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Original article

Study of root traits of forage maize (*Zea mays* L.) in different tillage systems, drought stress and nitrogen fertilizer

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Extended abstract

Introduction

The first factor limiting plant yield in many crop ecosystems is drought stress, and plant productivity under these conditions depends on the distribution of dry matter between plant organs and the spatial distribution of roots in the soil. Knowledge of root length conditions and its distribution in soil profile, which is an indicator of the ability of plants to absorb water from deeper layers and better root permeability in the soil, as well as understanding the shape of the root system, is important (Wasson et al., 2012). In general, the size, morphology, and architecture of the root system determine the plant's ability to absorb water and nutrients, as well as the relative size and growth rate of the shoot (Vamerali et al., 2003). Root growth is determined by the genetic characteristics of the plant as well as the physical and chemical characteristics of the soil. Even in wet areas in response to drought stress, root growth is limited to the topsoil, and when the soil dries, its infiltration resistance increases rapidly, resulting in a combination of drought stresses. Soil and its infiltration resistance (He et al., 2017). Reduction of root dry weight in rice (Nasiri et al., 2015), fresh weight of root in rapeseed (Razaviezadeh and Amoubeigi, 2013) indicate the negative effect of drought stress on root characteristics in Different plants. Tillage is the only crop method by which humans can directly affect soil properties. Moisture storage and aeration to the roots, depending on the desired or unfavorable application of tillage, affects the growth and development of plant roots and ultimately its yield (Bronick and Lal, 2005.(

Material and methods

This experiment was conducted in split -split plots based on randomized complete block design with three replications. Tillage systems as the main -plot in two factors was including no tillage and conventional tillage, Water stress as the subplot in three levels by 30, 60 and 90 Percent of moisture requirement and nitrogen urea as the sub-sub plot at three levels by 0, 50 and 100 percent of the recommended rate.

Results

The combined variance analyses indicated that the maximum root length (4147 cm per plant), root volume (158.13 cm^3 per plant), root area (3055.7 cm^2 per plant), root length density (0.44 $cm^2. cm^{-3}$), root dry weight (24.32 gr pl^{-1}) and plant fresh weight (6732.6 gr. m^{-2}) was obtained from the interaction

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of conventional tillage in mild drought stress (90% of the plant's water requirement) in 100% of the plant's nitrogen fertilizer requirement. Also, the interaction effect of severe drought stress (30% of plant water requirement) in 100% of plant nitrogen fertilizer requirement led to a sharp decrease in studied traits in both studied tillage systems. Although the conventional tillage system in this study ultimately increased the root growth characteristics and fresh weight of the forage maize plant, but because no significant difference in wet forage yield was observed in both studied tillage systems, the system no tillage is recommended because it can improve the physical and chemical properties of the soil in the long turn.

***Keywords*:** Forage maize, Root dry weight, Root length, Root length density, Root surface, Root volume.

Table 1. Physical and chemical soil properties of the experimental site.

Year	Total N	OC	Clay	Silt	Sand	Soil texture	EC	pH	Available P	Available K	Depth
	----------------------%---------------------						dS m^{-1}		---------mg kg^{-1}---------		cm
2018	0.09	0.76	31	44	25	ClayLoam	0.97	8.4	8.3	125	0-30
2019	0.09	0.76	31	44	25	ClayLoam	1	8.2	9.1	120	0-30

Table 2. Analysis of variance for root length, root volume, root surface, root length density, root dry weight, and plant fresh weight of Zea mays affected by tillage type, drought stress and nitrogen levels

S.O.V		Root length	Root volume	Root surface	Root length density	Root dry weight	Plant fresh weight
Year (Y)	1	28316.9^{ns}	0.9445^{ns}	4316.93^{ns}	0.000319^{ns}	1.38946^{ns}	28158.2^{ns}
E_y	4	46300.10	106.00	21182.67	0.00052	2.5729	585646
Tillage (T)	1	3629992*	6894.41**	1967573**	0.04090*	106.4257*	3084664^{ns}
T ×Y	1	2332.62^{ns}	1.6378^{ns}	60.017^{ns}	0.000026^{ns}	0.1800^{ns}	33843.2^{ns}
E_a	4	18360.94	23.334	6347.03	0.00020	5.4920	168485.1
Drought stress (W)	2	1181012**	40386.5**	9079244**	0.13309**	1052.85**	94480563**
D ×Y	2	4595.93^{ns}	5.843^{ns}	1677.01^{ns}	0.000051^{ns}	0.2706^{ns}	20011.6^{ns}
T × D	2	38673.6^{ns}	622.84**	77086.64*	0.000435^{ns}	34.2561**	806766.48*
T × D × Y	2	6298.04^{ns}	2.4428^{ns}	1367.55^{ns}	0.00007^{ns}	0.1004^{ns}	37865.88n
E_b	16	10674.58	23.642	1907.27	0.000120	3.0627	89717.4
Nitrogen (N)	2	627833**	2984.84**	588962**	0.00707**	133.55**	21288102**
N ×Y	2	4712.52^{ns}	8.668^{ns}	92.15^{ns}	0.000053^{ns}	0.020^{ns}	9683.3^{ns}
N × T	2	13461.0^{ns}	64.589^{ns}	10392.43*	0.000151^{ns}	0.377^{ns}	514417.22*
N × T ×Y	2	797.61^{ns}	7.34370^{ns}	348.88^{ns}	0.000009^{ns}	0.377^{ns}	19324.2^{ns}
N × D	4	969261**	2079.41**	560886**	0.01092**	22.136**	2073109**
N × D × Y	4	5599.28^{ns}	16.7487^{ns}	483.10^{ns}	0.00006^{ns}	0.491^{ns}	3492.3ns
N × T × D	4	27951.57*	14.8231^{ns}	7751.78*	0.00031*	30.316**	846998**
N × T × D × Y	4	2967.19^{ns}	9.89620^{ns}	1151.49^{ns}	0.00003^{ns}	0.3899^{ns}	18847.8^{ns}
E_c	48	29064.68	57.1261	8355.99	0.00032	3.0351	199410
C.V %	-	*5.87*	*6.83*	*4.56*	*5.87*	*12.02*	*10.52*

Ns, * and **: Non-significant, significant at 5 and 1% probability level, respectively.

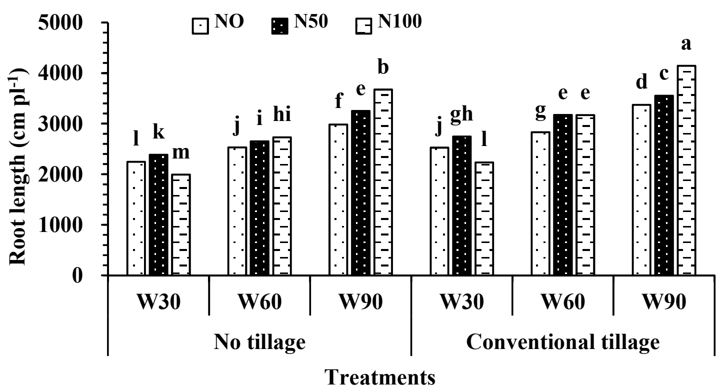

Fig. 1. Root length of maize forage affected by nitrogen levels and drought stress under tillage systems. N0, N50 and N100 are 0, 50 and 100 percent of nitrogen demand, respectively and W30, W60 and W90 are drought stress in 30, 60 and 90 percent of water requirement. (Means with the similar letters are not statistically significant)

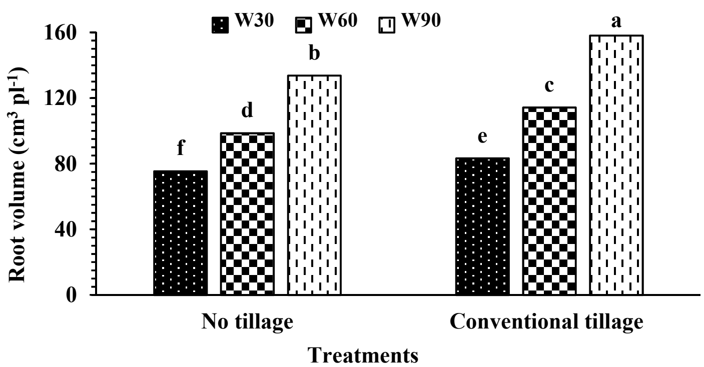

Fig. 2. Root volume of maize forage affected by drought stress and tillage systems. W30, W60 and W90 are drought stress in 30, 60 and 90 percent of plant water requirement.(Means with the similar letters are not statistically significant)

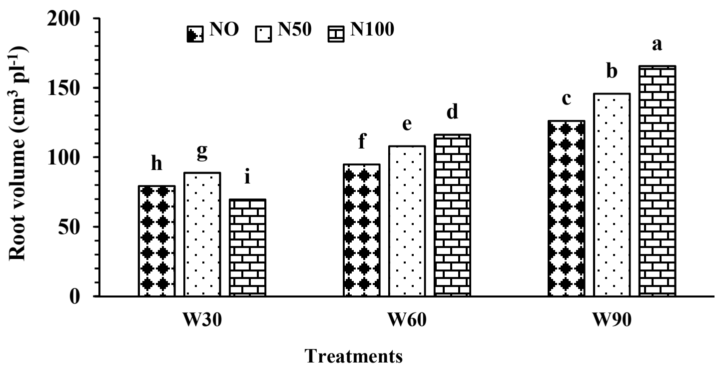

Fig. 3. Root volume of maize forage affected by nitrogen levels and drought stress. N0, N50 and N100 are 0, 50 and 100 percent of nitrogen demand, respectively and W30, W60 and W90 are drought stress in 30, 60 and 90 percent of plant water requirement. (Means with the similar letters are not statistically significant)

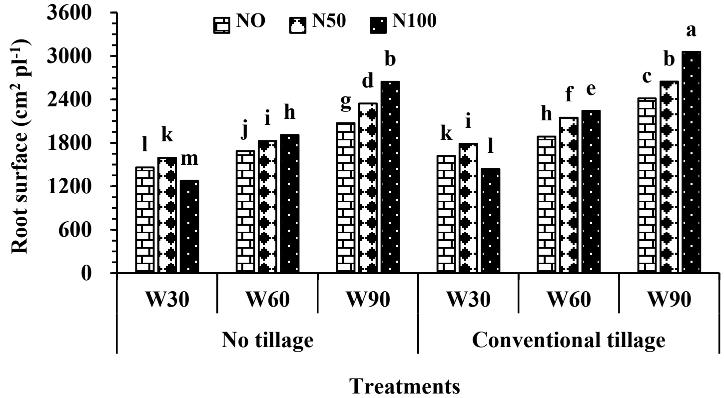

Fig. 4. Root surface of maize forage affected by nitrogen levels and drought stress under tillage systems. N0, N50 and N100 are 0, 50 and 100 percent of nitrogen demand, respectively and W30, W60 and W90 are drought stress in 30, 60 and 90 percent of water requirement. Means with the similar letters are not statistically significant.

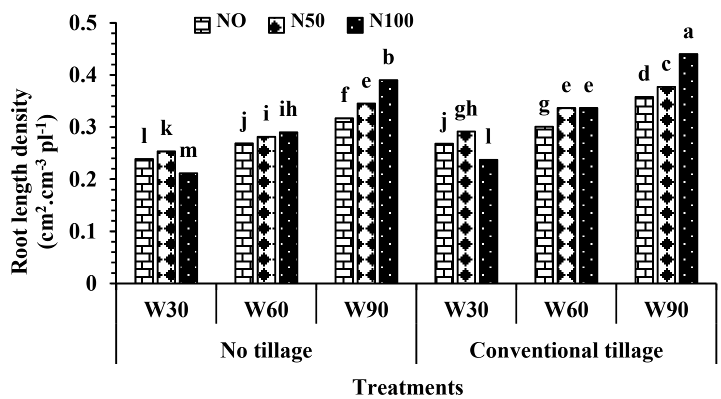

Fig. 5. Root length density of maize forage affected by nitrogen levels and drought stress under tillage systems. N0, N50 and N100 are 0, 50 and 100 percent of nitrogen demand, respectively and W30, W60 and W90 are drought stress in 30, 60 and 90 percent of water requirement. Means with the similar letters are not statistically significant.

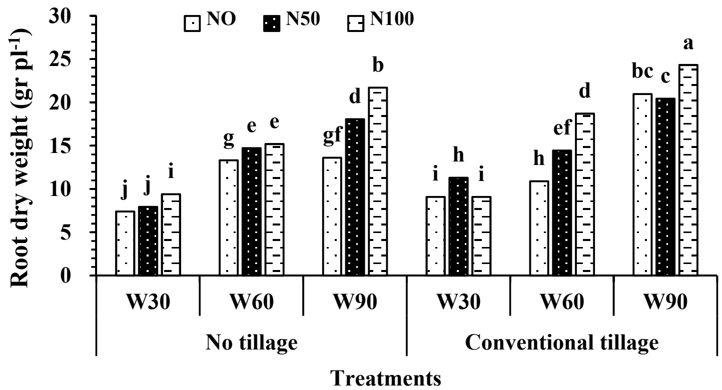

Fig. 6. Root dry weight of maize forage affected by nitrogen levels and drought stress under tillage systems. N0, N50 and N100 are 0, 50 and 100 percent of nitrogen demand, respectively and W30, W60 and W90 are drought stress in 30, 60 and 90 percent of water requirement. Means with the similar letters are not statistically significant.

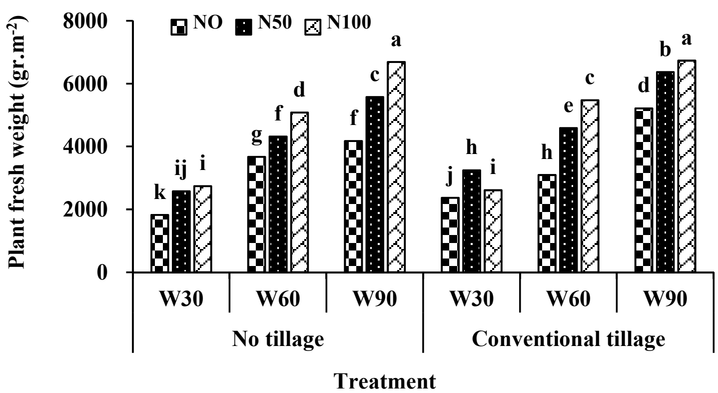

Fig. 7. Plant fresh weight of maize forage affected by nitrogen levels and irrigation regimes under tillage systems. N0, N50 and N100 are 0, 50 and 100 percent of nitrogen demand, respectively and W30, W60 and W90 are drought stress in 30, 60 and 90 percent of water requirement. Means with the similar letters are not statistically significant.

Table 3. Correlation between root length, root volume, root surface, root length density, root dry weight, and plant fresh weight of Zea mays affected by tillage types, drought stress and nitrogen levels

	Traits	1	2	3	4	5	6
1	**Root length**	1					
2	**Root volume**	0.99**	1				
3	**Root surface**	1**	1**	1			
4	**Root length density**	1**	0.99**	1**	1		
5	**Root dry weight**	0.93**	0.95**	0.95**	0.93**	1	
6	**Plant fresh weight**	0.91**	0.94**	0.93**	0.91**	0.97**	1