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Changes on Soil Biological Activity With Respect To Irrigation, Mulch and Calcium Application

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Abstract: Water resources diminishing over the time due to the global warming; therefore, the effects of prospective drought on soil biological activity, which is important components of soil fertility, should be evaluated for sustainable food production. Long and severe periods of drought are expected for the Mediterranean ecosystems in the near future. Long-term storage of water in the soil has a vital importance in terms of soil fertility and plant growth. Besides well-known benefits, mulch is also used for water conservation in the soil. The purpose of this study was to determine the effects of irrigation, mulch applications and different calcium doses on some microbial activity parameters of soil under greenhouse melon cultivation conditions. The experimental design consists of 3 mulch applications as control (M0), gray color mulch (MG) and black color mulch (MB); 3 irrigation level as 50%, 75% and 100% of Clas-A pan evaporation amount in the greenhouse and 5 Ca doses as 0, 50, 100, 200 and 300 kg ha^{-1}. Results revealed that mulch application reduced soil respiration. The CO_2 formation was 168 µg CO_2-C g soil^{-1} day^{-1} in control application whereas it was 298 in MB. The lowest microbial biomass carbon (166 µg C g soil^{-1} day^{-1}) and dehydrogenase activity (14.7 µg TPF g soil^{-1} day^{-1}) were found in MB.

Key words: Mulching, water stress, droght, soil microbiology

Introduction

Soil biologic activity is one of the most important fertility indicators of the soil which was affected from soil-use management as well as many soil properties. Soil fertility term is determining productivity of all farming systems and which is mostly defined as nutrient supply ability of the soils (Wild, 1993; Wodajo, 2015). Intensive tillage practices and agro-chemical usage to meet food requirement of growing human population cause degradation on the sustainability of crop production by reducing soil bio-diversity. Another stress factor is drought which humanity faced recently as a result of global warming. Drought is an important abiotic factor that limits soil fertility. Many studies showed that long and severe drought periods are expected for the Mediterranean ecosystems in the near future. Soil biological activities such as soil enzymes and respiration play an essential role in the nutrient availability. Drought is also affecting nutrient supply capacity of soil. Biologic activity is an exceptional sensor for predicting how much plant will be affected from drought condition. Temperature and humidity changes can significantly affect soil enzymes. According to a study results, soil urease and beta-glucosidase activities were positively correlated with soil temperatures in winter and negatively in summer (Sardans and Penuelas, 2004). Plastic mulching has become a globally applied agricultural practice for its instant economic benefits such as higher yields, earlier harvests, improved fruit quality and increased water-use efficiency (Steinmetz et al., 2016; Dogan et al., 2013). However plastic mulch materials may be harmful on soil productivity directly and indirectly. For this reason the choice of mulch materials and their colors have a priority for soil sustainability. Covering with mulch would provide long-term storage of water in the soil which has a vital importance in terms of soil fertility, soil microbiological activity, soil quality and plant growth. With some exceptions, fruits such as melons are not able to grow under limited water condition due to their high water content. Therefore, for successful plant cultivation adequate rainfall and optimum temperature are essential. In the undercover production systems this restriction can easily be eliminated. In addition, drip irrigation systems can provide water conservation in semi-arid climates, thereby increasing water use efficiency and thus avoiding drought severity. Mulch materials cover the soil surface, prevent evaporation and contributes to increased soil temperature.

Soil microbial activities are one of the fastest and most important indicators of changes in soil quality. The major advantages of mulching are to prevent weed growth, to retain soil moisture, to control wind and water erosion, to regulate temperature and to enhance soil structure (Kahlon and Lal, 2011; Pawlov et. al., 2015). And, as a result of those developments, yield will also increase. The purpose of this study was to determine the effects of irrigation, mulch applications and different calcium doses on some microbial activity parameters of soil under greenhouse melon cultivation conditions.

Materials and Methods

This research was carried out at Mustafa Kemal University, Faculty of Agriculture, between January to December 2017. The research facility has 7 blocks with dimensions of 45 m x 24 m and a floor area of 1080 m^2. The height of hot air heater equipped greenhouse is 4.0 m. The sides of the greenhouse covered with 8 mm thick double-layer polycarbonate sheets whereas the top is covered with a polyethylene plastic cover with 180 µm thickness with UV + IR + light diffusion additive.

The research station is located 134 m above the sea, 36º 19' north and 35º 11' east longitude and latitude. In the region where Mediterranean climate prevails, summers are hot and arid, winters are warm and rainy. As an experimental plant was used the melon (*C.ucumis mall*.) variety *cantalupensis* convariety. *Citrex*, which is an early varieties commonly produced in greenhouses at the Mediterranean Region in Turkey. The research was established as split-split plots trial design with three replication, three different mulch materials (black, gray and non-mulch), three irrigation levels (I_{50}, I_{75}, I_{100}) and five calcium doses (0, 50, 100, 200, 300 kg ha^{-1}). Black mulch material (MB) is a PE material with a thickness of 40 microns and black on both sides. The gray mulch material (MG) is 40 microns thick and covered with a gray matter, one side of which is black and the other side is grey which has the ability to reflect the sun's rays. All the mulch materials were laid on the soil surface before transplanting the seedlings to cover the whole plant root zone. Irrigation levels were calculated based on the evaporation of the Class-A Pan Evaporation vessel in the greenhouse. The amount of water given up to 50% of the evaporation is I_{50}, 75% of the evaporation is I_{75} and 100% of the evaporation is I_{100}. Calcium (Ca) doses were prepared from calcium nitrat as, Ca0: 0 kg da^{-1}, Ca5: 5 kg da^{-1},Ca10: 10 kg da^{-1}, Ca20: 20 kg da^{-1} and Ca30: 30 kg da^{-1}.

The trial parcels have a floor area of 12 m^2 on the dimensions of 8.0 m x 1.5 m. Plants in each plot are planted in double rows on a shoulder at 50 cm x 50 cm distances. There was a 100 cm gap between the individual parcels. A single fertilization program was carried out in the experiment and 25 kg da^{-1} nitrogen, 10 kg da^{-1}phosphorus and 30 kg da^{-1} potassium were used. Drip irrigation system was used in the experiment and the soil tensiometer was used for irrigation timing. The soil properties before the trial are given in Table 1.

Before and at the end of the experiment collected soil samples were analyzed to determine: soil texture class (Bouyoucos, 1951), lime (Caglar, 1949) and organic carbon contents (Schlichting and Blume, 1966), electric conductivity (EC) and pH (U.S. Salinity Labaratory Staff, 1954), carbon dioxide (CO_2) production (Isermayer, 1952), dehidrogenase enzyme activity (Thalman, 1967), microbial biomass carbon (MBC) amount (Ohlinger, 1993).

Table 1. Soil properties before trial.

pH (1/5)	**EC (µS/cm)**	**Org. C (%)**	**$CaCO_3$ (%)**
8.48	443	0.44	0.89
Texture Class	**CO_2 (*µg CO_2-C g soil^{-1}.day^{-1}*)**	**DHA (*µg TPF g.soil^{-1}*)**	**MBC (*µg C. g soil^{-1}*)**
CL	333	172	35.5

All data were subjected to one way analysis of variance with the MSTAT-C software (Version 1.2; Crop and Soil Department Michigan State University). Duncan's multiple range test were performed according to Bek (1983).

Results and Discussions

The effects of this research applications on CO_2 production of the soil are presented in Table 2. All treatments were significantly ($p<0.05$) effective on CO_2 production where black mulch material enhanced soil biological activity; therefore, the highest mean of CO_2 production was determined at MB. The mean values determined as 201, 132 and 224 µg CO_2-C g soil^{-1}day^{-1} in M0, MG, and MB, respectively. Most probably, black material tends to increase soil temperature resulting in a higher biological activity, thus higher CO_2 production as Sardans and Penuelas (2004) reported. The irrigation levels were also effective on respiration; however, there was no statistical difference between I_{75} and I_{100} based on the general average values. The determined mean values for I_{50}, I_{75} and I_{100} were 179, 188 and 190 µg CO_2-C g soil^{-1} day^{-1}, respectively. In Ca applications, the highest average values were determined as 209, 211 and 201 for Ca0, Ca5 and Ca30 doses. A number of researchers reported positive effects on soil respiration (Scopa and Dumantet, 2007; Bonanomi et al., 2008; Dogan et al., 2013); however, in this research it is clearly seen that CO_2 formation was affected not only from plastic mulch material but also from its colour.

Moreover, mulch applications decreased to positive effect of Ca applications on soil CO_2 values.

As a similar research results, studied by Bananomi et al., (2008), the application of soil solarization, one of the most promising techniques for the control of soilborne pathogens, is seriously limited by the drawback regarding the disposal of the used plastic materials. A possible solution to this problem is the use of biodegradable plastics. And according to another similar study results made by Stapleton (2000), in solarized soils, control of pests is imputable to multiple mechanisms which primarily involve thermal inactivation of plant pathogens, because of increased soil temperature under plastic films (Katan et al., 1976), or weakening of the pathogen propagules that become more susceptible to competition or antagonistic activity of the native soil microflora (Stapleton, 2000). According to another similar research results, studied by Oz et al. (2016), soil organic matter with solarization application improve availability of nutrients in the soil du to the higher temperatures lead to decomposition of organic matter. Mulching entails the application of natural or synthetic material to cover the soil surface to protect soil from some abiyotic environmental factors as weed growth, to control wind and water erosion, to regulate temperature and to enhance soil structure etc. However plastic mulch materials don't serve to this purpose. It is better to use organic based materials such as hay, leaves, manure, compost, vermicompost, wood, bark, cocoa hulls, rice straw, wheat straw, peanut hulls etc. than to use plastic mulch cover material for soil quality and sustainability (Kahlon and Lal, 2011; Pahlow et. al., 2015).

Dehydrogenase enzyme activity values are given in Table 3. The mean values obtained from M0, MG and MB were 27.8, 24.7 and 22.0 µg TPF g soil^{-1} which the differences between treatments were insignificant ($p>0.05$). DHA was influenced by the irrigation level ($p < 0.05$), the mean values for I_{50}, I_{75} and I_{100} being 29.3, 20.9 and 24.4 µg TPF g soil^{-1}. While the effects of Ca doses on DHA did not cause statistically significant differences, the lowest DHA value was found as 21.5 µg TPF g.soil^{-1} in Ca0 dose and the highest one was determined as 28.3 µg TPF g soil^{-1} in Ca5 dose. Dehydrogenase enzyme activity is an important indicator of soil microbial activity and it is used by many organisms in the soil (Haktanir and Arcak, 1997; Kumar et. al., 2013).

Table 2. The effect of applications on CO_2 production (□g CO_2-C g soil^{-1} day^{-1})

µg CO_2-C g. soil^{-1} day^{-1}		Irrigation Levels							
Mulch	Ca Doses	50		75		100		Average	
M0	Ca0	140	o-q	210	gh	153	m-o	168	**F**
	Ca5	220	e-g	241	d	250	d	237	**D**
	Ca10	213	fg	170	j-n	172	i-m	185	**E**
	Ca20	154	l-o	142	op	173	i-l	156	**G**
	Ca30	237	de	241	d	296	b	258	**C**
Average		**193 C**		**201 C**		**209 C**		**201**	***B***
Mg	Ca0	111	rs	182	ij	192	hi	162	**FG**
	Ca5	80	tu	121	qr	173	i-m	125	**H**
	Ca10	63	u	73	u	72	u	69	**J**
	Ca20	101	s	92	st	140	o-q	111	**I**
	Ca30	173	i-m	180	i-k	221	e-g	191	**E**
Average		**106 F**		**130 E**		**159 D**		**132**	***C***
Mb	Ca0	270	c	343	a	280	bc	298	**A**
	Ca5	340	a	231	d-f	240	d	270	**B**
	Ca10	333	a	282	bc	203	gh	272	**B**
	Ca20	101	s	152	no	130	p-r	128	**H**
	Ca30	150	no	160	k-o	150	o	153	**G**
Average		**239**	**A**	**234**	**A**	**201**	**C**	**224**	***A***
G. Average		***179***	***B***	***188***	***A***	***190***	***A***		
Ca G. Ave.	Ca0	**174**	**G**	**245**	**A**	**208**	**CD**	**209**	***A***
	Ca5	**213**	**BC**	**198**	**DE**	**221**	**B**	**211**	***A***
	Ca10	**203**	**C-E**	**175**	**G**	**149**	**H**	**176**	***C***
	Ca20	**119**	**J**	**129**	**I**	**148**	**H**	**132**	***D***
	Ca30	**187**	**F**	**194**	**EF**	**222**	**B**	**201**	***B***

Since DHA is endo-enzyme that plays a very active role in the mineralization of organic matter in the soil, close relation was expected between DHA and CO_2. Enzyme activity is another important microbial activity indicator like CO_2 production.

Based on the DHA values gathered, it can be said that mulching application decreased to DHA values. Neither irrigation levels nor Ca applications could prevent this decrease. However, the lowest irrigation levels (I_{50}) caused to the highest DHA value with 29.3 µg TPF g soil^{-1}. According to general averages, Ca applications increased DHA values in M0 treatment. Soil enzyme activities are very sensitive to both natural and anthropogenic disturbances and show a quick response to the induced changes. Soil dehydrogenase enzymes are one of the main components of soil enzymatic activities participating in and assuring the correct sequence of all the biochemical routes in soil biogeochemical cycles (Kumar et. al., 2013; Dick, 1993; Dogan, 2012). Mulch application strongly influences soil moisture and temperature; therefore, DHA showed variation depends on mulch material.

Table 3. The effect of applications on DHA activity (µg TPF g.soil^{-1})

DHA-µg TPF g.soil^{-1}		Irrigation Levels							
Mulch	Ca Doses	50		75		100		Average	
M0	Ca0	23,6	b	20,2	b	27,0	b	23,6	**A-C**
	Ca5	34,0	b	22,3	b	37,3	b	31,2	**A-C**
	Ca10	35,7	b	25,9	b	38,2	b	33,3	**A-C**
	Ca20	17,4	b	18,2	b	16,1	b	17,2	**BC**
	Ca30	43,0	b	34,1	b	24,2	b	33,8	**AB**
Average		**30,8 AB**		**24,1 AB**		**28,6 AB**		**27,8**	***A***
Mg	Ca0	15,9	b	12,3	b	18,1	b	15,5	**BC**
	Ca5	17,1	b	20,5	b	27,6	b	21,7	**BC**
	Ca10	28,0	b	11,2	b	19,2	b	19,5	**BC**
	Ca20	83,9	a	13,9	b	23,4	b	40,4	**A**
	Ca30	26,3	b	30,2	b	23,0	b	26,5	**A-C**
Average		**34,2 A**		**17,6 B**		**22,3 AB**		**24,7**	***A***
Mb	Ca0	26,0	b	23,7	b	26,6	b	25,4	**A-C**
	Ca5	33,0	b	35,7	b	27,3	b	32,0	**A-C**
	Ca10	17,1	b	14,3	b	21,2	b	17,5	**BC**
	Ca20	17,8	b	13,4	b	12,8	b	14,7	**C**
	Ca30	20,0	b	17,7	b	23,7	b	20,5	**BC**
Average		**22,8**	**AB**	**21,0**	**AB**	**22,3**	**AB**	**22,0**	***A***
G. Average		***29,3***	***A***	***20,9***	***B***	***24,4***	***AB***		
Ca G. Ave.	Ca0	**21,8**	**AB**	**18,8**	**B**	**23,9**	**AB**	**21,5**	***A***
	Ca5	**28,0**	**AB**	**26,2**	**AB**	**30,7**	**AB**	**28,3**	***A***
	Ca10	**26,9**	**AB**	**17,1**	**B**	**26,2**	**AB**	**23,4**	***A***
	Ca20	**39,7**	**A**	**15,1**	**B**	**17,4**	**B**	**24,1**	***A***
	Ca30	**29,8**	**AB**	**27,4**	**AB**	**23,6**	**AB**	**26,9**	***A***

The values related to microbial biomass carbon (MBC) contents are presented in Table 4. All tested treatments were statistically significant ($p < 0.05$) on the MBC values. The overall mean results for M0, MG and MB were 574, 379 and 470 µg C g soil^{-1}, respectively. Mean MBC values for I_{50}, I_{75} and I_{100} were 468, 456 and 498 µg C g soil^{-1}. According to the general average results, the highest MBC value that was affected by the Ca doses was determined as 517 mg C g soil^{-1} in Ca0 dose and the lowest value was determined as 420 mg C g soil^{-1} in Ca20 dose.

Table 4. The effect of applications on MBC content (µg C. g soil-1)

MBC- µg C g_soil-1		Irrigation Levels							
Mulch	Ca Doses	50		75		100		Average	
M0	Ca0	848	a	733	b-d	657	d-f	**746**	**A**
	Ca5	169	v	349	p-s	380	n-s	**300**	**GH**
	Ca10	829	ab	450	j-p	585	f-h	**621**	**C**
	Ca20	413	k-q	293	r-u	533	g-j	**413**	**E**
	Ca30	763	a-c	802	a-c	810	ab	**791**	**A**
Average		**604 A**		**525 B**		**593 A**		***574***	***A***
Mg	Ca0	160	v	161	v	177	v	**166**	**I**
	Ca5	727	b-d	578	f-h	751	a-d	**685**	**B**
	Ca10	347	p-s	449	j-p	462	j-o	**420**	**E**
	Ca20	399	l-r	283	s-u	352	p-s	**345**	**FG**
	Ca30	207	t-v	339	p-s	288	s-u	**278**	**H**
Average		**368 EF**		**362 F**		**406 DE**		***379***	***C***
Mb	Ca0	609	e-g	700	c-e	609	e-g	**639**	**BC**
	Ca5	370	n-s	309	q-t	449	j-p	**376**	**EF**
	Ca10	471	i-n	520	g-k	570	f-i	**520**	**D**
	Ca20	513	g-k	500	h-l	488	h-m	**501**	**D**
	Ca30	202	u-v	380	m-s	353	o-s	**312**	**GH**
Average		**433**	**D**	**482**	**C**	**494**	**BC**	***470***	***B***
G. Average		***468***	***B***	***456***	***B***	***498***	***A***		
Ca G. Ave.	Ca0	**539**	**AB**	**531**	**A-C**	**481**	**B-F**	***517***	***A***
	Ca5	**422**	**F-H**	**412**	**G-I**	**527**	**A-C**	***454***	***B***
	Ca10	**549**	**A**	**473**	**C-F**	**539**	**AB**	***520***	***A***
	Ca20	**442**	**E-H**	**359**	**I**	**458**	**D-G**	***420***	***C***
	Ca30	**391**	**HI**	**507**	**A-D**	**484**	**B-E**	***460***	***B***

According to these results, it was obvious that both mulching application and colour of mulch materials are effective on MBC values significantly. MG is an exception; M0 and MB are decreasing MBC values in case of Ca fertilization. Higher MBC values were observed in the soil that Ca applied and MG covered. Additionally, I_{100} irrigation levels caused the higher MBC values. The pH and Electrical Conductivity (EC) values are presented in Table 5 and Table 6, respectively. Both pH and EC values are significantly ($p<0.05$) affected from treatments.

The mean pH values for M0, MG and MB were 7.04, 7.52 and 7.38, whereas the mean values for I_{50}, I_{75} and I_{100} were 7.28, 7.25 and 7.41, respectively. The highest pH value, changes with Ca applications was 7.70 in Ca5 dose and the lowest is found as 6.55 in Ca20 dose according to the general average results.

The EC averages for M0, MG and MB were 500, 295 and 305 □S, respectively. EC was also affected by the irrigation levels and the values for I50, I75 and I100 were 394, 384 and 322 □S, respectively.

The highest values were determined as 462 and 459 µS for the Ca20 and Ca30 doses whereas the lowest value was found in Ca0 dose as 252 µS.

Table 5. The effect of applications on soil pH

pH 1/5		Irrigation Levels							
Mulch	Ca Doses	50		75		100		Average	
M0	Ca0	8,12	h	6,70	qr	6,88	op	**7,23**	**E**
	Ca5	7,80	ij	7,21	m	6,73	qr	**7,25**	**E**
	Ca10	7,21	m	6,40	s	7,62	k	**7,08**	**F**
	Ca20	5,72	v	7,10	mn	6,05	t	**6,29**	**I**
	Ca30	7,23	m	7,71	jk	7,14	m	**7,36**	**D**
Average		**7,22 C**		**7,02 D**		**6,88 E**		***7,04***	***C***
Mg	Ca0	6,97	no	6,39	s	8,52	cd	**7,29**	**DE**
	Ca5	8,18	f-h	8,42	de	8,15	gh	**8,25**	**A**
	Ca10	6,95	op	8,67	ab	7,42	l	**7,68**	**C**
	Ca20	6,16	t	6,32	s	7,13	m	**6,54**	**H**
	Ca30	7,91	i	6,87	op	8,70	a	**7,83**	**B**
Average		**7,23 C**		**7,33 B**		**7,98 A**		***7,52***	***A***
Mb	Ca0	8,19	f-h	8,16	gh	8,62	a-c	**8,32**	**A**
	Ca5	8,33	ef	8,16	gh	6,36	s	**7,62**	**C**
	Ca10	6,14	t	5,90	u	8,55	b-d	**6,86**	**G**
	Ca20	7,45	l	6,41	s	6,62	r	**6,83**	**G**
	Ca30	6,81	pq	8,30	e-g	6,65	r	**7,25**	**E**
Average		**7,38**	**B**	**7,39**	**B**	**7,36**	**B**	***7,38***	***B***
G. Average		***7,28***	***B***	***7,25***	***B***	***7,41***	***A***		
Ca G. Ave.	Ca0	**7,76**	**D**	**7,08**	**H**	**8,01**	**B**	***7,62***	***B***
	Ca5	**8,10**	**A**	**7,93**	**BC**	**7,08**	**H**	***7,70***	***A***
	Ca10	**6,77**	**J**	**6,99**	**I**	**7,86**	**C**	***7,21***	***D***
	Ca20	**6,44**	**L**	**6,61**	**K**	**6,60**	**K**	***6,55***	***E***
	Ca30	**7,32**	**G**	**7,63**	**E**	**7,50**	**F**	***7,48***	***C***

Table 6. The effect of applications on EC (µS)

EC (µS)		Irrigation Levels							
Mulch	Ca Doses	50		75		100		Average	
M0	Ca0	219	tu	322	m-u	358	kl	**300**	**F**
	Ca5	321	m-u	313	n-u	444	h	**359**	**D**
	Ca10	570	e	644	c	501	f	**572**	**B**
	Ca20	580	e	730	b	412	i	**574**	**B**
	Ca30	807	a	661	c	614	d	**694**	**A**
Average		**499 B**		**534 A**		**466 C**		***500***	***A***
Mg	Ca0	304	op	242	r-t	216	u	**254**	**H**
	Ca5	263	qr	215	u	225	s-u	**234**	**I**
	Ca10	311	no	93	x	246	rs	**216**	**J**
	Ca20	443	h	472	g	425	hi	**447**	**C**
	Ca30	324	m-o	494	fg	151	v	**323**	**E**
Average		**329 E**		**303 G**		**253 H**		***295***	***C***
Mb	Ca0	283	pq	207	u	121	w	**204**	**J**
	Ca5	247	rs	266	qr	345	lm	**286**	**G**
	Ca10	409	i	382	j	139	vw	**310**	**EF**
	Ca20	380	jk	418	i	301	op	**366**	**D**
	Ca30	446	h	303	op	333	mn	**361**	**D**
Average		**353**	**D**	**315**	**F**	**248**	**H**	***305***	***B***
G. Average		***394***	***A***	***384***	***B***	***322***	***C***		
Ca G. Ave.	Ca0	**269**	**IJ**	**257**	**J**	**231**	**K**	***252***	***D***
	Ca5	**277**	**I**	**265**	**IJ**	**338**	**G**	***293***	***C***
	Ca10	**430**	**E**	**373**	**F**	**295**	**H**	***366***	***B***
	Ca20	**468**	**D**	**540**	**A**	**379**	**F**	***462***	***A***
	Ca30	**526**	**B**	**486**	**C**	**366**	**F**	***459***	***A***

Conclusions

Results clearly stated that the mulching application is significantly effective on soil biologic activity as many researchers reported; however, in this research it is clearly seen that the colour of mulch is important as mulch material.

Considerable increases are expected on soil microbial activity in case of using organic material for mulching. This because the organic matters are source of energy for microorganisms and more or less the mulching material may mix to soil; therefore, the higher organic input results the higher biological activity. As an example both MG and MB reduced MBC comparing the control but respiration is not supporting this findings that MG reduces CO_2 formation contrarily respiration stimulated by MB. The mechanism of the stimulating effect of mulching strongly associated with elevated soil temperature and/or conserving soil moisture contents.

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