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Integrated weed management in altered crop geometry of irrigated maize and residual effects on succeeding Bengal gram

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ABSTRACT

A field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore during *Kharif* and *Rabi* seasons of 2018-19 to study the effect of altered crop geometry without changing the total plant population with integrated weed management methods in irrigated maize (*Zea mays* L.) and their residual effects on succeeding Bengal gram (*Cicer arietinum*). Based on the results, it could be ascertained that planting pattern of 60 x 25 cm proved to be effective in reducing weed biomass and recorded significantly higher grain yield of about 6.48 t/ha which was at par with the spacing of 75 x 20 cm. Pre-emergence (PE) application of atrazine at 1.0 kg/ha + hand weeding or twin wheel hoe weeding at 35 DAS was at par with hand weeding twice at 20 and 35 DAS with respect to grain yield. Herbicidal methods of weed management like 2, 4-D and atrazine application did not exert any residual effect on the succeeding Bengal gram.

Maize (*Zea mays* L.) is one of the important cereal crops in many developed and developing countries across the world. Maize occupies a predominant position in Indian agriculture, as it is the third most important crop after rice and wheat with respect to area and productivity. India accounts for about 25.89 million tonnes of maize production and productivity of 2.69 t/ha (indiastat.com 2016-17). Weeds are considered to be the major threat and cause 34% yield loss globally (Oerke 2006). Weeds compete for water, nutrients and light which results in reduction of crop productivity. The critical period of crop-weed competition for maize is 15 to 40 DAS and the per cent yield reduction ranges from 40 to 60%. Therefore, weed management is important for optimizing the grain yield.

Integrated weed management (IWM) is a multi-disciplinary approach that combines cultural, mechanical and chemical methods for controlling weeds in systemic manner and provides the significant advances in weed control technology (Verschwele *et al.* 2016).

While adopting mechanical methods as a component in IWM, plant damage is the major problem. Alteration in crop geometry may adopt as a strategy in order to reduce the plant damage percent. In the case of chemical method, the persistence of herbicides in the soil may cause adverse effects to succeeding crop growth and development (Shobha 2014). However, at present farmers are following two hand weeding at 20 and 35 DAS for controlling weeds but this practice demands higher labour, cost and consumes time. Moreover, scarcity of labour during peak periods also creates the necessity for the implementation of integrated weed management for weed suppression. Hence, the present study was conducted to evaluate the different integrated weed management methods under altered crop geometry in irrigated maize and the residual effect of herbicidal weed control on succeeding bengal gram.

The experiment was carried out in the field no. 36 E, Eastern Block, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *Kharif* and *Rabi,* 2018-19 to evaluate the different integrated weed management practices in irrigated maize under altered crop geometry and its residual effects on succeeding Bengal gram. The geographic co-ordinates of Coimbatore are 11° North latitude and 77° East longitude with an altitude of 427 m above the mean sea level. The soil is sandy clay loam with the medium level of available nitrogen (314 kg/ha), low in available phosphorus (6.02 kg/ha) and high in available potassium (489 kg/ha). The experiment was laid out in factorial randomized block design with the consideration of two factors - crop geometry and weed management treatments. The plot size of 24 m^2

(6 x 4 m) was taken for this experimental study. The treatment details with 2 replications of 3 levels of crop geometry and 8 levels of weed management methods were as follows, *viz.* crop geometry includes 60 x 25 cm (conventional), 75 x 20 cm, paired row method 90: 30 x 25 cm and weed management involves twin wheel hoe weeding at 20 and 35 DAS, power weeding at 20 and 35 DAS, atrazine at 1.0 kg/ha + twin wheel hoe weeding at 35 DAS, atrazine at 1.0 kg/ha + power weeding at 35 DAS, atrazine at 1.0 kg/ha + hand weeding at 35 DAS, fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS, two hand weeding at 20 and 35 DAS and unweeded check. TNAU maize hybrid CO 6 was sown and maintained with all general cultivation practices except for spacing and weed management methods. The observations recorded were weed density, weed biomass, yield attributes, yield of maize and their economic returns. Followed by maize, residue crop bengal gram '*JAKI 9218*' variety was sown and the observations recorded in bengal gram were germination, weed density, weed biomass and yield. Weed data were subjected to square root transformation ($\sqrt{x+0.5}$) for statistical analysis.

Weed flora

The dominant group of weeds found in the experimental field of maize were broad-leaved weeds (54.70%) followed by grassy weeds (43.63%) and sedges observed to be at lower proportion (1.67%). Among different weeds, the major weed species were present in the experimental site consisted of *Trianthema portulacastrum, Digera arvensis, Echinochloa colonum, Digitaria longiflora, Dactyloctenium aegyptium and Parthenium hysterophorus.*

Effect on weeds

Experimental results revealed that the wider spacing interval of crop rows observed to have higher weed density and weed growth rate. Maize with spacing 60 x 25 cm recorded lower weed density 3.54 no./m^2 and weed biomass 4.20 g/m^2 and it was found to be significantly higher. It was followed by the crop geometry 75 x 20 cm with the weed density 3.90 no./m^2 and weed biomass 4.69 g/m^2. Paired row method of planting recorded higher weed density 4.21 no./m^2 and also weed biomass of about 5.52 g/m^2. The results are in accordance with the findings of Sunitha *et al.* (2010) who had reported that narrow row spacing 60 cm had provided lesser space for weed emergence, which in turn reduced the light interception to the soil to induce the weed growth and development.

Among the different weed management practices, two hand weeding at 30 and 45 DAS and application of atrazine at 1.0 kg/ha as pre-emergence + one hand weeding at 35 DAS had recorded lower weed density and weed biomass. However, hand weeding at 30 and 45 DAS was significantly higher and recorded lower weed biomass 2.19 g/m^2 and it was statistically at par with PE atrazine at 1.0 kg/ha + one hand weeding at 35 DAS 2.60 g/m^2 and it was followed by PE atrazine application at 1.0 kg/ha + twin wheel hoe weeding at 35 DAS recorded the weed biomass of about 2.79 g/m^2, respectively. Similar results were earlier observed by Kandasamy (2017) who had concluded that the hand weeding twice resulted in effective weed control and also atrazine at 1.0 kg/ha + one hand weeding at 35 DAS would be better, thus atrazine inhibits the weed germination at initial period of crop growth and aids in weed free conditions for the critical period. The data on the effect of weed management methods under altered crop geometry at 60 DAS on weed density and weed biomass in irrigated maize are given in **Table 1**.

Interaction of conventional crop geometry with two hand weeding twice recorded lower weed density 2.78 no./m ^{2} and weed biomass 1.86 g/m^2 and it was found to be significantly higher. However, it was statistically at par with the weed management practice of application of atrazine at 1.0 kg/ha + hand weeding at 35 DAS and followed by atrazine application + twin wheel hoe weeding at 35 DAS. The results are in accordance with Hussein *et al.* (2008) findings that interaction of maize sown at 60 x 25 cm and weed management by integrating PE herbicide application followed by mechanical method had produced higher grain yield. This might be due to the optimum resource utilization by the crop and considerably reduced weed biomass at critical crop growth period.

Effect on weed control efficiency

Weed control efficiency (WCE) indicates the magnitude of reduction in weed biomass over weedy check by different weed control treatments. The efficiency of different integrated methods on weed control was worked out in terms of weed biomass in treated plot over control plot. At 60 DAS, hand weeding twice recorded higher WCE (93.82%) followed by PE atrazine application of 1.0 kg/ha + hand weeding on 35 DAS (90.95%). However, the difference between PE application atrazine at 1.0 kg/ha + hand weeding on 35 DAS and PE atrazine application of 1.0 kg/ha + twin wheel hoe weeding on 35 DAS (89.51%) was insignificant (**Table 2**). Mynavathi *et al.* (2015) who had observed the similar results that wheel hoe weeding had higher weed control efficiency (94.6% at 45 DAS) with increased maize grain yield to the significant level and concluded that wheel hoe weeding offered less time, less labour and cover maximum area with minimum cost of operation than hand weeding.

Weed control efficiency was highly influenced by the interaction of altered crop geometry and weed management methods as it exerted significant effect on weed biomass. It was observed that the paired row method of planting provides larger area for weed growth and while, for operating mechanical weeders, weeds in between the pairs are not effectively controlled which then leads to lowering of weed control efficiency when compared with 75 x 20 cm and 60 x 25 cm (conventional). Higher weed control efficiency was observed in narrow row spacing than wider ones. Crop row spacing 60 cm recorded lower weed biomass and effective control of weeds due to lesser space and resource availability for weed growth and decreased crop weed competition than 75 and 90 cm and this result is in accordance with the findings of Mahingaidze *et al.* (2009).

Effect on yield attributes

The yield components such as number of grains/cob and 100-grain weight were significantly influenced by altered crop geometry. Crop geometry of maize with 60 cm x 25 cm resulted in higher 100 grain weight and increased number of grains per cob which was on par with the crop geometry 75 x 20 cm (**Table 3**). Apparently, test weight and number of grains formed per cob was registered lower with paired row planting 90: 30 x 25 cm. The results were in confirmation with Peter *et al.* (2000) who reported that the effect of row spacing on yield components like number of grains formed and test weight of maize grains has significant effect and this might be due to effective growth resources availability and utilization by the crop which was present in the optimum plant arrangement with 60 cm row spacing.

Table 1. Effect of altered crop geometry and integrated weed management methods on total weed density and weed biomass of maize (60 DAS)

Treatment	Total weed density(no./m^2)				Total weed biomass(g/m^2)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Twin wheel hoe weeding at 20 and 35 DAS	3.91(14.8)	4.26(17.6)	4.72(19.7)	4.30(17.4)	5.18(26.7)	6.28(39.0)	6.62(43.3)	6.02(36.2)
Power weeding at 20 and 35 DAS	3.59(12.4)	4.15(16.7)	4.37(18.6)	4.04(15.9)	4.82(22.7)	5.59(30.8)	6.09(36.5)	5.50(30.0)
Atrazine at 1.0 kg/ha + twin wheel hoe weeding at 35 DAS	3.15(9.4)	3.53(11.9)	3.81(14.0)	3.50(11.8)	2.42(5.3)	2.66(6.6)	3.29(10.3)	3.22(7.4)
Atrazine at 1.0 kg/ha + power weeding at 35 DAS	3.49(11.7)	3.74(13.5)	3.97(15.3)	3.73(13.5)	3.28(10.3)	3.48(11.6)	3.89(14.7)	4.23(18.0)
Atrazine at 1.0 kg/ha + hand weeding at 35 DAS	2.94(8.1)	3.36(10.8)	3.63(12.7)	3.31(10.5)	2.08(3.8)	2.49(5.7)	3.05(8.8)	2.60(6.1)
Fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS	4.04(15.8)	4.09(16.2)	4.69(21.5)	4.27(17.8)	5.62(31.1)	5.83(33.5)	7.55(56.4)	6.33(40.3)
Two hand weeding at 20 and 35 DAS	2.78(7.2)	3.21(9.8)	3.38(10.9)	3.12(9.3)	1.86(3.0)	2.05(3.7)	2.65(6.6)	2.19(4.4)
Unweeded check	4.41(19.0)	4.83(22.8)	5.09(25.4)	4.78(22.4)	8.01(63.6)	8.48(71.3)	9.17(83.6)	8.35(69.5)
Mean	3.54(12.3)	3.90(14.9)	4.21(17.3)		4.20(20.8)	4.69(24.8)	5.52(33.9)	
	C	W	C x W		C	W	C x W	
LSD(p=0.05)	0.19	0.31	0.54		0.27	0.45	0.78	

C_1 – 60 cm x 25 cm (conventional); C_2 - 75 x 20 cm; C_3 - paired row method 90: 30 x 25 cm ; Figures in parentheses are means of original values; Data subjected to square root transformation

Table 2. Effect of altered crop geometry and integrated weed management methods on weed control efficiency (%) of maize (60 DAS)

Treatment	C_1	C_2	C_3	Mean
Twin wheel hoe weeding at 20 and 35 DAS	58.75	46.38	48.24	47.79
Power weeding at 20 and 35 DAS	46.97	47.37	51.45	56.78
Atrazine at 1.0 kg/ha + twin wheel hoe weeding at 35 DAS	91.61	89.28	81.74	87.54
Atrazine at 1.0 kg/ha + power weeding at 35 DAS	83.88	70.19	69.67	74.58
Atrazine at 1.0 kg/ha + hand weeding at 35 DAS	93.97	90.63	82.45	89.02
Fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS	51.15	45.41	32.50	43.02
Two hand weeding at 20 and 35 DAS	95.33	94.00	85.21	91.51
Unweeded check	-	-	-	-
Mean	74.52	69.04	64.47	

C_1 – 60 x 25 cm (conventional); C_2 - 75 x 20 cm; C_3 - paired row method 90: 30 x 25 cm; Data not statistically analyzed

Weed management has shown a significant effect on the number of grains per cob and 100 grain weight. Hand weeding twice plots had recorded significantly higher yield attributes like grain test weight and grain number per cob and it was statistically at par with PE atrazine application + hand weeding at 35 DAS followed by PE atrazine + twin wheel hoe weeding at 35 DAS. Weedy check recorded a distinctly lower number of grains per cob and 100-grain weight. These results were in confirmation with Saini *et al.* (2013). The lower yield components might be due to increased crop weed competition thus finally could result in reduced growth and development of the crop. Though weed management methods had significant effect on yield attributes, interaction of crop geometry and weed management methods has no significant effect on 100-grain weight but other yield parameter number of grains per cob was found to be significant. Combination of conventional spacing with two hand weeding was found to be significantly higher. These results are in accordance with the findings of Sunitha *et al.* (2010).

Effect on yield

As crop geometry highly influenced the resource availability for crop growth, grain yield was also greatly affected. The result showed that narrow row spacing 60 cm had recorded a significantly higher yield (6.48 t/ha) and it was statistically at par with 75 cm (6.44 t/ha) (**Table 4**). Maqbool *et al.* (2006) findings were found to be in accordance with these results and indicated that optimum maize row spacing of about 60 cm had been more appropriate due to higher resources availability and their utilization by the crop which ultimately resulted in higher yield.

Weeds are considered to be the major competitor for crop growth thus, its management practices have significant effects on grain and stover yield of maize. Significant higher grain yield was

Table 3. Effect of altered crop geometry and integrated weed management methods on yield attributes of maize

Treatment	No. of grains/cob				100 grain weight (g)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Twin wheel hoe weeding at 20 and 35 DAS	339	351	349	346	34.28	32.40	33.19	33.59
Power weeding at 20 and 35 DAS	352	348	329	343	35.37	34.03	33.77	34.39
Atrazine at 1 kg/ha + twin wheel hoe weeding at 35 DAS	496	487	468	484	37.22	35.15	34.85	35.74
Atrazine at 1 kg/ha + power weeding at 35 DAS	429	433	428	430	36.18	34.18	35.10	35.30
Atrazine at 1 kg/ha + hand weeding at 35 DAS	513	507	474	498	39.53	37.84	35.50	37.64
Fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS	346	342	353	347	35.61	33.35	32.87	34.08
Two hand weeding at 20 and 35 DAS	519	511	481	504	40.18	39.11	36.06	38.45
Unweeded check	291	297	273	287	33.09	31.96	30.43	31.83
Mean	411	409	394		36.65	34.75	33.98	
	C	W	C x W		C	W	C x W	
LSD (p=0.05)	13	48	83		2.47	4.04	NS	

C_1 – 60 x 25 cm (conventional); C_2 - 75 x 20 cm; C_3 - paired row method 90: 30 x 25 cm

Table 4. Effect of altered crop geometry and integrated weed management methods on yield of maize

Treatment	Grain yield (t/ha)				Stover yield (t/ha)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Twin wheel hoe weeding at 20 and 35 DAS	5.48	5.57	4.56	5.20	9.44	9.58	7.85	8.96
Power weeding at 20 and 35 DAS	5.22	5.36	4.51	5.03	8.96	9.22	7.75	8.64
Atrazine at 1 kg/ha + twin wheel hoe weeding at 35 DAS	7.91	7.94	6.99	7.61	13.99	14.04	12.36	13.47
Atrazine at 1 kg/ha + power weeding at 35 DAS	6.68	6.77	5.74	6.40	11.60	11.75	9.95	11.10
Atrazine at 1 kg/ha + hand weeding at 35 DAS	8.27	8.17	7.12	7.85	14.66	14.49	12.63	13.93
Fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS	5.43	5.42	4.47	5.11	9.29	9.27	7.66	8.74
Two hand weeding at 20 and 35 DAS	8.41	8.29	7.22	7.97	15.19	14.97	13.03	14.40
Unweeded check	4.39	4.11	3.44	3.98	7.42	6.94	5.81	6.72
Mean	6.47	6.45	5.51		11.32	11.28	9.63	
	C	W	C x W		C	W	C x W	
LSD (p=0.05)	0.38	0.61	1.06		0.66	1.08	1.88	

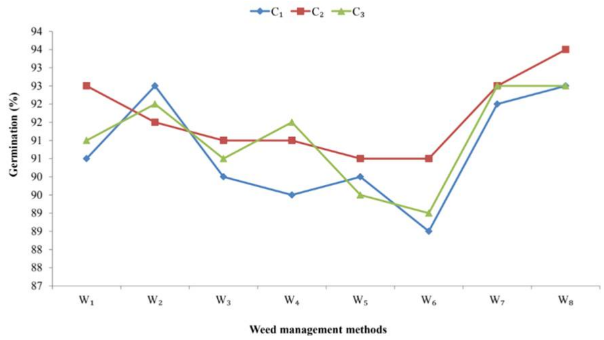
C_1 – 60 x 25 cm (conventional); C_2 - 75 x 20 cm; C_3 - paired row method 90: 30 x 25 cm obtained in hand weeding twice on 20 and 35 DAS (7.97 t/ha) and it was on par with PE atrazine application + hand weeding at 35 DAS (7.61 t/ha). These results are in confirmation with the findings of Prithwiraj *et al.* (2018) who had concluded that PE atrazine application followed by hand weeding at 35 DAS can be adopted as remunerative strategies in case of two hand weeding thus it would resulted in reduction of labour requirement and recorded higher grain yield and B:C ratio. However, PE atrazine application + twin wheel hoe weeding at 35 DAS was statistically at par with these treatments since twin wheel hoe weeding effectively reduced the weed growth and recorded the grain yield of about 7.6 t/ha. Mynavathi *et al.* (2015) findings showed that the twin wheel hoe weeding had significantly improved the maize grain yield to a certain extent. Significant interaction was observed with the altered crop geometry and integrated weed management practices in influencing economic grain yield of maize. It was observed that the yield of maize at the crop geometry of normal row spacing 60 x 25 cm with the weed control practice of two hand weeding at 20 and 35 DAS (60 x 25 cm (conventional) two hand weeding at 20 and 35 DAS) was significantly higher.

Effect on succeeding Bengal gram

The presence of herbicides in the soil as its original form (phytotoxic nature) even after its mission, then it is referred to as persistence and the quantity of herbicides that exist is termed as residue. (Sondhia 2014). Germination of the following crop Bengal gram was found to be unaffected and exerted its normal growth and development (**Figure 1**). This might be due to the degradation of phytotoxic form of herbicides by several ways and resulted in less persistence rate of herbicides.

The residual effect of integrated weed management methods of maize on total weed density and weed biomass of succeeding Bengal gram was found to be significant at 30 DAS. The results showed that the two hand weeded plot and PE application of atrazine + one mechanically weeded plots had recorded lower weed density and biomass. The results are in confirmation with Verma *et al.* (2009) findings that the lowered weed emergence and growth was due to reduced weed seed production in proceeding crop period ultimately leads to decreased weed biomass production. However, the weedy check with higher weed seed bank was observed to have the increased weed biomass production in the succeeding crop.

The growth and yield of succeeding Bengal gram crop were not having any adverse effect due to



C_1– 60 x 25 cm (conventional), C_2– 75 x 20 cm, C_3– paired row method 90: 30 x 25 cm and weed management involves W_1– twin wheel hoe weeding at 20 and 35 DAS, W_2– power weeding at 20 and 35 DAS, W_3– atrazine at 1 kg/ha + twin wheel hoe weeding at 35 DAS, W_4– atrazine at 1 kg/ha + power weeding at 35 DAS, W_5– atrazine at 1 kg/ha + hand weeding at 35 DAS, W_6– fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS, W_7– two hand weeding at 20 and 35 DAS and W_8– unweeded check

Figure 1. Effect of altered crop geometry and integrated weed management of preceding maize on germination of succeeding Bengal gram

the weed management practices for preceding maize. This is in accordance with Aladesanwa and Adejoro (2000) suggested that the crop sown next to maize without suffering a concomitant reduction in crop growth and yield of following crop and concluded that 2,4-D herbicide have negligible effect on succeeding pulse. Herbicide residual effect of atrazine and 2,4-D on subsequent crops were negligible if the interval of herbicide application and succeeding crop was longer and vice versa due to the increased degradation time availability and reduced the persistence of phytotoxic forms of chemicals. Crop rotation with pulses without suffering a yield reduction after maize with the chemical weed control may be adopted. Thus, herbicidal weed management with atrazine and 2,4-D for maize did not impart any significant effect on growth and yield of succeeding Bengal gram.

Application of atrazine at 1.0 kg/ha + hand weeding at 35 DAS recorded higher grain yield with spacing 60 cm x 25 cm and it was followed by PE application of atrazine + twin wheel weeding at 35 DAS (**Table 5**). However, 75 x 20 cm also recorded significant grain yield in comparable to conventional spacing and observed to have higher net returns and B: C ratio when compared to conventional spacing. Since, 75 x 20 cm had consumed less labour requirement and reduced time consumption for field operations. Thus, it is concluded that PE atrazine application at 1.0 kg/ha + twin wheel hoe weeder weeding at 35 DAS adopted in 75 x 20 cm resulted lower plant damage, higher grain yield, net returns and B:C ratio.

Table 5. Effect of altered crop geometry and integrated weed management of preceding maize on grain and haulm yield of succeeding Bengal gram

Treatment	Grain yield (kg/ha)				Haulm yield (t/ha)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Twin wheel hoe weeding at 20 and 35 DAS	662	659	673	665	1.59	1.57	1.58	1.58
Power weeding at 20 and 35 DAS	681	671	688	680	1.62	1.64	1.66	1.64
Atrazine at 1 kg/ha + twin wheel hoe weeding at 35 DAS	659	662	672	664	1.57	1.56	1.58	1.57
Atrazine at 1 kg/ha + power weeding at 35 DAS	675	684	691	683	1.58	1.66	1.64	1.63
Atrazine at 1 kg/ha + hand weeding at 35 DAS	692	691	669	684	1.64	1.66	1.64	1.65
Fodder cowpea as live mulch + brown manuring with 2,4-D at 0.5 kg/ha on 35 DAS	667	677	681	675	1.59	1.60	1.60	1.59
Two hand weeding at 20 and 35 DAS	691	686	679	685	1.64	1.66	1.63	1.64
Unweeded check	687	680	677	681	1.65	1.61	1.60	1.62
Mean	677	676	676		1.61	1.62	1.61	
	C	W	C x W		C	W	C x W	
LSD (p=0.05)	NS	NS	NS		NS	NS	NS	

C_1 – 60 x 25 cm (conventional); C_2 - 75 x 20 cm; C_3 - paired row method 90: 30 x 25 cm

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