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Effect of land configuration and weed management on productivity and profitability of hybrid maize (*Zea mays* L.) during *kharif* season

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Abstract
A field experiment was conducted at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology Kanpur, Uttar Pradesh to assess the effect of land configuration and weed management practices and their interaction on growth of *kharif* season hybrid maize for two consecutive years (2019 and 2020). The experiment consisted of three land configuration as main treatment *viz*; P_1 -flat-bed planting, P_2 -Ridge and furrow planting, and P_3 -Broad bed and furrow planting and six weed management were applied as sub treatment *viz*; W_1 -Pendimethalin @ 1.0 kg ha^{-1} as pre-emergence + Halosulfuron methyl @ 67.5g ha^{-1} at 15-20 DAS as post-emergence, W_2 -Atrazine @ 1.0 kg ha^{-1} as pre – emergence + Halosulfuron methyl @ 67.5g ha^{-1} at 15-20 DAS as post – emergence, W_3 -Pendimethalin @ 1.0 kg ha^{-1} as pre- emergence + Halosulfuron methyl @ 67.5g. ha^{-1} at 15-20 DAS as post – emergence + one hand weeding at 45 DAS, W_4 -Atrazine @ 1.0 kg ha^{-1} as pre – emergence + Halosulfuron methyl @ 67.5g ha^{-1} at 15-20 DAS as post – emergence + one hand weeding at 45 DAS, W_5 -Weed free and W_6 -Weedy check making eighteen treatment combinations which was assigned in a Split Plot Design (SPD) replicated thrice. Hybrid maize variety (DKC –7074) was grown with the recommended agronomic practices. Results showed that, among land configuration methods broad bed and furrow method of planting produce significantly highest grain (60.99 q ha^{-1}), stover (116.14 q ha^{-1}), and biological (176.64 q ha^{-1}) yield as compared to flat-bed method of planting, but statistically at par with the ridge and furrow method of planting. Among weed management practices, weed free plot produce significantly maximum grain (65.53 q ha^{-1}), stover (121.46 q ha^{-1}), and biological (186.99 q ha^{-1}) yield as compared to all other treatment and significantly at par with the treatment where atrazine @ 1.0 kg ha^{-1} as pre-emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS were applied. The maximum gross income (131606.15 ₹ ha^{-1}), net return (93454.34 ₹ ha^{-1}) and B: C ratio (3.43) recorded with the broad bed and furrow method of planting as compared to flat-bed method of planting. Weed free plot produce significantly maximum gross income (140785.30 ₹ ha^{-1}), and net return (100767.15 ₹ ha^{-1}) as compared to all other treatment and significantly at par with the treatment where atrazine @ 1.0 kg ha^{-1} as pre- emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS were applied. While the maximum B: C ratio (3.62) recorded with the herbicidal treatment where atrazine @ 1.0 kg ha^{-1} as pre-emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence applied and significantly superior to all other treatments during both the years as well as pooled basis.

Keywords: Land configuration, weed management, *kharif* hybrid maize, atrazine, halosulfuron methyl

1. Introduction
Maize (*Zea mays* L.) one of the most important cereal crop in the world. It belong to family Poaceae, broadly used in industries besides serving as human food and animal feed. Maize is called 'queen of cereal' because it has highest genetic yield potentiality and wide adaptability under various agro climatic condition than any other cereal crops (Singh, 2013) [18]. Globally, maize is grown on more than 175 m ha area across 165 countries with a production of around 1068.30 m tonnes. India ranks 5th in acreage and 8th in production of maize (Anonymous, 2020a) [2]. In India, maize is the third most important food grain crop after wheat and rice. It is cultivated on 9.72 million hectares area with the production of 28.64 million tonnes having productivity of 2945 kg ha^{-1} and contributes about 3% towards total world production (Anonymous, 2020b) [3].
Land configuration plays a major role in minimizing soil erosion and improving water use efficiency of field crops. Easy and uniform germination as well as growth and development of plant are provided by manipulation of sowing method.

Land configuration increases water use efficiency and also increases availability of nutrients to crops (Chiroma *et al.*, 2008) [5]. The superiority of ridges and furrow system could be ascribed to proper drainage of excess water coupled with adequate aeration at the time of irrigation or heavy rainfall. Ridges and furrow method of sowing improved grain as well as stover yield of maize over the flat bed method of sowing (Parihar *et al.*, 2010) [15].

Maize production suffers greatly due to weed problem, which offers multifarious limitations to the crop. It was found that due to continuous and heavy rains during entire vegetative and early reproductive stages of maize growth, weeds infestation becomes unmanageable throughout the growing period using the traditional method of interculturing and manual weeding. Though these methods are effective in controlling weeds during normal to low rainfall areas, they are tedious and time consuming besides labour intensive and costly. The choice of any weed control measures therefore, depends largely on its effectiveness and economics. Due to increased cost and non–availability of manual labour in required quantity for hand weeding, herbicides not only control the weeds timely and effectively but also offer a great scope for minimizing the cost of weed control irrespective of situation. Use of pre and post-emergence herbicides would make the herbicidal weed control more acceptable to farmers, which will not change the existing agronomic practices but will also allow for complete control of weeds.

Therefore, it is imperative to find out the most suitable weed management practice in relation to productivity and profitability of *kharif* hybrid maize planted with different land configuration methods.

2. Materials and Methods

The experiment was conducted during the mansoon (*kharif*) 19 and 20 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, which is situated in the alluvial tract of Indo - Gangetic plains in central plain zone of Uttar Pradesh between 25° 26' to 26° 58' North latitude and 79° 31' to 80° 34' East longitude at an elevation of 125.9 meters from the sea level. This region falls under agro-climatic zone V (Central Plain Zone) of Uttar Pradesh. This zone has semi-arid climatic conditions having alluvial fertile soil. The normal rainfall of the area is about 864.5 mm per annum (1971–2020) with average maximum temperature 33.09 °C and minimum temperature 24.54 °C. Most of the rains are received during June to September. The soil of the experimental field was originated from alluvial deposits.

The soil type and fertility status were determined by the mechanical and chemical analysis of the soil. In order to ascertain physico-chemical properties of the experimental soil, primary soil samples were drawn randomly up to 15cm depth from different spots of the entire experimental area. The soil of the experimental field was sandy loam in texture, well drained, plane topography, slightly saline in nature having initial values of pH (7.80), EC (0.34 dsm^{-1}), low in organic carbon (0.32%), low in available nitrogen (170.60 kg ha^{-1}), medium in phosphorus (14.10 kg ha^{-1}) and Potash (154.00 kg ha^{-1}).

The field experiment was laid out in Split Plot Design. There were eighteen treatment combinations consisting of three land configuration methods as a main treatment *viz*; P_1 -flat-bed planting, P_2 -Ridge and furrow planting, and P_3 -Broad bed and furrow planting and six weed management were applied as sub treatment *viz*; W_1 -Pendimethalin @ 1.0 kg ha^{-1} as pre – emergence + Halosulfuron methyl @ 67.5g ha^{-1} at 15-20 DAS as post- emergence, W_2 -Atrazine @ 1.0 kg ha^{-1} as pre – emergence + Halosulfuron methyl @ 67.5g ha^{-1} at 15-20 DAS as post – emergence, W_3 -Pendimethalin @ 1.0 kg ha^{-1} as pre-emergence + Halosulfuron methyl @ 67.5g. ha^{-1} at 15-20 DAS as post–emergence + one hand weeding at 45 DAS, W_4 -Atrazine @ 1.0 kg ha^{-1} as pre – emergence + Halosulfuron methyl @ 67.5g ha^{-1} at 15-20 DAS as post – emergence + one hand weeding at 45 DAS, W_5 -Weed free and W_6 -Weedy check. The treatments were replicated three times. Maize variety (DKC –7074) was sown at row to row spacing of 60 cm and plant to plant spacing of 20 cm apart during second week of July with the seed rate of 20 kg/ha during both the years.

The observations were recorded on yield parameters such as grain yield, stover yield, and biological yield. For determining the yield parameters such as grain yield was recorded after threshing and winnowing, weight of grain produce of each plot was done on pan balance and figures obtained were recorded as grain yield in kg per plot area, biological is also recorded after harvest, produce of each plot was weighed on spring balance and figures obtained were recorded in kilograms per plot. Later on these figures were converted into q ha^{-1} on the basis of plot area. While stover yield was worked out by differential method. Cob yield of each plot was subtracted from biological yield of respective treatment plot. Figures so obtained were taken as stover yield in kg per plot. Later it was converted into q ha^{-1} by multiplying with conversion factor on the basis of plot area. The gross monetary returns were calculated by considering the prices of maize cobs and stover yield prevailing at the time of harvest. The money value of both grain and stover yield was added together in order to achieve gross monetary return ₹ ha^{-1}. The net monetary return was calculated by deducting the cost of cultivation from the gross monetary returns.

$$\text{Net monetary returns} = \text{Gross monetry income} - \text{Total cost of cultivation}$$

The benefit cost ratio was calculated as follows

$$\text{B:C ratio} = \frac{\text{Gross monetary returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

The data collected from the experiments were subjected to statistical analysis by applying the procedure for Split Plot Design. Overall differences were tested by 'F' test at 5% level of significance as suggested by (Gomez and Gomez, 1984). In case of significant result, critical difference at 5% level of probability was also calculated for testing the significance between two treatment means.

3. Results and Discussion

3.1 Yield

It is obvious from the data given in (Table 1) grain, stover and biological yield was influenced significantly by different land configurations and weed management practices.

Grain and stover yield is an ultimate result of growth and yield components. Land configuration showed significant influence on yield of crop. Broad bed and furrow method of planting recorded the highest grain yield (60.99 q ha^{-1}), stover yield (116.14 q ha^{-1}), and biological yield (177.13 q ha^{-1}) than other land configuration methods. This was attributed to higher yield attributing characters recorded than ridge and furrow method of planting and flat-bed method of planting, respectively. These results further indicated that increased in yield attributing characters and yields in broad bed and furrow method of planting was due to better growing environment than other land configuration methods. These results are corroborated with the findings of Chavan (2011) [4], Halli and Angadi (2017) [8], Joshi *et al.*, (2018) [9] and Yadav *et al.*, (2019) [19].

Table 1: Effect of land configuration and weed management practices on yield of kharif hybrid maize

Treatment	Biological Yield (q ha^{-1})			Grain yield (q ha^{-1})			Stover Yield (q ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Land configuration									
Flat-bed planting	170.38	172.63	171.50	57.69	59.00	58.35	112.68	113.63	113.16
Ridge and Furrow Planting	174.66	175.41	175.04	59.04	60.35	59.70	115.62	115.06	115.34
Broad Bed and Furrow Planting	176.64	177.63	177.13	60.31	61.68	60.99	116.33	115.96	116.14
S.Em±	1.16	0.91	0.80	0.49	0.51	0.39	0.62	0.44	0.38
C.D (P=0.05)	4.55	3.58	2.60	1.94	1.99	1.28	2.42	1.73	1.24
Weed management									
Pendimethaline @ 1.0 kg ha^{-1} as pre-emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence	179.25	180.87	180.06	61.95	63.27	62.61	117.30	117.59	117.45
Atrazine @ 1.0 kg ha^{-1} as pre-emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence	180.63	182.74	181.69	62.12	63.47	62.79	118.52	118.71	118.62
Pendimethaline @ 1.0 kg ha^{-1} as pre-emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS	182.40	184.08	183.24	62.82	64.19	63.51	119.58	119.90	119.74
Atrazine @ 1.0 kg ha^{-1} as pre-emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS	184.70	185.23	184.96	63.67	65.08	64.38	121.03	120.14	120.59
Weed free	187.09	186.90	186.99	64.83	66.23	65.53	122.25	120.67	121.46
Weedy check	129.27	131.53	130.40	38.68	39.82	39.25	90.58	91.72	91.15
S.Em±	1.65	1.26	1.11	0.62	0.66	0.49	1.41	0.99	0.86
C.D (P=0.05)	4.77	3.65	3.13	1.78	1.91	1.38	4.09	2.86	2.44

Grain, stover as well as biological yield was influenced due to various weed management practices because the higher value of grain, strover, as well as biological yield obtain where the weed population was least. Significantly, the highest grain yield (64.38 q ha^{-1}), stover yield (120.59 q ha^{-1}), as well as biological yield (184.96 q ha^{-1}) can be attributed due to marked improvement in yield attributes under the herbicidal treatment where atrazine @ 1.0 kg ha^{-1} as pre-emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS was applied followed by the application pendimethaline @ 1.0 kg ha^{-1} as pre- emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS (W_3) both were statistically at par but significantly superior over all other treatments. However the maximum grain yield (65.53 q ha^{-1}), stover yield (121.46 q ha^{-1}), as well as biological yield (186.99 q ha^{-1}) recorded in weed free plot which was significantly at par with the treatment where atrazine @ 1.0 kg ha^{-1} as pre- emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS were applied due to relative weed free situation under herbicidal treatments reduced the crop weed competition and thus lead to higher vegetative growth and yield attributes significantly affected the grain and straw yield of maize and the minimum grain yield (39.25 q ha^{-1}), stover yield (91.15 q ha^{-1}), as well as biological yield (130.40 q ha^{-1}) recorded in weedy check plot because of more weed growth and poor performance of yield attributing characters, during both the years. These results are corroborated with the finding of Dash and Mishra (2014) [6], Abdullahi *et al.*, (2016) [1], Patil *et al.*, (2017) [16], Kumar (2018) [10], Nazreen *et al.*, (2018) [14] and Mitra *et al.*, (2018) [12].

3.2 Economics

If weed management is necessary, next step involves its implementation based on costs, returns and other factors. Maximum yield may not always be the ultimate goal. In modern farming maximum profit is more important than maximum yield. The real comparison of different treatments can only be judged on the basis of their economic viability.

The economics of different treatment (table 2) revealed that on the basis of two years data, the maximum gross income (131606.15 ₹ ha^{-1}), net returns (93454.34 ₹ ha^{-1}) and B: C ratio (3.43 ₹ ₹$^{-1}$ invested) was recorded under broad bed and furrow method of planting as compared to ridge and furrow method of planting and flat-bed method of planting, respectively during both the years as well as pooled basis. The results are corroborated with the findings of Nagdeote *et al.*, (2016) [13], Joshi *et al.*, (2018) [9] and Kumar *et al.*, (2018) [11].

Weed-free plot as usual resulted in the highest yields of maize. Accordingly, the gross returns and net return recorded higher than other treatments. Due to the higher cost incurred in hand weeding, net benefit: cost ratio were found to be lower. Among herbicidal treatments, sequential application of atrazine @ 1.0 kg ha^{-1} as pre- emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS recorded highest gross income (138535.37 ₹ ha^{-1}) and net return (99413.22 ₹ ha^{-1}) followed by application pendimethaline @ 1.0 kg ha^{-1} as pre-emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS, both were statistically at par but significantly superior all other treatments during both the years as well as pooled basis. While the maximum benefit: cost ratio (3.62) recorded with the herbicidal treatment where atrazine @ 1.0 kg ha^{-1} as pre-emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence followed by atrazine @ 1.0 kg ha^{-1} as pre- emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS was done recorded significantly superior result over all other treatments during both the years due to higher grain yield and lower cost of cultivation. The minimum gross income (87737.33 ₹ ha^{-1}), net return (53983.19 ₹ ha^{-1}) as well as benefit: cost ratio (2.60) recorded in weedy check plot during both the years due to lowest grain, stover yield and lower weed control efficiency. These results are corroborated with the findings of Abdullahi *et al.*, (2016) [1], Sheela *et al.*, (2016) [17], and Mitra *et al*., (2018) [12].

Table 2: Effect of land configuration and weed management practices on Economics of kharif hybrid maize

Treatment	Total Cost of Cultivation	Gross Income			Net Return			B:C Ratio		
		2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Land configuration										
Flat-bed planting	38354.81	121823.27	126284.25	126284.25	83468.45	92390.42	87929.44	3.16	3.39	3.28
Ridge and Furrow Planting	37803.81	124716.43	129115.59	129115.59	86912.62	95710.94	91311.78	3.28	3.51	3.40
Broad Bed and Furrow Planting	38151.81	127081.47	131606.15	131606.15	88929.65	97979.02	93454.34	3.31	3.55	3.43
S.Em±	-	896.11	974.14	876.89	1029.95	1023.53	922.38	0.01	0.01	0.01
C.D (P=0.05)	-	3518.58	3824.96	2859.69	4044.09	4018.89	3008.05	0.05	0.06	0.05
Weed management										
Pendimethaline @ 1.0 kg ha^{-1} as pre- emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence	38302.15	130151.87	139398.40	134775.13	91849.72	101096.25	96472.99	3.40	3.64	3.52
Atrazine @ 1.0 kg ha^{-1} as pre- emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence	37382.15	130658.33	140080.80	135369.57	93276.19	102698.65	97987.42	3.50	3.75	3.62
Pendimethaline @ 1.0 kg ha^{-1} as pre- emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS	40042.15	132092.87	141525.70	136809.28	92050.72	101483.55	96767.14	3.30	3.53	3.42
Atrazine @ 1.0 kg ha^{-1} as pre- emergence + Halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence + one hand weeding at 45 DAS	39122.15	133839.33	143231.40	138535.37	94717.19	104109.25	99413.22	3.42	3.66	3.54
Weed free	40018.15	136112.27	145458.33	140785.30	96094.12	105440.19	100767.15	3.40	3.64	3.52
Weedy check	33754.15	84387.67	91087.00	87737.33	50633.52	57332.85	53983.19	2.50	2.70	2.60
S.Em±	-	1039.66	1074.17	822.92	701.37	792.48	648.50	0.01	0.01	0.01
C.D (P=0.05)	-	3002.74	3102.43	2327.90	2025.71	2288.84	1834.50	0.04	0.04	0.03

4. Conclusion
The results obtained from the present investigation it has been concluded that the application atrazine @ 1.0 kg ha^{-1} as pre-emergence + halosulfuron-methyl @ 67.5 g ha^{-1} at 15-20 DAS as post emergence in relation to productivity and profitability of *kharif* hybrid maize planted with broad bed and furrow method of land configuration is most suitable for higher income.

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