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Influence of Plant Spacing and Weed Management Practices on the Growth and Yield of Hybrid Maize

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A B S T R A C T

Field experiments were conducted during *kharif* 2014 and 2015 at farmer's field under irrigated condition at Udumalaipettai of Tiruppur district of Tamil Nadu to find out the influence of plant spacing and weed management practices on the growth and yield of maize. The experiments were laid out in split plot design replicated thrice with three plant spacings *viz.*, 45 cm x 30 cm (74,074 plants per ha), 60 cm x 20 cm (83,333 plants per ha) and 60 cm x 25 cm (66,666 plants per ha) under main plot and four weed management practices *viz.*, atrazine @ 0.50 kg /ha as pre emergence + one hand weeding 30 DAS, atrazine @ 0.50 kg /ha as pre emergence + 2,4 – D sodium salt @ 0.75 kg / ha 30 DAS, atrazine @ 0.50 kg /ha as pre emergence + twin wheel hoe weeder weeding 30 DAS and unweeded control under subplot. The results of the experiment revealed that the plant spacing 60 cm x 25 cm among the plant spacings and atrazine @ 0.50 kg ha^{-1} + one hand weeding 30 DAS followed by atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding 30 DAS among the weed management practices favourably increased the growth parameters and grain yield. Among the treatment combinations, better growth and higher grain yield were recorded under the plant spacing of 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + one hand weeding 30 DAS followed by spacing of 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding 30 DAS.

Introduction

In India, maize occupies third place among the cereals after rice and wheat and is cultivated over an area of 8.81 million hectares with a production of 22.57 million tonnes and the average productivity is 2563 kg ha^{-1}. In Tamil Nadu, maize is cultivated in an area of 0.35 million hectares with a production of 2.49 million tonnes and the productivity is 7010 kg ha^{-1} (Indiastat, 2015-16).

Maize production is greatly affected by varying planting density than other members of the grass family because of its monoecious floral organization and its low tillering cognition. Therefore, maize should be grown under optimum plant population to obtain higher yield. By increasing the plant density,

yield per plant decreases but grain yield per unit area increases. Exceeding beyond a certain limit of plant density, yield is lost due to increase in plant to plant unevenness and increase in plant infertility as high plant density above the certain level elongate the duration between pollen shedding and silking resulting in more unproductive plants (Ali *et al*., 2017).

It is, therefore, suggested that recent maize hybrids should be rather grown at optimum communicate density for reduced competition between the plants and to achieve higher yields. It was found out that spacing combinations of 65 x 25 cm responded favorably in attaining higher grain yield of maize (Getaneh *et al*., 2016).

Of the several factors are responsible for the low yields of maize in India, the most critical factor responsible for the low yield appears to be the weed growth that competes with the crop for nutrients, water, sunlight and space. They cause yield losses worldwide with an average of 12.8 per cent despite weed control practices and 29.2% in case of unchecked weed growth (Dogan *et al.,* 2004).

Weeding has traditionally been a labour intensive operation in crop production. Manual weeding is seldom possible, because of greater demand and high cost of human labour. Pre- emergence application of atrazine is the most beneficial one in maize weed control compared to other chemicals for broad spectrum weed control. Weed management becomes more effective and economical when it is integrated with both the mechanical and chemical methods. Moreover, the late emerging weeds in maize may have to be controlled either chemically or by other methods for better yield. Hence, keeping the above points in view, an attempt was made to study the effect of different spacings and weed management practices on growth and productivity of hybrid maize.

Materials and Methods

Field experiments were conducted at farmer's field, Udumalaiapettai, Tiruppur district of Tamil Nadu during *kharif* 2014 and 2015 to study the response of maize hybrids to varied plant densities and weed control methods under irrigated condition. The soil of the experimental field was sandy clay loam in texture. The nutrient status of soil during start of the experiment was low in available nitrogen (242.6 kg ha^{-1}), medium in available phosphorous (16.5 kg ha^{-1}) and high in available potassium (552 kg ha^{-1}).

The maize hybrid, NK 6240 was chosen for the study. The experiment was laid out in a split plot design replicated thrice under irrigated condition. Three plant spacings viz., 45 x 30 cm (74,074 plants per ha), 60 x 20 cm (83,333 plants per ha) and 60 x 25 cm (66,666 plants per ha) were the treatments under mainplot. Four weed management practices viz., Atrazine @ 0.50 kg / ha as pre emergence 3 DAS + one hand weeding 30 DAS, Atrazine @ 0.50 kg / ha as pre emergence 3 DAS + 2,4 – D sodium salt @ 0.75 kg / ha 30 DAS, Atrazine @ 0.50 kg / ha as pre emergence 3 DAS + twin wheel hoe weeder weeding 30 DAS and Unweeded control were fitted in subplot. The observations on plant height, leaf area index were taken and dry matter production computed. Grain yield was recorded and analysed statistically.

Results and Discussion

Plant height

The plant height, one of the important morphological growth parameters showed a positive influence at all the stages of crop growth (Table 1). An increasing trend was noticed in plant height from 30 to 90 DAS and taller plants were observed under 60 cm x 20 cm initially upto 60 DAS and thereafter

under 60 cm x 25 cm at later stages. The plants were taller under the spacing of 60 cm x 20 cm (higher population) than the other spacings. This might be due to the higher interplant competition for sunlight which might have made the plants to grow taller to trap more sunlight and it decreased with increase in the plant spacing. This is clearly evident from the tallest plants observed under 60 cm x 20 cm than 60 cm x 25 cm and 45 cm x 30 cm plant spacing. Crop sown at closer spacing normally exhibits higher plant height than wider spacing as reported by Bangarwa *et al.,* (1989) is concomitant to the present finding.

Zamir *et al.,* (2011) reported that in normal plant spacing there is abundance of available resources and hence the plants were healthier than thick plant stands. In narrow plant spacing there was more competition for available resources and hence plants were tall but weaker than wider plant spacing.

Among the weed management practices, all the treatments with atrazine recoded taller plants than unweeded control. Taller plants with broader leaf area might have accumulated higher plant dry matter consistently at all the growth stages of maize with pre emergence application of atrazine 0.5 kg. Better weed control with favourable soil environment might have resulted in reduced crop weed competition for the growth factors such as light, space and nutrients which in turn helped in efficient photosynthetic activity recording taller plants. From the experimental results it is evident that high competition of weeds reduced the input availability to plants, thus reduced the plant height to a greater extent. The plots having higher weed control efficiency got more resources and produced taller plants as earlier reported by Nadeem *at al*. (2010). Unweeded control showed significant reduction of plant height at all the growth stages of the crop. These results are in line with the findings of Singh and Singh (2003) who reported that decrease in plant height might be due to the fact that weed suppressed the vegetative growth of plants by competition for light, moisture and nutrients. Efficacy of chemical or integration of chemical with hand weeding or mechanical weeding in controlling the weeds at critical crop weed competition at 30 DAS in maize might be the reason for the better growth of maize under atrazine 0.5 kg + hand weeding and atrazine + twin wheel hoe treatment..

Leaf area index

Leaf area index increased rapidly from 30 DAS to 60 DAS. LAI was significantly influenced by different spacing and weed management practices. The LAI increased upto 60 DAS and then decreased. This reduction might be due to the completion of vegetative phase and entering into the reproductive phase, causing senescence of leaves at harvest. Similar decrease in LAI at harvest stage was expressed by Verma and Joshi (1999) (Table 2).

The LAI of corn was significantly higher at 60 cm x 25 cm than 60 x 20 cm crop geometry. Wider space availability between the rows and the normal intra-rows might have increased the root spread which eventually utilized the resources such as water, nutrients, space and light very effectively. Better utilization of available resources might have increased the functional leaves and in turn enhanced the LAI. This is in conformity with the findings of Pandita *et al.,* (1998), Abo-Shetaia *et al.,* (2002) and Maddonni *et al.,* (2006) in maize.

The importance of leaf area index (LAI) on crop is well recognized. An increase in LAI results in better utilization of solar energy. Lesser weed competition resulting in higher availability of plant nutrients and moisture

favouring higher leaf area index and vigorous crop growth of maize with pre emergence application of atrazine 0.5 kg might be the reason for higher LAI recorded under treatments involving atrazine. Generally, the leaf area index was higher in all weed control treatments compared with that of unweeded control. Similar result of higher LAI under atrazine treatments reported by Shenbagam (2011) is in support of the present findings.

Dry matter production (DMP)

The dry matter production (DMP) increased steadily with time and age of the crop. At 30 DAS the DMP was less and at 60 and 90 DAS a steep increase was noticed. This might be due to rapid increase in plant height and leaf area at these stages (Table 3 and 4).

Significantly higher DMP at respective stages of the investigation was noticed under 60 cm x 25 cm crop geometry. This might be due to the utilization of available resources to a greater extent that could have favoured the LAI which in combination caused an increase in DMP at 60 cm spacing as compared to other spacings. Further, more availability of sunlight and CO_2 under wider spacing might have resulted in higher photosynthetic activities and ultimately higher production of dry matter. The present findings are in consonance with the reports of Chen *et al.,* (1990) and Cox *et al.,* (2006) in maize.

More plant dry matter production was recorded under the treatments with pre emergence application of atrazine 0.5 kg. This might be due to better weed control by optimum dosage of herbicide and either hand weeding or mechanical weeding which produced conducive environment favouring higher uptake of nutrients that reflected on higher leaf area index and better source sink relationship for accumulating higher dry matter. The findings are in accordance with the view of Kumar (2004) who observed that effective control of weeds right from germination of crop might have allowed the crop to utilize the resources effectively and this could be the reason for higher dry matter production of maize. In general reduction in nutrient removal by weeds through suitable weed management practices enhanced the nutrient uptake and dry matter production of the crops as reported by Balasubramanian and Veerabadran (1998).

The interaction effect was significant at all the stages. Higher DMP was recorded under the spacing 60 cm x 25 cm with atrazine @ 0.50 kg ha^{-1} + one hand weeding on 30 DAS which was on par with spacing 60 cm x 25 cm with twin wheel hoe weeder weeding. The spacing 60 cm x 20 cm under weedy check recorded lower amount of DMP at all the stages.

Grain yield

The data on the yield is presented in Table 5. Crop geometry had a positive influence on yield of maize. Maize grown at 60 cm x 25 cm spacing recorded higher grain yield than others. This increase in yield was probably due to effective utilization of applied nutrients, increased sink capacity and nutrient uptake by the crop. The yield potential of maize is mainly governed by the growth and yield components. The positive and significant correlation of LAI and DMP noticed at different stages, increased yield attributes and nutrient uptake would have resulted in enhanced cob yield. Paulpandi *et al.,* (1998) reported higher yield of maize under wider row spacing due to better availability of resources. The present finding corroborates with the findings of Chen *et al.*(1990)and Maddonni *et al.,* (2006) in maize. Sabo *et al.,* (2016) concluded that the intra-row spacing of 25 cm showed better performance than 20 cm and 30 cm and this result lend support to the present findings.

Table.1 Effect of spacing and weed management practices on plant height of maize

Treatment	(*Kharif* 2014)			(*Kharif* 2015)		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
S_1 - 45 × 30 cm (74,074 plants ha^{-1})	64.68	173.8	198.5	67.47	176.5	**201.5**
S_2 - 60 × 20 cm (83,333 plants ha^{-1})	67.15	184.2	183.9	70.04	187.0	**186.7**
S_3 - 60 × 25 cm (66,666 plants ha^{-1})	54.75	161.1	210.3	57.10	163.5	**213.5**
SEd	**1.30**	**3.6**	**4.2**	**1.35**	**3.7**	**4.2**
CD (P=0.05)	**2.60**	**8.1**	**9.6**	**2.76**	**8.3**	**9.8**
W_1 - Atrazine @ 0.50 kg ha^{-1} as PE + HW at 30 DAS	68.01	191.7	218.9	75.11	194.6	**222.2**
W_2 - Atrazine @ 0.50 kg ha^{-1} as PE + 2,4-D Sodium salt @ 0.75 kg ha^{-1} at 30 DAS	66.82	177.2	202.3	66.92	179.8	**205.3**
W_3 - Atrazine @ 0.50 kg ha^{-1} as PE + Twin wheel hoe weeder at 30 DAS	67.23	184.4	210.5	68.72	187.1	**213.7**
W_4 - Unweeded control	46.76	138.9	158.6	48.73	141.0	**161.0**
SEd	**1.80**	**4.9**	**5.7**	**1.88**	**5.0**	**5.75**
CD (P=0.05)	**3.78**	**10.4**	**11.9**	**3.94**	**10.6**	**12.08**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table.2 Effect of spacing and weed management practices on leaf area index of maize

Treatment	(*Kharif* 2014)			(*Kharif* 2015)		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
S_1 - 45 × 30 cm (74,074 plants ha^{-1})	1.57	4.92	3.97	1.60	4.97	**4.04**
S_2 - 60 × 20 cm (83,333 plants ha^{-1})	1.45	4.56	3.68	1.48	4.61	**3.74**
S_3 - 60 × 25 cm (66,666 plants ha^{-1})	1.66	5.22	4.21	1.69	5.27	**4.28**
SEd	**0.03**	**0.10**	**0.08**	**0.04**	**0.10**	**0.09**
CD (P=0.05)	**0.06**	**0.22**	**0.18**	**0.09**	**0.23**	**0.20**
W_1 - Atrazine @ 0.50 kg ha^{-1} as PE + HW at 30 DAS	1.67	5.43	4.38	1.76	5.48	**4.46**
W_2 - Atrazine @ 0.50 kg ha^{-1} as PE + 2,4-D Sodium salt @ 0.75 kg ha^{-1} at 30 DAS	1.66	5.02	4.05	1.63	5.07	**4.12**
W_3 - Atrazine @ 0.50 kg a.i. ha^{-1} as PE + Twin wheel hoe weeder at 30 DAS	1.66	5.22	4.21	1.69	5.27	**4.29**
W_4 - Unweeded control	1.25	3.93	3.17	1.28	3.97	**3.23**
SEd	**0.08**	**0.14**	**0.11**	**0.05**	**0.14**	**0.12**
CD (P=0.05)	**0.16**	**0.29**	**0.23**	**0.10**	**0.30**	**0.24**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table.3 Effect of spacing and weed management practices on dry matter production (kg ha^{-1}) of maize (*Kharif* 2014)

Treatment	30 DAS					60 DAS					Harvest				
	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean
S_1	526.8	507.6	517.6	393.0	**486.3**	7376	7107	7247	5503	**6808**	14192	13675	13944	10588	**13100**
S_2	498.2	443.8	471.7	388.7	**450.6**	6975	6213	6604	5442	**6308**	13421	11955	12707	10471	**12139**
S_3	564.0	535.3	557.9	383.8	**515.2**	8176	7494	7810	5373	**7213**	15732	14420	15029	10339	**13880**
Mean	**526.3**	**515.6**	**515.7**	**388.5**		**7509**	**6938**	**7220**	**5439**		**14449**	**13350**	**13893**	**10466**	
	S	**W**	**S at W**	**W at S**		**S**	**W**	**S at W**	**W at S**		**S**	**W**	**S at W**	**W at S**	
SEd	**10.2**	13.9	23.2	24.0		143	194	325	336		276	374	625	647	
CD(P=0.05)	**22.4**	**29.1**	**46.7**	**47.9**		**298**	**408**	**682**	**530**		**565**	**785**	**1313**	**1020**	

Table.4 Effect of spacing and weed management practices on dry matter production (kg ha^{-1}) of maize (*Kharif*2015)

Treatment	30 DAS					60 DAS					Harvest				
	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean
S_1	536.4	516.8	527.0	400.2	**495.1**	7413	7143	7283	5530	**6842**	14263	13744	14014	10641	**13166**
S_2	507.2	451.8	480.2	395.7	**458.7**	7010	6244	6637	5469	**6340**	13488	12015	12771	10524	**12199**
S_3	564.6	560.0	568.0	390.8	**524.6**	8217	7532	7849	5400	**7250**	15811	14492	15104	10391	**13950**
Mean	**526.0**	**514.5**	**525.1**	**395.5**		**7546**	**6973**	**7256**	**5467**		**14521**	**13417**	**13963**	**10519**	
	S	**W**	**S at W**	**W at S**		**S**	**W**	**S at W**	**W at S**		**S**	**W**	**S at W**	**W at S**	
SEd	10.4	14.1	23.6	24.5		144	195	326	338		277	376	628	651	
CD(P=0.05)	**21.9**	**29.7**	**48.6**	**50.6**		**390**	**410**	**686**	**533**		**389**	**789**	**1319**	**1025**	

Table.5 Effect of spacing and weed management practices on grain yield (kg ha^{-1}) of maize

Treatment	(*Kharif* 2014)					(*Kharif* 2015)				
	W_1	**W_2**	**W_3**	**W_4**	**Mean**	**W_1**	**W_2**	**W_3**	**W_4**	**Mean**
S_1	6591	5987	6493	4171	**5811**	6890	6475	6787	4394	**6137**
S_2	6287	5709	6006	4125	**5532**	6570	5961	6274	4346	**5788**
S_3	7198	6481	6920	4073	**6168**	7529	6785	7237	4291	**6461**
Mean	**6692**	**6059**	**6473**	**4123**		**6996**	**6407**	**6766**	**4344**	
	S	**W**	**S at W**	**W at S**		**S**	**W**	**S at W**	**W at S**	
SEd	109	147	246	255		114	155	259	269	
CD(P=0.05)	**224**	**289**	**507**	**519**		**230**	**326**	**525**	**534**	

Spacing

S_1 : 45 × 30 cm (74,074 plants ha^{-1})

S_2 : 60 × 20 cm (83,333 plants ha^{-1})

S_3 : 60 × 25 cm (66,666 plants ha^{-1})

Weed management practices

W_1 : Atrazine @ 0.50 kg ha^{-1} as PE + One hand weeding at 30 DAS

W_2 : Atrazine @ 0.50 kg ha^{-1} as PE + 2,4-D Sodium salt @ 0.75 kg ha^{-1} at 30 DAS

W_3 : Atrazine @ 0.50 kg ha^{-1} as PE + Twin wheel hoe weeder at 30 DAS

W_4 : Unweeded control

Among the weed management practices studied, pre emergence application of atrazine 0.5 kg ha^{-1} in combination with hand weeding 30 DAS registered higher grain yield (6692 kg ha^{-1}in 2014 and 6996 kg hya^{-1} in 2015, respectively). The yield increase over control is 69.0 % in 2014 and 61.0% in 2015, respectively. Similarly the yield increase due to atrazine 0.5 kg + twin wheel hoe weeder weeding on 30 DAS and atrazine 0.50 kg ha^{-1} + one hand weeding on 30 DAS was 57.0% and 47% during 2014 and 55.8% and 47.5% in 2015, respectively. The yield increase could be attributed to the reason that herbicide application might have killed the weeds at germination phase avoiding competition for crop growth from the inception of germination of the crop and hand weeding on 25 DAS lasting its efficiency at later growth stages. The results are in accordance with the findings of Singh and Singh (2009) who have observed that pre emergence application of atrazine 0.5 kg ha^{-1} followed by one hand weeding on 45 DAS produced maximum pod and haulm yield of groundnut when compared to farmer's practice of hand weeding twice.

The results of Deshmukh *et al.*, (2014) who reported that the atrazine 1.0 kg ha^{-1} as PE followed by mechanical / HW at 30 DAS proves better in controlling weed, dry matter accumulation, WCE, grain yield and net monetary returns and Kakade *et al.*, (2016) who reported that sequential application of PE and PoE herbicides *i:e*, atrazine 0.50 kg ha^{-1} followed by 2,4-D sodium salt 0.5 Kg PoE at 30 DAS proves better in controlling weeds and found economical compare to conventional weed management practice in maize lend support to the present findings.

The interaction between plant spacings and weed management practices on maize grain yield was significant. The treatment combination of 60 cm x 25 cm with pre emergence application of atrazine 0.5 kg ha^{-1} + one HW 30 DAS recorded significantly higher grain yield. In maize grown under 60 x 25 cm, there was little competition for various resources except intra-species competition and the immediate supply of nutrients might be the reason for increase in growth and yield parameters which would have increased the yields in the treatments mentioned. Similar result of higher maize yield under sole maize along with pre emergence application of atrazine 0.5 kg ha^{-1} + one hand weeding on 40 DAS as reported by Shah *et al.*, (2011) lends support to the present finding. The findings of Abouziena *et al.*, (2008) who reported that sowing maize in 60 cm x 25 cm and controlled weeds by one chemical produced the highest grain yield is also in line with the present findings.

From the results of the experiments conducted it can be concluded that the plant spacing 60 cm x 25 cm among the plant spacings and atrazine @ 0.50 kg ha^{-1} + one hand weeding on 30 DAS followed by atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding at 30 DAS among the weed management practices favourably increased the growth parameters and grain yield. Among the treatment combinations, better growth and higher grain yield were recorded under the plant spacing of 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + one hand weeding on 30 DAS followed by spacing of 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding at 30 DAS.

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