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Growth and yield of maize (*Zea mays* L.) as influenced by irrigation levels and chemical weed management in drip irrigated paired row system of maize

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Abstract
A field experiment was conducted at College of Agriculture, Vishweshwaraiah Canal Farm, Mandya during *kharif* 2018 to study the effect of drip irrigation levels and chemical weed management in paired row system of maize. The factorial- RCBD experiment consisted of two factor combination with 10 treatments and three replications, the results revealed that, irrigation at 80 or 100% CPE level recorded statistically comparable kernel yield (7,083 to 7,474 kg ha-1), stover yield (9,430 to 9,687 kg ha-1), WUE (143 to 147 kg ha-1), growth and yield parameter. However, 100% CPE irrigation level recorded a little higher economics such as net return and B: C ratio. Whereas, Pre emergence application of atrazine @ 1.25 kg a.i. ha-1 at 3 DAS recorded higher kernel yield (8,310 kg ha-1) and stover yield (11,615 kg ha-1) followed by rest of chemical weed control practices and were comparable with hand weeding twice at 30 and 45 DAS. Additionally, weed control efficiency (90.37%), net return (Rs.68028 ha-1) and B:C ratio (2.63) were higher with Pre emergence application of atrazine @ 1.25 kg a.i. ha-1 at 3 DAS. The yield reduction in unweeded control was 42%.

Keywords: Maize, irrigation, drip, paired row, weed management, pre emergence

Introduction
Maize (*Zea mays* L.) is a third most important cereal crop in the world both in area and production after rice and wheat. In India, it occupies an area of 9.4 m ha with a production of 22.27 m t and the productivity of 2.4 t ha-1(Anon., 2016a) [1], which is much lower than the global average productivity of 5,700 kg ha-1.While, in Karnataka maize cultivated in an area of 1.3 m ha with a production of 3.92 m t with the productivity of 2,883 kg ha-1(Anon., 2016b) [2]. In Mandya district of Karnataka, maize is grown in an area of 3,903 ha with a production of 15,978 t and productivity of 4,308 kg ha-1 (Anon., 2016c) [3].
Hence, there is a compass to match the local productivity of maize to global level by adopting improved cultural and input managements such as irrigation and weed management. The drip irrigation is the most advanced surface irrigation and need to be exploit under maize production with optimum level of management. Further, weed control through manual is laborious, time consuming, costly and tedious, besides, timely availability at the critical period. The new post emergence chemical weed control may be the obligation to contain the weeds by using tank mixture of two different herbicides during initial crop growth for specific time and ease of application at present in maize (Anjali *et al.*, 2018) [1]. With this background, the present field investigation was conducted.

Material and Methods
A field experiment was conducted at College of Agriculture, V. C. Farm, Mandya during 2018 to study the effect of chemical weed control practices and irrigation levels on growth and yield of maize. The treatment consists of two factors *viz.*, two irrigation levels (80 and 100% CPE) and five Chemical weed control practices (Atrazine @ 1.25 kg a.i. ha-1 at 3 DAS, Pendimethalin @ 0.45 kg a.i. ha-1 at 3 DAS, Halosulfuron methyl @ 90 g a.i. ha-1 + atrazine @ 625 g a.i. ha-1 at 20 DAS, Hand weeding twice at 30 and 45 DAS and Unweeded control) (Table 1).

The combinations of ten treatments were laid out in factorial-RCBD with three replications. The experimental site was red sandy loam (Alfisol) in texture with 68.1% sand, 17.6% silt and 14.3% clay. The soil was neutral in reaction (pH- 7.27) and low in soluble salts (0.32 dS m-1). The soil organic carbon was medium (0.68%), available nitrogen was low (237.08 kg ha-1) and medium in available P2O5 (48.31 kg ha-1), while it was high in K2O kg ha -1). The experimental site was prepared by ploughing twice with tractor drawn disc plough followed by harrowing to bring the soil to a fine tilth before sowing of maize. The maize was sown in paired row planting at 90 X 30 cm (between paired rows and between rows, respectively) and plant to plant spacing of 30 cm within the row. The hybrid MAH-14-5 was taken after sequentially treating the seed with Redomil MZ @ 4 g kg-1 and Chlorpyrifos @ 4ml kg-1 of seed. The recommended dose of FYM at 10 t ha-1 was applied 15 days prior to sowing during primary tillage operation. The recommended chemical fertilizer dose of 150: 75: 40 N, P2O5, K2O kg ha-1 was applied through urea, single super phosphate and muriate of potash respectively. The micronutrient such as zinc (10 kg ha-1) and boron (5 kg ha-1) were also applied as zinc sulphate and borax separately at the time of sowing. Half the dose of nitrogen and entire dose of phosphorus and potash were applied at the time of sowing and remaining nitrogen was top dressed in two equal split at 30 and 45 DAS.

Immediately after sowing of maize, the drip laterals were placed within paired rows at lateral spacing of 120 cm having 12 mm diameter and on line emitter spacing of 60 cm with 2 lit.sec.-1 discharge capacity. The crop was irrigated with common 5 cm depth through drip to ensure uniform germination and crop establishment, initially. Thereafter, the irrigation was scheduled once in two days interval. The required quantity of water for respective plot was calculated by taking the cumulative pan evaporation readings from USWB open pan evaporimeter data for the period of previous two days and which is multiplied by plot area. The quantity of water arrived as per treatment *viz*., 100 and 80% CPE was given through drip irrigation system which was connected with water meter and it included pump, filter unit and main and sub lines. The spray volume used was 700 and 500 lit. ha-1, for pre and post emergence herbicide application, respectively. The spray was taken with knap sac sprayer fitted flat pan and flood jet nozzle for spray pre and post emergence application, respectively as per the treatment. The species wise weed count and dry weight were recorded from 1.0 m2 area in each plot at different growth stages to work out the weed control efficiency. The periodic growth observation like Plant height (cm), leaf area Index and Yield attributes like number of rows per cob, kernels per row, Kernels per cob, test weight, grain yield and straw yield were taken from five tagged plants from net plot area. While, plants from the grass plot area were taken for recording dry matter accumulation in plant. The data was statistically analysed by following standard procedure developed by Gomez and Gomez, 1983 [6].

Results and Discussion

Growth parameter

Irrigation at 80 or 100% CPE level in maize recorded similar growth parameters *viz.*, plant height (36.51 to 37.20, 178.43 to 183.55 and 206.53 to 207.69 cm), leaf area index (0.83, 2.63 to 3.12 and 1.80 to 1.83) and total dry matter production (11.62 to 13.22, 159.14 to 169.43 and 242.99 to 256.63 g plant-1) at 30, 60 DAS and harvest, respectively. All these were statistically at par between 80 or 100% CPE, except for significantly higher LAI with 100% CPE at 60 DAS (Table 1). The results confirm that, irrigating the maize crop with 80% CPE could able to meet the adequate and sufficient water demand for evapotranspiration and cell activities like cell division and cell elongation in meristamatic region to attain potential photosynthetic activity, which intern helps to better dry matter production and accumulation in maize similar to 100% CPE irrigation. The results obtained are in conformity with Desai *et al.* (2017) [5] for IW/CPE ratio at 0.8 and 0.6.; Harshitha *et al.* (2017) [7] for irrigation at 80 and 100% CPE in maize.

Among weed control methods, pre-emergence (PE) application of atrazine @ 1.25 kg a.i. ha-1 at 3 DAS recorded higher plant height (192.18 and 224.72cm) and LAI (4.36 and 2.31) at 60 DAS and at harvest, respectively. Similarly, application of pre-emergence (PE) application of atrazine @ 1.25 kg a.i. ha-1 at 3 DAS recorded higher total dry matter accumulation (14.33, 187.98 and 280.12 g plant-1) at 30, 60 DAS and at harvest, respectively, but were comparable with hand weeding twice at 30 and 45 DAS (Tables 1). This could be attributed to better control of grasses and broad leaved weeds since from germination up to critical period of crop weed competition as noticed under this study which leads to the adequate availability of applied nutrients, moisture, sunlight, space etc., for maize crop which intern enhanced the photosynthetic activity resulted in higher or similar growth parameters in maize as compared to hand weeding. The results recorded are in conformity with Kamble *et al.* (2015) [11] and Javid Ehsas *et al.* (2016) [10] for atrazine as PE application. While, PE application of pendimethalin @ 0.45 kg a.i. ha-1 at 3 DAS was also recorded similar growth parameters but at later growth stages like at harvest, it could not able to prevent few species of broad leaved weeds germination due to faster degradation of residues within 30-50 DAS under irrigated conditions as resulted in more broad leaved weeds *viz.*, *Euphorbia geniculata*, *Boerhavia diffusa*, *Amaranthus viridis*, etc., The results obtained are in accordance with Kamble *et al.*, (2015) [11]. Whereas, the post emergence (PoE) tank mix application of halosulfuron methyl @ 90 g a.i. ha-1 + atrazine @ 625 g a.i. ha-1 at 20 DAS was also recorded statistical similar plant height (201.92 cm at harvest), LAI (0.94 and 1.43 at 30 DAS and at harvest, respectively) and total dry matter accumulation (12.42 g plant-1 at 30 DAS) at few growth stages as compared to former treatment, but failed to be superior in all crop growth (Tables 1). The reason beyond this, the PoE application of this chemical at 20 DAS allowed weeds to grow and compete with maize plant for initial 20 days. Further, halosulfuron methyl @ 90 g a.i. ha-1 + atrazine @ 625 g a.i ha-1 at 20 DAS could able to contain effectively for existing sedges and broad leaved weeds, but did not for grassy weeds. The similar results were reported by Pradeep Ram *et al.* (2017) [13] for atrazine as PoE application and Birendra Kumar *et al.* (2017) [4] for halosulfuron as PoE application.

Table 1: Effect of irrigation levels and chemical weed control practices on plant height, leaf area index (LAI) and total dry matter accumulation in maize at different crop growth stages and at harvest under paired row drip irrigation

Treatment	Plant height (cm)			LAI			Total dry matter (g plant-1)		
	DAS		At	DAS		At	DAS		At
	30	60	harvest	30	60	harvest	30	60	harvest
Factor- A: Irrigation levels									
I1: 80% CPE	36.51	178.43	206.53	0.83	2.63	1.80	11.62	159.14	242.99
I2: 100% CPE	37.20	183.55	207.69	0.83	3.12	1.83	13.22	169.43	256.63
S.Em+	1.16	3.08	5.56	0.02	0.09	0.01	0.42	4.80	4.64
CD (p= 0.05)	NS	NS	NS	NS	0.27	NS	NS	NS	NS
Factor-B: Chemical weed control practices									
W1: Atrazine @ 1.25 kg a.i. ha-1 at 3 DAS	36.83	192.18	224.72	0.82	4.36	2.31	14.33	187.98	280.12
W 2: Pendimethalin @ 0.45 kg a.i. ha-1 at 3 DAS	34.73	174.25	205.30	0.93	3.32	2.16	12.18	171.23	257.32
W 3: Halosulfuron methyl @ 90 g a.i. ha-1 + atrazine @ 625 g a.i. ha-1 at 20 DAS	36.82	174.25	201.92	0.94	2.42	1.43	12.42	154.82	248.40
W 4: Hand weeding twice (30 and 45 DAS)	34.50	190.58	218.22	1.08	3.04	1.87	12.10	179.28	261.62
W 5: Unweeded control	41.38	173.88	185.40	0.39	1.24	1.31	11.07	128.12	201.60
S.Em+	1.83	4.87	8.78	0.04	0.14	0.01	0.66	7.59	7.34
CD (p= 0.05)	NS	14.46	26.10	0.11	0.43	0.03	1.97	22.55	21.81

NS = Non significant; DAS = Days after sowing

Yield and yield parameters of maize

Irrigation at 80 or 100% CPE recorded statistically on par kernel yield (7,083 to 7,474 kg ha-1), stover yield (9430 to 9687 kg ha-1), WUE (143 to 147 kg ha-1) and yield parameter *viz.*, cob length (15.23 to 15.56 cm), cob girth (1,468 to 15.57cm), rows per cob (14.23 to 14.43), kernels per row (34.65 to 35.64), kernels per cob (493.38 to 524.05), kernel weight (160.84 to 162.61 g per cob), test weight (31.72 to 32.04 g) and shelling percentage (71.05 to 71.12) (Table 2 & 3). The comparable yield and yield parameters might be due to similar growth parameter production as explained in the above discussion with the either 80 or 100% CPE irrigation resulted in production of efficient sink and its related parameters. The results found under this study are in line with Hussein and Pibars (2012) [9] for irrigation at 100 and 75% ET; Mathukia *et al.* (2011) [12] for irrigation at 1.0 and 0.8 IW/CPE ratios. The higher kersnel and stover yield of maize was with PE application of atrazine @ 1.25 kg a.i ha-1 at 3 DAS (8,310 and 11,615 kg ha-1, respectively) and was statistically comparable with hand weeding twice at 30 and 45 DAS, pendimethalin @ 0.45 kg a.i. ha-1 at 3 DAS and PoE tank mix application of halosulfuron methyl @ 90 g a.i. ha-1 + atrazine @ 625 g a.i. ha-1 at 20 DAS, but were statistically superior over unweeded control (4,634 and 4,623 kg ha-1, respectively) (Table 3). The higher kernel and stover yield in the former treatments could be due to efficient control of two or more weed species either from the beginning or at later stages as indicated with good weed control efficiency and as also explained in the above discussion with growth parameter. All these resulted in higher nutrient uptake by maize, photosynthetic production and enhanced growth parameter. Also superior translocation of phtosynthates from source to sink as indicated by harvest index and shelling percentage resulted in production of superior yield and yield parameter in the former treatments (Table 2). The results obtained are in agreement with Birendra Kumar *et al.* (2017) [4] in PE and PoE application and Tapas *et al.* (2017) [14] in PE application of atrazine.

Table 2: Effect of irrigation levels and chemical weed control practices on yield parameters in maize at harvest under paired row drip irrigation

Treatment	Cob length (cm)	Cob girth (cm)	Rows per cob	Kernels per row	Kernels per cob	Kernel weight (g cob-1)	Test weight (g)	Shelling percentage (%)
Factor- A: Irrigation levels								
I1: 80% CPE	15.23	15.57	14.43	34.65	493.38	160.84	32.04	71.12
I2: 100% CPE	15.56	14.68	14.23	35.64	524.05	162.61	31.72	71.05
S.Em+	0.28	0.36	0.19	0.51	10.53	3.15	0.55	0.93
CD (p= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Factor-B: Chemical weed control practices								
W1: Atrazine @ 1.25kg a.i. ha-1 at 3DAS	17.62	17.40	14.78	41.23	615.58	170.22	34.38	71.52
W 2: Pendimethalin @ 0.45 kg a.i. ha-1 at 3DAS	14.85	14.88	14.82	34.47	524.76	162.70	31.39	71.27
W 3: Halosulfuron methyl @ 90g a.i. ha-1 + atrazine @ 625g a.i. ha-1 at 20DAS	14.38	13.28	14.37	32.20	457.37	155.60	32.45	71.83
W 4: Hand weeding twice (30 and 45 DAS)	17.60	17.95	15.20	38.23	572.87	172.80	33.02	73.28
W 5: Unweeded control	12.52	12.13	12.48	29.60	373.00	147.30	28.15	67.53
S.Em+	0.45	0.56	0.30	0.81	16.66	4.98	0.88	1.47
CD (p= 0.05)	1.33	1.67	0.89	2.39	49.49	14.80	2.61	NS

NS = Non significant

Table 3: Kernel yield, stover yield, weed control efficiency (WCE), water use efficiency (WUE), net return and benefit: cost ratio (B: C) as influenced by irrigation levels and chemical weed control practices in maize under paired row drip irrigation

Treatment	Kernel yield (kg ha-1)	Stover yield (kg ha-1)	WCE (%)	WUE (%) (Kg ha-1 cm)	Net returns (Rs. ha-1)	B:C Ratio
Factor- A: Irrigation levels						
I1: 80% CPE	7083	9687	64.55	147	51782.8	2.24
I2: 100% CPE	7474	9430	64.34	143	55937.8	2.33
S.Em+	195	316	NA	4.00		
CD (p= 0.05)	NS	NS	-	NS		
Factor-B: Chemical weed control practices						
W1: Atrazine @ 1.25kg a.i. ha-1 at 3DAS	8310	11615	90.37	165	68028	2.63
W 2: Pendimethalin @ 0.45 kg a.i. ha-1 at 3DAS	7788	10697	84.60	155	61102	2.47
W 3: Halosulfuron methyl @ 90g a.i. ha-1 + atrazine @ 625 g a.i. ha-1 at 20DAS	7718	10064	59.12	154	58551	2.36
W 4:Hand weeding twice (30 and 45 DAS)	7943	10796	88.14	158	61687	2.43
W 5: Unweeded control	4634	4623	0.0	92	19936	1.49
S.Em+	308	499	NA	6.00	NA	NA
CD (p= 0.05)	916	1484	-	19.0	-	-

NS = Non significant; NA = Not analysed statistically

Economics

Between irrigation levels, 100% CPE recorded slightly higher net returns, (55,397 Rs. ha-1) and B:C ratio (2.33) as compared to irrigation at 80% CPE (51,782 Rs. ha-1 and 2.25, respectively). This was due to a little higher kernel and stover yield at 100% CPE (Honnappa *et al*., 2014 and Harshitha *et al.*, 2017) [8, 7].

Among weed control methods, PE application atrazine @ 1.25 kg a.i. ha-1 at 3 DAS recorded higher net returns (68,028 Rs. ha-1) and B:C ratio (2.63) as compared to rest of chemical weed control methods (58,551 to 61,102 Rs. ha-1 and 2.36 to 2.47, respectively) and hand weeding twice (61687 Rs. ha-1 and 2.43, respectively). The higher net return and B: C ration were mainly either due to lower cost of weed management or due to higher produce or both in the former treatments. Similar result was reported by Birendra Kumar *et al.* (2017) [4].

From this study it can be inferred that, drip irrigation level at 80% CPE can be recommended to save irrigation water and to obtain similar maize growth and yield as that of irrigation level at 100% CPE. Further, PE application of atrazine @ 1.25 kg a.i ha-1 at 3 DAS could be recommended for effective control of weeds from the initial crop growth stages and to gain better growth, yield and economics similar to hand weeding. The other chemical methods such as PE application of pendimethalin @ 0.45 kg a.i. ha-1 at 3 DAS or PoE application of halosulfuron methyl @ 90 g a.i. ha-1 + atrazine @ 625 g a.i. ha-1 at 20 DAS can also be used to control specific species of weed and time of application to produce comparable yield.

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