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VISUAL PARAMETERS OF SOYBEAN (*GLYCINE MAX* L.) AS INFLUENCES BY MOLE DRAIN SPACING AND DEPTH IN VERTISOLS OF MADHYA PRADESH

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Abstract: Field experiments were conducted at farmer's fields in Hoshangabad district of Madhya Pradesh during 2010 to 2011 to assess visual parameters and profitability of soybean as influences by mole drain spacing and depth in temporary waterlogged vertisols of Madhya Pradesh. The mole drain spacing selected includes 2, 4, 6 and 8 m and these drains were formed at an average depth of 0.4, 0.5 and 0.6 m from ground surface. The average length of each lateral was 50 m and a 75 hp tractor was operated at a speed of 0.80 $km \cdot h^{-1}$ during the mole drain formation. Observation on physiological parameters like days to germination, days to 50% flowering, days to 75 % maturity were recorded visually for continuous two seasons, analyzed statistically. On the basis of the results obtained from the experiment, it can be concluded that mole drains at a spacing of 2 meter and at a depth of 0.4 meter was found optimal for better soybean profitability.

Key words: *drainage, drain spacing, drain depth, mole drains, soybean, vertisols*

INTRODUCTION

Mole drains are the pipe less drains formed with a mole plough exclusively in soils dominated with clay content. The spacing of mole drains are generally varies from 2 to 10 m. Although the spacing is related to soil texture in some countries in Eastern Europe, it is largely determined based on local experience in most countries [1]. However, it

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depends on the soil permeability and the necessity of drainage also. If the spacing is less than 2 m, there is a danger of damage of the previously constructed drain, where as if the spacing is greater than 5 m, the fissuring effect may not cover the intervening space. Local experience rather than the adopting a particular value determines the spacing of the mole drain. The length of mole channels depends on the grade of the mole drains formed, soil type, shape, size and topography of the field. Flat slopes require shorter drain. A balance has to be found between risk of scouring with high water velocities on deep grades and risk of pond and channel collapse at low grades in order to decide the length and grade of mole channel. In order to protect the outlet of mole drain, a small piece of approximately 1 m length PVC pipe is inserted at the outlet side of the drain. For longer life of mole drains, the timing of the installation is very critical. At the time of moling the soil at moling depth should be plastic and soil above this depth should be friable so that there is adequate traction and the soil will crack well from the leg slot to the soil surface. The ideal time for moling after one to two months after withdrawal of monsoon. Immediately after mole drains installation it would be better irrigate the field with sprinklers otherwise do not irrigate at all at least for a month, allowing the soil to ripen before the mole carries water. The useful life of mole channels varies from 2 to 10 years depending upon many factors. Success of moling depends on working with the correct soil type and installing the mole drainage at the right depth and spacing at a optimum moisture content i.e., near the lower limit of the ‘plastic’ range. The speed of operation of mole plough for mole drain formation is very important. Better mole drains are formed when the tractor speed is slow and steady. The generally recommended speed is less than 1.0 $km \cdot h^{-1}$.

Several researchers have studied the influence of mole drainage on crop production. [2] reported that the effects of different types of mole drains on some clay soil properties and wheat yield were tested in the study in heavy clay soil. Moles were composed of 3 different materials; compost, sand and mixture of compost with sand (1:1). Two depths of moles (0.3 and 0.5 m) and three distances among moles (10, 15 and 20 m) were investigated in this work. The results indicated that: The Piezometric head increases as the distance among moles increases and vice versa. At each mole spacing, the Piezometric head decreases as the time advances after irrigations. However, the 10 m mole spacing achieved the best significant results over the 15 and 20 m spacing. The highest yield (2737 $kg \cdot fed^{-1}$) was obtained by using compost, 10 m distance among moles and 0.5 m moles' depth. Decreasing distance among moles, increases yield penetration resistance (PR), hydraulic conductivity (Kh) and infiltration rate. Increasing mole depth, increases yield (Kh) and infiltration rate while decreases (PR).

[3] conducted the study in salt affected soils of Godavari western delta and concluded that sub-surface drainage technology has been very instrumental in achieving sustainable agricultural productivity levels in the saline-sodic soils of Godavari Western Delta that were badly affected by salinity and waterlogged situations and ECe of soils were reduced by 20.15% in surface soil and 28.58- 41.24% in sub surface soil indicating that desalinization of soil profile was taken place. They also concluded that the productivity levels of paddy were increased by 46% in kharif season and 50% in rabi seasons and sub-surface drainage technology is financially feasible, economically viable and cost effective with payback period of 2.18 years.

[4] reported that a system of subsurface drainage was implemented (simple drainage) and part of the site was equipped with mole drains (combined drainage) and

data from the two situations were used to calibrate the HYDRUS2D model and the dynamics of salt movement in the two situations were modeled. It was shown that high precipitation and low evapo-transpiration are important in controlling soil salinity. At the end of winter, both treatments presented Na+ concentrations of less than 1 $mg \cdot ml^{-1}$, but this value was close to 2 $mg \cdot ml^{-1}$ at the end of the irrigation period.

[5] examined the impact of pipeless drainage on soil properties and on soybean growth in Bangkok soils. The effects of pipeless drainage on soil physical and chemical properties were found to be very significant : basic infiltration rate increased by about 2.7 fold, porosity increased by 14% at 25 cm depth and by 19% at 40 cm depth, soil aeration improved markedly, saturated hydraulic conductivity increased by 34 fold at 25 cm depth and by 61 fold at 40 cm depth, and pipeless drains with liming showed along-lasting improvement in soil pH and EC in the lower soil profile. Because of these improvements in the soil properties it was found that the soybean crop responded very well to pipe less drainage. There was about 46% increase in grain yield and 118% increase in the dry matter per plant.

Four year (2004-2009) field experiment was carried out at Central Institute of Agricultural Engineering (CIAE), Bhopal feasibility of mole drainage for draining excess rain water in Vertisols and concluded that crop yields increased by about 50% in the mole drained plots as compared to the control, while the cost per ha for construction of mole drains at 2,4 and 6 m drain spacing were *Rs* 3200, *Rs* 1800 and *Rs* 1200 respectively [6]. [7, 8, 9] also reported an increase in crop yield due to pipeless drainage in Vertisol.

MATERIAL AND METHODS

The study area is located in the farmer's fields in the village Bamuriya in Hoshangabad district of Madhya Pradesh. The study area is situated between 22°37'30'' to 22°38'10'' N latitude and 77°39'30" to 77°40'59" E longitude with an altitude of 307 meters from mean sea level (*MSL*).

Table 1. Details of treatment combination for mole drains spacing and depths

Symbol	*Treatments detail for Soybean crop*	*Symbol*	*Treatments detail for Soybean crop*
T0	S_0D_0 - *Control*		
T1	S_1D_1 *(spacing 2 m + depth 0.4 m)*	*T7*	S_3D_1 *(Mole spacing 6 m + depth 0.4 m)*
T2	S_1D_2 *(spacing 2 m + depth 0.5 m)*	*T8*	S_3D_2 *(Mole spacing 6 m + depth 0.5 m)*
T3	S_1D_3 *(spacing 2 m + depth 0.6 m)*	*T9*	S_3D_3 *(Mole spacing 6 m + depth 0.6 m)*
T4	S_2D_1 *(spacing 4 m + depth 0.4 m)*	*T10*	S_4D_1 *(Mole spacing 8 m + depth 0.4 m)*
T5	S_2D_2 *spacing 4 m + depth 0.5 m)*	*T11*	S_4D_2 *(Mole spacing 8 m + depth 0.5 m)*
T6	S_2D_3 *(spacing 4 m + depth 0.6 m)*	*T12*	S_4D_3 *(Mole spacing 8 m + depth 0.6 m)*

The slope of the area is less than 1% with good drainage outlets. The dimensions of the mole plough designed and developed at *CIAE* include a leg with 1250 × 250 × 25 mm and a foot of 63 mm with 75 mm bullet or expander diameter. With a 3 point linkage the plough can be mounted on a wheeled tractor. The total weight of the plough was 75 kg. The treatments consisted of 13 combinations of mole drain spacing (4 levels) and mole drain depth (3 levels). The details of treatment combinations are given in Tab.

1. The mole drains installed 4 spacing (2,4,6 and 8 m spacing) at 3 depths (0.4,0.5 and 0.6 m depth) under a split plot designed experiment with 3 replications.

Following visual parameters were also recorded during soybean crop period:

Days to germination. Days to initiation of germination was recorded in each plot.

Days to 50% flowering. When flowering started the numbers of flowers plant/plot were counted in alternate days. At the time of 50% flowering stage the dates were recorded. Whenever to 50% plants of the total plants population of each plot reached flowering, the total number of days from sowing were counted and recorded.

Days to 75 % maturity. When pods started to mature the number of plants reaching maturity per plot were counted in alternate days. At the time of 75% pod mature plants, the dates were recorded.

Dry matter accumulation per plant. Dry matter accumulation per plant at 30, 45, 60 days after sowing and at harvest stage was recorded in each plots. Five randomly selected plants were uprooted and they were kept in oven at 65^0 C for 48 hours and then weighed. The data is converted on plant basis and analyzed.

Net monetary returns. Net monetary returns were obtained by subtracting cost of cultivation from gross monetary returns. Net monetary returns are considered to be a good indicator of suitability of a particular cropping system as this represents the accrued net income to the farmer.

Net monetary returns ($R_s \cdot ha^{-1}$) = Gross monetary return ($R_s \cdot ha^{-1}$) – Cost of cultivation ($R_s \cdot ha^{-1}$)

RESULTS AND DISCUSSION

Observation on physiological parameters like days to germination, days to 50% flowering, days to 75 % maturity content were recorded visually, analyzed statistically and presented in Tab. 2 and 3.

Non-significant differences were observed on days to germination, days to 50 % flowering and days to 75 % maturity due to different treatments of spacing and depth of mole drains and interaction of these two. Maximum values of all the parameters were observed under mole drain depth D_1: 0.4 m in most of the cases. As far as depth is concerned, maximum values of all the characters were recorded in almost under mole drain depth D_1: 0.4 m. No clear trends were observed in all the cases as spacing and depth of mole drains practices are concern.

Dry matter accumulation per plant (g). The data on dry matter accumulation per plant were recorded periodically at an interval of 15 days beginning from 30 DAS and analyzed statistically. The analysis of variance is given in Appendix VI. The mean dry matter accumulation per plant at different stages under different treatments is presented in Tab. 4, 5 and 6.

It can be seen from Tab. 4 and 5 that the dry matter accumulation per plant gradually increased with advancement of age of the crop. The maximum rate of increase was recorded between 30 and 60 DAS in almost all the treatments. Later on rate of increase in dry weight accumulation reduced. Among various mole drains spacing, the maximum dry matter on all the stages were recorded under mole drain spacing S_1: 2 m in both the years and in pooled data analysis. Minimum values of dry matter accumulation were observed in case of control followed by mole drain spacing S_4: 8 m. Influence on dry matter content when observed, it was recorded highest under mole drain depth of 0.4 m and lowest under mole drain depth D_3: 0.6 m in all the crop growth stages during the years 2010-11, 2011-12 and pooled data analysis.

Table 2. Effect of spacing (S) and depth (D) of mole drains on visual character of soybean at different growth and at harvest stages

Treatme-nts	Visual characters								
	Days to germination			Days to 50 % flowering			Days to 75 % maturity		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing of mole drains									
S_0: 0 m	4.67	4.33	4.50	41.73	39.27	40.50	96.67	98.33	97.50
S_1: 2 m	3.89	4.22	4.06	39.19	36.52	37.85	91.22	91.89	91.56
S_2: 4 m	4.33	4.11	4.22	38.99	37.56	38.27	92.11	91.89	92.00
S_3: 6 m	4.33	4.22	4.28	39.38	38.15	38.76	92.22	92.22	92.22
S_4: 8 m	4.22	4.44	4.33	39.36	37.91	38.63	93.44	93.11	93.28
SEm±	0.14	0.12	0.05	0.62	0.42	0.33	0.45	0.59	0.21
$CD_{5\%}$	NS	NS	0.16	NS	NS	NS	NS	NS	0.74
Depth of mole drains									
D_0: 0 m	4.67	4.33	4.50	41.73	39.27	40.50	96.67	98.33	97.50
D_1: 0.4 m	4.08	4.17	4.13	39.06	37.29	38.17	92.25	91.83	92.04
D_2: 0.5 m	4.25	4.25	4.25	39.23	37.47	38.35	92.25	92.42	92.33
D_3: 0.6 m	4.25	4.33	4.29	39.40	37.84	38.62	92.25	92.58	92.42
SEm±	0.23	0.12	0.16	0.48	0.31	0.32	0.42	0.33	0.25
CD5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of interaction S X D on visual character of soybean at different growth and at harvest stages

Treatme-nts	Days to germination			Days to 50 % flowering			Days to 75 % maturity		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
S_0D_0	4.67	4.33	4.50	41.73	39.27	40.50	96.67	98.33	97.50
S_1D_1	3.67	4.00	3.83	38.93	36.30	37.62	90.00	91.67	90.83
S_1D_2	4.00	4.33	4.17	39.10	36.30	37.70	92.00	91.67	91.83
S_1D_3	4.00	4.33	4.17	39.53	36.96	38.25	91.67	92.33	92.00
S_2D_1	4.33	4.00	4.17	39.57	37.29	38.43	92.67	91.67	92.17
S_2D_2	4.33	4.00	4.17	38.53	37.82	38.18	92.00	92.00	92.00
S_2D_3	4.33	4.33	4.33	38.87	37.56	38.21	91.67	92.00	91.83
S_3D_1	4.33	4.33	4.33	38.87	38.94	38.90	92.33	91.67	92.00
S_3D_2	4.33	4.33	4.33	39.67	37.49	38.58	92.00	92.67	92.33
S_3D_3	4.33	4.00	4.17	39.60	38.02	38.81	92.33	92.33	92.33
S_4D_1	4.00	4.33	4.17	38.87	36.63	37.75	94.00	92.33	93.17
S_4D_2	4.33	4.33	4.33	39.60	38.28	38.94	93.00	93.33	93.17
S_4D_3	4.33	4.67	4.50	39.60	38.81	39.21	93.33	93.67	93.50
SEm=	0.22	0.32	0.17	1.10	1.10	0.80	0.71	0.88	0.53
$CD_{(5\%)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Effect of spacing (S) and depth (D) of mole drains on dry matter accumulation of soybean at different growth and at harvest stages

Treatments	Dry matter accumulation (g)					
	30 DAS			45 DAS		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing of mole drains						
S_0: 0 m	2.11	2.02	2.06	6.54	6.61	6.58
S_1: 2 m	3.74	3.83	3.79	12.37	13.09	12.73
S_2: 4 m	3.58	3.63	3.61	11.73	12.50	12.11
S_3: 6 m	2.84	3.00	2.92	9.04	9.84	9.44
S_4: 8 m	2.47	2.54	2.50	7.60	7.85	7.73
SEm±	0.02	0.15	0.07	0.22	0.69	0.40
$CD_{5\%}$	0.07	0.52	0.25	0.76	2.40	1.39
Depth of mole drains						
D_0: 0 m	2.11	2.02	2.06	6.54	6.61	6.58
D_1: 0.4 m	3.30	3.41	3.36	10.55	11.41	10.98
D_2: 0.5 m	3.16	3.11	3.13	10.35	11.03	10.69
D_3: 0.6 m	3.02	3.22	3.12	9.65	10.02	9.84
SEm±	0.08	0.12	0.10	0.24	0.27	0.22
$CD_{5\%}$	NS	NS	NS	NS	1.07	0.85

Table 5 Effect of spacing (S) and depth (D) of mole drains on dry matter accumulation of soybean at different growth and at harvest stages

Treatments	Dry matter accumulation (g)					
	60 DAS			At harvest		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Spacing of mole drains						
S_0: 0 m	9.41	9.07	9.24	13.98	14.72	14.35
S_1: 2 m	20.90	21.85	21.37	28.02	28.31	28.17
S_2: 4 m	19.20	18.54	18.87	25.94	26.61	26.28
S_3: 6 m	16.05	16.38	16.22	21.49	21.89	21.69
S_4: 8 m	12.62	12.61	12.61	18.78	19.11	18.95
SEm±	0.51	0.60	0.39	0.26	0.36	0.16
$CD_{5\%}$	1.76	2.08	1.35	0.90	1.26	0.55
Depth of mole drains						
D_0: 0 m	9.41	9.07	9.24	13.98	14.72	14.35
D_1: 0.4 m	18.16	18.99	18.58	24.59	24.77	24.68
D_2: 0.5 m	17.43	17.97	17.70	23.48	24.18	23.83
D_3: 0.6 m	15.98	15.06	15.52	22.60	23.00	22.80
SEm±	0.28	0.29	0.02	0.34	0.29	0.21
$CD_{5\%}$	1.11	1.13	0.09	1.32	1.13	0.84

A close of the data in Tab. 6 further reveals that at 30 DAS and 45 DAS the influence of spacing and depth of mole drains on dry matter was non-significant, but at later growth stages, the dry matter was affected significantly due to different spacing and depth of mole drains. It is also observed that maximum dry matter accumulation at 60 DAS and at harvest of crop was recorded highest with S_1D_1 (mole drains at the spacing of 2 m on the depth of 0.4 m), which was significantly superior to control. The differences in dry matter accumulation between S_1D_1 with S_1D_2 (mole drains at the spacing of 2 m on the depth of 0.5 m) and S_1D_3 (mole drains at the spacing of 2 m on the depth of 0.6 m) were found non-significant. Dry matter content per plant at both stages was found lowest in case of Treatment S_4D_3 (mole drains at the spacing of 8 m on the depth of 0.6 m) in both the years.

Table 6. Effect of interaction S X D on dry matter accumulation of soybean at different growth and at harvest stages

Trea-tment	30 DAS			45 DAS			60 DAS			At harvest		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
S_0D_0	2.11	2.02	2.06	6.54	6.61	6.58	9.41	9.07	9.24	13.98	14.72	14.35
S_1D_1	3.80	3.93	3.87	12.68	13.25	12.97	21.43	22.35	21.89	28.57	29.53	29.05
S_1D_2	3.51	3.57	3.54	12.49	13.33	12.91	21.19	21.97	21.58	27.80	27.97	27.88
S_1D_3	3.91	3.99	3.95	11.93	12.70	12.31	20.09	21.22	20.65	27.70	27.43	27.56
S_2D_1	3.75	3.54	3.65	11.97	13.06	12.52	20.27	21.00	20.63	26.80	26.43	26.62
S_2D_2	3.63	3.59	3.61	12.19	13.23	12.71	19.60	21.84	20.72	25.62	26.16	25.89
S_2D_3	3.36	3.76	3.56	11.02	11.21	11.12	17.73	12.77	15.25	25.40	27.25	26.32
S_3D_1	2.94	3.46	3.20	9.55	10.53	10.04	15.69	16.94	16.31	21.49	22.01	21.75
S_3D_2	3.07	2.87	2.97	9.29	10.15	9.72	15.95	17.06	16.50	21.68	22.91	22.30
S_3D_3	2.49	2.66	2.58	8.28	8.84	8.56	16.52	15.15	15.83	21.31	20.75	21.03
S_4D_1	2.70	2.72	2.71	8.01	8.82	8.41	15.27	15.69	15.48	21.51	21.11	21.31
S_4D_2	2.42	2.40	2.41	7.41	7.40	7.41	12.97	11.02	11.99	18.84	19.67	19.25
S_4D_3	2.30	2.48	2.39	7.37	7.34	7.36	9.61	11.12	10.36	15.99	16.57	16.28
SEm=	0.27	0.20	0.19	0.64	0.81	0.60	0.64	0.98	0.54	0.68	0.73	0.46
$CD_{(5\%)}$	NS	NS	NS	NS	NS	NS	1.98	3.03	1.65	2.10	2.26	1.41

The Tab. 7 reveals that the highest net return of Rs 36561, 46100 and 41330 per ha was recorded with S_1D_1, while it was found lowest of Rs 19723, 22332 and 21027 per ha under S_0D_0 in the years 2010-11, 2011-12 and pooled data respectively. The other treatments were found in decreasing order of S_1D_2, S_2D_1, S_2D_3 in both the years and in pooled data analysis.

Table 7. Effect of interaction S x D on net return ($Rs{\cdot}ha^{-1}$) soybean under different treatments of mole drains

Treatment	Net return ($Rs{\cdot}ha^{-1}$)			Treatment	Net return ($Rs{\cdot}ha^{-1}$)		
	2010-11	2011-12	Pooled		2010-11	2011-12	Pooled
S_0D_0	700	2437	1568	S_3D_1	12544	20925	16735
S_1D_1	12538	26204	19371	S_3D_2	12279	20001	16140
S_1D_2	12120	26113	19116	S_3D_3	10001	15932	12966
S_1D_3	10578	23050	16814	S_4D_1	3716	10117	6916
S_2D_1	13257	21984	17621	S_4D_2	2940	8926	5933
S_2D_2	12694	19918	16306	S_4D_3	2223	8443	5333
S_2D_3	11314	21496	16405	SEm=	325.3	644.7	337.1
				$CD_{(5\%)}$	NS	1986.6	1038.8

The net return is the best index of profitability of soybean crop production .The lowest net return of Rs 700, 2437 and 1568 per ha was recorded under the control. Under various mole drain formation, the highest net return was recorded under S2D1 (Rs 13257 per ha) followed by S_3D_1 (Rs 13478 per ha), while the lowest net return was recorded under S_4D_3 (Rs 2223 per ha) in the year 2010-11. While, it was recorded higher under S_1D_1 followed by S_1D_2 (Rs 26204 and 19371 per ha) in 2011-12 and in pooled data analysis respectively. Similar trends from various field studies conducted in Vertisols on mole drainage in soybean crop [6,9].

CONCLUSIONS

Days to germination, days to 50 % flowering and days to 75 % maturity showed non-significant differences due to different treatments (spacing of mole drain, depth of mole drain and interaction of these two). Maximum values of all the parameters were observed under mole drain spacing S_1 (2 m) and mole drain depth D_1 (0.4 m) in most of the cases. No clear trends were observed in all the cases as spacing and depth of mole drains practices are concern. The net return under various mole drain spacing treatments, the higher net return was recorded under mole drain spacing S_1 (2 m) in case of 2011-12 and pooled data, while in the year 2010-11, it was highest with mole drain spacing S_2 (4 m). In case of mole drain depth, D_1 (0.4 m) gave highest net return as compared to other treatments in both the years as well as in pooled data analysis. Mole drain with S_1D_1 (spacing of 2 m at the depth 0.4 m) was found better in comparison with other spacing and depth as well as the control.

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VIZUELNI PARAMETRI SOJE (*GLYCINE MAX* L.) POD UTICAJEM RASTOJANJA I DUBINE KRTIČNE DRENAŽE U SMONICAMA OBLASTI MADHYA PRADESH

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Sažetak: Poljski ogledi su izvođeni na farmama u oblasti Hoshangabad u Madhya Pradesh tokom 2010 i 2011 da bi se procenili vizuelni parametri i profitabilnost proizvodnje soje pod uticajem različitog rastojanja i dubine krtične drenaže u povremeno plavljenim smonicama. Izabrane krtične drenaže imale su rastojanja od 2, 4, 6 i 8 m, a drenovi su formirani na srednjim dubinama od 0.4, 0.5 i 0.6 m ispod površine parcele. Srednja dužina svake laterale bila je 50 m, a za formiranje drena korišćen je traktor snage 75 KS koji se kretao random brzinom od 0.80 $km \cdot h^{-1}$. Tokom dve sezone su posmatrani, beleženi i statistički analizirani fiziološki parametri kao što su broj dana do: nicanja, pojave 50% cvetova i pojave 75% zrelosti. Na osnovu rezultata dobijenih iz ogleda se može zaključiti da su krtični drenovi na rastojanju od 2 mi na dubini od 0.4 m bili optimalni za poboljšanje proizvodnje soje.

Ključne reči: *drenaža, rastojanje drenova, dubina drenaže, krtični drenovi, soja, smonica*

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