Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP2: 876-879

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Yield and economics of hybrid maize as influenced by plant spacing and weed management practices

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Abstract
Field experiments were conducted during *kharif* 2014 and 2015 under irrigated condition at farmer's field at Udumalaipettai of Tiruppur district of Tamil Nadu to find out the influence of plant spacing and weed management practices on the yield and economics 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 experiments 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 among the weed management practices favourably increased the grain yield. Among the treatment combinations, higher grain yield was 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 atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding 30 DAS. The economic returns were higher with the plant spacing of 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + one hand weeding 30 DAS. However, higher B:C ratio was recorded with the spacing 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding 30 DAS.

Keywords: Maize, plant spacing, weed management practices, yield, economics

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) [5].

The agronomic practices, particularly plant spacing is of great importance in crop production. Proper adjustment of plants in the field not only ensures optimum plant population, but also helpful for plants to utilize the land, light, input resources such as water and fertilizers more efficiently and resolutely towards growth, development and towards final yield (Majid *et al.*, 1986) [8]. 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 that spacing combinations of 65 x 25 cm responded favorably in attaining higher grain yield of maize (Getaneh *et al*., 2016) [4].

Many factors are responsible for the low yields of maize in India. Of the several factors, the most critical 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) [3]. Although maize plant is vigorous and tall in nature, yet it is very sensitive to weed competition at early stages of growth. Hence, it is necessary that maize should be kept free of weeds for the first 30 days after crop emergence. Wide spacing and slow initial growth of maize favour the growth of weeds even before crop emergence. The yield losses due to season long weed infestation ranged from 30% to complete crop failure (Pandey *et al*., 2001) [10].

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 used 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.

The study of the interaction between plant population and weed control methods is also essential. Though, agronomic practices for the commercial crop have been standardized, the information regarding the optimum spacing and weed control methods of hybrid maize is scanty and hence an attempt was made to study the effect of different spacing and weed management practices on productivity and economics of hybrid maize.

Materials and Methods

Field experiments were conducted at farmer's field, Udumalaiapettai, Tiruppur district of Tamil Nadu during *kharif* season 2014 and 2015 to study the influence of varied plant densities and weed management practices on the yield and economics of maize under irrigated condition. The experiment was conducted in farmers field at Udumalaipettai situated at 10.58ºN latitude and 77.25ºE longitude at an altitude of 375 meters above mean sea level.

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 phosphrous (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 during *Kharif* 2014 and 2015 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 control methods 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. Observations on grain and stover yield were recorded and economics worked out.

Results and Discussion

Yield

The maize grain yield was significantly influenced by various spacings and weed management practices and the data on the yield is presented in Table 1 and 2.

Crop geometry had a positive influence on the 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) [11] reported higher yield of maize under wider row spacing due to better availability of resources. The present finding corroborates with the findings of Porter *et al.* (1997) [12] and Maddonni *et al.* (2006) [7] in maize.

Raising maize at 60 cm x 25 cm crop geometry registered higher stover yield than 60 x 20 cm in this investigation. The favourable effect of wider row crop geometry in promoting the stover yield might be due to the fact that maize grown at wider row crop geometry had helped the individual plants to make better spatial utilization of moisture, nutrients and light which in turn increased the plant height, LAI, DMP and ultimately grain yield as compared to narrow row crop geometry. This is in line with the findings of Malaiya *et al.* (2004) [9] in hybrid maize. Sabo *et al*. (2016) [14] 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.

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 ha^{-1} in 2015, respectively). The yield increase over control was 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 of Deshmukh *et al.* (2014) [2] 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) [6] 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) [15] lends support to the present finding. The findings of Abouziena *et al.* (2008) [1] 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.

Higher stover yield (10025 kg ha^{-1}) of maize was recorded with pre emergence application of atrazine 0.5 kg ha^{-1} 3 DAS + one hand weeding 30 DAS. Higher WCE and lower depletion of nutrients by weeds might have promoted the growth and development of maize, consequently favouring higher yield of stover. Unweeded control registered the least stover yields probably due to improper control of weeds which caused deficiency of nutrients and reduced dry matter accumulation in crop. The lowest grain and stover yield recorded under weedy check could be attributed to higher weed density which suppressed the growth and development of maize plants by competing for moisture, light and nutrients as reported by Stefanovic *et al*. (2004) [17].

Economics

The data pertaining to economics of spacing and weed

management practices are presented in Table 3.

Economic viability of crop management is the foremost criteria in transforming new investigations to farmer's field. The results revealed that the gross return of Rs.95,471, net return of Rs.51,281 during 2014 and Rs. 99,774 and 54, 959 during 2015 were recorded under plant spacing 60 cm x 25 cm with atrazine 0.5 kg ha^{-1} followed by atrazine 0.5 kg ha^{-1}+ twin wheel hoe weeder weeding on 30 DAS which recorded a gross return of Rs. 91, 728 and 50, 973 during 2014 and Rs. 95, 849 and Rs. 54, 469 during 2015, respectively This might be due to optimum plant population and improvement in growth parameters and. Similar findings were also reported by Singh *et al*. (1997) [16]. Ramu and Reddy (2007) [13] reported that the net return as well as BC ratio was the highest with 66, 666 plants ha^{-1} indicating the fact that the plant stand beyond this was not economical.

But, in any investment economics, it is the BC ratio which decides the recommendation and adoption of the technology. In the present investigation, even though the plant spacing of 60 cm x 25 cm along with atrazine 0.5 kg ha^{-1} + one hand weeding on 30 DAS has recorded higher gross and net return, higher BC ratio was recorded under 60 cm x 25 cm spacing with atrazine 0.5 kg ha^{-1} + twin wheel hoe weeder weeding on 30 DAS.

Although, pre-emergence application of atrazine 0.25 kg ha^{-1} followed by one hand weeding at 30 DAS recorded higher gross return, due to high labour requirement the cost of cultivation was increased, resulting in lesser B:C ratio compared to pre-emergence application of atrazine 0.25 kg ha^{-1} + twin hoe weeder weeding and pre-emergence application of atrazine 0.25 kg ha^{-1} + post emergence application of 2,4 D on 30 DAS.

Conclusion

The results of the experiments revealed that higher grain yield and economic returns 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. However, higher B:C ratio was recorded with the spacing 60 cm x 25 cm along with atrazine @ 0.50 kg ha^{-1} + twin wheel hoe weeder weeding at 30 DAS.

Table 1: 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	

Table 2: Effect of spacing and weed management practices on stover 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$_1$	10939	10540	10748	7361	9897	11338	10925	11140	7659	10265
S$_2$	10344	9214	9794	7271	9156	10722	9551	10152	7566	9497
S$_3$	12126	11114	11584	7169	10498	12568	11520	12006	7460	10889
Mean	11136	10290	10708	7267		11543	10665	11099	7561	
	S	**W**	**S at W**	**W at S**		**S**	**W**	**S at W**	**W at S**	
SEd	212	288	482	499		220	299	499	517	
CD(P=0.05)	431	592	984	1012		451	607	1029	1158	

Table 3: Effect of plant spacing and weed management practices on economics of maize hybrid

Treatment	(*Kharif* 2014)				(*Kharif* 2015)			
	Cost of cultivation (₹ ha^{-1})	**Gross return (₹ ha^{-1})**	**Net return (₹ ha^{-1})**	**B:C ratio**	**Cost of cultivation (₹ ha^{-1})**	**Gross return (₹ ha^{-1})**	**Net return (₹ ha^{-1})**	**B:C ratio**
S$_1$W$_1$	46175	87296	41121	1.89	46800	91184	44384	1.95
S$_1$W$_2$	40670	79749	39079	1.96	41295	85894	44599	2.06
S$_1$W$_3$	42740	85977	43237	2.01	43365	89799	46434	2.07
S$_1$W$_4$	39230	55573	16343	1.42	39855	58472	18617	1.47
S$_2$W$_1$	45305	83202	37897	1.84	45930	86881	40951	1.89
S$_2$W$_2$	39800	75419	35619	1.89	40425	78695	38270	1.95
S$_2$W$_3$	41870	79418	37548	1.90	42495	82902	40407	1.96
S$_2$W$_4$	38360	54953	16593	1.43	38985	57827	18842	1.48
S$_3$W$_1$	44190	95471	51281	2.16	44815	99774	54959	2.23
S$_3$W$_2$	38685	86108	47423	2.23	39310	90060	50750	2.29
S$_3$W$_3$	40755	91728	50973	2.25	41380	95849	54469	2.32
S$_3$W$_4$	37245	54253	17008	1.46	37870	57087	19217	1.51

Data not analyzed statistically

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

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