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Effect of Tillage Practices and Supplemental Irrigation Options on Growth, Yield and Soil Biological Properties of Hybrid Maize

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A B S T R A C T

Field experiment was conducted in two consecutive growing seasons at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu to evaluate the tillage practices, crop residue and supplemental irrigation through drip irrigation in maize under rainfed condition. The experiment was laid out in strip plot design with three replications. The main plot treatments were conventional tillage, minimum tillage without crop residue, minimum tillage with crop residue @ 5 t ha^{-1} and minimum tillage with crop residue @ 10 t ha^{-1}. The sub plot treatments were control (without irrigation), supplemental drip irrigation 4, 6, 8 and 10 times during the cropping period. Tillage practices and crop residue with supplemental drip irrigation practices could potentially lead to significant difference in growth parameters, microbes populations, yield attributes and maximum yield 8345, 8856 kg ha^{-1} of maize in both the seasons by application of minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation ten times. Therefore, minimum tillage (one pass of mouldboard plough followed by two passes of disk harrow) with crop residue 10 t ha^{-1} + supplemental irrigation through drip irrigation ten times was found to be more appropriate and profitable to improving yield of maize under rainfed condition.

Introduction

Soil quality (SQ) highly depends on its structure, natural productivity, and human influence. Soil organisms are important elements for preserved ecosystem biodiversity and services thus assess functional and structural biodiversity in arable soils is interest. Main threats to soil biodiversity occurred by mechanical impacts (soil compaction, soil tillage) and chemical stress (plant protection measures) in agricultural management.

Tillage is one of the major management practices affecting soil physical parameters. The influence of tillage systems on the total soil organic matter (OM) content is detectable only after several years of its application.

Microbial activity may respond to disturbances on a shorter period of time than those based on physical or chemical properties. As a consequence, microbiological properties such as soil enzyme activities have been suggested as potential indicators of SQ (Saviozzi *et al.*, 2001) because of their rapid response to changes in soil management (Kandeler *et al.*, 1999). In many cases, both bacteria and fungi were more abundant under no-tillage than conventional tillage (Helgason *et al.*, 2009).

Tillage systems affect the soil physical and chemical environment in which soil organisms live, thereby affecting soil organisms in different ways (Klavdivko 2001). Numerous studies in temperate regions have shown that decreasing tillage intensity results in higher organic C and N and improved soil quality (SQ) (Soon *et al.*, 2001). Conservation tillage practices (reduced or no-tillage) result in increasing enzyme activities (Acosta-Martinez *et al.*, 2003), microbial biomass (Franzluebbers *et al.*, 1995), and fungal and bacteria dominance under NT (Helgason *et al.*, 2009). Suitable soil management can be practiced through conservation tillage (including zero tillage), high crop residue return and crop rotation. Minimum-tillage (MT) is the most adapted conservation tillage system, which involves minimal disturbance of the surface residue.

Cropping systems that return crop residues to the field significantly increase the activity of a wide range of soil enzymes, compared to unamended soils, due to the stimulation of microbial activity (Frey *et al.*, 1999).

In dry areas mostly shortage of soil moisture occurs during the most sensitive growth stages like flowering and grain filling stage of the crops. As a resulting is poor crop growth and yield. Supplemental irrigation (SI), with limited amount of water, when applied during the critical crop growth stages, can result in substantial improvement in yield and water productivity. Hence SI is an effective method to alleviate the adverse impact of soil moisture stress during dry spells on the yield of rainfed crops (Oweis and Hachum, 2006).

Maize (*Zea mays* L.) is the third most important cereal next to rice and wheat, in the world as well in India. It may be a substitute over the other dominant cropping system and may fulfill the future demand of human and animal feed. In order to increase production further there is no other option except to increase productivity by using available resources most efficiently.

Keeping this in view, the present investigation was undertaken to study the combined effect of tillage, crop residue incorporation and supplemental irrigation methods on the growth, biological population and yield of maize in Tamil Nadu.

Materials and Methods

A field experiment was carried out for two consecutive growing seasons at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu. The experimental site is geographically situated at 10.56^0 North latitude and 78.49^0 East longitudes and at an altitude of 78 m above MSL. The soil was sandy loam in texture with pH 7.71. The fertility status of the soil was low, medium and high in the available N, P_2O_5, and K_2O, with the values of 212, 20 and 575 kg ha^{-1} respectively. The main plot treatments were conventional tillage, minimum tillage without crop residue, minimum tillage with crop residue @ 5 t ha^{-1} and minimum tillage with crop residue @ 10 t ha^{-1}. The sub plot treatments were (without irrigation) control, supplemental drip irrigation 4, 6, 8 and 10 times during the cropping period. The experiment was laid out in a strip plot design with three replications.

Conventional tillage included one pass of mouldboard plough to a depth of 15 cm and was followed by two passes of disk harrowing. Minimum tillage included only one pass of disk harrowing. The treatments were carried out on the same plots in the growing seasons. In both growing seasons, one of the most commercial maize NK6240 was sowing manually on paired row spacing of 60 + 30 x 20 cm (totally there were two rows per plot). Before sowing a uniform fertilizer schedule was followed at the rate of 135:62.5:50 kg of N, P_2O_5 and K_2O ha^{-1}.

Nitrogen was applied in three splits as 25: 50: 25 per cent as basal, at 25 and 50 DAS, respectively. The entire dose of phosphorus was applied basally. The potassium was applied in two equal split doses *viz*., basal and at 50 DAS.

Atrazine @ 0.5 kg a.i ha^{-1} was also applied for weed control after sowing of maize seed. During the growing season, the insecticides and fungicides were applied according to recommendations by the state agricultural university (SAU). All other necessary operations except those under study were kept normal and uniform for all the treatments.

The supplemental irrigation was given to the crop at the time of moisture stress period, which was determined based on the visual symptom (Wilting of plants). In study period four, six, eight and ten supplemental irrigations were given at various time period. The water was pumped by motor from farm pond and supplied to crops through drip irrigation system at a depth of 3 cm.

Observations on growth characters such as plant height and dry matter production were recorded at 30, 60, 90 DAS and at harvest from five randomly selected plants in each plot.

The samples were collected from sampling rows in each plot for dry matter production and were used for the estimation of DMP. The population density of bacteria, fungi and actinomycetes were enumerated using serial dilution plate technique. The data on yield parameters and yield were also recorded.

Results and Discussion

Effect of treatments on plant height

Growth and development in plants are a consequence of excellent coordination of several processes operating at different growth stages of plant. The growth of maize influenced by various tillage treatments has been elucidated through the positive response on plant height.

The growth parameters of maize were significantly influenced by tillage and crop residue with supplemental irrigation through drip irrigation. The growth parameters were not influenced by treatments at 30 DAS. Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher plant height (Table 1) (164, 198 cm and 159, 191 cm at 60 DAS and at harvest during 2012 and 2013, respectively). Regarding irrigation practices, supplemental irrigation at 10 times was recorded higher plant height than without supplemental irrigation plot.

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered distinctly higher plant height at 60 DAS and at harvest during both the years.

Effect of treatments on dry matter production

Tillage and crop residue with supplemental irrigation through drip irrigation significantly influenced the dry matter production (Tables 2 and 3). Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher dry matter production (8185, 10634 kg ha^{-1} and 8166, 10504 kg ha^{-1}) at 60 DAS and at harvest during 2012 and 2013, respectively. Among irrigation practices, supplemental irrigation at 10 times was recorded higher dry matter production in respective stages during both the seasons and it was comparable with supplemental irrigation at 8 times was recorded higher dry matter production than that in without supplemental irrigation plot.

Table.1 Effect of tillage, crop residue and supplemental drip irrigation on plant height (cm) of maize

Treatments	2012										2013									
	60 DAS					At harvest					60 DAS					At harvest				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	133	136	139	143	**138**	160	165	169	175	**167**	128	134	139	144	**137**	154	159	162	168	**161**
S_2	138	142	144	155	**145**	170	173	189	185	**179**	134	139	146	149	**142**	169	163	172	174	**170**
S_3	141	149	155	164	**152**	173	181	200	192	**186**	139	143	155	157	**149**	170	170	180	185	**177**
S_4	146	156	160	173	**159**	181	187	201	204	**193**	148	149	163	165	**156**	173	182	192	201	**187**
S_5	152	166	171	182	**168**	187	195	213	235	**208**	156	157	170	180	**166**	188	194	203	226	**203**
Mean	**142**	**150**	**154**	**164**		**174**	**180**	**194**	**198**		**141**	**145**	**155**	**159**		**171**	**174**	**182**	**191**	

	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)
M	5.1	12.4	6.9	17.0	3.7	9.1	5.5	13.4
S	4.4	10.2	6.9	15.8	4.2	9.8	6.7	15.1
M at S	6.2	14.7	8.4	20.3	4.3	10.1	7.0	16.4
S at M	5.6	13.0	8.4	19.5	4.7	10.9	7.8	17.9

M_1- Conventional tillage
M_2- Minimum tillage without crop residue
M_3- Minimum tillage with crop residue @ 5 tons ha^{-1}
M_4- Minimum tillage with crop residue @ 10 tons ha^{-1}
S_1-Control
S_2- Supplemental drip irrigation **four** times
S_3- Supplemental drip irrigation **six** times
S_4- Supplemental drip irrigation **eight** times
S_5- Supplemental drip irrigation **ten** times

Table.2 Effect of tillage, crop residue and supplemental drip irrigation on dry matter production (kg ha^{-1}) of maize 2012

Treatments	60 DAS					At harvest				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5926	5896	6345	6645	**6203**	7963	7793	8025	8324	**8026**
S_2	6745	6458	6942	7014	**6789**	8623	8124	9125	9624	**8874**
S_3	7156	6924	7468	7645	**7298**	9215	8745	10542	10457	**9739**
S_4	7724	7745	8102	8867	**8109**	9956	9456	11108	11526	**10511**
S_5	8541	8456	9023	10754	**9193**	10845	10245	12125	13242	**11614**
Mean	**7218**	**7096**	**7576**	**8185**		**9320**	**8872**	**10185**	**10634**	

	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)
M	220	539	367	899
S	236	544	449	1038
M at S	310	731	432	1014
S at M	317	731	501	1155

Table.3 Effect of tillage, crop residue and supplemental drip irrigation on dry matter production (kg ha^{-1}) of maize 2013

Treatments	60 DAS					At harvest				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5533	5568	6089	6458	**5912**	7563	7725	8023	8567	**7970**
S_2	6102	5984	6547	7324	**6489**	7958	8245	8757	9724	**8671**
S_3	6623	6548	7325	8135	**7158**	8567	8934	9547	10125	**9293**
S_4	7026	7102	7925	8935	**7747**	9001	9567	10167	11348	**10021**
S_5	7953	7892	8754	9978	**8645**	9563	10245	11025	12758	**10898**
Mean	**6648**	**6619**	**7328**	**8166**		**8531**	**8943**	**9504**	**10504**	

	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)
M	211	516	350	857
S	251	578	387	892
M at S	262	615	418	984
S at M	292	674	445	1027

Table.4 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on microbial population (cfu g^{-1} of soil) of maize at 60 DAS during 2012

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	62.5	59.0	65.6	67.1	**63.6**	22.0	21.0	24.0	24.5	**22.9**	12.0	14.3	16.4	18.5	**15.3**
S_2	64.6	62.2	67.5	69.8	**66.0**	23.6	22.5	25.6	26.2	**24.5**	13.5	15.6	17.3	21.2	**16.9**
S_3	65.6	64.5	70.2	71.3	**67.9**	23.0	23.9	27.5	29.3	**25.9**	13.6	16.1	18.2	23.5	**17.9**
S_4	65.7	66.5	71.2	74.5	**69.5**	24.6	24.8	28.1	30.2	**26.9**	14.1	16.5	19.0	24.6	**18.6**
S_5	66.2	65.1	72.4	75.5	**69.8**	25.1	24.6	27.8	30.8	**27.1**	14.0	17.1	21.2	26.0	**19.6**
Mean	**64.9**	**63.5**	**69.4**	**71.6**		**23.7**	**23.4**	**26.6**	**28.2**		**13.4**	**15.9**	**18.4**	**22.8**	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	1.57	3.83	0.62	1.51	0.48	1.18
S	1.73	3.98	0.66	1.51	0.50	1.15
T at S	1.79	4.21	0.80	1.89	0.60	1.41
S at T	1.92	4.42	0.82	1.90	0.60	1.38

Table.5 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on microbial population (cfu g^{-1} of soil) of maize at harvest during 2012

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	11.9	12.9	15.4	16.4	**14.1**	9.3	10.7	11.8	12.3	**11.0**	7.5	9.2	11.2	13.3	**10.3**
S_2	12.7	14.0	16.0	19.4	**15.5**	10.3	10.8	12.1	12.1	**11.3**	8.3	9.8	11.6	13.6	**10.8**
S_3	13.0	13.9	17.8	20.0	**16.2**	10.7	11.3	12.2	13.1	**11.8**	8.5	10.3	12.4	13.9	**11.3**
S_4	12.7	15.1	19.0	21.0	**17.0**	11.0	11.5	13.2	13.6	**12.3**	8.9	11.2	14.3	15.4	**12.5**
S_5	11.9	15.0	20.0	21.5	**17.1**	11.2	12.1	14.1	15.2	**13.2**	9.5	12.1	16.5	17.6	**13.9**
Mean	**12.4**	**14.2**	**17.6**	**19.7**		**10.5**	**11.3**	**12.7**	**13.3**		**8.5**	**10.5**	**13.2**	**14.8**	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	0.46	1.12	0.32	0.79	0.26	0.64
S	0.54	1.25	0.37	0.85	0.37	0.84
T at S	0.56	1.31	0.38	0.89	0.38	0.89
S at T	0.62	1.43	0.42	0.97	0.46	1.05

Table.6 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on soil microbial population (cfu g^{-1} of soil) of maize at 60 DAS during 2013

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	66.1	69.2	75.3	77.0	**71.9**	20.0	23.6	25.6	28.4	**24.4**	10.3	13.8	15.4	17.0	**14.1**
S_2	69.3	72.6	79.2	82.2	**75.8**	23.4	26.5	28.6	33.2	**27.9**	12.1	14.5	16.3	20.3	**15.8**
S_3	70.2	73.2	81.3	84.6	**77.3**	24.2	27.5	29.6	36.5	**29.5**	12.2	15.5	17.2	21.2	**16.5**
S_4	70.0	75.5	81.0	86.2	**78.2**	23.2	27.2	30.1	37.5	**29.5**	13.1	15.2	17.3	23.5	**17.3**
S_5	74.4	79.2	83.5	87.3	**81.1**	24.0	27.0	30.5	37.6	**29.8**	13.4	15.9	17.2	24.5	**17.7**
Mean	**70.0**	**73.9**	**80.1**	**83.5**		**23.0**	**26.4**	**28.9**	**34.6**		**12.2**	**15.0**	**16.7**	**21.3**	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	1.61	3.93	0.70	1.72	0.36	0.88
S	1.87	4.30	0.79	1.81	0.46	1.06
T at S	1.77	4.17	0.78	1.84	0.48	1.13
S at T	2.00	4.62	0.86	1.97	0.56	1.28

Table.7 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on microbial population (cfu g^{-1} of soil) of maize at harvest during 2013

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	18.0	20.1	24.5	26.3	**22.2**	8.3	10.2	12.2	13.4	**11.0**	7.0	10.2	11.9	13.9	**10.8**
S_2	18.6	21.3	25.5	27.3	**23.2**	8.3	10.0	12.5	14.2	**11.3**	8.1	11.2	12.5	13.5	**11.3**
S_3	19.5	21.2	25.6	27.2	**23.4**	9.6	11.6	12.6	15.6	**12.4**	8.3	13.2	12.6	14.1	**12.1**
S_4	20.6	24.2	26.3	27.0	**24.5**	10.3	11.6	13.5	15.3	**12.7**	8.5	13.1	13.2	14.6	**12.4**
S_5	22.2	25.5	27.1	28.7	**25.9**	11.2	12.1	14.5	15.9	**13.4**	9.2	13.2	14.1	15.2	**12.9**
Mean	**19.8**	**22.5**	**25.8**	**27.3**		**9.5**	**11.1**	**13.1**	**14.9**		**8.2**	**12.2**	**12.9**	**14.3**	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	0.61	1.50	0.32	0.78	0.28	0.68
S	0.63	1.45	0.33	0.77	0.28	0.64
T at S	0.84	1.98	0.46	1.08	0.37	0.88
S at T	0.84	1.94	0.46	1.06	0.37	0.85

Table.8 Effect of tillage, crop residue and supplemental drip irrigation on yield attributes and yield of maize 2012

Treatments	Cob length (cm)					Cob weight (g)					Yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	16.7	16.9	17.4	17.6	**17.2**	170	174	179	183	**177**	5034	5800	6783	6810	**6107**
S_2	16.6	17.0	17.9	18.1	**17.4**	174	179	184	190	**182**	5100	5890	7077	7328	**6349**
S_3	17.3	17.6	18.0	19.5	**18.1**	177	183	189	193	**186**	6103	6857	7350	7465	**6944**
S_4	17.0	18.2	19.0	19.3	**18.4**	181	189	200	204	**194**	6670	6945	7421	7724	**7190**
S_5	18.2	19.2	20.2	23.2	**20.2**	188	197	209	221	**204**	6745	7321	7945	8345	**7589**
Mean	**17.2**	**17.8**	**18.5**	**19.5**		**179**	**185**	**192**	**199**		**5930**	**6563**	**7316**	**7534**	

	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)
M	0.54	1.33	4.34	10.63	267	655
S	0.64	1.47	5.35	12.33	282	651
M at S	0.72	1.69	5.35	12.55	333	786
S at M	0.78	1.80	6.14	14.16	341	788

Table.9 Effect of tillage, crop residue and supplemental drip irrigation on yield attributes and yield of maize 2013

Treatments	Cob length (cm)					Cob weight (g)					Yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	15.4	15.9	16.4	17.1	**16.2**	136	149	150	152	**147**	5031	5089	5687	5983	**5448**
S_2	16.3	16.0	17.3	17.9	**16.9**	141	156	162	175	**159**	5245	5513	6021	6456	**5809**
S_3	16.4	16.6	17.9	18.2	**17.3**	153	172	170	191	**172**	6136	5987	6521	7215	**6465**
S_4	17.0	17.3	18.6	18.7	**17.9**	165	175	177	199	**179**	6123	6452	7034	8102	**6928**
S_5	17.3	18.8	20.1	21.8	**19.5**	176	186	205	214	**196**	6893	7024	7784	8856	**7639**
Mean	**16.5**	**16.9**	**18.1**	**18.7**		**155**	**168**	**173**	**187**		**5886**	**6013**	**6609**	**7322**	

	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)	S Ed	CD (P=0.05)
M	0.44	1.07	6.09	14.90	227	555
S	0.57	1.32	7.39	17.03	254	585
M at S	0.59	1.39	7.35	17.26	297	699
S at M	0.69	1.59	8.39	19.35	314	725

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered significantly higher dry matter production at 120 DAS and at harvest during both the years of study.

This might be due to the reason that minimum tillage conserved more soil moisture and crop residues have potential to increase of soil organic matter and nutrient levels, moderation of soil temperature and augmented soil biological activity, which provided better growing environment for increased plant height. Minimum tillage indirectly defines the species composition of the soil microbial community by improving retention of soil moisture and modifying soil temperature (Krupinsky *et al.*, 2002).

Microbiological population

Tillage and crop residue with supplemental irrigation through drip irrigation obviously influenced the microbe's population.

Soil organic matter distribution, nutrient cycling and microbial activity are influenced by the type and the degree of soil tillage (Salinas-Garcıa *et al.,* 2002).

The influence of tillage and supplemental irrigation on the soil biological properties was studied through the assessment of soil microbial population.

Practice of different tillage systems and supplemental irrigation significantly energized the soil microbial load at early stages during both the years of experimentation. The fluctuation in the microbial load in the soil is based on the availability of carbon source in the soil and enhanced microbial activity stimulated by crop residues and manures (Hoflich *et al.*, 2000).

Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher population (Tables 4-7) at 80 and 120 DAS during both the years of study.

Among irrigation practices, supplemental irrigation at 10 times was recorded higher number of bacteria, fungal and actinomycetes at 80 and 120 DAS during both the years than that in without supplemental irrigation plot.

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times had higher influence on the population of bacteria, fungal and actinomycetes at 80 and 120 DAS during both the years than others both the years of study.

Effect of treatments on yield attributes and yield

Yield attribute like cob length and cob weight and yield of maize was significantly influenced by tillage, crop residue and supplemental irrigation through drip irrigation.

Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher cob length and cob weight and yield (Tables 8 and 9) (19.5 cm cob length, 199 g cob weight, 7534 kg ha^{-1} and 18.7 cm cob length, 187 g cob weight, 7322 kg ha^{-1} during 2012 and 2013, respectively) Regarding irrigation practices, supplemental irrigation at 10 times was recorded higher cob length and cob weight and yield (20.2 cm cob length, 204 g cob weight, 7589 kg ha^{-1} and 19.5 cm cob length, 196 g cob weight, 7639 kg ha^{-1} during 2012 and 2013, respectively) than that in without supplemental irrigation plot.

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered laudably higher cob length and number of bolls per plant and yield during both the years.

This might be due to the reason that the minimum tillage plots had more main stem nodes, numbers of fruiting sites than those on conventional tillage. Consequently, the number of bolls retained was greater under the minimum tillage than under the conventional tillage system. Enhanced boll retention in the minimum tillage treatments could be due to other factors such as less competition from weeds, differences in nutrient supply and conserved soil moisture. Greater boll numbers on the minimum tillage plots contributed to yield improvements compared to the conventional tillage (Blaise. 2011). Tolessa Debele (2011) concluded that minimum tillage with residue retention increased yield particularly when crop faced terminal drought.

From these experiments, it is concluded that practicing of minimum tillage and application of crop residue at 10 t ha^{-1} + supplemental drip irrigation 10 times was found to be the promising agronomic practice for enhancing growth, microbial population and productivity of hybrid maize under rainfed situation.

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