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RESEARCH ARTICLE

Integration effect of drip irrigation and mulching on weeds and spring maize productivity

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ABSTRACT

A field experiment was carried out at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during spring season of 2020 and 2021. The experimental design was split-plot with three replications. The main plots included the combination of two methods of drip irrigation, *viz.* surface drip irrigation (SD) and sub-surface drip irrigation (SSD) and three mulch treatments, *viz.* plastic mulch (PM), straw mulch 6 t/ha (SM) and no mulch (NM) along with furrow irrigation (FI) as a control treatment. The sub-plots consisted of four weed control treatments, *viz.* pre-emergence application (PE) of atrazine 1000 g/ha, hand weeding twice at 30 and 60 days after seeding (DAS), weed free and weedy check. The dominant weed species were *Cyperus rotundus, Oenothera laciniata, Chenopodium album, Coronopus didymus, Rumex dentatus, Digitaria sanguinalis,* and *Dactyloctenium aegyptium.* The maize emergence was 6 days earlier under plastic mulch than the crop under straw mulch. The SD-PM, SD-SM, SSD-PM, SSD-SM and SSD-NM resulted in maximum maize plant height when compared to FI. SD-PM, SD-SM, SSD-PM and SSD-SM treatments recorded significantly lower total weed density and biomass at 30 DAS than the atrazine treated FI treatment. Maximum weed control efficiency of 88.89% was recorded under integration of drip irrigation with plastic mulch. Integration of drip irrigation and mulches resulted in significantly increased maize grain yield as compared to FI. Crop raised under SD-SM treatment resulted in 20.62% higher grain yield than FI. The integration of drip irrigation with mulching resulted in effective weed management and higher maize grain yield than furrow irrigation method.

Keywords: Drip irrigation, Irrigation methods, Maize, Mulches, Weed control efficiency, Weed management

INTRODUCTION

Maize (*Zea mays* L.) is the third most versatile cereal grain crop having worldwide significance after rice and wheat. It can be successfully grown under different seasons such as *Kharif* (summer), *Rabi* (winter) and spring season as it can sustain itself in varied agricultural ecosystems. Spring maize is becoming more popular among potato farmers in semi-arid sub-tropical regions of Punjab. This is due to the less or no incidence of insect-pest and diseases and its high productivity (8.0 t/ha) compared to the *Kharif* maize (6.0 t/ha). Spring sown maize also helps to meet the increasing green ear demands during summer and provides excellent profits (Verma and Mishra 1998).

Water is an extremely vital resource for crop growth and yield. However, its increasing paucity has raised concerns about its efficient utilization, management, and sustainability. Spring maize has high evapo-transpiration rates often exceeding 10 mm/day and experience water stress especially at flowering and pollination stages leading to inferior yields (Singh and Vashist 2016). Therefore, uniform, and continuous supply of irrigation water need to be ensured in Punjab due to absence of rainfall during spring season. However, Punjab's water resources are depleting at a distressing rate due to continuous cultivation of water-devouring paddy. The mean annual water balance in Punjab exhibits a deficit of 1.6 m ha which is met through over-utilization of groundwater (Brar *et al.* 2018). Therefore, it is necessary to devise effective in-situ water management methods to increase crop productivity with same or comparably less amount of water applied. Drip irrigation method have the highest water use efficiency of more than 90% making it the most efficient method among all other irrigation systems.

Amongst biotic constraints, weed-induced competition is a serious threat to spring maize productivity as it encounters both *Kharif* (summer) and *Rabi* (winter) season weeds. Severe weed infestation has been reported to reduce maize yield by 35 to 80% (Oerke and Dehne 2004). The practice of

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hand weeding is becoming less common currently due to soaring labour costs and migration of labour to urban areas. Thus, farmers are preferring the use of herbicides. However, excessive reliance on herbicides having similar mechanism of action has led to the evolution of herbicide resistance in weeds and hence, the focus should be shifted on using more economically viable and environmental-friendly weed management options. Mulching is a promising method for reducing weed infestation in maize (Bhatt and Khera 2006). Mulching effectively reduces soil evaporation losses and improves root growth leading to soil moisture conservation, thereby enhancing the crop yield (Chaudhary and Prihar 1974). There is a need to quantify the coupled effect of drip irrigation methods and mulching on weeds and spring maize productivity. Thus, the present study was conducted with an objective to assess the weed composition and management under integration of drip irrigation and mulches and compare it to the standard furrow irrigation method.

MATERIALS AND METHODS

Field trial was conducted during two successive spring seasons of 2020 and 2021 at Research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana (30° 56' N, 75° 52' E, 247 m above mean sea-level), Punjab. This region is located in the central plain region of Punjab under Trans-Gangetic agro-climatic zone of India. The climate of the region is sub-tropical and semi-arid with very hot and dry summer from April to June, hot and humid conditions from July to September, cold winters from November to January and mild climate during February and March. Soil of the experimental field was sandy loam with a normal pH of 7.6, low available nitrogen (175.4 kg/ha), high in available phosphorous (25.7 kg/ha) and available potassium (345.6 kg/ha). Maize hybrid 'PMH 10' was sown on February 11, 2020 and February 12, 2021 at a spacing of 60 cm × 20 cm using 25 kg seed per ha on the southern side of east-west ridges. The experiment was laid out in split plot design with three replications. The main plot consisted of seven treatments including combination of two drip irrigation treatments *viz*. surface drip (SD) and subsurface drip (SSD) irrigation and three mulch treatments *viz.* black plastic mulch of 25µ thickness (PM), paddy straw mulch 6 t/ha (SM) and no mulch (NM); and one standard (control) treatment of furrow irrigation (FI) without mulch in the main plots. In the sub-plots, four weed management treatments were taken *viz.* pre-emergence application (PE) of atrazine 1000 g/ha, hand weeding twice at 30 and 60 days after seeding (DAS), weed-free and weedy check. To prevent the interflow of water between plots, the buffer area of 1.0 m was maintained between the main plots. Atrazine was sprayed with knapsack sprayer using flat fan nozzle before laying down of mulches in straw mulched plots. Herbicide was sprayed before laying plastic mulch and dibbling was done afterwards by making punching holes in the plastic mulch. Days taken to 100% emergence under different treatments were noted to see the effect of treatment combinations on the crop emergence. Weed density (species wise) was recorded at 30 DAS by placing a quadrat (0.5 × 0.5 m). Weed biomass (group wise) was recorded at 30 DAS by cutting weeds at the ground level and then dried in the hot air oven at 60±2^{0}C till constant weight was obtained. Plant height was taken at harvest by recording height of randomly selected five maize plants. Total number of cobs per plot was counted and divided by total number of plants per plot to calculate number of cobs per plant. Cob diameter of five representatives randomly selected cobs were measured with the help of a vernier caliper from the base, center, and the top, and the mean value was multiplied with the value of ð (=3.14) to get the average cob girth. The grain yield from the net plot was recorded and computed as yield per hectare. Data of weed density and biomass were subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis. Weed control efficiency (WCE) was calculated as per standard formulas (Mani *et al.* 1973). Data was analysed using the two-way ANOVA (given below) to evaluate the difference between treatments. Significance of treatment means were evaluated at 5% level of significance with Fisher's Protected Least Significance Difference Test. Another post-hoc test, Dunnett's Multiple Comparison was computed to compare means of groups of main-plot treatments (SD-PM, SD-SM, SD-NM, SSD-PM, SSD-SM, SSD-NM) with mean of one control, furrow irrigation so that the integrative effect of drip irrigation and mulching on weeds and crop growth can be compared with conventional furrow irrigation method.

RESULTS AND DISCUSSION

Days taken to crop emergence: The number of days taken to crop emergence were recorded to determine whether different irrigation methods and mulches had a significant impact on seedling germination and emergence (**Table 1**). The minimum number of days were taken to achieve 100% emergence by crop under plastic mulch followed by crop sown under no mulch treatment whereas crop sown under straw mulch treatment took maximum number of days for complete emergence. The complete emergence under plastic mulch has occurred 6 days earlier than the crop under straw mulch. Similarly, crop with no mulch took 3 days less for complete emergence than crop under straw mulch. Plastic mulch elevates soil temperature which accelerates the crop emergence and growth in order to achieve the desired population structure at an early growth stage (Liu *et al.* 2014). More number of days taken for 50% emergence and 100% emergence under straw mulch 6 t/ha was possibly due to high mulch load.

Effect on weeds: The dominant weed species observed at the experimental field comprised of *Digitaria sanguinalis, Dactyloctenium aegyptium* (grass weeds); *Oenothera laciniata, Chenopodium album, Coronopus didymus* and *Rumex dentatus* (broad-leaved weeds) and *Cyperus rotundus* as sedge (**Table 2**). The integration of drip irrigation and mulches, including drip irrigation with no mulch treatments recorded significantly lower density of *Digitaria sanguinalis, O. laciniata* and *C. rotundus* at 30 DAS as compared to FI treatment. The lower weed density of *Chenopodium album* and *Rumex dentatus* was observed under SD-PM, SSD-PM, SSD-SM and SD-PM, SSD-PM, SSD-SM, SSD-NM treatments respectively when compared to FI. Treatment combinations *i.e.*, SD-PM, SD-SM, SSD-PM and SSD-SM significantly reduced density of *Coronopus didymus* in comparison to FI. The SD-PM, SD-SM, SSD-PM, SSD-SM and SSD-NM led to significantly less weed biomass of grass and broad-leaved weeds as compared to FI (**Table 3**). Thus, the drip irrigation resulted in effective control of weeds when integrated with mulches as compared to furrow irrigation method. Retention of crop residue on soil surface coupled with subsurface drip irrigation resulted in reduced weed seed germination due to less sunlight and moisture on the soil surface (Jat *et al.* 2019). Sub-surface drip irrigation showed significant reduction in density and biomass of grass weeds and broadleaf weeds mainly *O. laciniata, Chenopodium album, R. dentatus*. Application of plastic mulch led to significant reduction in weed density and biomass followed by straw mulch as compared to no mulch treatment. Application of atrazine significantly reduced the weed density and biomass as compared to weedy check. Application of high dose of atrazine PE resulted in lower weed density and biomass of grass weeds in maize (Gopinath and Kundu 2008). All the treatment combinations resulted in remarkable reduction in sedge weed biomass in comparison to FI. The maximum WCE of 88.89% was recorded under integrated use of drip irrigation with plastic mulch (SD-PM and SSD-PM) whereas lowest WCE of 11.11% was recorded under FI treatment. Sub-surface drip irrigation resulted in higher WCE owing to less weed emergence. Use of plastic mulch resulted in maximum WCE. The integrated use of drip irrigation and mulches (SD-PM, SD-SM, SSD-PM and SSD-SM) results in significant reduction in total weed density and biomass even under weedy conditions as compared to the atrazine treated FI treatment at 30 DAS (**Table 4**) suggesting that the use of herbicides and/or hand weeding may be avoided with the integrated use of drip irrigation and mulches.

Table 1. Effect of irrigation methods, mulching and weed control treatments on days taken to emergence, crop growth and yield of spring maize (pooled data of 2020 and 2021)

Treatment	Days taken to 100% emergence	Plant height at harvest (cm)	Cob girth (cm)	No. of cobs/plant	Grain yield (t/ha)		
					2020	2021	Pooled
Furrow irrigation v/s other main-plot treatments (FI v/s others)							
SD-PM	10.67	187.40*	14.77*	1.56	8.68	8.46	8.57*
SD-SM	16.79*	191.50*	15.70*	1.89*	8.83	8.61	8.72*
SD-NM	13.88*	165.13	13.62	1.30	7.35	7.24	7.30
SSD-PM	10.92	190.10*	15.02*	2.00*	8.88*	8.67*	8.78*
SSD-SM	16.88*	193.51*	15.54*	2.18*	9.06*	8.83*	8.95*
SSD-NM	14.46*	168.41*	13.68	1.55	7.75	7.54	7.64
FI	11.79	162.33	13.76	1.55	7.54	7.31	7.42
d-crit. (p=0.05)	0.70	5.43	0.33	0.12	1.51	1.40	0.35
Drip irrigation (D)							
Surface drip	13.78	181.34	14.71	1.59	8.30	8.10	8.20
Sub-surface drip	14.08	184.01	14.76	1.91	8.56	8.35	8.46
LSD (p=0.05)	NS	2.51	NS	0.07	NS	NS	0.21
Mulching (M)							
Plastic mulch (25µ)	10.79	188.75	14.90	1.79	8.78	8.56	8.67
Straw mulch (6 t/ha)	16.83	192.50	15.63	2.04	8.94	8.72	8.83
No mulch	14.17	166.77	13.66	1.43	7.57	7.39	7.47
LSD (p=0.05)	0.47	3.07	0.22	0.08	0.45	0.41	0.25
Weed Control treatments (W)							
Atrazine 1000 g/ha as pre-emergence	13.86	176.62	14.62	1.67	8.12	7.92	8.02
Hand weeding twice at 30 and 60 DAS	13.38	183.85	14.49	1.76	8.56	8.33	8.44
Weed free	13.55	193.68	15.13	1.93	8.91	8.69	8.80
Weedy check	13.71	164.92	14.10	1.52	7.63	7.43	7.53
LSD (p=0.05)	NS	4.95	0.34	0.10	0.41	0.39	0.30

*Denotes significant difference from furrow irrigation

Table 2. Effect of different irrigation methods, mulching and weed control treatments on weed density at 30 DAS in spring maize (pooled data of 2020 and 2021)

Treatment	Weed density (no./m^2)						
	Grasses		Broad-leaved weeds				Sedge
	D. sanguinalis	*D. aegyptium*	*O. laciniata*	*C. album*	*R. dentatus*	*C. didymus*	*C. rotundus*
Furrow irrigation v/s other main-plot treatment							
SD-PM	1.20 (1)*	1.08 (0)*	2.51 (8)*	1.29 (1)*	1.13 (0)*	1.08 (0)*	2.72 (10)*
SD-SM	1.74 (3)*	1.35 (1)	2.85 (11)*	1.67 (2)	1.59 (2)	1.15 (0)*	3.71 (21)*
SD-NM	2.03 (4)*	1.53 (2)	3.53 (18)	1.72 (3)	1.74 (3)	1.36 (1)	4.28 (28)*
SSD-PM	1.13 (0)*	1.05 (0)*	1.82 (4)*	1.23 (1)*	1.00 (0)*	1.09 (0)*	2.68 (9)*
SSD-SM	1.60 (2)*	1.26 (1)*	2.23 (6)*	1.38 (1)*	1.31 (1)*	1.25 (1)*	3.37 (17)*
SSD-NM	1.86 (3)*	1.37 (1)	3.16 (15)*	1.57 (2)	1.42 (1)*	1.33 (1)	4.26 (29)*
FI	2.25 (6)	1.50 (2)	3.77 (22)	1.84 (3)	1.74 (3)	1.42 (1)	4.89 (38)
d-crit. (p=0.05)	0.15	0.16	0.43	0.19	0.16	0.14	0.31
Drip irrigation							
Surface drip	1.66 (2)	1.32 (1)	2.96 (12)	1.56 (2)	1.48 (2)	1.20 (1)	3.57 (20)
Sub-surface drip	1.53 (2)	1.22 (1)	2.40 (8)	1.39 (1)	1.24 (1)	1.22 (1)	3.44 (18)
LSD (p=0.05)	0.08	0.08	0.17	0.10	0.08	NS	NS
Mulching							
Plastic mulch (25µ)	1.16 (0)	1.06 (0)	2.16 (6)	1.26 (1)	1.06 (0)	1.08 (0)	2.70 (9)
Straw mulch (6 t/ha)	1.67 (2)	1.30 (1)	2.54 (8)	1.53 (2)	1.45 (1)	1.20 (1)	3.54 (19)
No mulch	1.94 (4)	1.45 (1)	3.34 (17)	1.64 (2)	1.58 (2)	1.34 (1)	4.27 (29)
LSD (p=0.05)	0.10	0.10	0.20	0.11	0.10	0.09	0.22
Weed control treatment							
Atrazine 1000 g/ha as pre-emergence	2.13 (4)	1.49 (1)	4.12 (19)	1.87 (3)	1.56 (2)	1.34 (1)	6.15 (39)
Hand weeding twice at 30 and 60 DAS	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weedy check	2.61 (7)	1.72 (2)	5.23 (29)	2.25 (4)	2.11 (4)	1.62 (2)	6.66 (48)
LSD (p=0.05)	0.11	0.13	0.26	0.14	0.11	0.10	0.30

*Denotes significant difference from furrow irrigation; Weed data is subjected to square root transformation (x+1) and means of original values are given in parentheses

Table 3. Effect of irrigation methods, mulching and weed control treatments on weed biomass at 30 DAS and weed control efficiency in spring maize (pooled data of 2020 and 2021)

Treatment	Weed biomass (g/m^2)				Weed control efficiency (%)
	Grasses	Broad-leaved	Sedge	Total	
Furrow irrigation v/s other main-plot treatments					
SD-PM	1.18 (0)*	1.22 (1)*	1.28 (1)*	1.55 (2)*	88.89
SD-SM	1.25 (1)*	1.55 (2)*	1.56 (2)*	2.04 (5)*	72.22
SD-NM	1.89 (4)	2.24 (6)	2.08 (5)*	3.16 (14)	22.22
SSD-PM	1.16 (0)*	1.25 (1)*	1.26 (1)*	1.55 (2)*	88.89
SSD-SM	1.28 (1)*	1.35 (1)*	1.62 (2)*	1.95 (4)*	77.78
SSD-NM	1.50 (2)*	1.83 (3) *	1.98 (4)*	2.62 (9)*	50.00
FI	1.95 (4)	2.28 (6)	2.33 (6)	3.35 (16)	11.11
d-crit. (p=0.05)	0.16	0.19	0.16	0.20	-
Drip irrigation					
Surface drip	1.44 (2)	1.67 (3)	1.64 (2)	2.25 (7)	61.11
Sub-surface drip	1.31 (1)	1.48 (2)	1.62 (2)	2.04 (5)	72.22
LSD (p=0.05)	0.09	0.06	NS	0.07	-
Mulching					
Plastic mulch (25µ)	1.17 (0)	1.24 (1)	1.27 (1)	1.55 (2)	88.89
Straw mulch (6 t/ha)	1.26 (1)	1.45 (2)	1.59 (2)	1.99 (4)	77.78
No mulch	1.70 (3)	2.04 (4)	2.03 (4)	2.89 (11)	38.89
LSD (p=0.05)	0.12	0.07	0.10	0.09	-
Weed control treatment					
Atrazine 1000 g/ha as pre-emergence	1.73 (2)	1.97 (4)	2.31 (5)	3.18 (11)	38.89
Hand weeding twice at 30 and 60 DAS	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	100
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	100
Weedy check	2.11 (4)	2.73 (7)	2.62 (7)	4.10 (18)	-
LSD (p=0.05)	0.11	0.13	0.11	0.15	

*Denotes significant difference from furrow irrigation; Weed data is subjected to square root transformation (x+1) and means of original values are given in parentheses

Maize growth, yield attributes and yield: Straw mulch application led to significant increase in plant height of spring maize (**Table 1**). Among weed control treatments, weedy check recorded significantly shorter plant height as compared to atrazine and hand weeding. The number of cobs per plant were higher when crop was grown under SD-SM, SSD-PM and SSD-SM as compared to FI treatment. Higher number of cobs per plant were recorded under sub-surface drip irrigation compared

Table 4. Interactive effect of FI v/s other methods and weed control treatments on total weed density and biomass at 30 DAS in spring maize (pooled data of 2020 and 2021)

Furrow irrigation v/s other methods) × Weed control treatments	SD-PM	SD-SM	SD-NM	SSD-PM	SSD-SM	SSD-NM	FI
	Total weed density (number/m^2)						
Atrazine 1000 g/ha as pre-emergence	6.02 (36)	8.33 (70)	10.27 (105)	5.67 (32)	6.33 (42)	7.72 (59)	11.71 (136)
Hand weeding twice at 30 and 60 DAS	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weedy check	6.52 (42)	9.60 (91)	11.42 (130)	4.94 (24)	8.45 (71)	12.35 (152)	12.78 (163)
LSD (p=0.05)	For comparing two weed control treatments at same main-plot (furrow irrigation v/s other methods) treatment = 0.86						
	For comparing two main-plot (furrow irrigation v/s other methods) treatments at same or different weed control treatments = 0.84						
	Total weed biomass (g/m^2)						
Atrazine 1000 g/ha as pre-emergence	1.96 (3)	2.48 (5)	4.79 (22)	1.88 (3)	2.37 (5)	3.47 (11)	5.26 (27)
Hand weeding twice at 30 and 60 DAS	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Weedy check	2.25 (4)	3.68 (13)	5.86 (33)	2.31 (4)	3.43 (11)	5.01 (24)	6.14 (37)
LSD (p=0.05)	For comparing two weed control treatments at same main-plot (furrow irrigation v/s other methods) treatment = 0.40						
	For comparing two main-plot (furrow irrigation v/s other methods) treatments at same or different weed control treatments = 0.39						

to surface drip irrigation and under straw mulch treatment compared to no mulch treatment. SD-PM, SD-SM, SSD-PM and SSD-SM resulted in increased cob girth as compared to FI treatment (**Table 1**). Straw mulch application resulted in significantly higher cob girth followed by plastic mulch treatment. Cob girth and number of cobs per plant recorded under atrazine PE and hand weeding was statistically at par but significantly higher than weedy check. Integration of drip irrigation and mulches resulted in significant increase in maize grain yield as compared to FI (**Table 1**). Crop raised under SD-SM treatment resulted in 20.62% higher grain yield than FI. Shah *et al* (2014) also reported that integration of drip irrigation with paddy straw mulch recorded improvement in grain yield by 14% compared to flood irrigation. Sub-surface drip irrigation recorded higher grain yield than surface drip irrigation treatment. Application of paddy straw mulch resulted in higher maize grain yield by 18.21% than no mulch. Among weed control treatments, hand weeding (twice) resulted in significantly higher maize grain yield.

Thus, it can be concluded that weeds can be managed effectively by integration of drip irrigation (surface or sub-surface) and mulching (with plastic or straw) and maize productivity can be improved, when compared to furrow irrigation.

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