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Research Article

ROOT DISTRIBUTION AND PRODUCTIVITY OF SPRING MAIZE AS INFLUENCED BY DIFFERENT DRIP IRRIGATION REGIMES AND PLANTING METHODS

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Abstract: Drip irrigation has affect on root distribution and productivity of maize (*Zea mays* L.). An experiment was planned to determine effect of various drip irrigation regimes and planting methods on root growth and yield of spring maize at Punjab Agricultural University, Ludhiana for two years. Experiment consisted of 11 (9+2) combination of treatments, out of which nine treatments consisted of three levels of drip irrigation *i.e.* 60 (DI_{60}), 80 (DI_{80}) and 100 (DI_{100}) percent of cumulative pan evaporation (CPE) in combination with three methods of planting i.e. 1row per ridge, 1row per bed and 1row(zigzag) per bed. Conventional irrigated treatments *i.e.*, ridge and flat sown were kept as control. Root density was higher in 0-30 cm under DI_{100} but below 30 cm, it was higher under DI_{60} and DI_{80}. Each increase in drip irrigation regime led to significant increase in cob and grain yield. Among the control treatments, root density, cob yield and grain yield was higher under ridge sown control treatment. Averaged over drip irrigation treatments, root density was significantly higher in top 15 cm soil layer in comparison with control treatments. While, the trend reversed below 15 cm soil layer. Cob and grain yield was significantly higher under drip irrigated maize than conventional irrigated maize. Frequent drip irrigation at 100 percent of CPE kept maize crop in favorable soil moisture conditions thus produced shallow and higher root mass (especially in top 30 cm) which resulted in better yield attributes and yield as compared to conventional irrigation method.

Keywords: Deficit Irrigation, Irrigation System, Root-Shoot Ratio, Sowing Geometry

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Introduction

Maize is a versatile crop and can be grown under tropical to temperate climatic conditions. In Punjab, maize was traditionally a *Kharif* season crop. Presently, area under *Kharif* maize has been replaced by rice. Moreover, cultivation of maize has become popular among the farmers in spring season when the evaporative demand is very high. The rate of evapotranspiration of spring maize field generally exceeds 10 mm day^{-1} leading to yield losses due to water stress [1]. Thus, a frequent and uniform water supply is indispensable. Water scarcity faced by maize during flowering and pollination stages decreases productivity [2, 3 and 4]. Moreover, present crop water requirement for the Punjab state is estimated as 4.53 m ha-m, contrary to the availability of only 3.26 m ha-m, which comprises 1.58 m ha-m of surface and 1.68 m ha-m of ground water resources [5]. The Punjab state is deficit in about 1.27 m ha-m of total water. The extensive use of traditional irrigation systems has led to overexploitation of groundwater and over use of surface water [6]. Under such water scarce conditions, drip irrigation is an option to adopt. Different types of stresses have a varied influence on maize root growth. Water scarcity decreased the shoot/root ratio of plants [7]. While, a decrease in root/shoot ratio with water scarcity reported by Amos and Walters, (2006) [8]. Drip irrigation affects root growth and development because of different water distribution pattern and less water storage in root zone soil as compared to conventional irrigation methods. The root growth under drip irrigation preferentially occurs in the top 0-40 cm of soil layer. Roots mass was concentrated near emitter along lateral line [9]. This may have a significant influence on plant growth and yield. So, there is need to study root growth under different drip irrigation regimes and their effect on yield. In addition to drip irrigation, planting methods might also alter root growth and development differentially to water stress.

The differential aeration condition of soil under different planting methods influence root growth and development. Knowledge of root growth pattern under different conditions will be helpful for assessing yield and planning of field work for maize cultivation. Thus, keeping in view the above discussion, field experiment was conducted to study different drip irrigation regimes and planting methods and their effect on root growth and productivity of maize.

Materials and Methods

Experimental site

A field study was conducted during spring season of 2011 and 2012 at Punjab Agricultural University, Ludhiana, Punjab (30°54'N latitude and 75º48'E longitude). The experimental site was located in Trans-Gangetic agro-climatic zone of India and having an altitude of 247 metres. Summarizes the meteorological data during the crop season is given in [Table-1]. Experimental field had a loamy sand soil texture with a bulk density of 1.59 g/cc and soil moisture storage in 0-180 cm soil profile of 41.27 cm at field capacity and of 10.99 cm at permanent wilting point. The available N (157 kg ha^{-1}) and organic carbon (0.11%) were low, while available P (14.6 kg ha^{-1}) and K (284.8 kg ha^{-1}) fill in the medium range.

Experimental design and treatments

Experiment consisted of 11 (9+2) combination of treatments, out of which nine treatments (T_1 to T_9) consisted of three levels of drip irrigation *i.e.* 60, 80 and 100 percent of cumulative pan evaporation (CPE) in combination with three methods of planting *i.e.* 1row per ridge, 1row per bed and 1row(zigzag) per bed. The two treatments, flat sown with border irrigation (T_{10}) and ridge sown with furrow irrigation (T_{11}) at IW/CPE ratio 1.0 were kept as control treatments [Table-2].

Table-1 *Meteorological data during the months of February to June*

Month	Mean air temperature (°C)			Mean relative humidity (%)			Monthly rainfall (mm)			Monthly evaporation (mm)		
	20011	2012	Normal	2011	2012	Normal	2011	2012	Normal	2011	2012	Normal
February	15.3	13.3	14.4	81	69	69	44.2	4.6	29.9	55.6	70.2	68.2
March	20.4	19.4	18.9	72	62	63	6.5	0	26.1	117.9	137	118.4
April	25.7	26	25.5	49	54	47	26.5	38.6	18.3	187	173.9	213
May	32.2	31.1	30.3	45	33	39	34.4	1.6	21.6	277.1	295.9	312.1
June	30.3	33.9	32.3	68	45	49	352.9	3.5	66.4	180.5	320.2	293.4

Agronomic practices

Ridges and beds were laid in east-west direction and sowing of maize hybrid PMH-1 was done. Planting geometry in case of ridge, bed and flat sown was 60 cm × 20 cm, 67.5 cm × 17.8 cm and 60 cm × 20 cm, respectively. Seed was dibbled in a zigzag pattern in case of 1Row (zigzag)/Bed. A Uniform plant population was maintained in all the treatments. Nitrogen @ 156.3, phosphorus @ 60, potassium @ 30 and zinc sulphate heptahydrate @ 25 kg ha^{-1} were applied on soil test basis. Root samples along with soil were taken layer wise (0-15, 15-30, 30-60 and 60-90 cm) by using root sampling pipe at knee high and pre-tasselling stages of crop from centre of ridge/bed in each experimental plot. The roots were dried at 60°C in an oven to constant dry weight. In different layers of soil, the root density was expressed in g plant^{-1}. Sun dried and de-husking cobs were expressed as tonne ha^{-1}. After shelling, grain yield was expressed as tonne ha^{-1} after adjusting it to 15 percent moisture content. Analysis of variance (ANOVA) of the data was done as per factorial experiment with additional treatments [10 and 11]. The LSD was used to separate means of different treatments.

Table-2 *Detail of treatments*

SNo	Treatment	SNo	Treatment
T_1	DI_{60} + 1Row/Ridge	T_7	DI_{100} + 1Row/Ridge
T_2	DI_{60} + 1Row/Bed	T_8	DI_{100} + 1Row/Bed
T_3	DI_{60} + 1Row(zigzag)/Bed	T_9	DI_{100} + 1Row(zigzag)/Bed
T_4	DI_{80} + 1Row/Ridge	T_{10}	Control-I (Flat sown)*
T_5	DI_{80} + 1Row/Bed	T_{11}	Control-II (Ridge sown)**
T_6	DI_{80} + 1Row(zigzag)/Bed		

*100 % replenishment of IW/CPE ratio = 1.0 through border method of irrigation, taking depth of irrigation as 75 mm; **100 % replenishment of IW/CPE ratio = 1.0 through furrow irrigation, taking depth of irrigation as 60 mm

Results

Root distribution

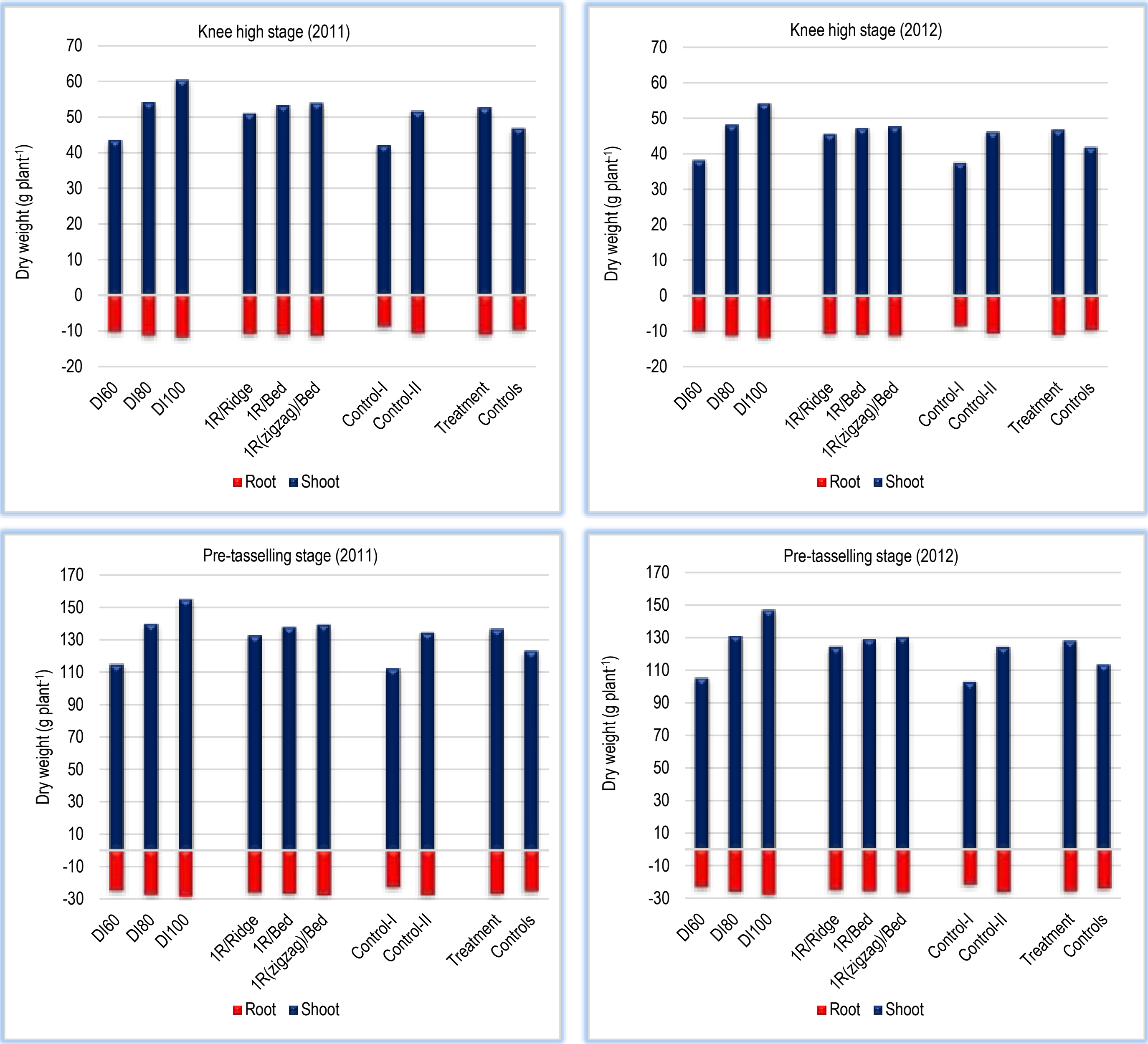
At knee high stage, under all the combination of drip irrigation regimes and planting methods [Table-3], highest amount of the root mass confined in 0-15 cm of soil profile was 79.5-82.3 percent followed by 14.6-16.2 percent in 15-30 cm and lowest root mass was found in 30-60 cm soil depth and was 2.8-4.3 percent. At pre-tasselling stage, root mass percentage decreased in the upper 0-15 cm soil profile while it increased in the deeper soil layers [Table-4]. Root density observed in 0-15 cm of soil profile was 72.7-76.1 percent followed by 16.2-17.1 percent in 15-30 cm and 6.0-8.6 percent in 30-60 cm soil depth and non-significant amount (less than 2.2 percent) was recorded in 60-90 cm soil profile. In upper soil layers of 0-15 and 15-30 cm, root mass density under well-watered drip irrigation regime DI_{100} was significantly higher than stressed treatment DI_{60} at both the stages of determination [Table-3 and 4]. In 30-60 cm soil layer root density did not differ significantly at both stages during both the years. However, at pre-tasselling stage, in 60-90 cm soil layer, growth of root was higher under mild stressed irrigation regime DI_{80} than well-watered regime DI_{100} and deficit irrigation regimes DI_{60} [Table-4]. Among the various planting methods, the root density did not differ significantly in any of the soil profile depths at both the stages of determination during the two years study, [Table-3 and 4]. This may be because, the different planting methods (ridge and both bed planting) were almost similar with raised platform for planting crop plant and deeper furrows. Under two control treatments, at knee high stage in 0-15 cm soil layer root mass was 73.6-76.5 percent but it was reduced to 64.9-66.7 percent at pre-tasselling stage, due to higher root growth in deeper soil layers at later stage. In soil layers of 0-15 and 15-30 cm, root mass under ridge sown control was significantly higher than recorded under flat sown control during both the years. Below 30 cm of soil depth, the trend remained same but the differences were not significant at both stages of determination. Averaged over all the drip irrigation treatments, frequent drip irrigation results in shallow root systems having higher root mass of 80.0-82.1 and 73.3-75.0 percent in 0-15 cm; as compared to that of control treatments, 73.9-76.4 and 65.2-66.7 percent at knee high and at pre-tasselling stage, respectively. Root mass at knee high as well as at pre-tasselling stage in 0-15 cm soil profile was significantly higher under the drip irrigated treatments than the mean of two control treatments [Table-3 and 4]. Different drip irrigation treatments maintain sufficient moisture condition for root growth in upper soil layer. On the other hand, in soil profile of 15-30, 30-60 and 60-90 cm, trend got reversed in favour of control treatments due to less frequent and heavy irrigation under control treatments. But difference, in root mass were significant only in soil layers of 30-60 and 60-90 cm. The percentage of root mass under conventional irrigation was 5.3-6.4 percent at knee high stage and 11.4-11.6 percent at pre-tasselling stage in 30-60 cm layers, of soil as compared to drip irrigated treatments (3.1-3.9 percent at knee high and 6.9-7.8 percent at pre-tasselling stage).

Root and shoot dry matter

Shoot dry matter increased with increase in drip irrigation regimes at both the stage of determination [Fig-1]. Root dry weight also increased with increase in drip irrigation regimes from stressed (DI_{60}) to moderately stressed (DI_{80}), while further increase in drip irrigation regimes (DI_{100}) cause comparatively lesser increase in root mass at both the stages of determination. Root and shoot dry weights were almost similar among the three planting methods, because of similar frequency and rate of drip irrigation. Ridge sown control had higher root and shoot dry weight than that of flat sown control [Fig-1]. In comparison, drip irrigation vs conventional irrigation, mean root and shoot dry weight was higher under drip irrigated treatments than the mean of two control treatments. Differences were higher at knee high stage and reduced at pre-tasselling stage.

Yield attributes and yield

Drip irrigation regime DI_{100} had significantly higher cob yield than under DI_{80} which was in turn significantly higher than DI_{60}. Number of grains per cob under DI_{100} and DI_{80} were statistically at par with each other and both were significantly better than DI_{60} during both the years [Table-5]. Grain yield also increased significantly with each increase in drip irrigation regime. Linear and positive relation between grain yield and root mass at knee high stage with R^2 values of 0.823 and 0.876 in 2011 and 2012, respectively. While at pre-tasselling stage, grain yield was highly related to root mass density with higher coefficient of determination (R^2) of 0.832 and 0.903 in 2011 and 2012, respectively. The grain yield was higher by 35.9 and 40.9 percent under DI_{100} and by 22.2 and 25.3 percent under DI_{80} over that of DI_{60} during 2011 and 2012, respectively. The various planting methods did not differ significantly with respect to yield attributes and grain yield of spring maize. Between the two conventional irrigated control treatments, ridge planted control resulted in significantly higher cob yield and grain yield as compared to flat planted control treatment [Table-5]. Grain yield under ridge planted control was higher by a margin of 18.5 and 20.4 percent during 2011 and 2012, respectively to flat planted control. The better root development with higher root mass accumulation resulted in higher cob and grain yield. Drip irrigated treatments produced significantly higher cob yield by the margin of 11.3 and 12.3 percent and number of grains per cob by the margin of 8.1 and 8.6 percent than the mean obtained from two control treatments during the years 2011 and 2012, respectively. Drip irrigated treatments also had significantly higher grain yield by margin of 13.0 and 16.6 percent during 2011 and 2012, respectively than the grain yield obtained from control treatments.



Note: Bars above the X-axis depicts shoot mass and bars below the X-axis depicts root mass

Fig-1 Root and shoot mass under different treatments at knee high and pre-tasselling stages of spring maize

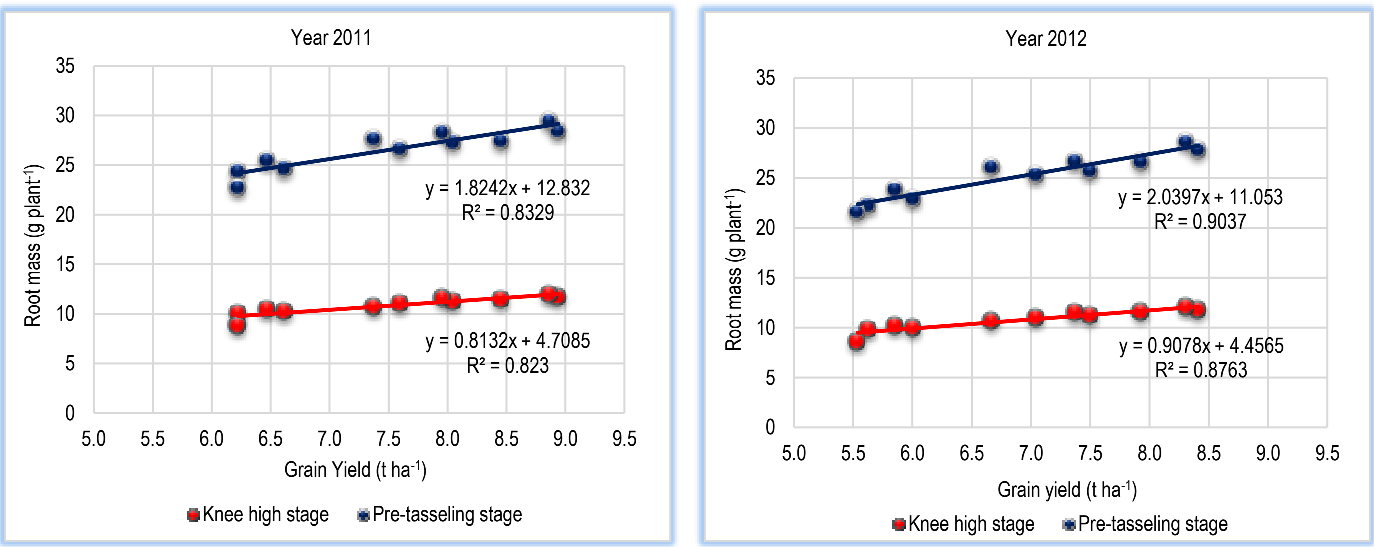


Fig-2 Relationship between root mass and grain yield during 2011 and 2012

Table-3 *Root distribution in different layers of soil at knee high stage under different drip irrigation regimes and methods of planting during 2011 and 2012*

Treatment	Root density (g/plant) in different layers at knee high stage					
	0-15 cm		15-30 cm		30-60 cm	
	2011	2012	2011	2012	2011	2012
Drip irrigation regimes						
DI_{60}	8.13 (79.5)	8.17 (81.8)	1.652 (16.2)	1.460 (14.6)	0.442 (4.3)	0.360 (3.6)
DI_{80}	9.04 (80.1)	9.24 (82.2)	1.804 (16.0)	1.646 (14.6)	0.439 (3.9)	0.353 (3.1)
DI_{100}	9.39 (80.3)	9.70 (82.3)	1.887 (16.1)	1.761 (14.9)	0.415 (3.6)	0.327 (2.8)
CD (p=0.05)	0.82	0.74	0.163	0.152	NS	NS
Planting methods						
1Row/Ridge	8.66 (79.9)	8.86 (82.2)	1.748 (16.1)	1.587 (14.7)	0.426 (3.9)	0.342 (3.2)
1Row/Bed	8.84 (80.0)	9.01 (82.1)	1.774 (16.1)	1.622 (14.8)	0.431 (3.9)	0.347 (3.2)
1Row(zigzag)/Bed	9.06 (80.0)	9.25 (82.2)	1.822 (16.1)	1.658 (14.7)	0.439 (3.9)	0.351 (3.1)
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Control *vs* Control						
Control-I (Flat sown)	6.49 (73.6)	6.58 (76.5)	1.722 (19.5)	1.529 (17.8)	0.607 (6.9)	0.489 (5.7)
Control-II (Ridge sown)	7.94 (74.2)	8.10 (76.2)	2.117 (19.8)	1.991 (18.7)	0.646 (6.0)	0.534 (5.0)
CD (p=0.05)	1.41	1.28	0.282	0.264	NS	NS
Treatments *vs* Controls						
Treatment mean*	8.85 (80.0)	9.04 (82.1)	1.781 (16.1)	1.622 (14.7)	0.432 (3.9)	0.346 (3.1)
Control mean**	7.21 (73.9)	7.34 (76.4)	1.919 (19.7)	1.760 (18.3)	0.627 (6.4)	0.512 (5.3)
CD (p=0.05)	0.78	0.71	NS	NS	0.039	0.032
Interaction	NS	NS	NS	NS	NS	NS

*Mean of all combination of drip irrigation and planting method treatments; **Mean of flat and ridge planted control treatments

Table- 4 *Root density at different depths recorded at pre-tasselling stage of spring maize under drip irrigation regimes and methods of planting*

Treatment	Root density (g/plant) in different layers at pre-tasselling stage							
	0-15 cm		15-30 cm		30-60 cm		60-90 cm	
	2011	2012	2011	2012	2011	2012	2011	2011
Drip irrigation regimes								
DI_{60}	18.03 (72.7)	17.08 (74.3)	4.12 (16.6)	3.72 (16.2)	2.12 (8.6)	1.77 (7.7)	0.531 (2.2)	0.420 (1.8)
DI_{80}	20.00 (73.0)	19.27 (74.5)	4.61 (16.8)	4.28 (16.5)	2.19 (8.0)	1.85 (7.1)	0.590 (2.2)	0.478 (1.8)
DI_{100}	21.04 (74.0)	21.05 (76.1)	4.87 (17.1)	4.53 (16.4)	1.97 (6.9)	1.65 (6.0)	0.541 (1.9)	0.427 (1.5)
CD (p=0.05)	1.66	1.66	0.52	0.45	NS	NS	0.039	0.038
Planting methods								
1Row/Ridge	19.08 (73.0)	18.47 (74.7)	4.46 (17.1)	4.11 (16.6)	2.04 (7.8)	1.71 (6.9)	0.539 (2.1)	0.432 (1.7)
1Row/Bed	19.64 (73.3)	19.12 (75.1)	4.51 (16.8)	4.16 (16.3)	2.08 (7.8)	1.75 (6.9)	0.553 (2.1)	0.441 (1.7)
1Row(zigzag)/Bed	20.35 (73.4)	19.80 (75.2)	4.63 (16.7)	4.26 (16.2)	2.17 (7.8)	1.82 (6.9)	0.571 (2.1)	0.451 (1.7)
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Control *vs* Control								
Control-I (Flat sown)	14.89 (65.6)	14.40 (66.7)	4.14 (18.2)	3.89 (18.0)	2.75 (12.1)	2.58 (12.0)	0.928 (4.1)	0.700 (3.3)
Control-II (Ridge sown)	17.91 (64.9)	17.35 (66.6)	5.61 (20.3)	5.11 (19.6)	3.12 (11.3)	2.84 (10.9)	0.968 (3.5)	0.748 (2.9)
CD (p=0.05)	2.87	2.88	0.90	0.78	NS	NS	NS	NS
Treatments *vs* Controls								
Treatment mean*	19.69 (73.3)	19.13 (75.0)	4.54 (16.9)	4.18 (16.4)	2.10 (7.8)	1.76 (6.9)	0.554 (2.1)	0.441 (1.7)
Control mean**	16.40 (65.2)	15.88 (66.7)	4.88 (19.4)	4.50 (18.9)	2.93 (11.6)	2.71 (11.4)	0.948 (3.8)	0.724 (3.0)
CD (p=0.05)	1.59	1.59	NS	NS	0.24	0.16	0.038	0.037
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

**Mean of all combination of drip irrigation and planting method treatments; **Mean of flat and ridge planted control treatments; Figures in parenthesis are percent of total root dry weight*

Table- 5 *Effect of drip irrigation regimes and methods of planting on yield and yield attributes of spring maize during 2011 and 2012*

Treatment	#Cob yield (t/ha)		No. of grain/cob		Grain yield (t/ha)	
	2011	2012	2011	2012	2011	2012
Drip irrigation regimes						
DI_{60}	10.04	9.39	325.5	313.8	6.44	5.83
DI_{80}	11.79	11.21	356.1	343.9	7.87	7.31
DI_{100}	12.89	12.35	368.1	357.9	8.75	8.22
CD (p=0.05)	0.80	0.82	24.2	22.2	0.57	0.59
Planting methods						
1Row/Ridge	11.21	10.61	346.3	335.4	7.43	6.87
1Row/Bed	11.80	11.20	350.7	340.9	7.87	7.31
1Row(zigzag)/Bed	11.70	11.13	352.7	339.2	7.77	7.18
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Control *vs* Control						
Control-I (Flat sown)	9.78	8.98	307.3	296.3	6.23	5.54
Control-II (Ridge sown)	11.34	10.49	340.0	326.8	7.38	6.67
CD (p=0.05)	1.38	1.42	NS	NS	0.99	1.03
Treatments *vs* Controls						
Treatment mean*	11.57	10.98	349.9	338.5	7.69	7.12
Control mean**	10.56	9.73	323.7	311.6	6.80	6.10
CD (p=0.05)	0.76	0.79	23.2	21.2	0.55	0.57
Interaction	NS	NS	NS	NS	NS	NS

De-husked cobs harvested for threshing; *Mean of all combination of drip irrigation and planting method treatments; **Mean of flat and ridge planted control treatments

More frequent irrigation in case of drip resulted in higher root dry matter accumulation, higher cob yield and a greater number of grains per cob which led to a higher grain yield.

Discussion

Several researchers have addressed the concept root growth and distribution [7, 8, 9, 12 and 13]. In general, root mass was varying with stage of crop growth, management practices and different layers of soil profile. In this study, root mass was higher in the upper soil layer at knee high stage, while at pre-tasselling stage its percentage decreased in the upper layer and increased in the deeper soil layers as compared to knee high stage. This was because of root growth in deeper layers of soil at later stage. Roots of maize penetrate deeper and also spread more horizontally [14]. Laboski [15] reported that 94% of total root length was found within 60 cm and 85% of total root length was found within 30 cm at tasselling stage. In upper soil layer root mass density was significantly higher under well-watered drip irrigation regime than stressed treatment. While, in deeper soil layer, root mass was higher under mild stressed irrigation regime (DI_{80}) than well-watered regime (DI_{100}) and deficit irrigation regime (DI_{60}). This may be attributed to moderate soil drying resulted into more root growth in deep soil layer as compared to the sufficient irrigation [16]. However, Wang [17] reported that, higher root dry mass in well-watered plants over moderately stressed plants which in turn had increased root dry mass than that of severely stressed plants. In sufficient soil moisture conditions root system was distributed in all sections of soil [12]. While, under drip irrigation roots concentrates within the top 40 cm layer near the wetted emitter area of the soil profile [3].

Shoot dry matter and cob yield respond significantly to each increase in drip irrigation regime from DI_{60} to DI_{100}. Decrease in drip irrigation levels from DI_{100} to DI_{60} had more affect on shoot dry weight as compared to root dry which led to decrease in shoot/root ratio. Well-watered irrigation regimes resulted in significantly higher root and shoot dry matter, cob yield and number of grains per cob led to significant higher grain yield. Cob yield and kernels cob^{-1} are the main contributing attributes to grain yield [13, 16, 18, 19 and 20]. The yield differences in different irrigation regimes were more during the second year of investigation [Table-5]. Because weather conditions during 2012 were comparatively drier during later stages of crop growth (comparatively lesser rainfall during the month of May and June, 2012 than the year 2011 and normal rainfall data). Stress during pollination resulted in lower number of grains cob^{-1} which ultimately reduced the grain yield under water deficit treatments. The various planting methods did not differ significantly on the basis of root density, yield and yield attributes during both the years. This was because of all the three planting methods (ridge and both bed planting) had almost similar raised platform for planting crop, deeper furrows and same frequency and level of drip irrigation resulted in statistically similar root and shoot mass, cob yield and grains per cob^{-1}. Drip irrigation among all bed/ridge planted crop create optimum moisture condition for root development led to statistically similar grain yield production [18]. Ridge sown crop had higher root and shoot dry weight as compared to flat sown control. The better root development with higher root mass accumulation in ridge sown crop resulted in higher cob and grain yield. Light and frequent furrow irrigations under ridge planted crop avoid moisture stress to crop resulted significantly higher yield as compared to flat sown crop [18]. Ahmed [21] also reported that ridge planted crop produced higher grain yield as compared to that produced under flat planted crop of maize. Mitigation of moisture stress by more frequent irrigation in case of drip irrigation regimes resulted in higher root and shoot dry matter accumulation, higher cob yield and a greater number of grains cob^{-1}, which led to a higher grain yield of maize. Better soil moisture condition under drip irrigation register significantly higher cob yield than surface conventional irrigation [13 and 22]. Drip irrigation reduces water leaching from root zone, which led to better productivity under water scarce conditions [23, 24].

Conclusion

Results of two-year study showed that frequent drip irrigation avoided moisture stress to crop by maintaining an optimum moisture condition in upper soil layer which produced shallow and higher root mass, resulting in better yield attributes and yield of maize crop. While under conventional irrigation, root was distributed in all sections of soil due to moderate drying of upper soil layer and sufficient moisture in deeper layers of soil.

Application of research: This study helps in planning of future research on root growth and development especially in micro irrigation system as well as helpful for assessing yield and planning of field walk for maize cultivation

Research Category: Water management

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***Research Guide or Chairperson of research: Dr Krishan Kumar Vashist**
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Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Research farm, Punjab Agricultural University, Ludhiana

Cultivar / Variety / Breed name: PMH-1

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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