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Full Length Research Paper

Effect of length of pre-harvest drying-off period during the cool season on soil moisture content and cane quality of sugarcane cultivars at Metahara Sugar Estate

[1]Abiy Getaneh and [2]Tadesse Negi

Sugarcane Agronomist, Sugar Corporation, Research and Training, P.O.Box-15, Wonji, Ethiopia.

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An investigation was undertaken on clay soils in cool season (November – January) of two crop years at Metahara Sugar Estate to study the relationship of length of pre-harvest drying-off period with cane quality parameters. The experiment was laid out in split plot design with four replications. The main plot factor was sugarcane varieties, namely 'B52298', 'B41227', 'NCo376' and 'NCo334' which were evaluated by subjecting them to eight length of drying-off periods (sub-plot). The result of the study in both years showed that drying off period treatment resulted in gradual decline in soil moisture percentage. In crop year 1 better estimate recoverable sugar (ERS) were obtained for soil moisture between 24-28% which observed within 5 to 9 weeks drying off period treatment. In crop year 2, soil moisture was initially very low and the rainfall shower improved juice quality as it relieved the crop from being drastically harmed by extended moisture stress. When rainfall occurred after the cane is subjected to moisture stress, proper monitoring of soil moisture status is recommended to decide when to harvest the crop. Generally, the result of the study in both years indicates that drying off treatment exerted its effect on cane quality through its influence on soil moisture status, which in turn is dictated by soil moisture regime and prevailing weather condition in each year. Thus, to attain high cane quality, it is essential to precisely determine soil moisture status during pre-harvest drying off treatment.

Key words: Drying-off, juice quality, recoverable sugar, soil moisture, sugarcane.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of those crops which are seriously affected in quality by lesser moisture stress and growing sugarcane out of proportion to water availability exposes the crop to drought effect (Humbert, 1983). Moisture demand of the cane plant varies depending on its growth stage (Chapman, 1996,); it is smaller at early stage and higher in grand growth period, the stage at which growth occurs at a very rapid rate. As the cane approaches maturity, however, moisture stress becomes very essential for proper ripening of the crop. According to Yang et, al. (1999), higher irrigation water application during ripening period lowers the percentage of recoverable sugar in the cane since juice quality is associated with moisture content of the cane. Thus, in areas where sugarcane is cultivated under irrigation, ripening is induced by withholding water prior to harvest (Blackburn, 1984) and forced ripening through moisture stress has been credited with increased sugar recovery (Humbert, 1983).

Sugarcane ripening through moisture stress is easily regulated by extending the irrigation interval and lowering the amount of water applied to the crop, taking into consideration the age and condition of the crop. By decreasing moisture content of the stalks, dehydration forces conversion of reducing sugars to sucrose (Alex, 1973). According to Humbert (1983), progressively inducing gradual soil moisture stress in a planned way helps in better and earlier ripening of cane due to the effect of moderate drought which subdues the activities of

*Corresponding author. E-mail: abiygz@yahoo.com

the cells and substantially retards vegetative growth, and the sugar will be stored rather than being used for further vegetative growth (Alex, 1973).

Blackburn (1984) described that drying for harvest is easily accomplished on deep soils of good moisture holding capacity by simply discontinuing irrigation for some weeks (typically six weeks) prior to harvest. On unsuitable (shallow) soils drying off may introduce serious problems, as the leaf canopy may excessively be damaged or, in extreme cases, the whole plant may be killed. Extraction of juice from stalks exposed to too drastic moisture stress (drying off) is difficult (Kakde, 1985). Severity of stress could therefore be linked to the change in relative stalk dry mass (RSDM). Thus, it would be expected that as stress becomes more severe the stressed cane would reflect a decreasing amount of dry mass compared with that produced by the well-irrigated cane. The analysis of the combined South African, Zimbabwe and Australian data showed that sucrose yields are either increased or unchanged when RSDM is reduced to 96% (Robertson et al., 1999). Further stress after maturity also deteriorates the cane rapidly through protein hydrolysis. In severe cases, the deficit increases fibre and bagasse percentage as well as various intermediate products of metabolism through protein and carbohydrate hydrolysis. These increase the non-sugar compounds like pentosans, amides, amino acids and other nitrogenous substances in the cane juice, whose clarification becomes difficult at the clarification plant (Kakde, 1985).

To minimize loss of cane yield and juice quality due to exposure to severe drought, or due to harvesting of wet fields, proper scheduling of pre-harvest drying off is very essential. In fact optimum length of the pre harvest drying off period should be determined experimentally under a given set of environmental conditions.

Even though at Metahara Sugar Estate the length of pre-harvest drying off period varies from 6 to 8 weeks the optimum has not been determined through investigation in different seasons. Hence, the objective of this study was to study the relationship of length of drying off period on cane juice quality parameters in cool season at Metahara Sugar Estate.

MATERIALS AND METHODS

The study was conducted at Metahara Sugar Estate which is situated at 8^{o}53 N' & 39^{o}52' E with an elevation of 950 m.a.s.l. in the Rift Valley Region of Ethiopia about 200 km South East of Addis Ababa. It receives an annual rainfall of 554 mm, with a mean maximum and minimum temperature of 32.6 and 17.4 ^{o}C, respectively.

Drying off test was conducted in cool season for two years; in crop year-1 the drying off treatment started on November 22, 2001 and ended on January 10, 2002 while crop year-2 the treatment started on November 24, 2003 and continued up to January 10, 2004. In the study only plant cane crop was considered. The experiment was laid out in split plot design with four replications. The four sugarcane varieties through, 'NCo334', 'B41227', 'B52298' and 'NCo376' were assigned to the main plot while to the subplots drying off period treatment (Table 1). Varieties were selected based on their area coverage at the estate. The soils type of the fields selected for the experiment was clay in texture (Appendix 1). The size of each plots were 8 rows of 8 m length. The path between the replication and between varieties was 3 m and 2m, respectively.

The experimental fields were planted and managed following the standard cultural practices being followed at the Estate. At the age of 17 months after planting, the cane was subjected to eight different length of drying off periods (4, 5, 6, 7, 8, 9, 10, and 11 weeks).

Parameters measured were soil moisture percent at the end of each drying off period from each sampling plot from 0 - 30 and 30 - 60 cm depth following the gravimetric method. From 10 randomly collected stalks per each experimental plot, mean stalk weight, Pol % cane, °Brix, estimate recoverable sugar (ERS) were determined. Meteorological data during the study period were obtained from Metahara Sugar Estate meteorological station.

The collected data were subjected to General Linear Models Procedure (GLM) using SAS software statistical package (SAS, 1989) following a procedure appropriate to the design of the experiment (Gomez and Gomez, 1984). The treatment means that were significantly different were separated using the Duncan Multiple Rang Test (DMRT) at 5% levels of significance.

RESULTS AND DISCUSSION

The combined statistical analysis over the crop years showed significant differences for all parameters under consideration. Thus, the data were analysed separately for each crop year.

Effect of drying-off on soil moisture

Figure 1 and 2 shows the relationship between drying-off periods and soil moisture content in two crop years. In crop year 1, at both 30 and 60cm soil depths, soil moisture content at the fourth week after withholding irrigation was higher and then a sharp decline was observed till the sixth week. Thereafter, constant soil moisture percent were observed between sixth and ninth weeks after withholding irrigation. Furthermore, a sharp decline from ninth weeks onwards was observed. This could be attributed to moisture loss due to evapo-transpiration since there was no replenishment of soil moi-

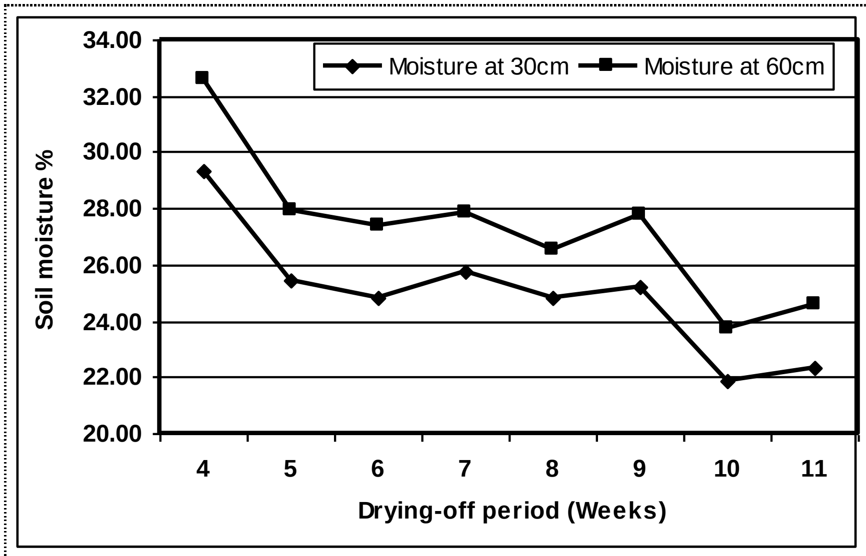

Figure 1. Relationship between drying-off period and soil moisture content (%) in crop year -1 (Nov, 2001 – Jan, 2002) at Metahara Sugar Estate.

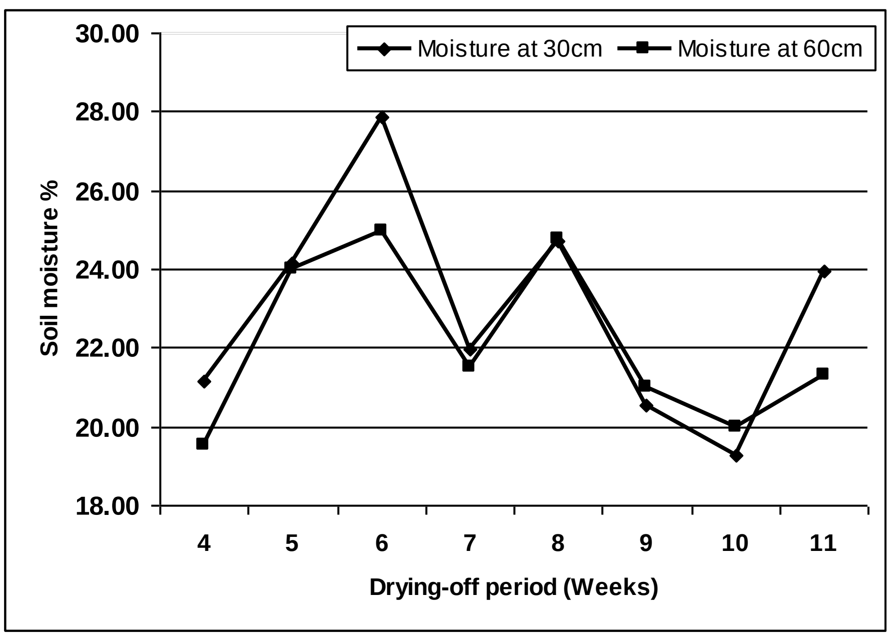

Figure 2. Relationship between drying-off period and soil moisture content (%) in crop year-2 (Nov, 2003 – Jan, 2004) at Metahara Sugar Estate.

sture in the form of irrigation or rainfall. The effect was relatively more pronounced on the upper 30cm depth than at 60cm since this soil layer is more influenced by weather conditions; and it is also the region where major concentration of the absorbing roots are situated and thus moisture is subjected to depletion for physiological function of the cane plants. In crop year 2, the initial soil moisture content at fourth week after withholding irrigation was lower as compared to crop year 1. However, due to rainfall occurrences during the 6^{th}, 8^{th} and 10^{th} weeks of moisture stress, which was about 14.3, 29.6, 15.5 mm, respectively (Appendix 2), soil moisture percent at both depths, that is, at 30cm and 60cm were observed to rise on the corresponding dates. This reveals that moisture content under irrigated condition could be affected by rainfall and the expected soil moisture status

Table 2. Effect of variety and drying off periods on soil moisture content and sugarcane stalk weight and juice quality parameters during 1st crop year (Nov, 2001 – Jan, 2002).

Treatment	°Brix	Pol (%)	ERS (%)	SW (kg/stalk)
Variety (V)				
B52298	21.49a	19.41b	13.48c	1.90a
B41227	20.51c	19.22b	13.71bc	1.95a
NCo376	20.94b	19.61ab	14.01ab	1.31c
NCo334	21.30a	19.93a	14.23a	1.51b
Dryoff Period (D)				
4 weeks	21.00bcd	19.48bc	13.92ab	1.89a
5 "	21.49ab	19.99ab	14.31a	1.76ab
6 "	21.68a	20.12a	14.38a	1.70bc
7 "	21.03bcd	19.70abc	13.70abc	1.59bc
8 "	21.25abc	19.91ab	13.95ab	1.65bc
9 "	20.85cd	19.44bc	13.73bc	1.54c
10 "	20.57d	18.95c	13.27c	1.60bc
11 "	20.60d	19.15c	13.63bc	1.59bc
V * D	ns	ns	ns	**
CV (%)	3.1	4.1	5.4	10.8

Means with the same letter within a column are not significantly different from each other by DMRT ($P < 0.05$)

may not be perfectly attained at the desired time during drying-off treatment, that is, the benefit from drying-off period depends on the prevailing weather condition (Figure 2).

This shows weather condition may modify the outcome of moisture stress condition (Table 1 and 2). Oliver *et, al*. (2006) observed that climatic variation in different seasons to be one of the difficulties in drying-off treatments. Robertson *et, al*. (1999) also found that rainfall is an important factor for effective drying-off treatment and the required duration of drying-off can be highly variable which could also be related to other factors. When soil moisture percentage at 30cm and 60 cm are compared (Figure 2), gain was relatively better at 30cm depth than at 60cm and the plant roots could easily access and absorb moisture, since the upper soil layer is the area where more of the absorbing roots of sugarcane is found. Gosnell and Thompson (1965) also stated that the sugarcane crop is known to remove readily available moisture from the surface strata of soil before exploiting progressively deeper depths.

Regardless of the differences in weather conditions and the initial soil moisture status there is less probability of getting identical condition in different years. Any meteorological factor that affects evapo-transpiration exerts its effect on soil moisture; therefore it is important to focus on soil moisture status when setting up drying-off period experiments.

Effect of Drying-Off on Juice Quality Parameters

°Brix

Analysis of variance of the data on °brix revealed that there is a significant variation in the main effect of varieties and drying-off period in both crop years, but no interaction effects were observed. In crop year 1, variety 'B52298' and 'NCo 334' showed significantly higher °brix, whereas B41227 was the least (Table 2). Brix readings displayed declining trend starting from the 6th week after withholding irrigation; this happened when the soil moisture level decreased substantially which could be attributed to the negative effect of drastic moisture stress. When stress progressed to severe levels the photosynthetic capacity of the plant was affected so that biomass and sucrose accumulation slowed down and eventually ceased. A similar sequence of the onset of water stress was observed in all experiments. In crop year 2, variety B52298 gave significantly higher in obrix (20.75) than the rest varieties, though the rain fall shower during this period modified the stress condition (Table 3).

Pol % Cane

Statistical analysis showed significant ($P<0.05$) differences in the main effect of varieties, drying-off period

Table 3. Effect of variety and drying off periods on soil moisture content and sugarcane stalk weight and juice quality parameters during 2nd crop year (Nov, 2003 – Jan, 2004).

Treatment	**°Brix**	**Pol (%)**	**ERS (%)**	**SW (kg/stalk)**
Variety (V)				
B52298	20.75a	17.45a	11.74a	2.44a
B41227	19.89b	16.72b	11.20b	2.34a
NCo376	19.78b	16.64b	11.08b	1.59c
NCo334	19.62b	13.38b	10.86b	2.14b
Dryoff Period (D)				
4 weeks	19.00c	16.30b	11.06abc	2.20ab
5 "	19.62bc	16.33b	10.80c	2.04ab
6 "	19.57bc	16.33b	10.84bc	2.03b
7 "	19.74bc	16.65b	11.15abc	2.08ab
8 "	20.36ab	17.22ab	11.55ab	2.11ab
9 "	20.27ab	16.73ab	11.13abc	2.18ab
10 "	21.07a	17.62a	11.71a	2.14ab
11 "	20.44ab	17.19ab	11.49abc	2.25a
V * D	ns	ns	ns	ns
CV (%)	6.2	7.3	8.1	12.1

Means with the same letter within a column are not significantly different from each other by DMRT (P< 0.05).

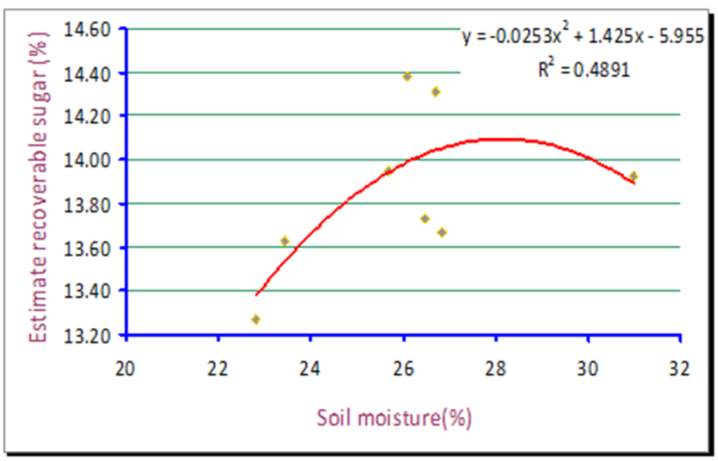

Figure 3. Relationship between Estimated recoverable sugar and soil moisture content in crop year1

and no interaction in Crop year 1 (Table 2). In crop year-2 even if there was significant variation in the main effect, no interaction exist between varieties and drying-off period (Table 3). The highest pol percent were recorded for variety NCo334 (19.93%) and B52298 (17.45%) in crop year 1 and 2, respectively. In the first crop year, an increase in pol percent were observed as dry-off period extended up to the 8th week, thereafter when the drying-off period prolonged the percent pol decreased, this could be connected with deterioration of sucrose found in cane (Table 2). On the other hand, in the second crop year low pol percent at the initial that is, after 4 weeks of withholding irrigation was found when and continued till the 7th week. This might be because of the lowest initial soil moisture content; and an increasing trend for pol percent towards a prolonged drying-off were observed and rainfall had improved juice quality as a result of the crop recovery (Table 3 and Appendix 2).

Estimated Recoverable Sugar (ERS)

Estimated recoverable sugar was significantly ($P<0.05$) affected by the main effect of variety, drying-off period

Table 4. Interaction effect of stalk weight with dry off period treatment in crop year 1(2001/02).

Drying off period (weeks)	Varieties			
	B52298	**B41227**	**NCO376**	**NCO334**
4	2.28A	2.11AB	1.160JK	1.938CD
5	2.02ABC	2.12AB	1.280IJ	1.590EFGH
6	1.92BCD	2.01ABC	1.345HIJ	1.513GHI
7	1.80CDEF	1.87BCDE	1.310HIJ	1.388HIS
8	1.90BCD	1.773CDEFG	1.413HIJ	1.370HIJ
9	1.89BCD	1.90BCD	0.970K	1.378HIJ
10	1.695DEFG	1.91BCD	1.270IJ	1.533FGHI
11	1.82BCDE	1.90BCD	1.360HIJ	1.350HIJ
CV %	10.56			

Means with the same letter within a column are not significantly different from each other by DMRT (P< 0.05)

and, their interaction, except the second crop year (Tables 2 and 3). In the second crop year, the rainfall shower that occurred seemed to favour juice quality improvement, as the growth of the cane was not highly affected and photosynthetic product was diverted to storage cells and allowing sucrose accumulation (Inman-bamber, 2004).

In the first crop year, though there was moisture depletion corresponding improvement in juice quality parameters were not observed (Figures 3). This indicates that the observed estimated recoverable sugar grand mean is around 13.82 %. The higher value indicating peak ripening of the cane under the context of Metehara, and the treatment could not increase this parameter beyond this limit.

In crop year 2, the grand mean was 11.2 and there was still potential for improvement of estimated recoverable sugar. On the other hand a drop in recoverable sugar observed for variety B52298 was the manifestation of moisture rise observed in the 10^{th} week of the treatment (Table 4). Generally, extending dry off period up to the 11^{th} week in crop year 2 didn't result in deterioration of juice quality (Table 3). According to Yang et al. (2009) and Oliver et al. (2006) the percentage of recoverable sugar was inversely proportional to soil moisture.

Effect of drying-off on stalk weight

The analysis of variance for stalk weight at time of sampling showed significant ($p<0.05$) differences in variety, drying-off and their interaction in both crop years except interaction effect in crop year 1 (Tables 2 and 3). In crop year 2, there was increase in the weight of stalks regardless of the drying off treatment, which could be attributed to the growing tendency of cane as a result of rain which relieved the cane from stress. Comparatively stalk weight in crop year 1 was lower than those in crop year 2 with grand mean of 1.66 and 2.13 kg per stalk, respectively. In other words vegetative growth was favoured than sucrose accumulation in crop year 2 resulting in lower sucrose accumulation. In agreement with this an experiment conducted by Robertson and Donaldson (1998) as cited by Martin and Lebret (2001) on the variability of sugarcane water content as a function of environmental conditions and of drying-off show that apparent ripening is very often due both to an increase in the stalk sucrose content and to dry out, i.e. a decline in water content.

Generally, the changes observed in stalk weight, especially in the earlier part of the treatment (up to 6 – 8 weeks) when juice quality parameters were not negatively affected could be attributed to moisture losses and this could be advantageous in reducing the bulk weight of cane transported to the factory, which may reduce transportation cost. According to Robertson et. al. (1999), Donaldson and Bezuidenhout (2000) and Singels and Inman-Bamber (2002) drastic moisture stress affects photosynthesis and biomass accumulation that slowed down and resulted in cane yield reduction. However it has less probable to cause risk if it doesn't exceed 4%.

CONCLUSION AND RECOMMENDATION

From the result of the study it was found that under normal condition in cool season, extending moisture stress beyond 9 weeks resulted in a sharp drop in soil moisture. Better ERS were obtained for soil moisture between 24-28% almost within 5 to 9 weeks drying off treatment for the tested varieties. On the other hand, where soil moisture was initially very low and intermittent rainfall shower occurred, improvement in juice quality was observed as rainfall shower relieved the crop from being drastically harmed by extended moisture stress. It was also observed that, drying off treatment exerted its effect on cane quality via its influence on soil moisture status, which in turn is dictated by soil moisture regime and prevailing weather condition.

Generally, under normal condition in cool season, it is recommended to harvest varieties within 5 to 9 weeks after withholding irrigation. However, if there is rainfall after the cane is subjected to moisture stress, harvesting time should be decided based on proper monitoring of soil moisture status. As a whole, to achieve the desired cane quality through moisture stress, besides using meteorological data, it is recommended to precisely determine soil moisture status from the very start of pre-harvest drying off treatment until the desired soil moisture level is attained.

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Appendix Table 1. Physico - chemical properties of soil of the experimental fields.

Parameter	**Sampling Depth (cm)**			
	Field No. T8		**Field No. V31**	
	0 - 30	**30 - 60**	**0 - 30**	**30 - 60**
Texture				
Sand (%)	24	24	12	19
Clay (%)	50	48	54	50
Silt (%)	26	28	34	31
Textural class	C	C	C	C
PH	8.48	8.73	8.47	8.53
EC (m S/cm)	0.408	0.543	0.263	0.295
OC (%)	1.13	0.99	1.69	1.15
Total N (%)	0.11	0.1	0.113	0.076
Available P (ppm)	6.4	6.2	11.74	5.44
Available K (%)	255	245	__	__
$CaCO_3$ (%)	10.5	10.7	5.75	5.83

Tab`cxle 2. Weather data during the stalk sampling period (Ten days mean) for the year 2001/2002 and 2003/2004.

Year	Month	Date	Air Tem. + 1.5m		Avg. R.H		Evaporation (mm/day)	Wind Speed		Rain fall (mm)
			Min	Max.	Min.	Max.		Day	Night	
2001	Oct.	1 - 10	16.4	35.2	38	96	6.70	3.27	0.23	0.00
		11 - 20	18.2	34.6	42	94	6.70	3.58	0.23	6.7
		21 - 31	17.2	32.9	35	94	6.6	4.09	0.20	0.3
2001	Nov.	1 - 10	12.5	32.1	33	97	7.3	4.23	0.14	0.0
		11 - 20	13.4	32.3	39	97	6.7	2.82	0.25	0.0
		21 - 30	14.3	30.9	41	95	6.6	4.17	0.37	0.0
2001	Dec.	1 - 10	14.7	31.9	39	93	6.2	3.57	0.40	0.0
		11 - 20	15.0	31.2	39	93	5.9	3.86	0.48	0.0
		21 - 31	12.6	29.9	40	96	6.1	4.04	0.48	0.0
2002	Jan.	1 - 10	18.0	30.0	47	94	5.2	3.98	0.61	2.0
		1 - 20	18.1	30.4	45	89	6.0	4.63	1.53	0.0
		21 - 31	11.9	30.7	36	93	6.5	4.64	0.32	0.0
2003	Oct.	1 - 10	16.1	34.2	29	92	6.6	2.53	0.11	0.0
		11 - 20	17.4	34.0	35	87	6.9	2.95	0.38	0.0
		21 - 31	13.7	33.3	29	91	6.9	3.04	0.19	0.0
2003	Nov.	1 - 10	16.1	33.2	30	82	6.4	3.24	0.57	0.0
		11 - 20	15.7	31.7	34	89	6.4	4.33	0.24	0.0
		21 - 30	15.9	32.2	34	87	6.4	3.85	0.42	0.0
2003	Dec.	1 - 10	18.2	30.3	40	91	4.6	3.01	0.62	14.3
		11 - 20	12.0	30.1	30	95	5.4	3.13	0.17	0.0
		21 - 31	11.8	30.4	33	94	5.6	3.53	0.29	29.6
2004	Jan.	1 - 10	14.9	33.6	34	92	6.1	2.67	0.50	0.0
		11 - 20	18.6	30.7	44	94	4.6	2.64	0.57	15.0
		21 - 30	19.9	31.5	41	89	5.2	3.64	0.43	0.0