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Effect of altered crop geometry and integrated weed management methods on productivity and profitability of irrigated maize and its residue effect on succeeding Bengal gram

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Abstract
To evaluate the effect of different crop geometry without altering plant population and integrated weed management methods on productivity and profitability of maize under irrigated condition and also to study the residual effect of weed management practices on succeeding Bengal gram, the field experiment was conducted in Eastern block, Department of Agronomy, TNAU, Coimbatore during *Kharif* and *Rabi* season of 2018-19. The experiment result showed that normal row planting 60 cm x 25 cm have higher growth and yield attributes which is statistically on par with normal row planting 75 cm x 20 cm. Among weed control treatments, pre-emergence (PE) application of atrazine at 1 kg ai/ha + hand weeding at 35 DAS resulted higher grain yield (7.85 t/ha) and it is statistically on par with PE atrazine application at 1 kg ai/ha + twin wheel hoe weeder weeding at 35 DAS (7.61 t/ha). From this study, it may concluded that adoption of normal row planting at 75 cm x 20 cm with weed control practice of atrazine application as pre-emergence followed by twin wheel hoe weeder weeding at 35 DAS could result higher grain yield and profitability of maize and inferred that residual effect of herbicides used for preceding maize does not exist any significant effect on growth and yield of succeeding Bengal gram.

Keywords: Altered crop geometry, Integrated weed management, Productivity and profitability of maize, Residual effect on Bengal gram.

Introduction
Today, maize (*Zea mays* L) has become one of the most important leading food grain crops across different parts of the world. Maize is also known as "Queen of cereals" because of its higher genetic yield potential among other cereals. It is cultivated in diverse soil conditions, climate and with different management strategies among 160 countries which nearly contributes 36% of global food grain production (Anilkumar *et al.*, 2015) [2]. In Indian agriculture, maize occupies a predominant position owing to its utilization for food and mainly as feed especially for poultry production. After rice and wheat, maize is the most important food grain crop in India cultivated in 9.63 million hectares with the average production and productivity of 25.89 million tonnes and 2689 kg/ha respectively. In Tamil Nadu, maize occupies an area of 315.03 thousand hectares and accounts about 953.38 thousand tonnes with 3026 kg/ha productivity (Indiastat, 2016-17) [7].

Weeds are one of the most important biotic constraints for maize production which competes for soil water, nutrients and light results in yield decline. Due to weed infestation, 33-90% grain yield reduction was recorded (Pradeep *et al.*, 2017) [11]. Thus, weed management results in maximizing production potential of grain yield. Every individual method of weed management has its own limitations *viz.*, chemical method will leave its residue in the soil, plant damage per cent is higher in mechanical method and higher input cost and labour scarcity for physical method. Simultaneously, repeated practice of single weed management method will result in weed flora shift and development of resistance biotypes. In order to overcome these problems, integration of different weed management practice will paves the way. Integrated weed management (IWM) includes all possible and feasible methods that combine physical, chemical and mechanical methods in systemic manner (Verschwele *et al.*, 2016) [13]. Therefore, IWM is sustainable and economic tool for weed control.

While adopting mechanical weed management method, row spacing can be widened in order to reduce the plant damage percent during weeder operations. By altering crop geometry, it significantly influences the weed emergence and growth and yield attributes of maize. Planting pattern is a cost effective tool that modifies the crop canopy, reduces plant damage caused by mechanical weeders, enhances resource utilization and maximizing productivity of crops

(Sunitha *et al.*, 2010) [12]. Therefore, these facts demand the study of manipulation of planting pattern and weed management methods on performance of maize under altered crop geometry and also weed dynamics. By keeping this in view, present study of integrated weed management practices was undertaken with altered crop geometry under irrigated condition in order to reduce plant damage in maize and to study the effect of planting pattern on growth and yield of maize. The other objective of this study is to know the residual effect of different weed control practices on succeeding bengal gram.

Materials and Methods

Field experiment was conducted in Field No. 36E, Eastern Block Farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-3 situated in Western Agro-climatic zone at 11° N latitude, 76°57' E longitude and altitude at 426.7 m above MSL. The soil texture was sandy clay loam with 314 kg/ha available nitrogen (medium), 6.02 kg/ha available phosphorus (low) and 489 kg/ha available potassium (high). Maize crop was raised during *Kharif* to evaluate the different weed management methods under altered crop geometry in irrigated maize and the succeeding crop Bengal gram raised during *Rabi* season of 2018-19 to study the residual effect of weed management practices. The design adopted for the study is Factorial Randomized Block Design (FRBD) with the considerations of two factors namely, crop geometry and weed management methods. The levels of altered crop geometry are 3, weed management practices are 8 and it replicated twice. The treatment includes crop geometry of M_1- 60 cm x 25 cm (Conventional), M_2 - 75 cm x 20 cm, M_3 - paired row method 90: 30 cm x 25 cm and weed management involves S_1 – Twin wheel hoe weeder weeding at 20 and 35 DAS, S_2 – Power weeder weeding at 20 and 35 DAS, S_3 – Atrazine at 0.5 kg/ha + Twin wheel hoe weeding at 35 DAS, S_4 – Atrazine at 0.5 kg/ha + Power weeder weeding at 35 DAS, S_5 – Atrazine at 0.5 kg/ha + Hand weeding at 35 DAS, S_6 - Fodder cowpea as live mulch + Brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS, S_7 – Two hand weeding at 20 and 35 DAS and S_8 – Unweeded check. The plant population maintained on all the three crop geometry treatments was 66,667/ha. The test variety for maize is TNAU maize hybrid CO 6 and Bengal gram is JAKI 9218. All general cultivation practices are followed for maize expect the treatments and Bengal gram was maintained as bulk crop with same management practices. The observations recorded in maize crop were plant height, leaf area index, dry matter production, yield attributes, grain yield, net returns and B:C ratio and in succeeding Bengal gram was germination percentage, dry matter production, grain and haulm yield.

Results and discussion

Crop geometry had greater influence on the growth and development of maize which ultimately have significant effect on yield and its attributes. In addition, it determines the weed emergence and efficiency of weed management methods. However, the herbicides used for preceding maize may not exert any residual effect on succeeding Bengal gram. The results obtained due to altered crop geometry and weed management methods on growth and yield parameters of maize and its residual effect on succeeding crop were discussed below.

Plant height of maize

Experiment results revealed that both altered crop geometry and integrated weed management had significant effect on growth parameters of maize. The result showed that the normal planting methods with 60 cm x 25 cm (M_1) and 75 cm x 20 cm (M_2) had recorded higher plant height than the paired row planting method. Though M_1 and M_2 are statistically on par with each other, M_1 (200.7 cm) had obtained the higher plant height than M_2 (195.6 cm) and it was statistically superior to paired row method of planting (187.9 cm). The results are in conformation with the findings of Bhagirath and Jhoana (2013) [3] who had reported that the difference in plant height of normal rows under altered planting pattern was significantly non-significant but it is significantly higher when compared to paired row method. This may due to the increased competition for resources by the plants in paired row than the normal row.

Table 1: Effect of altered crop geometry and integrated weed management methods on plant height and dry matter production (60 DAS)

Treat-ments	Plant height (cm)				Dry matter production (kg/ha)			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
S_1	189.3	185.2	177.5	184.3	5871	5709	5433	5671
S_2	162.8	154.9	146.3	154.7	5233	5073	4816	5041
S_3	234.6	228.7	219.7	227.6	7219	7042	6877	7046
S_4	203.2	196.3	188.5	196.0	6451	6311	6117	6293
S_5	245.4	241.9	233.9	240.4	7674	7357	7184	7405
S_6	174.1	169.6	159.8	167.3	5639	5532	5293	5488
S_7	252.7	249.2	241.2	247.7	7896	7694	7412	7667
S_8	143.8	140.1	136.2	140.0	4682	4518	4349	4516
Mean	200.7	195.6	187.9		6333	6155	5935	
	M	S	MS		M	S	MS	
SEd	5.79	9.45	16.37		181.73	296.77	514.01	
CD (P=0.05)	11.98	19.56	33.87		375.94	613.91	1063.32	

Among different weed management methods, two manual weeding had recorded higher plant height (247.7 cm) than the other treatments but it was statistically on par with pre-emergence (PE) application of atrazine + hand weeding at 35 DAS (240.4 cm) followed by PE atrazine application + twin wheel hoe weeder weeding at 35 DAS (227.6 cm). However, weedy check had recorded lower plant height of 140 cm when compared to other treatments. The results are in accordance with Mynavathi *et al.* (2009) [9] who had reported that two hand weeding treatment and integration of herbicide with one hand weeding resulted in significant plant height due to significant weed reduction of weed density and weed competition.

For the interaction of planting pattern and integrated weed management methods was found to be significant and narrow row spacing (conventional) planting at 60 cm with the weed

management practice of two hand weeding had obtained higher plant height (252.7 cm) and it is comparable with PE atrazine application + one hand weeding at 35 DAS. The result was comparable with the findings of Huseyin *et al.* (2004) [5] reported that among different row spacing of maize, 60 cm had recorded higher plant height due to production of optimum root biomass and efficient utilization of resources by the plants.

Dry matter production

Dry matter accumulation (DMP) greatly affected by the planting pattern and also by weed interference. For optimum dry matter production, sufficient land area is required for normal growth and development. Thus, crop geometry of 60 cm x 25 cm had produced higher DMP (6333 kg/ha) and it is statistically significant with the normal row planting method 75 cm x 20 cm (6155 kg/ha) but it is reduced in case of paired row method (5935 kg/ha). The result was found to be in confirmation with the findings given by Yang *et al.* (2017) [14]. The significant dry matter production was due to the reduced inter-plant competition and complementary use of available resources.

Higher DMP obtained with the cultural weed management method with two manual weeding at 20 and 35 DAS (7667 kg/ha) and it is statistically on par with the integrated weed management with PE atrazine application + one hand weeding at 35 DAS (7405 kg/ha) and it is followed by PE application of atrazine at 0.5 kg/ha + twin wheel hoe weeder weeding at 35 DAS (7046 kg/ha). Mynavathi *et al.* (2015) [10] findings were found to be in confirmation with this result and indicated that the manual weeding and pre-emergence application with mechanical weeder had better dry matter accumulation due to lesser weed competition and higher moisture and plant nutrient availability favouring vigorous maize growth.

Combined effect of altered crop geometry and integrated weed management had significantly influenced the dry matter accumulation. The result showed that the normal row planting with two hand weeding at 20 and 35 DAS had recorded higher DMP at 60 DAS (7896 kg/ha) which statistically on par with pre-emergence atrazine application + hand weeding at 35 DAS (7694 kg/ha) which is comparable with the PE atrazine followed by twin wheel hoe weeder weeding (7219 kg/ha).

The result was found in accordance with the findings given by Bhagirath and Jhoana (2013) [3] who had resulted that the dry matter accumulation is higher in 60 cm row spacing with manual weeding due to proper partitioning of resources to plants and effective reduction in weed density and weed biomass production.

Leaf area index

As leaf area index is based on the plant growth parameters (number of leaves, leaf length and leaf breadth), it is also highly influenced by crop geometry and weed management methods. Among altered spacing, normal row planting with 60 cm x 25 cm had higher leaf area index (4.94) followed by 75 cm x 20 cm (4.68). These were found to be in accordance with Getaneh *et al.* (2016) [4] findings the narrow spacing had recorded lower leaf area index than wider row spacing. Thus, leaf area index decreased with increase in intra and inter- row spacing.

This could be due to the high number of plants per unit area and also result in efficient interception of solar radiation in narrow row spacing of maize.

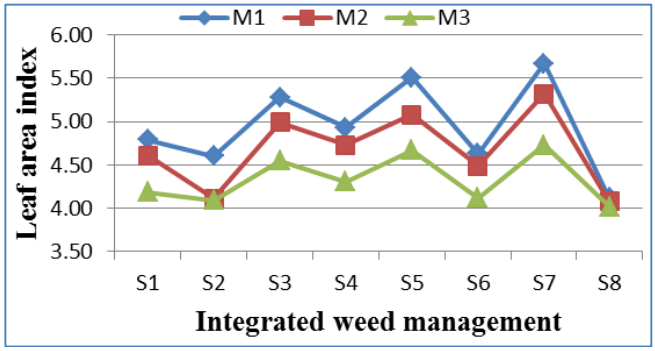


Fig 1: Effect of altered crop geometry and integrated weed management methods on leaf area index (LAI) of maize (60 DAS)

Weeds are one of the important biotic factors that compete with crop for solar radiation. Consequently, weed management practices provides the greater influence on leaf area index. Among the different weed management methods, LAI recorded higher value for two hand weeding (5.24) it was statistically on par with pre-emergence atrazine application + one hand weeding (5.09) and comparable with PE application of atrazine + twin wheel hoe weeder weeding at 35 DAS (4.94). Lower leaf area index recorded for weedy check (4.07). Hussein *et al.* (2008) [6] findings was found confirmation with this result and reported that the atrazine + one hand weeding promote higher weed control and utilization of plant growth resources. Thus it results in larger leaf surface area for capture of more solar radiation for increased photosynthesis and higher yield. However, the interaction of altered crop geometry and integrated weed management had not significantly influence the leaf area index.

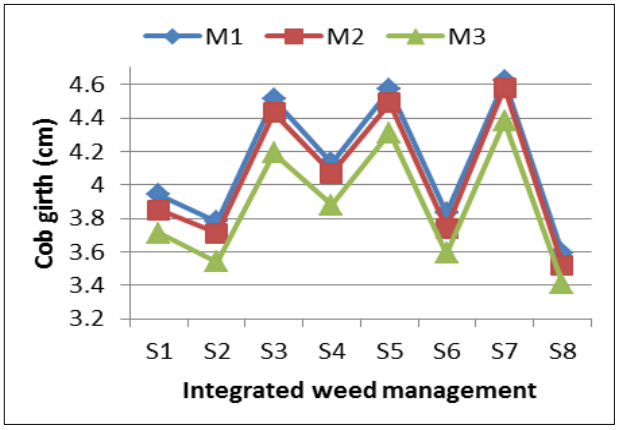
Yield and its attributes

Yield and yield attributes of maize is higher depends on planting pattern and weed management methods. As crop geometry decides the availability of growth resources and weed management methods reduces competition by weeds. The yield attributes, grain and stover yield of maize were higher for conventional normal row planting with 60 cm x 25 cm which is statistically on par with the normal row planting with 75 cm x 20 cm whereas paired row method of planting recorded significantly lower yield and yield attributes like cob girth, grain yield per cob.

Weed infestation can greatly affect the yield and yield attributes of maize. Significantly higher yield and yield attributes of maize obtained in two hand weeding at 20 and 35 DAS which was on par with atrazine application as pre-emergence + one hand weeding at 35 DAS and it is comparable with the atrazine application + twin wheel hoe weeder weeding at 35 DAS. The result was found to be in accordance with the findings of Mynavathi *et al.* (2009) [9] who had concluded that pre-emergence application of atrazine with one hand weeding recorded higher followed by twin wheel hoe weeder weeding. This may due to the reduced vegetative growth of weeds and increased nutrient availability to plants. Thus, it showed the importance of weed management in influencing the grain yield and yield attributes of maize under irrigated condition.

Grain yield and stover yield was found to be significant for the interaction effect of planting pattern and weed management methods. However, yield attribute like grain yield per cob had shows significant but cob girth was found to be non-significant for interaction effect of crop geometry and weed management practice. Grain yield and stover yield

recorded higher for the spacing of 60 cm x 25 cm with the weed management of pre-emergence atraizne application with one hand weeding and it was followed by PE atraizine application with twin wheel hoe weeder weeding. However, normal row planting at 75 cm x 20 cm was also found to be significant but lower than conventional planting. Hussein *et al.* (2008) [6] result was found to be in confirmation with this result. Higher yield was due to the narrow row spacing that reduced the weed emergence and effective in reducing the weed density which in turn improves the biological and grain yield of maize.



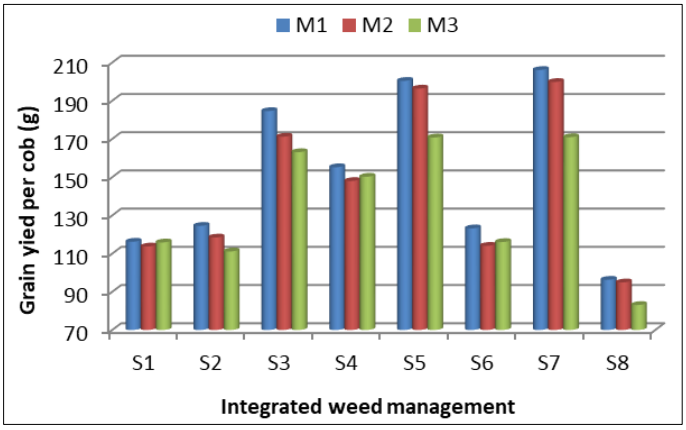


Fig 2 & 3: Effect of altered crop geometry and integrated weed management methods on cob girth (cm) and grain yield per cob (g) of maize

Table 2: Effect of altered crop geometry and integrated weed management methods on grain yield and stover yield of maize

Treatments	Grain yield (kg/ha)				Stover yield (kg/ha)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	5484	5567	4562	5204	9442	9585	7855	8961
S_2	5216	5364	4509	5030	8963	9217	7748	8643
S_3	7911	7936	6988	7612	13995	14040	12362	13466
S_4	6682	6773	5736	6397	11596	11754	9954	11102
S_5	8268	8172	7123	7854	14661	14491	12631	13927
S_6	5433	5418	4475	5109	9295	9270	7656	8740
S_7	8415	8291	7219	7975	15194	14970	13035	14400
S_8	4391	4106	3437	3978	7417	6936	5806	6720
Mean	6475	6453	5506		11321	11282	9631	
	M	S	MS		M	S	MS	
SEd	182	297	514		321	534	907	
CD (P=0.05)	376	614	1064		663	1083	1876	

Economics

Based on the cost of cultivation and B: C ratio, normal row planting at 75 cm x 20 cm with the weed management practice of pre-emergence atrazine application at 1 kg/ha + twin wheel hoe weeder weeding at 35 DAS had proved to have reduced cost of cultivation with higher B: C ratio (2.42). This result was found to be in confirmation with Mynavathi *et al.* (2015) [10] who had concluded that using of twin wheel hoe weeder resulted in reduced of cost of cultivation and attained higher net returns. This may due to the reduction in labour requirement, time consumption and reduced plant damage percent.

Table 3: Effect of altered crop geometry and integrated weed management methods on cost of cultivation and B: C ratio of maize production

Treatments	Cost of cultivation (□/ha)			B: C ratio		
	M_1	M_2	M_3	M_1	M_2	M_3
S_1	54285	53925	53565	1.60	1.64	1.35
S_2	53125	52765	52405	1.56	1.61	1.36
S_3	52475	52155	52515	2.39	2.42	2.11
S_4	52795	52435	52435	2.01	2.05	1.74
S_5	56775	54975	54255	2.31	2.36	2.09
S_6	52049	52049	52049	1.66	1.65	1.36
S_7	67185	65385	65385	1.99	2.02	1.76

Data is not statistically analysed

Residual effect of altered crop geometry and integrated weed management methods of preceding maize on succeeding Bengal gram

While using herbicide for weed management, it leaves their residue in the soil and may affect the succeeding crop. The residual effect of integrated weed management methods and altered crop geometry on germination was found to be non-significant. Weed management practice with 2,4 – D had lower germination percent than all the other treatments. This result was found to be in accordance with findings of Janaki *et al.* (2015) [8] that the relative persistence of atrazine was found to be 3 months and for 2,4 – D about less than one month respectively. Therefore, these herbicides do not have significant effect on germination of succeeding bengal gram.

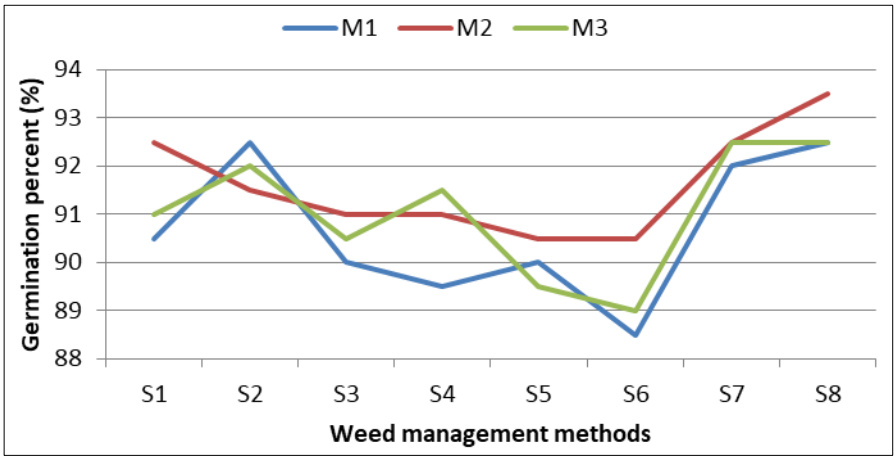


Fig 4: Residual effect of altered crop geometry and integrated weed management methods of preceding maize on germination of succeeding Bengal gram

As germination is not significantly affected by the herbicides, dry matter production and grain yield of Bengal gram is also not significantly affected. Thus, grain and haulm yield of succeeding Bengal gram does not have any adverse effect by weed management practices practiced for preceding maize. This is in accordance with the results of Aladesanwa and Adejoro (2009) [1] concluded that the succeeding pulse crop sown followed by maize does not suffer any significant reduction in growth and yield with the application of 2, 4 – D herbicide and also the usage of atrazine does not possess any residual effect on succeeding crops.

Table 4: Residual effect of altered crop geometry and integrated weed management methods of preceding maize on grain and haulm yield of succeeding Bengal gram

	Haulm yield (kg/ha)				Grain yield (kg/ha)			
	S1	**S2**	**S3**	**Mean**	**S1**	**S2**	**S3**	**Mean**
W1	1633	1627	1648	1636	662	659	673	665
W2	1698	1666	1702	1689	681	671	688	680
W3	1617	1643	1637	1632	659	662	672	664
W4	1664	1684	1713	1687	675	684	691	683
W5	1732	1728	1628	1696	692	691	669	684
W6	1648	1672	1684	1668	667	677	681	675
W7	1723	1707	1676	1702	691	686	679	685
W8	1709	1691	1669	1690	687	680	677	681
Mean	1678	1677	1670		677	676	679	
	S	W	SW		S	W	SW	
SEd	39.23	64.07	110.97		15.89	25.95	44.94	
CD (P=0.05)	NS	NS	NS		NS	NS	NS	

Conclusion

Based on the experimental results, it can be concluded that by adopting the planting pattern 75 cm x 20 cm with atrazine application at 1 kg/ha as pre-emergence + twin wheel hoe weeder weeding at 35 DAS as weed management practice would result in higher yield, improves net returns and B: C ratio of maize production. However, application of herbicides (atrazine and 2, 4 – D) for weed control in preceding maize does not possess any significant effect on germination, growth and yield of succeeding bengal gram.

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