appeared to be associated with the onset or high levels of disease severity, weeks 1 to 12 and 42 to 52 (Fig. 4.2a).

Weekly mean maximum temperatures above 30°C was associated with absence or decrease in disease severity in weeks 13 to 42 (Fig. 4.2b). The onset of the measured disease epidemic was not observed until the average temperature was around 20°C, at week 42 (Fig. 4.2b). There was no evidence of a direct relationship between any of the above climatic parameters and disease severity over the year.

Weekly average relative humidity decreased to levels below 80%. The end of the rainy season was associated with disease outbreaks or high severity levels during weeks 1 to 12 and 42 to 52 (Fig. 4.2b). No evidence of direct relationship between the relative humidity and disease severity could be detected.

DISCUSSION

The present data show that for the study period, the powdery mildew epidemic progressed in the southern part of Mozambique as a typical bi-modal epidemic. Towards the end of the crop season, i.e., November, 1999, a sharp severity decline was observed due to lack green florets on the panicle. Therefore when new flowers emerged from the same panicle under observation, then powdery mildew pathogen activity restarted. This abnormality is probably a response of the tree to the severe attack of the pathogen on the first set of florets. The first main epidemic built up from the end of June towards the end of September. The second minor peak was reached in November, after which it declined until the following season. Our findings are similar with previous studies (Nathaniels *et al.*, 1993) at Naliendele, Tanzania, where the disease appeared for the first time on flowers around the first week of July. The intensity reached almost 100% by mid-August. These authors also found that terminal flower disease was lower (75-80%) than during the first flowering flush. It is noted from our findings that symptoms of powdery mildew occur on panicles up to November. This period coincides with that registered for the emergence of panicles in the southern part of Mozambique (Fig. 2.1 Chapter 2) (Milheiro & Evaristo, 1994). Therefore, the results suggest that late decline of the disease is related to limited availability of susceptible tissue. Higher prevalence of the disease in the south is probably related to a longer period of availability of susceptible tissues.

Our results further showed that the onset of cashew powdery mildew epidemic does not start until conditions of a mean maximum temperature below 30°C, prevailing mean maximum relative humidity above 80% and mean maximum dew point below 15 are reached. Castellani and Casulii (1981) reported conidial germination at a RH ranging between 88 and 100% with an optimum around 95%. Nathaniels *et al.* (1993) stated that exposure to low humidity may rapidly reduce viability through shrivelling and loss of conidial turgidity. However, cashew powdery mildew conidia were demonstrated to germinate under humidity conditions from 20 to 100% (Shomari & Kennedy, 1998). Therefore it is likely that in our observations, disease epidemic onset may have been trigged by the levels of maximum temperature combined with maximum dew point rather than by the changes in levels of minimum and maximum relative humidity. During our study, the average relative humidity prevailed between 60 and 80% throughout the year. This encompasses what is reported for Mozambique (73 to 79%) (Milheiro & Evaristo, 1994). The wide interval observed may be explained by the occurrence of abnormally high rainfall (floods) during the study period.

Previous observations on inoculated shoots showed that at 15 or 35°C, mildew development does not occur (Shomari & Kennedy, 1998). In addition, a decline in the rate of conidial germination below 20°C and above 35°C or no germination at all below 10 or above 40°C, has been reported (Nathaniels *et al.*, 1993). Furthermore, Gupta (1988) studying mango powdery mildew (*Oidium mangiferae* Berth.) reported no infection at 10 and 35°C, but that infection could take place even at relative humidities as low as 15%. Therefore, it can be concluded that maximum and minimum temperatures are the key parameters that restrict powdery mildew epidemic development. Similar observations were made by Xu and Butt (1998), who studied the effect of temperature and atmospheric moisture on early growth of apple powdery mildew caused by *Podosphaera leucotricha* Ell. & Everh.

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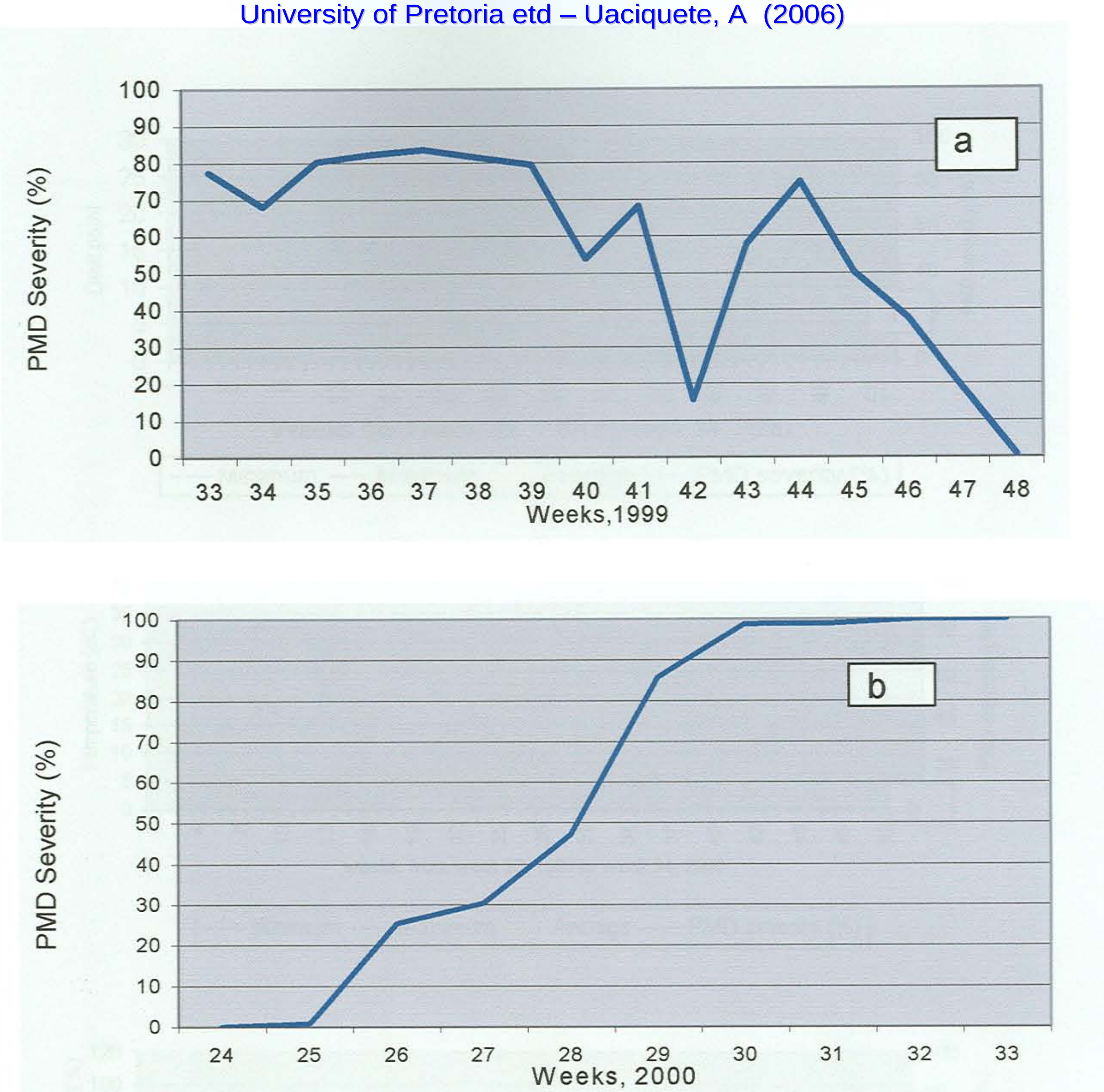

Figure 4.1 Progress of powdery mildew disease (PMD) development on cashew (*Anacardium occidentale* L.) flowers at Ricatla research station from a) August to November, 1999 and b) from June to August 2000, over two consecutive crop seasons.

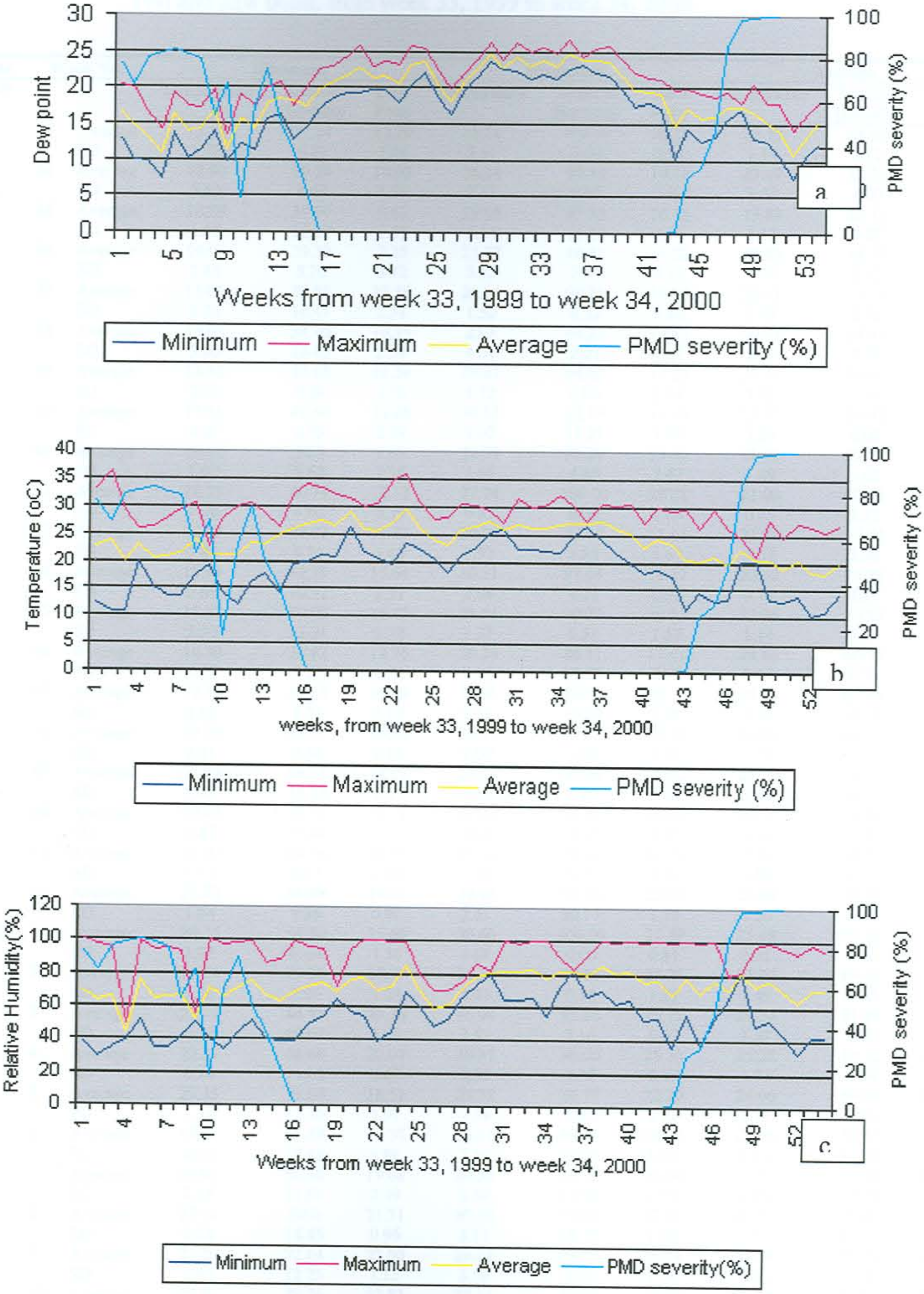

Figure 4.2 Progress of powdery mildew disease (PMD) development on cashew flowers at Ricatla Research station during the 1999/2000 and 2000/2001 crop seasons, in relation to various climatic parameters at mean minimum, average and maximum levels: (a) Dew point; (b) Temperature and (c) Relative humidity.

Table 4.1 Weekly average and standard deviation (SD) for temperature (°C), relative humidity (%) and dew point, from week 33, 1999 to week 34, 2000

Year	Week No.		Minimum			Maximum			Average		
1999			Temperature	Relative Humidity	Dew Point	Temperature	Relative Humidity	Dew Point	Temperature	Relative Humidity	Dew Point
	33	Average	12.37	37.74	12.70	33.21	100.00	20.20	22.79	68.87	16.45
		SD	1.27	6.23	1.08	2.51	0.00	0.95	1.17	3.12	0.89
	34	Average	10.80	29.24	10.02	36.14	97.49	19.75	23.47	63.36	14.89
		SD	3.42	4.42	1.29	1.11	6.65	0.90	1.50	4.00	0.58
	35	Average	10.59	34.96	9.61	29.08	95.33	16.55	19.84	65.14	13.08
		SD	1.85	10.19	1.58	6.14	11.80	2.90	3.12	8.87	1.30
	36	Average	19.92	39.39	7.25	25.87	48.81	14.22	22.89	44.10	10.73
		SD	1.88	5.70	3.72	3.15	7.94	4.15	1.78	6.12	3.16
	37	Average	15.01	50.91	13.58	26.24	99.76	19.22	20.63	75.29	16.40
		SD	1.75	10.41	2.71	1.50	0.52	0.98	1.49	5.32	1.71
	38	Average	13.62	34.90	10.23	27.7	94.33	17.53	20.75	64.61	13.88
		SD	3.10	10.88	3.39	4.04	7.21	1.67	3.29	7.74	2.42
	39	Average	13.42	35.43	11.24	29.31	94.63	17.25	21.37	65.03	14.25
		SD	2.01	9.89	1.16	5.72	6.06	2.14	3.62	6.66	1.37
	40	Average	17.41	41.66	13.98	30.53	92.19	19.60	23.97	66.92	16.79
		SD	4.37	9.75	2.39	3.02	11.21	1.70	3.24	6.08	1.96
	41	Average	19.21	50.3	9.69	22.59	55.29	13.40	21.02	52.14	11.47
		SD	1.60	3.62	2.28	1.66	4.40	2.47	1.49	3.62	2.18
	42	Average	14.25	40.74	12.13	27.74	100.00	19.02	21.00	70.37	15.58
		SD	1.06	4.60	2.39	0.93	0.00	1.04	0.75	2.13	1.33
	43	Average	12.07	34.07	11.33	29.96	97.60	17.43	21.02	65.84	14.38
		SD	3.84	6.76	1.48	3.97	4.88	1.67	2.57	2.38	1.41
	44	Average	15.93	43.79	15.64	30.51	97.64	19.87	23.22	70.71	17.75
		SD	2.60	10.92	2.31	2.64	4.28	0.97	0.73	4.87	1.45
	45	Average	17.57	50.99	16.42	28.54	99.70	20.83	23.06	75.34	18.63
		SD	2.99	13.21	1.77	1.37	0.51	1.53	1.14	6.09	1.85
	46	Average	14.30	39.82	12.76	26.24	86.11	17.41	24.86	66.73	18.12
		SD	5.19	9.95	1.30	4.54	21.56	2.07	2.14	8.79	1.08
	47	Average	19.54	39.23	14.63	31.98	88.06	20.17	25.76	63.64	17.40
		SD	2.99	9.73	3.22	5.51	19.09	3.86	3.33	13.09	3.06
	48	Average	19.70	39.07	16.90	33.91	99.31	22.58	26.80	69.19	19.74
		SD	2.21	7.64	2.13	2.00	1.32	1.19	1.72	3.46	1.57
	49	Average	21.06	48.71	18.61	33.53	95.80	23.02	27.30	72.26	20.81
		SD	0.88	15.23	2.41	4.50	5.20	1.41	2.52	9.37	1.74
	50	Average	20.68	53.73	19.11	32.00	95.29	24.23	26.34	74.51	21.67
		SD	2.47	11.04	1.56	3.63	11.18	1.17	2.54	7.06	1.01
	51	Average	26.07	64.16	19.09	31.42	72.33	25.78	28.83	69.22	22.74
		SD	1.15	6.17	2.50	1.43	3.39	1.54	0.80	4.25	1.41
	52	Average	21.82	56.89	19.61	29.93	95.10	23.03	25.88	75.99	21.32
		SD	1.64	6.36	0.92	2.51	10.17	1.75	1.30	3.41	1.24
2000	1	Average	20.35	54.80	19.66	30.60	100.00	23.59	25.48	77.40	21.62
		SD	1.27	6. 64	1.56	1.01	0.00	0.81	0.91	3.32	1.07
	2	Average	19.64	39.21	17.77	34.75	99.86	23.25	27.20	69.54	20.51
		SD	1.96	7.96	1.24	3.53	0.35	1.21	2.49	4.05	1.04
	3	Average	23.19	44.91	20.36	35.94	98.86	25.77	29.57	71.89	23.06
		SD	0.72	10.67	1.39	2.82	2.10	0.69	1.57	5.00	0.68
	4	Average	22.37	68.46	22.07	30.87	99.00	25.30	26.28	84.72	23.58
		SD	0.76	11.03	0.67	3.00	2.14	0.60	1.77	5.54	0.61
	5	Average	20.35	59.60	18.51	27.77	79.77	22.20	24.06	69.69	20.36
		SD	1.41	12.30	1.97	2.58	6.88	2.23	1.81	8.75	1.98
	6	Average	18.01	47.53	16.30	28.11	69.60	19375	23.06	58.56	18.03
		SD	0.70	12.43	1.96	2.79	12.33	1.07	1.51	11.55	1.25
	7	Average	20.95	52.30	19.68	30.50	69.37	22.04	25.73	60.84	20.86
		SD	2.15	11.84	2.49	2.30	15.89	2.33	1.49	13.35	2.38
	8	Average	22.64	66.0	21.31	30.18	75.60	23.86	26.41	70.80	22.58
		SD	0.28	18.85	0.96	3.17	15.70	1.06	1.56	17.23	0.95
	9	Average	25.29	72.64	23.50	29.27	86.59	26.14	27.24	78.33	24.74
		SD	1.80	12.25	1.12	3.50	8.93	2.06	2.00	8.60	0.66
	10	Average	25.91	79.36	22.52	27.14	82.33	23.87	25.96	80.58	22.64
		SD	1.91	3.79	2.12	1.97	3.72	2.38	1.91	3.64	2.20
	11	Average	22.26	64.71	22.26	31.58	100.00	26.35	26.92	82.36	24.31
		SD	1.10	8.58	1.27	3.34	0.00	1.49	2.14	4.29	1.36
	12	Average	22.37	64.11	21.14	29.98	98.70	24.90	26.17	81.41	23.02
		SD	1.25	7.60	1.96	1.81	2.83	1.76	1.41	4.85	1.81
	13	Average	22.20	65.94	21.90	30.26	100.00	25.64	26.23	82.97	23.77
		SD	0.81	6.98	0.64	1.06	0.00	0.75	0.67	3.49	0.63

14	Average	21.77	55.01	21.27	31.99	100.00	24.66	26.88	77.51	22.96
	SD	0.56	4.04	0.60	0.74	0.00	0.61	0.47	2.02	0.50
15	Average	24.59	72.16	22.54	30.10	90.51	26.61	27.19	82.09	24.69
	SD	3.00	8.30	0.79	2.53	10.98	2.00	2.17	5.87	1.02
16	Average	26.45	81.43	23.20	27.46	82.81	24.28	27.03	81.90	23.76
	SD	0.75	2.00	0.46	0.85	1.80	0.46	0.78	1.88	0.44
17	Average	23.91	66.57	22.12	30.67	91.79	25.45	27.29	79.18	23.79
	SD	1.77	12.86	0.68	3.91	9.50	2.50	1.25	3.56	1.34
18	Average	21.88	69.83	21.55	30.28	100.00	25.80	26.08	84.91	23.68
	SD	0.91	10.53	1.24	2.59	0.00	1.08	1.57	5.26	0.81
19	Average	19.86	61.96	19.53	30.53	99.47	23.90	25.19	80.71	21.72
	SD	0.83	14.54	0.73	3.33	1.29	0.95	1.68	7.36	0.55
20	Average	18.01	64.10	17.45	27.20	100.00	22.01	22.61	82.05	19.73
	SD	1.57	11.72	2.30	5.24	0.00	2.63	3.26	5.86	2.14
21	Average	18.72	52.61	17.94	29.97	99.69	21.42	24.23	75.63	19.39
	SD	1.54	4.93	1.65	1.61	0.50	1.86	1.37	2.45	1.70
22	Average	17.36	53.06	17.27	29.28	100.00	21.19	23.25	76.51	19.14
	SD	1.22	2.63	0.99	1.00	0.00	0.71	0.83	1.31	0.62
23	Average	11.42	36.16	10.16	29.74	99.11	19.55	20.58	67.64	14.85
	SD	2.13	9.99	1.67	3.53	2.17	5.12	1.57	5.12	2.74
24	Average	14.36	55.69	14.44	26.25	99.83	19.83	20.30	77.76	17.14
	SD	1.02	10.26	0.92	2.37	0.42	1.20	0.91	5.01	0.58
25	Average	13.04	38.21	12.55	29.46	98.93	19.25	21.25	68.57	15.90
	SD	1.83	10.49	1.42	1.64	2.14	1.87	1.36	5.33	1.46
26	Average	13.26	52.94	13.33	26.08	99.83	18.85	19.67	76.39	16.09
	SD	1.74	12.90	1.37	2.41	0.42	0.47	1.24	6.40	0.48
27	Average	20.02	65.70	15.72	24.45	79.41	19.43	22.35	71.34	17.47
	SD	3.22	14.88	2.08	3.95	9.16	2.84	2.12	8.41	0.99
28	Average	20.14	80.24	16.98	21.00	81.31	17.95	20.57	80.78	17.47
	SD	0.13	0.55	0.21	0.13	0.51	0.21	0.10	0.45	0.16
29	Average	13.07	48.77	12.93	27.57	97.44	20.54	20.32	73.11	16.74
	SD	3.73	14.51	2.48	4.86	6.26	5.49	1.77	4.93	2.50
30	Average	12.98	52.10	12.63	24.68	99.66	17.93	18.83	75.88	15.28
	SD	1.54	8.82	0.81	0.57	0.54	0.87	0.88	4.46	0.51
31	Average	13.81	43.71	10.50	26.98	93.51	17.93	20.40	70.11	14.21
	SD	3.97	15.34	6.95	2.65	7.46	3.79	2.95	10.24	5.02
32	Average	10.31	32.77	7.42	26.37	92.80	14.15	18.34	62.79	10.78
	SD	1.74	12.69	2.46	2.98	9.39	3.39	1.91	9.65	2.48
33	Average	10.98	43.01	10.75	25.46	98.01	16.56	18.05	70.99	13.38
	SD	1.94	8.00	1.01	1.92	3.51	1.58	1.60	4.63	0.99
34	Average	14.46	43.09	12.40	26.74	94.31	18.16	20.12	70.83	15.38
	SD	3.36	10.13	2.10	1.44	13.44	1.58	1.54	7.06	1.39