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CROP RESIDUE MANAGEMENT IN NO-TILL MAIZE: INFLUENCE THE GROWTH, YIELD AND ECONOMICS OF *KHARIF* MAIZE (*ZEA MAYS* L.)

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SUMMARY

In a field experiment conducted at Regional Research Station, Uchani, Karnal of CCS Haryana Agricultural University, Hisar during *kharif* 2015, maize (*Zea mays* L.) under zero tillage (ZT) with residue retention recorded superior growth parameters *viz*. plant height, leaf area index, dry matter accumulation at all crop growth stages with improvement in grain yield (7322 kg/ha), stover yield (9115 kg/ha), biological yield (16437 kg/ha) and harvest index (HI) (44.64%). However, the benefit cost ratio (B: C) was more under ZT without residues. Zero tillage with residue recorded maximum crop growth rate (CGR) (2.77-25.64 g/m^2/day) at all growth stages except at harvest where maximum CGR (25.44 g/m^2/day) was recorded under raised bed with residue than other methods. The hybrid HM-4 provided maximum grain yield (7037 kg/ha), net returns (Rs. 58749/ha) and B: C (2.18), while hybrid HM-10 recorded higher growth parameters, stover yield (9409 kg/ha) and biological yield (16241 kg/ha). Atrazine @ 750 g/ha pre-emergence followed by 1 hand weeding at 30 days after sowing with better growth parameters, yield and HI proved more remunerative as compared to unweeded check.

Key words : Economics, growth parameter, maize, residues, yield, zero-tillage

Maize (*Zea mays* L.) is one of the most important grain and fodder crop in many parts of world. It is grown over an area of 177 m ha with total production of 967 m tones in more than 150 countries of the world. Major maize growing countries are USA, China, Brazil, Mexico, France and India. It accounts for 18% cereal acreage, 25% productivity and 28% production of world. India ranks fourth in area and sixth in production of maize. It is the third important cereal crop with an area of 9.4 m ha and production of 23 m tones; with the highest per day productivity after rice and wheat in India (Anonymous, 2014a). India contributes about 15% and 5% to total maize area, while 8% and 2.4% to total production in Asia and world, respectively (FAOSTAT, 2014). It has high nutritive value as it contains protein (7.7-14.6%), crude fiber (0.8-2.3%), carbohydrates (69.7-74.5%), fats (3.2-7.7%) and ash (0.7-1.3%). About 50-55% of total maize production is used as food in developing countries (Anjum *et al*., 2014).

Global maize demand and supply are influenced by the rapid expansion of the bio-fuel industry and high fossils energy costs in recent years. The increasing demand for maize is rapidly transforming cropping systems in certain parts of Asia. In India, its current consumption is as poultry-pig-fish feed (52%), human diet (24%), cattle feed (11%) and seed and brewery industry (1%) (Yakadri *et al.*, 2015). In Haryana, it was grown in an area of 9,000 ha with production of 27,000 tones and productivity of 3.0 t/ha during the year 2014 (Anonymous, 2014b). So, Haryana state has an ample scope to increase its acreage and productivity as it can be a strong candidate in the drive of crop diversification to displace puddled transplanted rice. A number of hybrids are available for cultivation in Haryana and their suitability to different establishment methods, crop residue and weed management practices may vary. Hence, there is need to evaluate the performance of different hybrids including quality protein maize under different planting methods and residue retention on productivity and economics during *kharif* season.

MATERIALS AND METHODS

A field experiment was conducted at CCS Haryana Agricultural University, Regional Research Station, Uchani, Karnal, Haryana (India) during *kharif* 2015 to study the effect of different planting methods with and without residue and weed management on the growth, yield and economics of *kharif* maize hybrids. Karnal is situated at 245 meters above mean sea level with longitude of 67.58^0 North and latitude 29.43^0 East. The climate of area is distinguished as sub-tropical and semi-arid with a severe cold during winter and hot days often with desiccating winds of average intensity during summer. The climate data were recorded at meteorological observatory of Central Soil Salinity Research Institute (CSSRI), Karnal. The average maximum temperature varied from 29.8^0 to 41.6 ^{0}C and minimum temperature from 16.5^0 to 27.9 ^{0}C during the crop season. The mean weekly value for morning and evening relative humidity ranged from 57.1 to 97.4% and 31.0 to 77.1%, respectively. A total of 430.3 mm rain was received during the crop season and sunshine hours ranged from 1.7 to 9.8. The soil of experiment field was clay loam in texture with electrical conductivity (0.31 dS/m), low in available N (123.0 kg/ha), medium in available P_2O_5 (25.2 kg/ha), available K_2O (225.0 kg/ha) and organic carbon (0.41%) and slightly alkaline in reaction (pH 8.4). Four main plot treatments (planting methods) included *viz*., raised bed with residue (RB+R), raised bed without residue (RB-R), zero tillage with residue (ZT+R) and zero tillage without residue (ZT-R). Six sub-plot treatments comprised combination of three maize hybrids *viz*., HQPM-1, HM-4 and HM-10 and two weed control treatments *viz*., atrazine 750 g/ha pre-emergence (PRE) followed by (*fb*) one hand weeding (HW) at 30 days after sowing (DAS) and unweeded check. The experiment was laid out in split plot design with three replications. After the harvest of wheat in April, land preparation was done as per treatments for raised bed sowing (3 harrowing, two cultivator and planking before making raised beds). Sowing of maize hybrid HQPM-1, HM-4 and HM-10 was done on 25 June, 2015 using a seed rate of 20 kg/ha. Sowing in raised bed was done with bed planter and in flat bed with zero-till seed-cum- fertilizer drill keeping row to row spacing of 75 cm. After that surface application of wheat residue @4 t/ha was done in raised beds and zero tillage sowing as per treatments. In order to maintain spacing of 75 × 20 cm, need based thinning and gap filling was done manually at 20 DAS. The plant height (cm) was measured from the base of the plant to the fully opened top leaf at 20, 40, 60 DAS and at crop maturity. After tasseling, plant height was measured from the base of the plant to collar of the flag leaf and expressed in centimetre (cm). Leaf samples from three randomly selected plants for each plots were taken at 20, 40, 60 DAS and at harvest. Leaf area index (LAI) was worked out by using the formula given by Sestak *et al.* (1971).

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied per plant (cm}^2\text{)}}$$

Plant dry matter accumulation (PDMA) and crop growth rate (CGR) were calculated by selecting the number of plants per 0.5 meter row length (mrl) from each plot and carefully uprooting to take dry matter accumulation at 20, 40, 60 DAS and crop maturity. These samples after sun-drying were further dried at 70 ^{0}C in oven to achieve a constant weight and PDMA (g/m^2) was calculated. Dry weight gained by plant material per unit of time was expressed as CGR (g/m^2/day). CGR was computed as:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{\text{Land area (m}^2\text{)}}$$

Where, W_1 and W_2 dry matter accumulation at time t_1 and t_2, respectively.

Harvesting of maize hybrid HM-4 was done on 22 September 2015 and; HQPM-1 and HM-10 on 29 September 2015 from respective plots manually. Net returns was computed for each treatment after subtraction of total cost of cultivation from gross returns and benefit-cost ratio was calculated by dividing gross returns with total cost of cultivation.

RESULTS AND DISCUSSION

Effect of planting methods and residues on growth parameters

Growth parameters (plant height, LAI, CGR and PDMA) play the most important role contributing to the grain yield, stover yield, biological yield and ultimately the economics of maize. Maximum plant height was recorded in ZT+R at 20, 40, 60 DAS and at harvest (all growth stages), but at par with ZT-R (at 20, 40 and 60 DAS) and RB+R (at harvest) (Table 1). This can be ascribed to earlier establishment and better vigour under more favourable soil micro climate under ZT. More plant height of maize was reported earlier also under ZT *fb* furrow irrigated raised bed system (FIRBS) (Awasthi, 2014). Under ZT, emergence of seedlings was early, root penetration was deeper and it escaped from temperature stress during initial growth period due to decreased soil temperature (Jat, 2015). LAI increased up to 60 DAS under different planting

TABLE 1

Effect of planting methods, residue and weed management on growth parameters in different maize hybrids at different growth stages

Treatment	Plant height (cm)				Leaf area index				Plant dry matter accumulation (g/m²)			
	DAS			Harvest	DAS			Harvest	DAS			Harvest
	20	40	60		20	40	60		20	40	60	
Planting methods												
Raised bed with residue	21.72	99.02	213.78	231.61	0.37	4.57	6.29	5.22	47.12	405.22	901.51	1623.20
Raised bed without residue	20.94	92.47	204.50	219.06	0.33	4.18	5.76	4.65	41.04	381.75	853.73	1567.43
Zero tillage with residue	26.21	126.39	220.54	235.33	0.66	5.58	6.35	5.42	55.47	444.90	957.57	1665.14
Zero tillage without residue	24.79	122.67	215.84	226.67	0.55	4.47	5.47	4.61	47.51	431.43	936.39	1625.93
SEm±	0.53	1.52	1.70	1.52	0.01	0.11	0.07	0.14	0.18	2.03	5.58	3.14
CD (P=0.05)	1.82	5.26	5.85	5.24	0.03	0.37	0.24	0.49	0.61	7.01	19.26	10.83
Maize hybrids												
HQPM-1	22.06	106.25	210.65	226.54	0.50	4.86	5.30	4.65	46.52	375.72	844.01	1596.82
HM-4	22.94	108.39	210.78	227.04	0.47	4.53	6.07	5.09	44.97	412.30	916.59	1582.93
HM-10	25.24	115.77	219.57	230.92	0.45	4.72	6.53	5.18	51.86	459.45	976.31	1681.54
SEm±	0.62	0.91	1.33	0.89	0.01	0.09	0.08	0.08	0.18	1.90	3.79	3.30
CD (P=0.05)	1.76	2.61	3.81	2.56	0.02	0.25	0.23	0.23	0.51	5.44	10.84	9.44
Weed control												
Atrazine 750 g/ha (PRE) fb 1 HW at 30 DAS	24.46	115.59	225.96	240.47	0.54	5.24	6.33	5.16	52.92	498.15	1043.56	1796.71
Unweeded check	22.37	104.68	201.37	215.86	0.42	4.16	5.61	4.79	42.65	333.50	781.04	1444.14
SEm±	0.50	0.74	1.09	0.73	0.01	0.07	0.07	0.07	0.15	1.55	3.10	2.70
CD (P=0.05)	1.44	2.13	3.11	2.09	0.02	0.20	0.19	0.19	0.42	4.44	8.85	7.71

methods, maize hybrids and weed control treatments, but it declined at maturity which might be attributed to drying of leaves (Table 1). Higher LAI was found at all growth stages under ZT+R, but at par with RB+R (at 60 DAS and harvest). Awasthi (2014) has also reported highest LAI under ZT *fb* FIRBS and conventional tillage (CT) in maize. Higher CGR at 20, 40 and 60 DAS was recorded under ZT+R, however, it was at par with ZT-R (at 40 and 60 DAS) and RB+R (at 60 DAS). In general, CGR showed

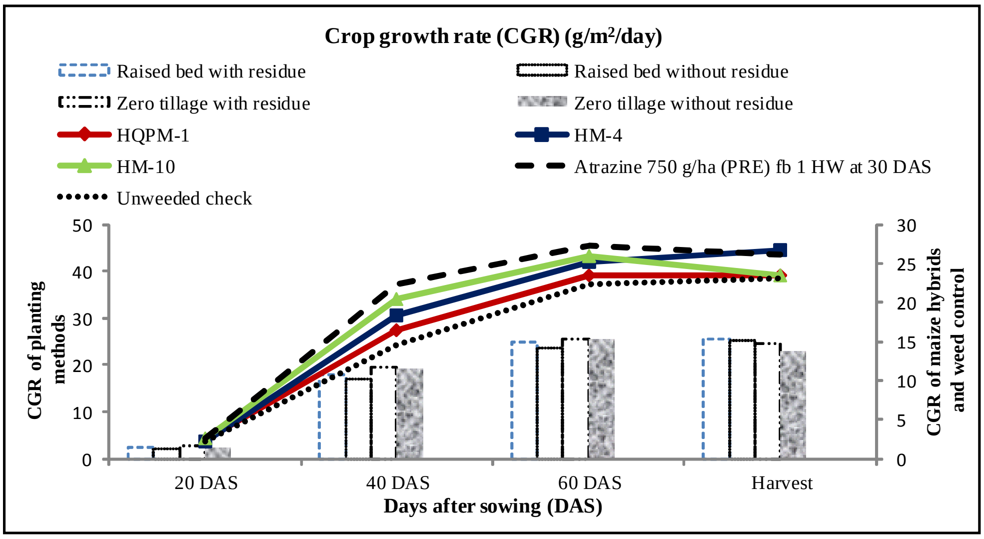

Fig. 1. Crop growth rate as influenced by different planting methods, maize hybrids and weed control.

increasing trend from 20 DAS to harvest across planting methods except ZT+R and ZT-R at harvest. Maximum CGR (25.44 g/m^2/day) at harvest was recorded under RB+R *fb* ZT+R (24.69 g/m^2/day), ZT-R (22.97 g/m^2/day) but, at par with RB-R (25.17 g/m^2/day) (Fig. 1). Higher CGR might be attributed to vigours growth of maize crop, higher plant height and LAI. Maximum PDMA was recorded in ZT+R *fb* ZT-R, RB+R and lowest in RB-R at all growth stages (Table 1). This could be due to better environment for growth and development, where moisture was used more efficiently resulting in increased photosynthetic potential (Avatar *et al.*, 2010).

All growth parameters were higher under residue retention as compared to without residue (Fig. 1 and Table 1). Better moisture retention and micro climate under residue mulch might be the reason for improved growth parameters. Mulching has been reported to result in increased plant height over no-mulching (Singh *et al.*, 2015).

Effect of maize hybrids and weed control on growth parameters

Maize hybrid HM-10 recorded the higher plant height, LAI (except at 20 and 40 DAS), CGR (except at harvest) and PDMA at all growth stages than other maize hybrids, but LAI was at par with HM-4 at harvest. Higher LAI at 20 and 40 DAS was recorded under HQPM-1 than other hybrids, but at par with HM-10 at 40 DAS (Table 1). HM-10 recorded the maximum CGR from 20 to 60 DAS (2.59-25.84 g/m^2/day) except at harvest (23.51 g/m^2/day) than other maize hybrids. While, HM-4 performed better with respect to CGR (26.65 g/m^2/day) at harvest, because maturity period for HM-4 was less than HM-10 and HQPM-1. In general, CGR showed an increasing trend from 20 DAS to harvest (Fig. 1). Higher CGR might be attributed to vigours growth of maize crop, higher plant height and LAI. Such variations in different hybrids of maize are expected due to their inherent growth habits. Growth parameters are also strongly influenced by environmental conditions during stem elongation and other growth stages, although there is considerable varietal variation in this characteristic (Dawadi and Sah, 2012). Plant height, LAI, CGR (2.65-26.12 g/m^2/day) and PDMA were higher under atrazine 750 g/ha (PRE) *fb* 1 HW at 30 DAS than unweeded check at all growth stages (Fig. 1 and Table 1). This could be attributed to better control of weeds in early and late growth stages of crop which provided the crop plants better environment for utilizing growth

TABLE 2
Effect of planting methods, residue and weed management on grain yield, stover yield, biological yield, harvest index and economics in different maize hybrids

Treatment	Yield (kg/ha)			Harvest index (%)	Net returns (Rs./ha)	B : C
	Grain	Stover	Biological			
Planting methods						
Raised bed with residue	6996	9002	15998	43.53	50866	1.88
Raised bed without residue	6290	8605	14894	42.22	50791	2.08
Zero tillage with residue	7322	9115	16437	44.64	59958	2.13
Zero tillage without residue	6421	9009	15429	41.63	57474	2.35
SEm±	125	47	164	0.35	-	-
CD (P=0.05)	432	161	565	1.22	-	-
Maize hybrids						
HQPM-1	6402	8408	14811	42.98	49230	2.01
HM-4	7037	8980	16017	43.42	58749	2.18
HM-10	6832	9409	16241	42.60	56388	2.14
SEm±	64	36	56	0.35	-	-
CD (P=0.05)	184	103	160	NS	-	-
Weed control						
Atrazine 750 g/ha (PRE) fb 1 HW at 30 DAS	7701	9811	17512	44.06	66593	2.29
Unweeded check	5813	8054	13867	41.94	42951	1.93
SEm±	53	29	46	0.25	-	-
CD (P=0.05)	150	84	131	0.71	-	-

resources efficiently resulting in better growth. Yakadri *et al*. (2015) have also concluded that integrated weed management like PRE application of atrazine (1.5 kg/ha) *fb* HW at 30 DAS resulted into higher growth parameter over unweeded check at all stages of crop growth.

Yield and yield attributes

Maize under ZT+R recorded highest grain yield, stover yield, biological yield and harvest index (HI) among all establishment methods; however, ZT+R was statistically similar to RB+R (grain yield, biological yield and HI) and ZT-R (stover yield) (Table 2). The increase in grain yield of maize under ZT+R could be attributed to higher yield attributes whereas; the increase in stover and biological yield were due to higher growth parameter. Higher grain yield under ZT might also be due to better soil environment and longer grain filling duration resulting in bolder grains (Jat, 2015). Residue retention resulted in improved grain yield, stover yield, biological yield and HI as compared to without residue under both methods of planting, *viz*. ZT and raised bed (Table 2). Singh *et al.* (2015) also reported that maize had significantly higher grain yield and stover yield in the plots under mulching. Increase in number of plants, plant height along with LAI, through dry matter production resulted in higher growth parameters and hence better stover and biological yield under ZT *fb* raised bed system (Singh *et al*., 2010).

Maize hybrid HM-4 provided maximum grain yield but the stover and biological yield were significantly higher in HM-10 (Table 2). The increase in grain yield could be attributed to the higher yield attributing parameters in HM-4, whereas, higher stover and biological yield were mainly because of more PDMA in HM-10 maize hybrid. Harvest index was not significantly influenced by maize hybrids. This could be due to the fact that grain and biological yield almost increased in the similar pattern under different maize hybrids as reported earlier also (Zamir *et al*., 2011). Significantly higher grain yield, stover yield, biological yield, and HI were recorded under atrazine 750 g/ha (PRE) *fb* 1 HW at 30 DAS than unweeded check (Table 2). Yakadri *et al*. (2015) has also concluded that integrated weed management like PRE application of atrazine (1.5 kg/ha) *fb* HW at 30 DAS lowered the weed density and dry matter in maize with significantly higher yield over unweeded check at all stages of crop growth.

ECONOMICS

Economic analysis of crop decides the economic viability of the treatments. So, maize sown in ZT+R recorded highest net returns among all establishment methods. It might be due to saving in cost of preparatory tillage and irrigation water, ultimately lowest the total cost of cultivation. Lower net returns were recorded under raised beds, which might be due to maximum cost incurred on bed making and tillage operations (Table 2). Residue retention resulted in improved net returns as compared to without residues under both methods of planting, *viz*. ZT and raised bed due to maximum harvest index. Benefit cost ratio (B: C) was more under ZT than raised bed, but less with residue retention than without residues (Table 2). Lower B: C under residue retention could be attributed to counting the cost of crop residues. HM-4 provided maximum net returns and B: C *fb* HM-10 and HQPM-1. Net returns and B: C were more under atrazine 750 g/ha (PRE) *fb* 1 HW at 30 DAS than unweeded check (Table 2). Yakadri *et al*. (2015) have also concluded that PRE application of atrazine (1.5 kg/ha) *fb* HW at 30 DAS resulted into lower weed density and dry matter in maize with significantly higher B: C and net returns over unweeded check.

Based on the present findings, it might be elucidated that *kharif* or rainy season maize attained better growth and productivity under zero tillage with wheat residues retention. However, B-C ratio was more under ZT without residues. This becomes important for making decision to opt for ZT accordingly particularly in areas where wheat residue is short in supply. Hybrid maize HM-4 resulted into higher productivity and profitability compared to HM-10 and HQPM-1. Atrazine 750 g/ha applied pre-emergence *fb* 1 HW at 30 DAS proved very effective to manage weeds in maize.

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