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Impact of Fertigation and Herbigation on Growth and Yield of Hybrid Maize (*Zea mays* L.)

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Abstract

A field experiment was carried out during the Kharif, 2023 at the Experimental Farm, Department of Agronomy, Annamalai University, Tamil Nadu. The study aimed to find the Impact of fertigation and herbigation on growth and yield of hybrid maize (*Zea mays* L.). The experiment was structured using a Split Plot Design (SPD) with three replications. The treatments viz., In main plot, M_1- 100% RDF by broadcasting, M_2- 100% RDF by fertigation, M_3- 75% RDF by fertigation, M_4- 50% RDF by fertigation. In sub plot, S_1- Control (unweeded), S_2- Hand weeding Twice (on 20 & 40 DAS), S_3- PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying, S_4 - PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Topramezone 33.6% SC @ 30 g a.i ha^{-1} on 21 DAS spraying. Among different fertigation practices, 100% RDF by fertigation (M_2) registered the higher growth, yield and yield characters. While different weed management practices, Hand weeding Twice (S_2) recorded maximum growth, yield parameters and yield. However, this was statistically comparable with PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (S_3). With respect to Integration of fertigation and weed management, 100% RDF by fertigation and Hand weeding Twice (M_2S_2) has recorded higher growth, yield and yield attributing characters. Although, it aligned statistically with 75% RDF by fertigation and hand weeding twice (on 20 & 40 DAS) (M_3S_2), 100% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_2S_3) and 75% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_3S_3).

***Key words*:** *Zea mays* L., Fertigation, Herbigation, WSF, Mesotrione

Maize (*Zea mays* L.) holds a pivotal role in global agriculture, serving as both a food crop and a key industrial raw material. Maize crop has been ranked at the third-place after wheat and rice, globally [1]. As demand for maize continues to rise, effective weed management and resource-efficient practices have become critical to optimizing its growth and yield. Drip irrigation, being a proven technology, has offered special agronomical, economical, and agro-technical advantages for efficient use of water and fertilizer [2]. Amongst those pressurized irrigation methods, drip irrigation has proved its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of root zone. Improper management of water and nutrient has contributed extensively to the current water scarcity and pollution problems in many parts of the world, and is also a serious challenge to future food security and environmental sustainability. Addressing these issues requires an integrated approach to soil-water-plant-nutrient management at the plant-rooting zone [3]. Fertigation, which integrates fertilizer delivery with irrigation, and herbigation, the application of herbicides through irrigation systems, are emerging as innovative solutions to enhance productivity while addressing challenges such as resource conservation and environmental sustainability. Fertigation improves nutrient use efficiency by synchronizing nutrient supply with crop growth stages, leading to enhanced plant vigor and higher yields. Likewise, herbigation provides a targeted approach to weed control, ensuring uniform herbicide application and reducing chemical runoff, thus promoting eco-friendly farming practices [4]. The synergy of these methods offers a comprehensive strategy to address the twin goals of higher productivity and sustainable resource use. This study was undertaken to evaluate the effectiveness of fertigation and herbigation-based weed management on hybrid maize during the *Kharif* season.

MATERIALS AND METHODS

The field experiment was carried out at Agronomy Department's experimental farm at Annamalai University, located in Cuddalore district, Tamil Nadu. The experiment took place during the *kharif*, 2023 in field number 12A (garden land). The farm lies at 11°24' N latitude, 79°44' E longitude, at

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an altitude of +5.79 meters above sea level, approximately 15 km from the Bay of Bengal coastal zone. The soil is classified as clay loam and has a low nitrogen content (269.00 kg ha^{-1}), medium phosphorus (19.00 kg ha^{-1}), and high potassium (314.80 kg ha^{-1}) availability, with a pH of 7.4 and an electrical conductivity (EC) of 0.37 dSm^{-1}. The field was prepared to achieve a fine tilth, and plots measuring 10 m × 5 m were established with a 30 cm buffer zone around each bed. Drip irrigation was used, with one lateral line per row, shared by two maize rows. Inline emitters with a discharge rate of 4 liters per hour (lph) were installed.

The experiment was designed in split plot design (SPD) and replicated thrice with four treatments in main plot and four treatments in subplot. The treatments viz., In main plot, M_1 - 100% RDF by broadcasting, M_2 - 100% RDF by fertigation, M_3 - 75% RDF by fertigation, M_4 - 50% RDF by fertigation. In sub plot, S_1 - Control (unweeded), S_2 - Hand weeding Twice (on 20 & 40 DAS), S_3- PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying, S_4 - PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Topramezone 33.6% SC @ 30 g a.i ha^{-1} on 21 DAS spraying. For the maize crop, the recommended fertilizer dose (RDF) was 250:75:75 kg ha^{-1} of nitrogen, phosphorus, and potassium for broadcasting (M_1), using conventional fertilizers like urea, SSP, and MOP. For fertigation treatments (M_2-M_4), 150:75:75 kg ha^{-1} of N, P_2O_5, and K_2O were applied using water-soluble fertilizers such as urea and 19:19:19. The maize hybrid DKC 9178 was used for the study. The fertigation was given every three days once. Data on plant height, dry matter production, number of cobs per plant, and number of grains per cob were recorded from five tagged plants in each plot. The average values for each treatment were calculated and presented in tabular form. Yield data were obtained from the net plot area, with the harvested produce cleaned, weighed, and expressed in kilograms per hectare (kg ha^{-1}). Statistical analysis of the collected data was conducted following the methodology outlined by Gomez and Gomez [5]. Critical differences were calculated at a 5% probability level to determine the significance of the results.

RESULTS AND DISCUSSION

Growth characters

The data of plant height (cm) and dry matter production (kg ha^{-1}) are given in (Table 1). Different fertilizer application approaches and herbigation based weed management methods exhibited significant effect on plant height and dry matter production.

Among the different fertilizer application approaches, the plot receiving 100% RDF by fertigation (M_2) registered the maximum plant height of 195.21 cm and dry matter production of 10791 kg ha^{-1}. This was followed by application of 75% RDF by fertigation (M_3). The lower plant height of and dry matter production of were recorded in 50% RDF by fertigation (M_4). Irrespective of the different weed management practices hand weeding twice (on 20 & 40 DAS) (S_2) recorded maximum plant height of 197.04 cm and dry matter production of 11080 kg ha^{-1}. However, this was statistically comparable with PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (S_3). The lower plant height and dry matter production were recorded in unweeded control (S_1).

Table 1 Plant height (cm) and dry matter production (kg ha^{-1}) of hybrid maize as influenced by fertigation and herbigation based weed management practices

	Plant height (cm)					Dry matter production (kg ha^{-1})				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	112.79	188.22	186.72	152.95	160.17	6271	10790	10425	8752	9060
M_2	144.63	226.89	224.29	185.04	195.21	7525	12856	12508	10106	10749
M_3	114.38	222.40	218.80	154.49	177.52	6336	12224	12029	8948	9884
M_4	108.69	150.65	148.15	146.59	138.52	6129	8450	8185	7820	7646
Mean	120.12	197.04	194.49	159.77		6565	11080	10787	8907	

	Plant height		Dry matter production	
	SE_D	CD (p=0.05)	SE_D	CD (p=0.05)
M	3.58	8.74	205.59	503.09
S	3.58	7.37	205.59	424.32
M × S	7.15	15.44	411.18	888.03
S × M	7.15	14.76	411.18	848.65

Combining fertigation with herbigation-based weed control in hybrid maize significantly enhanced the plant height and dry matter production. The results revealed that 100% recommended dose of fertilizers (RDF) by fertigation and Hand weeding Twice (on 20 & 40 DAS) (M_2S_2) has recorded maximum plant height of 226.89 cm and dry matter production of 12856 kg ha^{-1}. Still, it was statistically indistinguishable from 75% RDF by fertigation and Hand weeding Twice (on 20 & 40 DAS) (M_3S_2), 100% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_2S_3) and 75% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_3S_3).The lower plant height and dry matter production were recorded with the application of 50% RDF by fertigation and unweeded control (M_4S_1).

Increased plant height by the application of water-soluble fertilizers through drip irrigation may have been caused by a favorable microclimate for the plants and the application of enough nutrients in a form that was easily accessible. This would have speed up the production of growth regulators like auxins (IAA) and cytokinin, which in turn stimulated cell division and elongation in maize crop thus, increasing plant height. In contrast to surface irrigation, drip irrigation keeps the plants turgid throughout the day. For a longer time, the stomata may have opened widely, which could have led to a high gas exchange. It's also possible that leaves developed more leaf surface and remained turgid. Consequently, the turgor condition facilitates the absorption of more solar energy and light [3]. And also, in the initial stages of the crop growth, weed free

environment was created by hand weeding. Thus reduced the competition between the crop and weed for all the essential commodities like light, moisture, nutrients and CO_2 [6].

Yield attributes

Information related to number of cobs plant^{-1}, number of rows cob^{-1}, number of grains cob^{-1} and test weight (g) are furnished in (Table 2). Different fertilizer application approaches and herbigation based weed management methods exhibited significant effect on number of rows cob^{-1} and number of grains cob^{-1}. However, number of cobs plant^{-1} and test weight were not significantly affected by different fertigation and herbigation practices.

Among the different fertilizer application approaches, the plot receiving 100% RDF by fertigation (M_2) registered the maximum number of rows cob^{-1} of 16.75 and no. of grains cob^{-1} of 304. This was followed by application of 75% RDF by fertigation through water soluble fertilizers (M_3). The least number of rows cob^{-1} of 14.94 and number of grains cob^{-1} of 234 were recorded in 50% RDF by fertigation (M_4). Regardless of the various weed management approaches Hand weeding Twice (on 20 & 40 DAS) (S_2) recorded maximum row number of 16.85 cob^{-1} and no. of grains of 308 cob^{-1}. However, this was statistically comparable with PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (S_3). The least number of rows cob^{-1} of 14.50 and no. of grains cob^{-1} of 219 were recorded in unweeded control (S_1).

The application of fertigation alongside herbigation for weed management in hybrid maize greatly improved the number of rows cob^{-1} and No. of grains cob^{-1}. The results revealed that 100% RDF by fertigation through water soluble fertilizers and Hand weeding Twice (on 20 & 40 DAS) (M_2S_2) has recorded maximum row number of 17.95 cob^{-1} and number of grains of 347 cob^{-1}. Although, it aligned statistically with 75% RDF by fertigation and Hand weeding Twice (on 20 & 40 DAS) (M_3S_2), 100% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_2S_3) and 75% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_3S_3).The least number of rows cob^{-1} of 14.28 and no. of grains cob^{-1} of 208 were recorded with the application of 50% RDF by fertigation and unweeded control (M_4S_1).

Table 2 Number of cobs plant^{-1}, number of rows cob^{-1}, number of grains cob^{-1}, test weight (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) of hybrid maize as influenced by fertigation and herbigation based weed management practices

	Number of cobs plant^{-1}					Test weight (g)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	1.00	1.01	1.01	1.00	1.01	20.98	22.58	22.34	21.82	21.93
M_2	1.00	1.02	1.02	1.00	1.01	21.46	23.06	23.01	22.11	22.41
M_3	1.00	1.01	1.01	1.00	1.01	21.18	22.92	22.86	21.86	22.21
M_4	1.00	1.00	1.00	1.00	1.00	20.85	21.76	21.65	21.60	21.47
Mean	1.00	1.01	1.01	1.00	1.01	21.12	22.58	22.47	21.85	22.00
	Number of rows cob^{-1}					Grain yield (kg ha^{-1})				
M_1	14.32	16.68	16.52	15.45	15.74	3429	5909	5815	4806	3429
M_2	15.01	17.95	17.72	16.33	16.75	4399	7032	6907	5730	5909
M_3	14.37	17.54	17.36	15.64	16.23	3564	6812	6730	4912	5815
M_4	14.28	15.24	15.15	15.07	14.94	3275	4708	4603	4504	4806
Mean	14.50	16.85	16.69	15.62	15.91	3667	6115	6014	4988	5196
	Number of grains cob^{-1}					Stover yield (kg ha^{-1})				
M_1	212	298	291	252	263	7087	9371	9262	8243	8491
M_2	239	349	343	285	304	7911	10606	10442	9143	9526
M_3	216	340	335	256	287	7112	10344	10256	8338	9013
M_4	208	246	243	240	234	7034	8164	8078	7990	7817
Mean	219	308	303	258	272	7286	9621	9510	8429	8711

	No. of cobs plant^{-1}		No. of rows cob^{-1}		No. of grains cob^{-1}		Test weight		Grain yield		Stover yield	
	SE_D	CD (p=0.05)	SE_D	CD (p=0.05)	SE_D	CD (p=0.05)	SE_D	CD (p=0.05)	SE_D	CD (p=0.05)	SE_D	CD (p=0.05)
M	0.07	NS	0.15	0.37	4.60	11.26	0.67	NS	119.69	292.88	209.64	513.01
S	0.07	NS	0.15	0.32	4.60	9.50	0.67	NS	119.69	247.03	209.64	432.69
M x S	0.01	NS	0.31	0.67	9.20	19.88	1.35	NS	239.38	516.98	419.31	905.54
S x M	0.01	NS	0.31	0.64	9.20	19.00	1.35	NS	239.38	494.06	419.31	865.38

The increased yield attributes of hybrid maize were probably due to the split nutrient delivery using drip fertigation would provide increased nutrient availability during the crop's growth period and satisfy the crop's requirements for improved photosynthetic output and accumulation. Additionally, a notable improvement in development and production characteristics led to a larger maize kernel and stover output. The results are concurred with the findings of Sampathkumar and Pandian [7] and Reddy and Krishnamurthy [8]. This could be the result of less crop competition with weed and a more favorable growing environment, which allowed the crop to use nutrients, moisture, light, and space to their fullest potential and produced greater yield components [9].

Grain yield and stover yield

The data related to grain yield and stover yield are presented in (Table 2). Various fertilizer application strategies and weed management techniques using herbigation significantly influenced the grain yield and stover yield of hybrid maize. Among the different fertigation rates, 100% RDF

by fertigation (M_2) significantly increased grain production of 5909 kg ha^{-1} and straw yield of 9526 kg ha^{-1}, respectively. This was followed by 75% RDF by fertigation through WSF (M_3). The lowest grain and stover yield were achieved by 50% RDF by fertigation (M_4). Despite variations in weed control practices, Hand weeding Twice (on 20 & 40 DAS) (S_2) recorded maximum grain yield of 6115 kg ha^{-1} and stover yield of 9621 kg ha^{-1}. Nonetheless, it was similar to PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (S_3). The lowest grain and stover yield were achieved by unweeded control (S_1).

Fertigation coupled with herbigation-driven weed control in hybrid maize markedly increased the grain yield and stover yield of hybrid maize. The observations confirmed that, 100% RDF by fertigation and Hand weeding Twice (on 20 & 40 DAS) (M_2S_2) has recorded higher grain yield of 7032 kg ha^{-1} and stover yield of 10606 kg ha^{-1}. Although, it aligned statistically with 75% RDF by fertigation and hand weeding twice (on 20 & 40 DAS) (M_3S_2), 100% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_2S_3) and 75% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_3S_3). The lower grain and stover yield were recorded with the application of 50% RDF by fertigation and unweeded control (M_4S_1).

The reason for the increase in yield under 100% RDF with WSF may be that fertigation using more easily accessible form clearly increased the availability of all three (NPK) major nutrients in the soil solution, which in turn improved assimilate translocation from source to sink and increased uptake. The concentration of accessible plant nutrients in the top layer was greater with water-soluble fertilizer. By applying key nutrients by fertigation, which increased the plant's total vegetative development and biological efficiency, the stover output per hectare was greatly increased. The weed free environment created that plant nutrients are made available to the crop for enhanced leaf area formation that increases solar radiation interception thereby favouring better utilization of photosynthesis for higher grain yield [10].

CONCLUSION

According to the results of the research, it is concluded that 75% RDF by fertigation and PE application of Mesotrione 40% SC @ 90 g a.i ha^{-1} on 3 DAS Herbigation + PoE application of Tembotrione 34.4% SC @ 110 g a.i ha^{-1} on 21 DAS spraying (M_3S_3) resulted similar growth and yield like higher dose RDF fertigation and Hand weeding (M_2S_2). Hence, 25% additional fertilizer is saved and extra cost on weeding is also saved.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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