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National Academy of Agricultural Science (NAAS) Rating : 3.03

Determination of Optimum Dry-off Period for Efficient Machine Performance in Sugarcane Harvesting and Loading systems

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ABSTRACT: *This experiment was conducted at Sennar sugar factory to determine the effect of dry-off period for efficient machine performance. Two systems of harvesting were studied, namely, mechanical and manual harvesting. Five dry-off periods were tested, one-, two-, three-, four- and five weeks dry-off periods. Although there were no significant differences, it was found that the optimum dry-off period could be the four and five weeks because it gave the lowest fuel consumption, the lowest loading time and the best and second best machine output.*

INTRODUCTION

The dry-off period practice is usually employed by sugarcane growers to prepare sugarcane field for harvesting, (Eltahir, 2002). The accompanying mild moisture stress causes sucrose to be deposited preferentially in sugarcane stalks so that sucrose yield may be improved. The rule of thumb in the industry states that a crop should be dried-off for the time it would take pan evaporation to equal twice the available water holding capacity of the soil in which the crop is rooted (Donalson and Bezuidenhout, 2000). Despite this useful rule, cane growers often dry-off their crops excessively. To avoid such practice, the dry-off period is implemented in terms of dry-off days to prevent losses in sucrose yield.

When drying-off a sugarcane field for harvesting the main target would be the reduction of soil moisture content to a level that permits machine trafficability, as well as improving cane quality. The quantity and availability of soil moisture content must be based on a thorough understanding of the dynamic balance of water in the soil. The soil water balance is the difference between the amount of water addedand the amount of water withdrawn during a certain period of time.

Fields irrigation water constitutes the main source of water added to the soil. Part of this water will be lost by evapotranspiration, part will evaporate directly from the soil surface, some is taken by the plant for growth, some may percolate deep into the soil beyond the root zone, whereas the remainder adds to the moisture storage at the root zone (Hillel, 1980). Soil moisture content has a major influence on soil strength and consistency, and thus on how the soil will react to a certain type of pressure (Krause and Lorenz, 1984).

A more objective assessment of soil workability should be provided from actual field records through estimating the probability distribution of the days in which the farmer can get in the field to accomplish specific tasks. Simalenga (1989) indicated that a soil is considered workable under the following conditions:

1. It has sufficient shear strength to withstand the weight of the machine.
2. It has sufficient shear strength to meet the machine traction requirement with acceptable wheel slippage.

Moreover, quantitative soil behavior in response to its workability and vehicular traffic have been investigated and reported by many researchers (Knight and Fretiag,1982; Batesman,1963 and Tulu *et al.* (1974) used the soil moisture content as a function of field capacity in the prediction of working days. Allman and Knoke (1947) reported that a soil is trafficable when the soil moisture content is near field

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capacity. Elfadil et al (2004) indicated that the optimum range of soil moisture content lies between 14.0 and 29.9%. They observed that wheel slip and draft were affected by the soil moisture content and were directly proportional to it until up to the soil moisture content of 30.7% above which it became impractical to operate machines due to excessive wheel slip.

Moisture content influences ripening of sugarcane at the maturity phase. Ripening of sugarcane involves the accumulation of sucrose in the cane stalks (Van Dellewijn,1952). However, ripening can be more broadly defined as an increase in sucrose concentration in the cane stalks on fresh weight basis. This definition is used in almost all sugarcane producing countries, whereby the fresh weight measure of sugar content is used to describe cane quality.Ripening occurs naturally in response to crop age and seasonal factors when the crop is accumulated adequate stem biomass and when climatic conditions favor a slowing of stem elongation. Inducing mild water stress can also cause ripening (Robertson et al.1999). Ripening can be enhanced by dry-off cane (Robertson and Donaldson,1998), reducing soil moisture content and lowering of the temperature (James,1999).

The success of the harvesting program depends to a large extent on a well-planned dry-off period schedule. Drying-off of sugarcane fields for harvesting has not been experimentally tested throughout the history of the scheme, and what has been practiced is based on personal observations and accumulated experience of the field staff. Due to the inherent inaccuracy judgment in practice, the harvest operation may be carried out under wet conditions, which leads to machine spinning, increase in fuel consumption, slowing down of loading operation, hauling and transporting excess water, machine damage and low sugar recovery and extraction. On the other hand if the dry-off period extended beyond the optimum it may lead to over-burning, increased fiber content and reduction of cane moisture content.Maximum yield of sugarcane can be realized only if the crop is well ripened before harvest (Eltahir, 2002). To be ripe, the cane stalks must first show retardation in the rate of growth. Low temperature, moderate drought and nitrogen starvation are effective ripening agents. As the growth rate declines, less of the sugar produced each day is expended in building new tissue and most of it is stored as sucrose.Drought from natural causes, or by lengthened irrigation intervals, promotes the conversion of reducing sugar to sucrose (Humbert, 1968). As ripening proceeds, the percentage of sucrose in the stalk gradually increases while the percentage of glucose and fructose diminishes. However, moisture is considered as an extremely important factor either in natural maturity of sugarcane in the tropics or where forced ripening programs are implemented. At harvest time the cane grower is concerned with the moisture content of the millable cane since juice quality is associated with low moisture content (Humbert, 1968).

This research was conducted in Sennar Sugar Factory Fields (Sudan). The total area is about 15750 hectare, most of the soil is Vertisol.

The objective of this work was to determine the optimum dry-off period suitable for efficient machine performance and soil trafficability.

MATERIAL AND METHODS

Experimental Work

Two systems of harvesting were evaluated, which were manual and mechanical cane harvesting. The experimental design was completely randomized block with four replications. Plots were established for five periods of two-, three-, four five- and six-weeks after the last irrigation under each system of harvesting to evaluate the workability of Vertisol of Sennar Sugar Factory.

The measured parameters were:

1. Fuel consumption:

   This was determined by dividing the total fuel consumed by the covered area.

2. Loading time:

   This was calculated by subtracting the work start time from the work finishing time.

3. Machine output per unit time:

This was calculated in terms of area per unit time which achieved, by dividing the effective harvested area by the harvesting or loading time. Also it can be expressed as mass per unit time which obtained parameters by dividing the mass of harvested cane by the harvesting or loading time.

Equipment

Equipment used for data collection are: 50 meter measuring tape to measure the distance, digging hoe, cans (10cm diameter and 12cm height) for soil sample, polyethylene bags, card tags, drum, one inch diameter hose, 20 liters plastic containers, one liter measuring cylinder, stop watch electronic for loading time measurement and speed balance, an oven, weighbridge and ropes. Harvesting machines used were grab loader, a Cameco tractor, a Bell tractor and three trailers as well as a harvester.

RESULTS AND DISCUSSION

Fuel Consumption

The results obtained of fuel consumption for different machines involved in both mechanical (with the use of harvester) and manual harvesting (with the use of grab loader) under the different dry-off period treatments are shown in Table (1), while Table (2) represents the fuel consumption for shunter tractors in mechanical and manual harvesting.

Table (1) showed that there were no significant differences in fuel consumption for both the harvester and grab loader under the different dry-off period treatments. However, as shown in Table (1) the four-weeks dry-off period gave the lowest fuel consumption (0.56 and 0.21 liter/tonne) for both methods of harvesting, and resulted in fuel saving of 0.09 and 0.08 liter per tonne for the harvester and loader, respectively. On the other hand, the two-weeks dry-off period gave the highest fuel consumption (0.65 and 0.28 liter per tonne) which could be attributed to the relatively wet soil conditions prevailing that led to appreciable rolling resistance and wheel spinning of the machine and necessitated the use of low speed with heavy gears to make it possible for the machine to work. Moreover, it was observed that the six-weeks dry-off period gave, also, a high harvester fuel consumption, which could be attributed to the fact that the harvester had to travel through a wide area to cut one tonne of cane.

Table (2) revealed that there were no significant differences in fuel consumption of the shunter tractors used with both mechanical and manual harvesting under the different dry-off period treatments. Although there were no significant difference Table (2) shows that, on average, the five-week dry-off period gave the lowest fuel consumption (0.16 liter per tonne), and that both the two-weeks and three-weeks dry-off periods gave the highest fuel consumption (0.23 and 0.27 liter per tonne, respectively). Moreover, it was observed that under the two shortest dry-off periods the shunters and trailers were subjected to wheel spinning, which may explain their high rate of fuel consumption. Table (2), also, shows that the shunters working with the harvesters consumed more fuel than those working with the loaders under all dry-off period treatments, except under the shortest period (two weeks), which could be attributed to their continuous working with slow speed and heavy gears and the slippery conditions under the shortest period.

Loading Time

The results for loading time under different dry-off period treatments are shown in Table (3) for both mechanical and manual harvesting. The results obtained showed no significant differences between all treatments. However, the four-week dry-off period showed the lowest loading time for mechanical harvesting (0.74minute per tonne) and manual harvesting (0.81miute per tonne) respectively. Moreover, the shortest dry-off period (two weeks) gave the highest loading time for both mechanical and manual harvesting (0.95 and 1.07 minute per tonne, respectively). This may be explained by the poor traction conditions and difficult movement of machines under the soil conditions prevailing after that dry-off period.

Table (3) shows that when implementing the four-week dry-off period instead of the two-week dry-off period, a saving of about 0.2 min per tonne in the loading time will be achieved. Then, if the total quantity of harvested cane is estimated to be 900 000 tonnes and that the effective working day is 20 hours, the about 150 working days will be saved, which constitute a considerable factor in cost reduction.

Field Capacity

The results for machine field capacity, in terms of tonne of cane harvested and/or loaded per minute are shown in Table (4). The results showed no significant differences between the dry-off period treatments for both mechanical and manual harvesting. However, the highest machine outputs of 1.2 and 1.3 tonnes per minute were obtained by the harvester and the loader at three-week and the four-week dry-off periods, respectively.

On the other hand, the lowest machine field capacity of 1.1 and 1.0 tonnes per minute were obtained at the two-week dry-off period. Accordingly, carrying out the harvesting operation of sugarcane at a four-weeks or five-weeks dry-off period will increase machine output by about 0.15 to 0.30 tonnes per minute, which means an increased machine output of 180 to 360 tonnes per day, on the bases of a 20-hours effective working day.

Conclusion

Although there were no significant differences between treatments, it could be concluded that the optimum dry-off period could be the four-week or the five-week because they gave:

1. Lowest fuel consumption.
2. Lowest loading time.
3. Best and second best machine output.

Table 1
Effect of dry-off period on harvester and loader fuel consumption

Dry-off period	*Harvesting method*	
	Mechanical (liter/tonne)	*Manual (liter/tonne)*
2 weeks	0.65(A)	0.28(a)
3 weeks	0.61(A)	0..23(a)
4 weeks	0.56(A)	0.21(a)
5 weeks	0.62(A)	0.23(a)
6 weeks	0.62(A)	0.26(a)
Mean	0.61	0.24
SE±	0.11	0.06
CV%	15.82	12.48

Note: For each harvesting system means followed by the same letter are not significantly different at P=0.05 according to Duncan multiple range test (DMRT).

Table 2
Effect of dry-off period on shunter fuel consumption:

Dry-off period	*Harvesting method*	
	Mechanical (liter/tonne)	*Manual (liter/tonne)*
2 weeks	0.23(A)	0.27(a)
3 weeks	0.23(A)	0..18(a)
4 weeks	0.21(A)	0.18(a)
5 weeks	0.18(A)	0.14(a)
6 weeks	0.22(A)	0.16(a)
Mean	0.22	0.19
SE±	0.06	0.09
CV%	13.11	35.80

Note: For each harvesting system means followed by the same letter are not significantly different at P=0.05 according to Duncan multiple range test (DMRT).

Table 3
Effect of dry-off period on loading time:

Dry-off period	*Harvesting method*	
	Mechanical (minute/tonne)	*Manual (miute/tonne)*
2 weeks	0.95(A)	1.07(a)
3 weeks	0.94(A)	0..96(a)
4 weeks	0.74(A)	0.81(a)
5 weeks	0.85(A)	0.83(a)
6 weeks	0.85(A)	0.86(a)
Weeks	0.87	0.91
Mean	0.11	0.13
SE±	10.85	14.55
CV%	0.23(A)	0.27(a)

Note: For each harvesting system means followed by the same letter are not significantly different at P=0.05 according to Duncan multiple range test (DMRT).

Table 4
Effect of dry-off period on machine field capacity

Dry-off period	*Harvesting method*	
	Mechanical (tonne/minute)	*Manual (tonne/minute)*
2 weeks	01.1(A)	0.27(a)
3 weeks	1.1(A)	0..18(a)
4 weeks	1.2(A)	0.18(a)
5 weeks	1.2(A)	0.14(a)
6 weeks	1.2(A)	0.16(a)
Mean	1.2	1.1
SE±	0.14	0.15
CV%	13.05	15.13

Note: For each harvesting system means followed by the same letter are not significantly different at P=0.05 according to Duncan multiple range test (DMRT).

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