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Effect of spacing and weed management practices on yield parameters irrigated hybrid maize

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Abstract
A field experiment was conducted at Dinnabellur village, Dharmapuri district, Tamilnadu to during June 2021 to October 2021 to find an effect of spacing and weed management practices on irrigated hybrid maize. The experiment was laid out in Split Plot Design (SPD), the main plot treatments comprised of different spacing *viz.*, 60 x 10 cm (M_1), 60 x 15 cm (M_2) and 60 x 20 cm (M_3). The sub-plot treatments comprised of different weed management practices *viz.*, Unweeded Control (S_1), Twice hand weeding at 20 and 40 DAS (S_2), Pre - emergence application of Atrazine 50% WP @ 1 Kg a.i. ha^{-1} on 3 DAS (S_3) and Pre emergence application of Atrazine 50% WP @ 1 Kg a.i. ha^{-1} on 3 DAS + One hand Weeding on 30 DAS (S_4).
Among the different spacing and weed control treatments, M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS + one hand weeding on 30 DAS excelled over other treatments by recording higher values of g yield components at harvest such as Number of grains cob^{-1} (529), Cob length (26.32 cm), Cob diameter (6.55), Grain yield (6390 kg ha^{-1}), Stover yield (10224 kg ha^{-1}) and this was on par with M_3S_2 (spacing of 60 × 20 cm along with two hand weeding on 20 and 40 DAS). This was followed by Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS (M_3S_3). M_1S_1 (spacing of 60 × 10 cm with unweeded control) recorded the highest weed counts and weed biomass resulting in very poor grain yield (3085 kg ha^{-1}).
Hence, from the experiment revealed that M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS was the efficient method of weed control which produce highest grain yield and reduce the nutrient uptake by weeds and higher economic returns. M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS was efficient and economically viable agronomic practices to manage the weeds and get higher yield as well as economic returns from hybrid maize.

Keywords: Spacing, weed management, yield attributes, hybrid maize

Introduction
Maize (*Zea mays* L.) is one of the most adaptable developing crops, with a wide range of adoption under various agro-climatic conditions. Due to its superior genetic production potential compared to other cereals, maize is referred to as the "Queen of Cereals" internationally (Mritunjay Kumar, 2018) [13]. Its ability to convert solar energy into dry matter very well and its extremely high genetic yield potential make it a C4 plant, one of the most resilient food grain crops under a variety of edaphological situations (Ravisankar *et al*., 2017) [18].

Maize grain contains starch (72%), protein (10%), oil (4.8%), fiber (5.8%), sugar (3.0%) and ash (1.7%) (Sakthivel, 2014) [16]. Besides of its multiple utility recently it is been used as biofuel and nutritional security for the many sectors in the country (Kumar *et al*., 2016). Maize is one of the most important cereal crops in the world grown over an area of 203.89 million haters and production of 1210.45 million tonnes and productivity of 5.94 t ha^{-1}. In India, maize occupies an area of 9.9 million hacters with a production of 32.50 million tonnes and productivity 3.28 t ha^{-1}(USDA 2021-2022). In Tamil Nadu it is cultivation in an area of 0.33 million ha with a production of 2.61 million tones and productivity of 7.83 t ha^{-1} (tnagriculture.in, 2019-2020).
Maize production is significantly more impacted by variable planting density than other grass family members, because of its monoecious floral arrangement and its low tillering cognition, In order to provide a greater yield, maize should be planted with the ideal plant population.

The yield per plant drops as plant density rises, but grain yield per unit area rises. When plant density exceeds a specific threshold, yield is lost due to an increase in plant-to-plant disparity and a rise in plant infertility because the longer time between pollen shedding and silking and subsequent increase in unproductive plants results from higher plant density (Ali *et al*., 2017) [1].

Therefore, it is recommended that current maize hybrids be grown at optimal communicate density to limit plant competition and to provide higher yields. The spacing combinations of 60 x 20 cm were discovered to be helpful in achieving a greater grain yield of maize (Getaneh *et al*., 2016) [3]. Increased plant population from 4:5 to 13:5 plants per meter square significantly changed the following characteristics like cob length, cob weight, number of grains per cob. Plant population and row spacing are two key agronomic factors having a great influence on maize grain yield (Van rockel and Coulter, 2011) [22].

Management of weeds is considered to be an important factor for achieving higher productivity as weed problem is more severe and the extent damage by this weed in different crops has been reported to vary from 30 to 90 per cent several authors (Misra *et al*., 1993) [12], (Virendra Kumar *et al*., 1996) [25]. Weed control in maize can be highly important because of wider spacing the mechanical control of weeds growing between the rows is labour intensive. Manual weeding is often difficult due to inadequate supply of labour in proper time, higher cost and non-workable condition of the labour (Khatam *et al*., 2013) [6].

Excessive growth of weeds in maize field leads to 25 to 80 per cent reduction crop yield of maize or some times to a complete crop failure if weeds are left Uncontrolled (Karki *et al.*, 2014) [5]. therefore, the full expression of the production potential of maize crop depends on the degree of weed infestation (Kostov *et al.*, 2006) [7]. To minimize the weed losses, several weed control methods are available such as mechanical, cultural, chemical and biological methods. In general, mechanical methods are still helpful even then they are very expensive.

With the gradual increase in indication of our country, coupled with the raising standard of living and literacy, manual labour is becoming scarce. In Tamil Nadu, traditional hand weeding is the most efficient and widely adopted practice of weed control. However, it is back breaking, labour intensive, time consuming and costly due to high wage rates which narrowed down the profits of the cultivation. Hence weed management by using herbicides could be the best alternative measures.

Chemical method of weed control has become inevitable in the context of high cost of labour during peak season and labour shortage for crop properly to reduce the weed competition at critical period of weed interference without much disturbance to crop growth and soil health (Muoni *et al*., 2013) [14] However, the continuous use of single herbicide or herbicides having the same mode of action may lead to resistance problem in weeds. Hence, it is necessary to test combination of the existing and new herbicides (Perry *et al*., 2004) [16], (Donovan and Hackett, 2010) [15] to control mixed weed flora in maize. The need of herbicides is often realized by the growers to combat weeds emerging at early growth stages of crop. On the other hand, herbicides offer economic and efficient weed control if applied at proper dose and stage.

Due to the increased demand and high expense of human labour, manual weeding is rarely feasible. Atrazine pre-emergence spraying is the most advantageous method for controlling broad-spectrum weeds in maize when compared to other chemical methods. When the mechanical and chemical methods are combined, weed control becomes more efficient and cost-effective. In addition, for a greater yield, it might be necessary to suppress the late-emerging weeds in maize using chemicals or other techniques. Therefore, an effort was made to research the impact of various spacings and weed management techniques on the yield and productivity of hybrid maize while keeping the aforementioned points in mind.

The yield of the is low which could be increased with proper management of production factors. In fact none of the weed control methods is best under all condition. So there is a need to make a comparative study of different weed management techniques in maize and to develop an integrated weed management approach, which should be efficient, cost effective and environmentally safe.

Therefore, the present investigation was undertaken to study the effect of spacing and weed management practices on irrigated hybrid maize. To find out the optimum spacing and the effect of herbicide application and on yield of hybrid maize.

Materials and Methods

The experiment was laid out in Split Plot Design (SPD), the main plot treatments comprised of different spacing *viz.*, 60 x 10 cm (M_1), 60 x 15 cm (M_2) and 60 x 20 cm (M_3). The sub-plot treatments comprised of different weed management practices *viz.*, Unweeded Control (S_1), Twice hand weeding on 20 and 40 DAS (S_2), Pre -emergence application of Atrazine 50% WP @ 1 Kg a.i. ha^{-1} on 3 DAS (S_3) and Pre emergence application of Atrazine 50% WP @ 1 Kg a.i. ha^{-1} on 3 DAS + One hand Weeding on 30 DAS (S_4). The trail was layout in a split plot design with three replication plot size was 5 x 4 m (Hybrid Maize Pioneer 30B70). N,P and K were applied in the form of urea, single super phosphate and potash at 250:75:75 NPK kg ha^{-1} respectively was followed as RDF. The pre-emergency herbicide of atrazine on 3 DAS + one hand weeding on 30 DAS. Atrazine sprayed with 500 liters of water ha^{-1} through knapsack sprayer fitted with flood jet nozzle separately in specified plots as per the treatments schedule. All the agronomic practices were carried out.

Result and Discussion

Yield components

Cob length

Significant difference was observed among the treatments in influencing the cob length of hybrid maize.

Among the spacing 60 × 20 cm (M_3) recorded the highest cob length of 23.97 cm. This was followed by spacing of 60 x 15 cm (M_2). The least cob length was registered in 17.13 cm (M_1) spacing of 60 x 10 cm.

Among the weed management practices, Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS (S_4) recorded the highest cob length of 22.84 cm. the least cob length was recorded in 18.04 cm (S_1) Unweeded cotrol.

Among the interaction between spacing and weed management practices. The highest cob length of 26.32 cm was recorded in the treatment combination of M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of

atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS). The treatment combination of M_1S_1 (spacing of 60 × 10 cm with unweeded control) recorded the least cob length of 15.28 cm.

Cob diameter

There was significant difference among the main plot, sub plot treatments and interaction effect regarding the cob diameter of hybrid maize.

Among the main treatments, spacing 60 × 20 cm (M_3) recorded the highest cob diameter of 5.09 cm. This was followed by spacing of 60 x 15 cm (M_2). The treatment (M_1) spacing of 60 x 10 cm recorded the least cob diameter of 3.96 cm.

In sub treatments, significantly influenced the cob length of hybrid maize. Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS (S_4) highest cob diameter of 5.54 cm. This was on par with two hand weeding on 20 and 40 DAS (S_2).This was followed by (S_3) Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS. The (S_1) Unweeded control treatment recorded the recorded the least cob diameter of 4.29 cm.

In interaction effect, the highest cob diameter of 6.55 cm was recorded in the treatment combination of M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS). The treatment combination of M_1S_1 (spacing of 60 × 10 cm with unweeded control) recorded the least cob diameter of 3.14 cm.

Number of grains cob^{-1}

Number of grains cob^{-1} was found to be significantly influenced by different spacing practices, different weed management practices and interaction effect.

Among the main treatments, spacing 60 × 20 cm (M_3) recorded the highest number of grain cob^{-1} of 491. This was followed by spacing of 60 x 15 cm (M_2). The treatment (M_1) spacing of 60 x 10 cm recorded the least number of grain cob^{-1} of 375.

In sub treatments, Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3DAS and one hand weeding on 30 DAS (S_4) recorded the highest number of grain cob^{-1} of 471. This was on par with two hand weeding on 20 and 40 DAS (S_2) This was followed by (S_3) Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS. The (S_1) Unweeded control treatment recorded the recorded the least number of grain cob^{-1} of 457.

In interaction effect, the highest number of grain cob^{-1} of 529 was recorded in the treatment combination of M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS). This was followed by the treatment combination of M_3S_3 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS). The treatment combination of M_1S_1 (spacing of 60 × 10 cm with unweeded control) recorded the least number of grain cob^{-1} of 388.

Grain yield

The grain yield of hybrid maize exhibited significant variation due to spacing treatments.

Among the main treatments, the maximum grain yield of 5849 kg ha^{-1} was recorded in Treatment (M_3) spacing of 60 × 20 cm. This was followed by spacing of 60 × 15 cm (M_2) and significantly higher than other treatments. The minimum grain yield of 3692 kg ha^{-1} was recorded in treatment (M_1) spacing of 60 x 10 cm.

In sub treatments, Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS (S_4) recorded the maximum grain yield of 5411 kg ha^{-1}. This was on par with two hand weeding on 20 and 40 DAS (S_2). This was followed by (S_3) Pre-emergence application of atrazine 50% WP @ 1.0 kg^{-1} a.i ha^{-1} on 3 DAS. The (S_1) Unweeded control recorded the minimum grain yield of 4189 kg ha^{-1}.

In interaction, the maximum grain yield of 6390 kg ha^{-1} was recorded in the treatment combination of M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of Atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS) his was followed by the treatment combination of M_3S_3 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS) The treatment combination of M_1S_1 (spacing of 60 × 10 cm with unweeded control) recorded the minimum grain yield of 3085 kg ha^{-1}.

Stover yield

There was significant difference among the treatments pertaining to stover yield of hybrid maize.

Among the main treatments, spacing of 60 × 20 cm (M_3) recorded the maximum stover yield of 9087 kg ha^{-1}. This was followed by spacing of 60 x 15 cm (M_2) and significantly higher than other treatments. The treatment (M_1) spacing of 60 x 10 cm recorded the minimum stover yield of 5713 kg ha^{-1}.

In sub treatments, Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS (S_4) recorded the maximum stover yield of 8659 kg ha^{-1}. This was on par with two hand weeding on 20 and 40 DAS (S_2). This was followed by (S_3) Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS. The (S_1) Unweeded control recorded the minimum stover yield of 6400 kg ha^{-1}.

In interaction effect, the maximum stover yield of 10224 kg ha^{-1} was recorded in the treatment combination of M_3S_4 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS and one hand weeding on 30 DAS) This was followed by the treatment combination of M_3S_3 (spacing of 60 × 20 cm along with Pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS) The treatment combination of M_1S_1 (spacing of 60 × 10 cm with unweeded control) recorded the minimum stover yield of 4627 kg ha^{-1}.

The yield attributes were significantly influenced by the different spacing practices. Among the main treatments spacing at 60 x 20 cm (M_3) recorded. The maximum cob diameter (23.97 cm) and cob length (5.9 cm), Number. Grain cob^{-1} (491) respectively. This might be due to higher population (60 x 20 cm) have the adverse effect on the grain yield. Filling was noticed due to intense interplant competition to fulfill the grain yield and floral abortion. The young kernel abortion immediately after fertilization is due to a lower supply of carbon and nitrogen to the ear to high competition among the plant which bring the cobs left unfilled or bare cobs (Liu *et al.*, 2015) [9].

With increase in plant population density ha^{-1}, there will be

lesser the no of cob per plant due to mutual shading of leaves low photosynthesis rate and lower availability of nitrogen and water to the growing ear. If plant population dense there will be significantly decreased in number of cob per plant. Similar data was inline different experimental by Mahapatra *et al.* (2006) [10], Zheng (2009) [26] and Mashiqa (2012) [11]. Low plant population density ha^{-1} grain weight plant^{-1} was high because of low interplant competition for photoperiod, available moisture and wider space is available in plant as compared to high plant population density plant population increased low to high significantly decreased per plant grain weight as per their crop under their condition. Velayudham and Thavaprakash (2013) [23].

Among the weed management practices of the pre-emergency application of atrazine 50% WP @1.0 kg a.i ha^{-1} on 3 DAS + one hand weeding on 30 DAS (S_4) recorded the highest grain yield (5849 kg ha^{-1}). The enhancement in yield of hybrid maize may be because of improved growth and growth attributes. Significantly enhancement of yield obtained with this treatment was due to positive association between yield attributing characters like no. of cob /plant, cob girth (cm), test weight (g), no. of row/cob, no. of grain/row and harvest index due to reduced weed competition as well as improvement in crop growth characteristic, these results are in agreement with those of Pratik Sandiya *et al.* (2013) [17] and Kamani *et al.* (2019) [4].

They are recording significantly highest stover yield of (9087 kg ha^{-1}) over weedy check. This increase in stover yield might be due to better leaf area, dry matter accumulation in plant which is mainly because of availability of plant growth resources to plant on account of reduced. Weed competition. Similar conducive effect was noticed by Vijay *et al.* (2017) [24].

The interaction between different spacing and weed management practice significantly influenced the grain yield and stover yield of hybrid maize. The highest grain yield (6390 kg ha^{-1}) and stover yield (10224 kg ha^{-1}) was recorded in the treatment combination (M_3S_4) pre-emergence application of atrazine 50% WP @ 1.0 kg a.i ha^{-1} on 3 DAS + one hand weeding on 30 DAS.

Weed is weedy check reduced the grain and stover yield of maize drastically when compared with the best treatment, which was in line with the findings of Kuree *et al.* (2017) [8]. The lowest grain yield (3155 kg ha^{-1}) was obtained in weedy check as a consequence of highest removal of nutrient and moisture by weeds and severe crop weed competition resulting in poor yield components. Similar type of results was also reported by Singh *et al.* (2014) [20] and Subash Chandran (2017) [21]. The least grain yield (3085kg ha^{-1}) and stover yield (4627 kg ha^{-1}) was recorded in the treatment combination of M_1S_1 (Spacing 60cm x 10cm and unweeded control).

Table 1: Effect of spacing and weed management practices on yield parameters of irrigated hybrid maize

Treatments	Yield components				
Main plot (Spacing)	**Cob length**	**Cob diameter**	**Number of grains cob^{-1}**	**Grain yield**	**Stover yield**
M_1(60 x10 cm)	17.13	3.96	375	3680	5713
M_2(60 x15 cm)	21.46	5.21	452	5226	8235
M_3(60 x20 cm)	23.97	5.09	491	5849	9087
S.Em (±)	0.08	0.12	1.6	57.01	88.21
CD (P=0.05)	0.34	0.49	6.5	223.83	346.38
Sub Plot (Weed management)					
S_1– Unweeded control	18.4	4.29	395	4166	6400
S_2 - Twice hand weeding on 20 and 40 DAS	21.78	5.32	457	5224	8369
S_3 - Pre emergence application of atrazine 50% WP @1.0 kg a.i ha^{-1} on 3DAS	20.54	4.95	433	4866	7297
S_4 - Pre emergence application of atrazine 50% WP @1.0 kg a.i ha^{-1} on 3DAS + One hand weeding on 30 DAS	22.84	5.54	471	5411	8659
S.Em (±)	0.12	0.08	2.9	38.64	62.32
CD (P=0.05)	0.37	0.23	8.8	114.81	185.17
Interaction					
S.Em (±) M X S	0.20	0.17	4.7	81.29	128.53
CD (P=0.05) M X S	0.61	0.52	14.1	241.55	381.90
S.Em(±) S X M	0.21	0.13	5.1	66.93	107.95
CD (P=0.05) S X M	0.64	0.41	15.1	198.86	320.73

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