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Determination of the number of working days for mechanized planting and semi-mechanized harvesting of sugar beet in Nahavand region

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ABSTRACT

A study was conducted to determine the appropriate number of working days in mechanized planting and semi-mechanized harvesting of sugar beet in Nahavand city, Iran in 2010. The most important limiting factor for agricultural operations in agricultural calendar is the time of operation which is a function of soil moisture for some operations such as ploughing. To determine the number of working days, the parameters considered in this study included determination of the proper threshold for the most effective limiting factor in mechanized planting and semi-mechanized harvesting of sugar beet, determination of the factors affecting the limiting factor and also to determine the probability of the number of days appropriate for mechanized planting and semi-mechanized harvesting of sugar beet. The allowed limit of soil moisture in clay-loam texture, for having the capability of running field operations was determined to be 14.5% of the weight. In this limit, soil has acceptability of 6.34 mm of water (rainfall) for sowing and 10.62 mm for harvesting at the depth of operation in each turn of rainfall or irrigation. Factors influencing the soil moisture changes are the amount and intensity of rainfall, soil drainage, moisture content percentage in air, evapotranspiration, soil surface runoff, the rate and intensity of solar radiation (day and night length), ambient temperature, the rate of crop cover, and the soil profile. At sowing and harvesting times, 19.3% and 7.5% of the rainfall is converted to runoff. Therefore, the maximum allowable rainfall in a situation that doesn't change the soil condition from the proper situation for mechanized sowing and harvesting operation is 7.6 and 11.41 mm, respectively, in each rainfall turn. For the drainage of excess moisture after rainfall, in sowing and harvesting operations, five and seven days are required, respectively. The number of working days for mechanized planting was estimated about 20 days, and for semi-mechanized harvesting was about 23 days with 99% confidence.

Keywords: drainage, proper working days, runoff, soil profile, tillage

INTRODUCTION

The most uncontrollable variable in agricultural operations is the number of proper working days in a cropping year. A method for determining the appropriate working days is to obtain a reasonable relationship based on the previous year's temperature and rainfall. This method of probability distribution clarifies the appropriate dates for each key activity throughout a year. Field capacity and climate conditions are the main factors for determining the appropriate time for agricultural operations during the year. The required time for working with field machinery depends on the machine capacity and the number of appropriate working days. Each region of the country has its own climate pattern. Working days of the field is determined by two factors. First, the soil moisture content should not exceed the plasticity limit; second, the rainfall on that day should not be greater than 10 mm. The effect of other climate conditions such as freezing occurrence probability or snowing are not included in the analysis of soil working days (Witney 1988). In West Islamabad, the number of working days for mechanized plant-

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Table 1. Results of analysis on some physicochemical properties of the soil in the studied area

Depth of sampling	Region number	Electrical conductivity (milimos/cm)	Soil reaction	Neutralizing materials (%)	Organic carbon (%)	Absorbable phosphate (mg/kg)	Absorbable potassium (mg/kg)	Sand (%)	Loam (%)	Clay (%)	Soil class (clay-loam)
0-30	3	1.2	7.8	13.5	1.34	46	490	27.7	39	33.3	CL
0-30	2	2.95	7.51	19.35	1.11	48.4	556	22.4	46.1	31.5	CL
0-30	1	0.67	7.85	14.4	1.3	57	367	27.7	39	33.3	CL

ing of sugar beet is less obtained in heavy soil texture compared with light soil texture (Bazyar 2004). Also, the proper time for tillage operation in clay soil was reported in 14-16% moisture content (Zarin Kafsh 1998). Lack of timely field operations will result in the loss of quality and quantity of the product (Almassi et al. 2009). The number of proper working days for mechanized spraying of wheat crop in Qazvin province as a weekly check for pests, diseases and key weeds, and also for land spraying in order to control wheat maternal Sunn (*Eurygaster integriceps*), nymph, and wheat rust, with 98% probability were estimated to be 14.75, 13.67 and 24.96 days, respectively and in aerial spraying were found to be 5.320, 5.87 and 9.98 days, respectively. Also, in land spraying, the number of proper working days for broadleaf weed control, thin leaf aphid and Russian aphid were estimated to be 25.73, 24.7 and 13.42 days, respectively (Usofi 2001).

Knowing the number of working days for planning the timely field operation is important, especially for sugar beet in which timely sowing and harvesting has significant effect on crop yield (khodabandeh 1994).

Based on agricultural statistics, the studied city produces a remarkable rate of sugar beet in Hamedan province so that the investigations which may affect the operation management of this crop can be quite cost-effective (Anonymous 2012).

MATERIALS AND METHODS

Nahavand city is located in the southwest of the Hamedan province (34°12´N and Longitude 48 °22´E). It is a semi-arid region with cold climate. The average annual rainfall is about 400 mm. According to the semi-detailed soil test report, the total area of the fields in the city is 23000 hectares and about 94% of the land (excluding rock samples and fen) has relatively heavy to very heavy textured soil. The results of the soil samples from three areas of the Kian region as a main producer of sugar beet, is presented in Table 1. This area has heavy soil texture (clay-loam). Therefore, further work to determine the proper working days were done on heavy soil texture (clay loam) (Khosh Fetrat 1977).

A significant part of the annual rainfall occurs in spring during sugar beet sowing and the sowing date has a significant influence on final yield and in case of delay in operation, the farmers face the extra costs as a result of not performing operations in a timely manner. Since sugar beet is sown in this city in spring, during the harvest time, as the region has cold autumn, sugar beet may be exposed to early freezing which may reduce the crop yield. Therefore, it is very important for farmers to be aware of the number of the days in which mechanized sowing and harvesting can be planned. The most important factor which limits the time of sugar beet sowing and harvesting, in farming calendar, is the soil moisture (Bazyar 2004). To determine the number of appropriate working days for sugar beet sowing and harvesting in Nahavand city, the following parameters were evaluated:

1. determination of the threshold for allowable limiting factor (soil moisture) in sugar beet sowing and harvesting
2. determination of the effective parameters which may change the limiting factor
3. determination of the appropriate number of working days for sugar beet sowing and harvesting according to limiting factor.

Allowable extent for limiting factor

The following equation calculates the maximum soil moisture capacity:

$$W = \frac{(FC - Pwp) \times z \times d}{100} \quad (1)$$

where:

W=the height of the water maintained to a z depth (cm)

FC=the weight of the soil moisture storage capacity (field capacity)

Pwp=the weight of the soil moisture at wilting point (permanent wilting point)

Z=soil depth (cm)

d=soil bulk density (bulk density) (g/cm^3)

Equation (1) calculates the soil capacity to accept moisture up to field capacity (FC) in a specified depth, while in this capacity, soil has high moisture content and as a result machine operation is not feasible. Therefore, the above equation should be modified in some way to determine the appropriate mode of soil moisture for farm operation. Thus, equation (2) which was obtained from equation (1), calculates capacity of the soil to accept moisture without change of the proper mode for field operation.

$$W = \frac{(c - pwp) \times z \times d}{100} \qquad (2)$$

where:

W=height of water (cm) until Z cm of the soil depth. i.e. the soil capacity to accept moisture in the appropriate mode of operation.

C=soil moisture in appropriate mode for machine operation which was estimated between 14 to 16% for heavy textured soil (Bakhtiari 1997).

Pwp=weight of soil moisture at permanent wilting point which was considered 10.2% in this study (Zarin Kafsh 1998).

In this study the soil moisture based on dry weight was obtained in an appropriate situation for operation. To determine the bulk density of the soil, samples were taken from a depth of 0-20 cm (the depth in which sowing and harvesting machines work) by sampling cylinders during planting and harvesting of the sugar beet from major areas of the study fields and through the equation (3) the soil bulk density was calculated. The average bulk density for sowing was equal to 1.23 g/cm^3 and the average bulk density estimated for harvesting was 1.3 g/cm^3. The soil bulk density was measured in a clay-loam texture.

$$d = \frac{M}{V} = \frac{4M}{\pi D^2 L} \qquad (3)$$

where:

d=soil bulk density (g/cm^3)

M=weight of dry soil in the sampling loop (g)

V=volume of the cylinder containing the sample (cm^3)

L= height of the sampling loop (cm)

D= diameter of the sampling cylinder (cm)

Z= the maximum depth of the soil in which the machine can penetrate. This depth is measured based on the sowing and harvesting machines in the field during operation.

In this research, for planting, the soil depth was considered equal to the depth of furrower penetration of pneumatic seed drilling machine of sugar beet. The depth to which the seed was placed by seed driller was 3 cm, the depth of the tractor wheel penetration was 6 cm, and the depth of the furrower penetration was 12 cm. For this reason, this depth is the maximum penetration depth of the planter and the tractor and thus, the soil moisture should be in a good condition to prevent soil adherence to the machine's wheel. For harvesting operation, this depth is equal to the depth of penetration of beet digger blades. Sugar beet harvesting is done in semi-mechanized condition. The roots are primarily taken out by sugar beet harvester and then crop collection and crown removing is carried out by hand. Triangle-shaped, two-blade harvesting machine is mainly used for sugar beet harvesting in the region. For this reason, the depth was considered equal to the depth that triangle blades penetrate. This depth was practically measured in the field and estimated to be approximately 19 cm.

Some effective parameters on soil moisture variation

Some effective factors on changing the rate of soil moisture are rainfall, soil drainage condition, evapotranspiration, and runoff. Rainfall is the most important factor in soil moisture changes which removes the soil from its proper condition for machine operations. To estimate the number of appropriate working days for sowing and harvesting, 18 years (1994-2011) and 19 years (1993-2011) statistics were used, respectively. Nahavand weather station was launched in July 1991 so the rainfall statistics which were available for all years were collected and analysed. In the studied soil (clay-loam), the penetration rate was measured between 0.25-1.5 (average 0.8) cm per hour (Husseini 1997). The soil surface temperature fluctuation is so high in nature. The soil surface temperature is high in summer and is low in winter. In the soil depths, temperature fluctuation is lower than soil surface. Similarly, a stream of water in vapour shape moves from the depth to the top, and a steady stream of water from the soil surface to the depths are established in winter (Alizadeh 2006). Factors that influence the rate of water evaporation from the soil surface are solar radiation, wind, relative humidity and temperature (Alizadeh 2009). Therefore, it is concluded that vapour always moves from cold to warm place and from wet to dry area, and since the soil surface is warmer during sugar beet sowing (April) than harvest time (November), vapour moves upward and rapidly leaves the soil which makes the soil suitable for operation. At harvest time (November), because the soil surface remains cold for a longer period than sowing time and it has more moisture than the depth, water and vapour movement toward down is lower than sowing time and consequently soil moisture reduction is slower than sowing season. In general, the needed time for water drainage after raining (more than filed capacity), evapotranspiration, and the soil reaching to proper limit for machine operation depends on season (day length, sunshine hours, solar radiation intensity, relative humidity, wind and etc.) which is between 4 to 8 days based on the report of researchers from Hamedan Agricultural Research Centre. According to the description given in this study, required time for excess water drainage after rainfall more than field capacity and reaching to the proper limit for machine operation is 5 days and for harvesting it is considered 7 days.

Surface runoff

Using the method proposed by the Soil Conservation Service (SCS), runoff rate was calculated based on equation 5 description:

$$W=\frac{(P-0.2\times S)^2}{P+0.8\times S} \qquad S=\frac{1000}{CN}-10 \tag{5}$$

where:

P=rainfall height (inch)
Q=runoff height (inch)
S=surface storage coefficient
CN=curve number method

To estimate the runoff, first, the soil penetration was determined according to the soil group penetration table (for clay-loam texture, soil permeability is 0.8 cm/ha). Then, the CN number of the group was determined based on the characteristics of the basin coverage. Since sugar beet is considered as a raw crop, CN for this crop was determined in two situations of medium coverage for planting and good coverage for harvesting and the surface storage coefficient was obtained through its contribution (Alizadeh 2009). To estimate the rainfall height (P), the average rainfall information which was available for different years during planting (April) and harvesting (July) in the region was considered.

Using equation 5, runoff rate during planting and harvesting was estimated and through equation 6 allowable rainfalls during planting and harvesting was estimated:

$$M=W+(W\times R) \tag{6}$$

where:

M=rainfall allowed so that the soil does not leave the appropriate mode of machine operation (mm)
W=allowable capacity of the soil to accept water so that the soil doesn't leave the appropriate mode of machine operation (mm)
R=rate of runoff from rainfall (%)

To determine the proper working days, first, the agronomical calendar for planting (April) and harvesting (July) in this city was divided into five days categories and for each category, the proper working days were estimated. The rainfall statistics was taken from weather station for different years and for each categories, the number of days in which the rainfall rate was higher than the allowable limit differed from the number of days in that category but the remained days are definitely not the proper days because after excess rainfall, some time is required for excess water drainage and this time for sowing is 5 days and for harvesting is 7 days and also this time should differ from the number of days in calendar after excess rainfall (Bazyar 2004). Finally, mean, standard deviation and confidence interval of mean (99%) were estimated.

The mean of each category was calculated by the following equation:

$$\bar{x}=\sum\frac{x_i}{n}$$

Results and Discussion

The results of the physicochemical analysis of soil properties are given in Table 1.

Based on the results of soil analysis, the following estimates were done:

- Soil moisture in the appropriate mode for machine operation in clay-loam profile:

$$C=\frac{50-43.64}{46.64}\times 100=14.5\%$$

- Soil moisture at permanent wilting point in clay-loam profile equals to 10.2% (Zarin Kafsh 1998).
- The maximum depth that sugar beet seed drilling machine penetrates equals to the depth of the furrower penetration which was 12 cm.
- The maximum depth that the harvesting machine penetrates equals to the harvester plows and the depth was 19 cm.

Runoff estimation during crop planting

Average rainfall during planting was 60.17 mm (2.36 inches) and according to the permeability of the studied texture (0.8 cm/hour) and tables (Alizadeh 2009), this profile was placed in group A and estimated CN for this crop was 72 during planting (Alizadeh 2009). Therefore, the rate of runoff from rainfall during planting equals to 11.63 mm.

$$S=\frac{1000}{72}-10=3.88\Rightarrow$$
$$Q=\frac{(2.36-0.2\times3.88)^2}{2.36+0.8\times3.88}=0.45\ In=11.63\ mm$$

Accordingly, 19.3% of the total rainfall changed to runoff during planting.

Runoff estimation at harvest

Average rainfall at harvest was 48.03 mm (1.89 inch). As explained before, the studied soil was placed in group A and with respect to this subject the estimated CN of this crop for runoff estimation was 67 (Alizadeh 2009). Thus, the rate of runoff from rainfall at harvest time was 3.58 mm:

$$S=\frac{1000}{67}-10=4.9\Rightarrow$$
$$Q=\frac{(1.89-0.2\times4.9)^2}{1.89+0.8\times4.9}=0.14\ In=3.58\ mm$$

The rate of runoff at harvest time was 7.5% of the rainfall.

- Estimation of the maximum soil capacity for moisture acceptance so that the soil didn't leave the appropriate mode for mechanized planting operation:

$$W=\frac{(c-pwp)\times z\times d}{100}=$$
$$=\frac{(14.5-10.2)\times12\times1.23}{100}=0.634\ cm=6.34\ mm$$

The maximum allowable rainfall

At harvest, 19.3% of the rainfall changed to runoff so the maximum allowable rain which did not change the soil proper situation for planting was:

$$w+(w\times R)$$
$$=6.34+(6.34\times19.3\%)=7.56\,mm\approx7.6\,mm$$

- To estimate the maximum soil capacity for moisture acceptance so that the soil didn't leave the appropriate mode for operation, following equation was calculated:

$$w=\frac{(C-pwp)\times z\times d}{100}=\frac{(14.5\text{-}10.2)\times19\times1.23}{100}$$
$$=1.062\,cm=10.62\,mm$$

Since 7.5% of the total rainfall changed to runoff at harvest, the maximum allowable rainfall that did not change the soil appropriate mode for harvest was equal to:

$$W+(W\times R)=10.62+(10.62\times7.5\%)=11.41\ mm$$

Number of appropriate working days for planting machine

According to Table 4, sowing calendar of sugar beet (April) was divided into 5 days groups, and in each group, number of the days in which rainfall was more than 7.6 mm (allowable rainfall) in addition to 5 days needed for field capacity differed in the number of the days in that group. The remained days were working days and in the same way, working days were calculated for different years. Then, the statistical parameters were estimated for each group. Since the t value for confidence level of 1% and degree of freedom of 17 (number of years minus one) were obtained from Table t, appropriate working days for each group were placed between the high and low levels ($p<0.01$). Therefore, average sum of the two categories thresholds was determined in calendar ($p<0.01$). In this study, estimated number of these days was 19.69 days (Table 2).

Proper working days for harvesting machine

According to Table 3, number of the days in which rainfall was higher than 11.41 mm (allowable rainfall) at harvest (November) plus seven days for soil moisture to reach the appropriate mode of operation differed from the number of days in each group and remained days were considered as

Table 2. Number of appropriate working days in a calendar for mechanized sugar beet sowing in Nahavand region

		Number of working days in mid-April in 5-day groups			Number of working days in second late-April in 5-day groups		
	Symbol	**16-20**	**21-25**	**26-31**	**1-5**	**6-10**	**11-15**
Average	$\bar{X}$	4.11	3.27	3.16	2.77	2.83	3.55
Correction factor	Cf	304.22	193.38	180.5	138.88	144.5	227.55
Sum of squares	SS	45.78	77.62	98.5	67.12	74.5	62.45
Degree of freedom	DF	17	17	17	17	17	17
Variance	S^2	2.69	4.56	5.79	3.94	4.38	3.67
Standard deviation	S	1.64	2.13	2.4	1.98	2.09	1.91
Higher threshold	L	8.86	9.44	10.11	8.5	8.88	9.08
Lower threshold	$\bar{L}$	-0.64	-2.9	-3.79	-2.96	-3.22	-1.98
Number of working days for each group	Medium	4.11	3.27	3.16	2.77	2.83	3.55

Table 3. Number of proper working days in agronomical calendar for semi-mechanized sugar beet harvesting in Nahavand region

		Average number of working days in 5- day groups in November					
	Symbol	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**
Average	$\bar{X}$	5	4.69	3.69	3.23	3.15	3.46
Correction factor	Cf	407.57	320.21	222.36	183.21	236.26	195.84
Sum of squares	SS	26.43	51.79	88.64	89.79	72.74	73.16
Degree of freedom	DF	18	18	18	18	18	18
Variance	S^2	1.46	2.87	4.92	4.98	4.04	4.06
Standard deviation	S	1.19	1.69	2.21	2.23	2	2.01
Higher threshold	L	8.42	9.55	10.05	9.64	8.9	9.24
Lower threshold	$\bar{L}$	1.57	-0.17	-2.67	-3.18	-2.6	-2.32
Number of working days for each group	Medium	5	4.69	3.69	3.23	3.15	3.21

a working days for that group. Number of working days for each year took the same way. Then, mean and standard deviation for appropriate working days in each category were obtained and t value with 1% probability and 18 degrees of freedom were obtained from Table t and upper and lower limits of each category were determined. Appropriate working days are between these two limits ($p<0.01$). Therefore, considering the grand mean of the two categories thresholds, with 99% probability, proper working days for machine will be determined in farming calendar. Based on Table 3, number of these days was 23.22. Estimated t value at 1% probability and 18 degrees of freedom was equal to 1.33.

Number of working days for mechanized planting and semi-mechanized harvesting operations in Nahavand region in Hamedan province were 19.69 and 23.22, respectively, with 99% probability in clay-loam soil. To predict the number of machines in order to timely complete the operation and prevent the costs due to failure in timely operation, it is essential to be aware of the planting acreage and the machine working capacity as well as the number of proper working days.

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