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Effect of pre and post-emergence herbicides and irrigation levels on yield, weed flora, and weed index on drip irrigated paired row 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 chemical weed management and drip irrigation levels on paired row maize. The experiment consists 10 treatments and replicated thrice in factrorial- RCBD design. Pre-emergence (PE) application of atrazine at 1.25 kg a.i. ha-1 at 3 DAS resulted in no adverse effects on maize compared to the unweeded control. Additionally, this treatment achieved complete control of both dicot and monocot weeds at 10 and 20 DAS, leading to superior visual weed control ratings (9.3-10 and 9.0-9.1, respectively). PE application of pendimethalin at 0.45 kg a.i. ha^{-1} at 3 DAS also showed no maize toxicity but provided less effective weed control compared to atrazine (7.3-8.3 and 6.8-7.8 visual weed control ratings at 10 and 20 DAS, respectively). Post-emergence (PoE) application of halosulfuron methyl at 90 g a.i. ha^{-1} combined with atrazine at 625 g a.i ha^{-1} at 20 DAS provided moderate control of sedges, grasses and broad-leaved weeds, resulting in average visual weed control ratings of 6.1-6.2 and 5.2-5.7 at 10 and 20 DASP (30 and 40 DAS), respectively. Further, Irrigation at 80% CPE recorded significantly lower total weed population (70.67 and 367.70 No.m-2), weed dry weight (55.31 and 72.45 g m-2) at 60 DAS and at harvest respectively as compared to 100% CPE. Among weed control methods, pre-emergence application of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS recorded higher kernel yield (8,310 kg h^{-1}), lower WI (-4.61%) total weed population (70.67 and 201,83 No.m-2) and weed dry weight (21.57 and 21.57 g m^{-2}) at 60 DAS and at harvest respectively and were comparable with hand weeding twice at 30 and 45 DAS or rest of the chemical weed control practices.

Keywords: Pre emergence, post emergence, days after sowing, days after spraying (DASP), weed index (WI).

Introduction

Maize (*Zea mays* L.) is third most important cereal crop in the world both in area and production after rice and wheat. On the other hand, for productivity it supresses all cereals. It gives average kernel yield of 4.1 t ha^{-1} as compared to other major cereals such as rice (3.7 t ha^{-1}), wheat (2.5 t ha^{-1}) and millets (1.2 t ha^{-1}) (Panda, 2010) [16]. Besides, it is a stable food for poor people in most of the developing country. Hence invariably, it is referred as the "queen of cereals". Maize provides about 30 per cent of the food calories for more than 4.5 billon people in 94 developing countries. Most importantly the significance of maize to sustainable development cannot be exaggerated. In Recent global projection of maize indicated that, demand will exceed than rice and wheat by 2020. Further, the demand will be more acute in Asia than other part of the world (Bhat *et al.*, 2020) [6].

Globally, maize is grown over an area of 179 m ha with the annual production of 1,054 m t and the productivity is 5,700 kg ha^{-1}(Anon., 2016) [2]. In India, it occupies an area of 9.4 m ha with the production of 22.27 m t and the productivity is 2.4 t ha^{-1}, which is much lower than the global average (Anon., 2016a) [3]. While, in Karnataka maize cultivated in an area of 1.3 m ha with a production of 3.92 m t with productivity of 2,883 kg ha^{-1} (Anon., 2016b) [4]. 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 4308 kg ha^{-1} (Anon., 2016c) [5].

In maize, irrigation and weed management are the two important agronomic practices for enhancing production, poor management of these two practices leads to widening of potential and actual yield obtained. In order to narrow down the yield gap, adoptions of suitable irrigation and weed management practice are required.

At present drip irrigation is the most advanced surface irrigation but this hinders the frequent inter-cultivation or manual hand weeding between the maize rows due to lateral tubes aligned for irrigation on surface. Moreover, hand weeding is laborious, time consuming, costly and tedious. Besides, labour is not available at the critical period. Added to this, in *kharif* rainy period weather condition may not permit hand weeding. Hence, to minimizing the losses caused by weeds in drip irrigated paired row maize; the chemical weed control by using herbicide may be the obligation to contain the weeds. Because it found to be quicker, more cost effective, ease of application and involves less drudgery (Sharma *et al.*, 2018) [22].

Hence, pre and post emergence herbicide has to be needed in specific to time and ease of application in maize. However, at present post-emergence herbicides used are narrow spectrums used to control only specific weed flora. Hence, there is need to achieve broad spectrum weed control, for that tank mixture of two different chemicals can become effective tools to enhance efficiency and achieves broad-spectrum weed control (Anjali *et al.*, 2018) [1].

With this background, the present field investigation entitled "Studies on chemical weed control and irrigation levels under drip irrigated paired row maize (*Zea mays* L.) in alfisol'' was conducted during *kharif*, 2018

Materials and Methods

A field experiment was conducted at College of Agriculture, V. C. Farm, Mandya during 2018 to study the effect of different chemical weed control practices and irrigation levels on growth and yield of maize. The experiment was laid out in factorial RCBD design with ten treatments and three replications. The net plot size was 2.4 m × 3.0 m. The recommended dose of FYM (10 t ha^{-1}) was applied 15 days prior to sowing and fertilizer dose of 150: 75: 40 N, P_2O_5, K_2O 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 reaming nitrogen was top dressed in two equal splits at 30 and 45 DAS. 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 P_2O_5 (48.31 kg ha^{-1}), while it was high in K_2O (322.66 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. Then weeds, stubbles were removed and the land was levelled. The field was demarked for laying out experiment as per the plan and plots were prepared manually by using spade. After the Seed bed preparation, on 16th July 2018 furrows were opened as per the paired row spacing (90 cm between paired rows and 30 cm between rows). Then the hybrid seeds of maize (MAH-14-5) were sown at plant to plant spacing of 30 cm within the furrow as two seeds per hill and later seeds were covered with moist soil. Before sowing, maize seeds were treated with Redomil MZ @ 4 g kg^{-1} of seed to prevent seed born disease followed by chlorpyrifos @ 4 ml kg^{-1} of seed to avoid pest attack at germination stage. Gap filling was done after 10 DAS in order to maintain 100% population in the plot.

The treatments consist of two factors Factor-1: Two Irrigation levels -Irrigation at 80% CPE (I_1), Irrigation at 100% CPE (I_2). (Note: CPE = Cumulative pan evaporation). Factor-2: Five chemical weed control practices- atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS (W_1), pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS (W_2), halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS (W_3), Hand weeding twice (30 and 45 DAS) (W_4) and Unweeded control (W_5). Prior to the implementation of irrigation treatment all the experimental plots were irrigated with common depth of 5 cm, to ensure the uniform germination and crop establishment. Further, 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 for the period of previous two days after irrigation and which is multiplied by plot area to obtain volume of water to be applied. 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, filer units, main line and sub lines. In line laterals, 12 mm size with 2 lph capacity. The species wise weed count was taken randomly at two points in each plot in 1.0 m^2 area at different crop growth stages and were averaged. The averaged count was classified into grasses, sedges and broad leaved weeds. The dry weight of weeds was recorded by uprooting the weed from respective plot from 1.0 m^2 area at 60 DAS and at harvest. Further, the weeds were oven dried to a constant weight at 65 ^{0}C and dry weight of weeds was recorded as g m^{-2} separated as species wise. The data on weed count and weed dry weight showed high variation and hence the value of the weed population and weed dry weight were transformed using log (x+2) and $(x+1)^{1/2}$ to make the analysis of variance valid as suggested by Gomez and Gomez (1983) [8].

Results and Discussion

Weed observation

Crop toxicity ratings

The visual observation on crop toxicity rating recorded at 5, 10, 15 and 20 days after spraying (DASP) of pre and post-emergence herbicides (Table 1).

After pre-emergence herbicides

At 5, 10, 15 and 20 DASP of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS or pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS showed no toxicity on maize crop (zero) as compared to unweeded control. These results obtained are in conformity with the findings of Anjali (2018) [1] for atrazine as PE application and Nadeem *et al.* (2023) [15]. This suggests that both atrazine and pendimethalin can be effective options for weed control in maize fields without negatively impacting the maize crop's health and growth.

After post-emergence herbicides

At 5, 10, 15 and 20 DASP of halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS showed no morphological crop toxicity on maize (zero) as compared to unsprayed unweeded control. The similar results of selectivity and zero toxicity as also reported by Anjali (2018) [1] for atrazine as PoE.

Weed control ratings

The visual observation on weed control rating recorded at 10 and 20 DASP in pre and post-emergence application of herbicides are given in the Table 2.

After pre-emergence application of herbicides

At 10 and 20 DASP of PE application atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS showed complete control of both dicot and monocot weeds and there by recorded higher visual weed control rating (9.3 to 10 and 9.0 to 9.1, respectively) as compared to PE application of pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS (7.3 to 8.3 and 6.8 to 7.8, respectively).

Similar such reports were also made by Burhanuddin *et al.* (2021) and Yayan *et al.* (2023) [25]. The findings suggest that the application of atrazine or pendimethalin post-emergence can effectively control weed growth in corn fields, providing results similar to manual weeding practices, thus offering a viable alternative for weed management in maize cultivation.

After post-emergence application of herbicides

At 10 DASP (30 DAS) and 20 DASP (40 DAS) of PoE application of halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i ha^{-1} at 20 DAS showed average control of sedges, grass and broad-leaved weeds and thereby recorded visual weed control rating of 6.1 to 6.2 and 5.2 to 5.7, respectively. However, PE application of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS or pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS still continued to record higher visual weed control rating at 30 (8.9 to 9.00 and 6.5 to 7.6, respectively) and 40 DAS (8.5 to 8.8 and 6.0 to 7.4, respectively) and were comparable with hand weeding twice (9.3 to 9.5 and 8.5 to 8.9 respectively) in the experiment. The results obtained are in conformity with Ram *et al.* (2017) [19] and Anjali (2018) [1] for atrazine as PoE application.

Table 1: Phytotoxicity ratings (0-10 scale) as influenced by irrigation levels and chemical weed control practices in paired drip irrigated maize

Treatment	After pre-emergence herbicides				Before post-emergence herbicides			
	5 DASP	10 DASP	15 DASP	20 DASP	5 DASP	10 DASP	15 DASP	20 DASP
T_1: I_1W_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_2: I_1W_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_3: I_1W_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_4: I_1W_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_5: I_1W_5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_6: I_2W_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_7: I_2W_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_8: I_2W_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_9: I_2W_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_{10}: I_2W_5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: DASP- Days after spraying.

Treatment details

T_1: I_1W_1 - 80% CPE + atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS
T_2: I_1W_2 - 80% CPE + pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS
T_3: I_1W_3 - 80% CPE + halosulfuron methyl @ 90 g a.i ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS
T_4: I_1W_4 - 80% CPE + hand weeding twice at 30 and 45 DAS
T_5: I_1W_5 - 80% CPE + unweeded control
T_6: I_2W_1 - 100% CPE + atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS
T_7: I_2W_2 - 100% CPE + pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS
T_8: I_2W_3 - 100% CPE + halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS
T_9: I_2W_4 - 100% CPE + hand weeding twice at 30 and 45 DAS
T_{10}: I_2W_5 - 100% CPE + unweeded control

Table 2: Weed control ratings (0-10 scale) at 10 and 20 DASP of pre and post-emergence herbicide spray in paired drip irrigated maize

Treatment	After pre-emergence herbicides		After post-emergence herbicides	
	10 DASP	20 DASP	10 DASP	20 DASP
T_1: I_1W_1	10	9.1	9.0	8.8
T_2: I_1W_2	7.2	6.8	6.5	6.0
T_3: I_1W_3	0.0	0.0	6.1	5.7
T_4: I_1W_4	0.0	0.0	9.5	8.5
T_5: I_1W_5	0.0	0.0	0.0	0.0
T_6: I_2W_1	9.3	9	8.9	8.5
T_7: I_2W_2	8.3	7.8	7.6	7.4
T_8: I_2W_3	0.0	0.0	6.2	5.2
T_9: I_2W_4	0.0	0.0	9.3	8.9
T_{10}: I_2W_5	0.0	0.0	0.0	0.0

Note: DASP- Days after spraying.

Treatment details

T_1: I_1W_1 - 80% CPE + atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS
T_2: I_1W_2 - 80% CPE + pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS
T_3: I_1W_3 - 80% CPE + halosulfuron methyl @ 90 g a.i ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS
T_4: I_1W_4 - 80% CPE + hand weeding twice at 30 and 45 DAS
T_5: I_1W_5 - 80% CPE + unweeded control
T_6: I_2W_1 - 100% CPE + atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS
T_7: I_2W_2 - 100% CPE + pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS
T_8: I_2W_3 - 100% CPE + halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS
T_9: I_2W_4 - 100% CPE + hand weeding twice at 30 and 45 DAS
T_{10}: I_2W_5 - 100% CPE + unweeded control

Weed flora observed in experimental site

The major weed flora observed and identified in the experimental plot during course of investigation are presented in. There were about fifteen species of weeds, consisted of five different grasses belongs to poaceae family such as *Cynodon dactylon* L, *Digiteria arvensis* L, *Dactyloctenium aegyptiacum*

L, *Elucina indica* L. and *Eergrostis tenella* L; Among sedges *Cyprus rotundus* L., which belongs to family cyperacea. In broad leaved, nine weeds were recorded such as Ageratum conizoides L., *Amaranthus viridis* L., *Commelina benghalensis* L., *Euphorbia hirta* L., *Trianthimum portulacastrum* L., *Boerhavia diffusa* L., *Phylantus neruri* L., *parthenium heterophorus* L., *Gamphorina documbence* L., various earlier authors were reported similar weed flora in maize (Birendra *et al*., 2017 and Anjali *et al*., 2018) [1].

Weed density (number m^{-2}) and dry weight (g m^{-2})
Weed density (number m^{-2})

Irrigation at 80% CPE recorded lower total weed density at 60 DAS and at harvest significantly lower at harvest (70.67 and 367.07 No. m^{-2}, respectively) as compared to irrigation at 100% CPE (96.33 and 475.13 No. m^{-2}, respectively).

Among weed control methods, hand weeding twice at 30 and 45 DAS recorded significantly lower total weed count (62.33 No. m^{-2}) which is closely followed by PE application of atrazine @ 1.25 kg a.i ha^{-1} at 3 DAS (70.67 No. m^{-2}) as compared to rest of the weed control methods (96.33 to 138.67 No. m^{-2}) and unweeded control (262.50 No. m^{-2}) at 60 DAS. Whereas, at harvest PE application of atrazine @ 1.25 kg a.i ha^{-1} at 3 DAS recorded lower total weed density (201.83 No. m^{-2}) followed by pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS (213.67 No. m^{-2}) and hand weeding twice at 30 and 45 DAS (216.00) and were statistically lower than rest of weed control practice (482.33 No. m^{-2}) and unweeded control (991.67 No. m^{-2}). The results obtained are in accordance with Milevsky *et al.* (2023) [14] atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS showed effective weed control with lower weed density compared to other methods, indicating its potential in weed management.; Nadeem *et al.* (2023) [15]; Ramandeep *et al.* (2023) [20]; Tibugari *et al.* (2022) [24].

Dry weight (g m^{-2})

At 60 DAS, there was no significant difference among 80 and 100% CPE irrigation levels with respect to total dry matter of weeds (55.31 and 63.18 g m^{-2}). Between weed control methods, hand weeding twice at 30 and 45 DAS recorded significantly lesser total dry weight of weeds (13.52 g m^{-2}) compared to rest of the weed control methods (20.87 to 40.48 g m^{-2}) and unweeded control (199.80 g m^{-2}).

At harvest, lower total dry matter of weeds recorded with 80% CPE (72.45 g m^{-2}) as compared to 100% CPE (90.27 g m^{-2}). Among weed control methods, PE application of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS recorded significantly less total dry weight of weed [1] (21.57 g m^{-2}) followed by pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS (26.70 g m^{-2}) but was statistically superior in control of total dry weight of weeds over rest of the treatments (34.82 to 92.20 g m^{-2}) and unweeded control (231.53 g m^{-2}).

Irrigating the crop at 100% CPE recorded statistically higher density and dry matter of broad-leaved weeds, might due to excess moisture with 100% CPE irrigation favours the growth of broad-leaved weed unlikely in irrigating the crop at 80% CPE, where only optimum moisture was maintained in the plot. Among weed control methods, PE application of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS resulted in significantly lower density of broad leaved weeds at 30, 60, 90 DAS and at harvest and dry weight at 30, 90 DAS and at harvest. (Table 3 and 4) could be due to broad spectrum and non-selectiveness of atrazine chemical for broad leaved weed resulted in lower density and dry weight. The similar results were also reported by Nadeem *et al.* (2023) [15] irrigating the crop at 100% CPE led to higher density and dry matter of broad-leaved weeds, possibly due to excess moisture favouring their growth, unlike with 80% CPE where optimal moisture levels were maintained. Further, use of pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS as PE application also recorded similar lower broad leaved weed density at 60 DAS and dry weight at 60 DAS, but not at later stages indicated the narrow spectrum non selectiveness of pendimethalin on broad leaved weed killing and also at later stages faster degradation of chemical with irrigation could resulted in lower control at remaining stages. The results obtained are in conformity with Kamble *et al*. (2015) [11]. Whereas, the PoE tank mix application of halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS also showed similar lower broad leaved weed density at 60 and at harvest and dry weight at 60 DAS. This might be due to effectiveness of these chemical particularly halosulfuron on broad leaved weeds killing as foliar applications resulted in lower density and weight after 30 DAS in the experiment. But, the left over selective broad leaved weeds continued to grow and accumulate dry matter at later stages (at harvest) of crop growth. The results obtained are in accordance with Kumar *et al.* (2017) [12] for halosulfuron; Ram *et al.* (2017) [19] for atrazine as PoE application Infant *et al.* (2023) [18].

Among weed control methods, pre-emergence application of atrazine at 1.25 kg a.i. ha^{-1} at 3 DAS resulted in significantly lower density of broad-leaved weeds at 60 DAS and at harvest, as well as lower dry weight at harvest. This effect could be attributed to the broad-spectrum and non-selective nature of atrazine, which effectively reduced the density and dry weight of broad-leaved weeds throughout the crop growth period.

Kernel yield (kg ha^{-1})

The irrigation at 80 and 100% CPE recorded on par kernel yield of maize (7,083 and 7,474 kg ha^{-1}, respectively). Among weed control methods, PE application of atrazine @ 1.25 kg a.i. ha^{-1} recorded higher kernel yield (8,310 kg ha^{-1}) followed by hand weeding twice at 30 and 45 DAS (7,943 kg ha^{-1}), PE application of pendimethalin @ 0.45 kg a.i. ha^{-1} (7,788 kg ha^{-1}) and PoE application of halosulfuron methyl @ 90g a.i. ha^{-1} + atrazine @ 625 g a.i ha^{-1} at 20 DAS (7,718 kg ha^{-1}), however all were statistically on par with each other, but significantly superior over unweeded control (4,634 kg ha^{-1}) (Table 4). The results obtained are in accordance with Alptekin *et al.* (2023) [9]. The higher kernel yield in PE application of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS could be due to efficient control of sedges, grass and broad leaved weeds (Table 1 to 3) resulted in higher nutrient uptake by maize and photosynthesis production and which helps for enhanced growth parameter and further their translocation to sink as indicated by HI and shelling percentage, resulted in superior yield in turn helped in production of higher economic produce such as maize kernel and stover yield. The Results obtained are in agreement with Birenbra kumar *et al.* (2017) [12] and Tapas *et al.* (2017) [23].

However, PE application of pendimethalin @ 0.45 kg a.i ha^{-1} at 3 DAS was also able to produce comparable maize kernel yield as compared to former treatment or hand weeding twice at 30 and 45 DAS indicated the uncontrolled broad leaved weeds at later stage (Table 1 to 3) might not have significant effects on yield parameter such as rows per cob and kernel weight per cob (Table 4.10) and their by comparable economic produces such as maize kernel and stover yield. The results obtained were in conformity with Birenbra kumar *et al.* (2017) [12] and Tapas *et al.* (2017) [23].

Table 3: The density of weeds category wise- sedges, grasses, broad leaved and total (No. m^{-2}) at 60 DAS and at harvest as influenced by irrigation levels and chemical weed control practices under drip irrigated paired row maize

Treatment	Density of weeds at 60 DAS				Density of weeds at harvest			
	Sedges#	**Grasses#**	**Broad leaved#**	**Total#**	**Sedges@**	**Grasses@**	**Broad leaved@**	**Total@**
Factor- A: Irrigation levels								
I_1: 80% CPE	1.37 (24.53)	1.63 (60.80)	1.51 (34.27)	10.50 (70.67)	1.85 (71.20)	1.99 (146.13)	2.01 (149.73)	18.12 (367.07)
I_2: 100% CPE	1.42 (28.26)	1.67 (63.73)	1.59 (40.6)	11.14 (96.33)	1.87 (76.88)	2.06 (209.93)	2.14 (188.40)	20.52 (475.13)
S.Em±	0.04	0.04	0.05	0.29	0.03	0.05	0.03	0.53
CD (p= 0.05)	NS	NS	NS	NS	NS	NS	0.09	1.57
Factor-B: Chemical weed control practices								
W_1: Atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS	1.36 (22.0)	1.36 (22.33)	1.43 (26.33)	8.42 (70.67)	1.84 (69.67)	1.72 (56.5)	1.87 (75.67)	14.17 (201.83)
W_2: Pendimethalin @ 0.45 kg a.i.ha^{-1} at 3 DAS	1.40 (24.67)	1.49 (30.33)	1.61 (41.33)	9.78 (96.33)	1.81 (63.33)	1.83 (67.67)	1.91 (82.67)	14.59 (213.67)
W_3: Halosulfuron methyl @ 90g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS	1.41 (24.67)	1.92 (84.00)	1.47 (30.00)	11.76 (138.67)	1.76 (56.33)	2.39 (308)	2.06 (48)	21.82 (482.33)
W_4: Hand weeding twice (30 and 45 DAS)	1.13 (11.67)	1.32 (19.67)	1.48 (31.00)	7.9 (62.33)	1.89 (79.5)	1.77 (60.83)	1.87 (75.67)	14.68 (216)
W_5: Unweeded control	1.69 (49.00)	2.16 (155.00)	1.77 (58.50)	16.23 (262.50)	2.00 (101.17)	2.41 (397.17)	2.69 (493.33)	31.32 (991.67)
S.Em±	0.06	0.06	0.08	0.46	0.05	0.07	0.05	0.84
CD (p= 0.05)	0.18	0.17	0.22	1.36	0.15	0.21	0.14	2.49
Interaction								
S.Em±	0.09	0.08	0.11	0.65	0.07	0.10	0.07	1.19
CD (p= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: Figures in parenthesis indicate original values, # = (√x+1) and @ = Log (x+2) transformed values

Table 4: The dry weight of weeds (g m^{-2}) category wise- sedges, grasses, broad leaved and total at 60 DAS and at harvest as influenced by irrigation levels and chemical weed control practices under drip irrigated paired row maize

Treatment	Dry weight of weeds (g m^{-2})				Dry weight of weeds (g m^{-2})			
	Sedges@	**Grasses@**	**Broad leaved@**	**Total@**	**Sedges#**	**Grasses#**	**Broad leaved#**	**Total#**
Factor- A: Irrigation levels								
I_1: 80% CPE	2.80(7.15)	1.13(21.27)	1.19(26.89)	6.58(55.31)	3.05(8.54)	1.37(34.49)	1.21(29.42)	7.69(72.45)
I_2: 100% CPE	3.00(842)	1.17(23.62)	1.22(31.14)	6.92(63.18)	3.24(9.84)	1.43(43.94)	1.35(36.48)	8.60(90.27)
S.Em±	0.09	0.02	0.02	0.17	0.07	0.03	0.02	0.21
CD (p= 0.05)	NS	NS	NS	NS	NS	NS	0.06	0.62
Factor-B: Chemical weed control practices								
W_1: Atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS	2.65(6.08)	0.81(4.50)	1.10(10.98)	4.74(21.57)	2.43(4.92)	1.01(8.55)	0.98(8.10)	4.73(21.57)
W_2: Pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS	2.71(6.47)	0.93(6.53)	0.98(7.87)	4.66(20.87)	2.74(6.50)	1.04(8.97)	1.11(11.23)	5.25(26.70)
W_3: Halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS	3.07(8.48)	1.40(23.52)	1.02(8.48)	6.43(40.48)	3.45(11.05)	1.84(70.10)	1.11(11.05)	9.58(92.20)
W_4: Hand weeding twice (30 and 45 DAS)	2.29(4.25)	0.74(3.50)	0.88(5.77)	3.80(13.52)	3.50(11.35)	1.13(11.73)	1.13(11.73)	5.96(34.82)
W_5: Unweeded control	3.79(13.63)	1.87(74.18)	2.05(111.98)	14.12(199.80)	3.61(12.15)	1.98(96.75)	2.09(122.63)	15.19(231.53)
S.Em±	0.15	0.03	0.04	0.26	0.11	0.04	0.03	0.33
CD (p= 0.05)	0.44	0.09	0.11	0.78	0.34	0.12	0.09	0.99
Interaction								
S.Em±	0.21	0.04	0.05	0.37	0.16	0.06	0.04	0.47
CD (p= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note: Figures in parenthesis indicate original values, # = (√x+1) and @ = Log (x+2) transformed values.

Table 5: Kernel yield, stover yield, harvest index (HI), weed index (WI), weed control efficiency (WCE) and water use efficiency (WUE) as influenced by irrigation levels and chemical weed control practices in maize under paired row drip irrigation

Treatment	Kernel yield (kg ha^{-1})	Harvest index (%)	Weed index (%)	Total water used (mm)
Factor- A: Irrigation levels				
I_1: 80% CPE	7083	45.42	5.91	481
I_2: 100% CPE	7474	44.56	10.83	524
S.Em±	195	1.08	NA	
CD (p= 0.05)	NS	NS	NA	
Factor-B: Chemical weed control practices				
W_1: Atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS	8310	41.72	-4.61	
W_2: Pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS	7788	42.32	1.95	
W_3: Halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i. ha^{-1} at 20 DAS	7718	43.50	2.83	
W_4:Hand weeding twice (30 and 45 DAS)	7943	47.98	0.00	
W_5: Unweeded control	4634	49.41	41.66	
S.Em±	308	1.71	NA	
CD (p= 0.05)	916	5.09	NA	
Interaction				
S.Em±	436	2.42	NA	
CD (p= 0.05)	NS	NS	NA	

Further PoE application of halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i ha^{-1} at 20 DAS also recorded similar kernel yield as that of PE application of atrazine @ 1.25 kg a.i ha^{-1} at 3 DAS or hand weeding twice at 30 and 45 DAS (Table 4.11) showed that, the uncontrolled grassy weeds after PoE did cause significant reduction in stover but not on kernel yield of maize. The reason might be existence of grasses in maize crop with after PoE application of halosulfuron methyl and atrazine @ 625 g a.i ha^{-1} at 20 DAS was not having active growth and hence could supress the foliage only, but not on the economic produces as also indicated by production of statistically kernel yield of maize. The results obtained are in conformity with Birenbra kumar *et al.* (2017) [12].

Harvest index (HI)

Among irrigation levels, irrigating the crop with 80% CPE recorded higher harvest index (45.42%) as compared to 100% CPE (44.56%), but were on par with each other.

Among different chemical weed control practices, unweeded control recorded higher harvest index (49.41%) followed by hand weeding twice at 30 and 45 DAS (47.98%) and were significantly superior to rest of the treatment (41.72 to 43.50%). The results obtained are in conformity with Paul and Basciano (2022) [17].

Weed index (%) (Table 4)

Among the weed control methods, PE application of atrazine @ 1.25 kg a.i. ha^{-1} at 3 DAS recorded no yield loss of maize as due to weeds indicated by negative weed index (-4.61%) in comparison to hand weeding twice at 30 and 45 DAS. The yield loss as showed by weed index in PE application of pendimethalin @ 0.45 kg a.i. ha^{-1} at 3 DAS was 1.95% as compared to 2.83% with PoE application of halosulfuron methyl @ 90 g a.i. ha^{-1} + atrazine @ 625 g a.i ha^{-1} at 20 DAS. While, the higher yield loss of 41.66% noticed in unweeded control. The results found under this study are in line with Ram *et al.*, (2017) [19] for atrazine and Shankar *et al.* (2015) [21] for pendimethalin as PE application. This might be due to irrigation at 80 and 100% CPE recorded on par kernel yield of maize (7083 and 7474 kg ha^{-1}, respectively). Among weed control methods, PE application of atrazine @ 1.25 kg a.i. ha^{-1} recorded higher kernel yield (8,310 kg ha^{-1}) followed by hand weeding twice at 30 and 45 DAS (7,943 kg ha^{-1}), PE application of pendimethalin @ 0.45 kg a.i. ha^{-1} (7,788 kg ha^{-1}) and PoE application of halosulfuron methyl @ 90g a.i. ha^{-1} + atrazine @ 625 g a.i ha^{-1} at 20 DAS(7,718 kg ha^{-1}), however all were statistically on par with each other, but significantly superior over unweeded control (4,634 kg ha^{-1}) (Table 4).

Total water used (mm)

The total water 481 mm was used with irrigation at 80% CPE as against 524.4 mm at 100% CPE. While, irrigation at 80% CPE saves 8.28% of total irrigation water over 100% CPE (Table 4). Irrigation at 80 and 100% CPE recorded statistically on par kernel (7,083 and 7,474 kg ha^{-1}, respectively) (Table 4). The comparable yield levels might be due to water applied with irrigation at 80% CPE could enough to meet the evapotranspiration demand and metabolic activities in maize crop which in turn helped in optimum photosynthesis production and translocation to sink as a result in similar yield parameter and comparable kernel between 80 and 100% CPE irrigation. The results found under this study are in line with Hussein and Pibars (2012) [10] for irrigation at 100 and 75% ET_c and Mathukia *et al.* (2011) [13] for irrigation at 1.0 and 0.8 IW/CPE ratios.

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