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Time, intensity of detasseling rainfed maize (*Zea mays*) for improving productivity, economics and rainwater-use efficiency

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ABSTRACT

A field experiment was conducted in factorial RBD with three replications during *kharif*, 2010–2012 at Bhilwara, India to study the effect of time and intensity of detassling of rainfed maize on its productivity, economics and rainwater use efficiency. Maize was detassled for 3 time series namely Just after emergence (JAE), 3 Days after emergence (3 DAE) and 7 Days after emergence (7 DAE) and for 4 intensities such as 25, 50, 75 and 100% removal. Detassling had strong positive effect on productivity and economics, particularly during moisture stress situations, suggesting that detasseling is beneficial. Detasseling 7 DAE increased the grain and yield by 22, 9 and 12% in comparison to detasseling JAE during 2010, 2011 and 2012, respectively. The respective figures for these three years for detasseling at 3 DAE were 15, 6 and 10%. Among the intensities, tassel removal up to 50% was the most effective in improving yield characters and yields during all three years and was economically viable. The higher net return and B:C ratio were recorded with detasseling 7DAE. The 50% tassels removal gave the highest net returns. The factor productivity and rainwater use efficiency also improved by various treatments. Detasseling was highly sustainable for physical production and moderately sustainable for viable sustainable Index.

Key words: Detassling, Net returns, Rainwater use efficiency, Sustainability

Maize (*Zea mays* L.) is versatile crop having wider adaptability under varied agro-climatic conditions and has the highest genetic yield potential among cereals (Yadav *et al.* 2015). In India, its acreage is around 6 Mha since early 1970s, but production is much below the potential (Jakhar *et al.* 2017a) because productivity remains highly unstable with annual twists primarily fashioned by the behaviour of rainfall. Pattern of rainfall decides the length of crop season with or without incidence of dry spells during growth and reproduction stages, and has determining effect on productivity (Jakhar *et al.* 2017b) that needs to be improved for livelihood security in rainfed maize based production systems (Mozafari *et al.* 2018). Detasseling alleviate negative effects of water deficits stress on maize yield (Subedi 1996).

Fodder production is equally important, as livestock is integral part of maize based farming system of Rajasthan and adequate availability of green fodder is a challenge. Farmers pull out the tassels from standing maize crop intermittently and feed them to livestock and this additional supply of quality green fodder improves their productivity without additional expenses. Tassels disperse their pollen after 3–7 days of their emergence and most likely, the pollens seldom fertilize the silk of same plant. The single plant tassel produces the amount of pollen that can fertilize minimum four plants in vicinity (Smith *et al.* 2004), therefore, excessive production of pollens goes waste but still extracts huge amount of energy. The energy consumed in producing pollens that are destined to be as wasted, may be diverted towards sink of the plant by removing some tassels for better crop productivity through accumulating the higher biomass and improved translocation of the accumulated biomass towards sink (Jakhar *et al.* 2017b). There is lack of credible information available pertaining to effects of tassel removal during different times of crop phenologies and intensities of removal. Under such background, present research experiment was formulated and conducted for 3 years.

MATERIALS AND METHODS

An experiment was conducted at Dryland Farming Research Station (MPUAT), Bhilwara (India), situated at 24°20' N and 74°20' E and 432 m AMSL during the *kharif* 2010, 2011 and 2012. Experimental soil was sandy clay loam having pH, EC, organic carbon and bulk density as 8.15, 0.43 dS/m, 0.48% and 1.63 g/cc, respectively. The soil was having available N, P_2O_5 and K_2O as 245, 41 and 465 kg/ha, respectively. The moisture retention of soil

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at field capacity and permanent wilting point were 21.3 and 9.1%, respectively and the water holding capacity was 27.4%. The area is semi-arid with annual rainfall of 657.5 mm (Table 1) with expected crop growth season of about 86–106 days. The field was prepared through one deep ploughing by disc plough followed by two cross harrowing and planking. The experiment was laid out in Factorial RBD with three replications. Three time series for tassel removal, viz. 'Just after emergence' (JAE), '3 Days after emergence' (3 DAE) and '7 days after emergence' (7 DAE) and four tassel removal intensities (25, 50, 75 and 100%) were taken as two factors. Observed data were also analysed as control versus rest for assessing the impact of detassling. Composite maize Navjot was taken during first two years of experimentation, however, during 2012, due to very late onset of monsoon rains, short duration hybrid PEHM-2 was taken for raising test crop. The crop was sown in rows 60 cm apart and plant-to-plant distance was maintained as 25 cm by thinning out extra plants after 10 days. The crop was sown on 26.06.2010, 28.06.2011 and 15.07.2012 and harvested on 05.10.2010, 07.10.2011 and 08.10.2012, respectively. Other package of practices was followed as per the zonal recommendations. Detassling was done manually and a simple process was adopted in which the plant tassels were grabbed and pulled upward keeping all the upper maize leaves intact without any harm to them. Removed tassels weighed and imputed value @ ₹ 2 per kg of fresh tassel was used while calculating economics. For recording yield attributes, three random plants were selected from sampling rows of each plot and average of values, thus obtained, were used. The observations recorded were analysed statistically following standard statistical methods.

To work out rainfall water use efficiency for physical production and monetary returns following formulae were used;

$$\text{Rainfall Water Use efficiency (kg grain/ha/mm)} = \frac{\text{Grain Yield (kg/ha)}}{\text{Rainfall received during crop season (mm)}}$$

$$\text{Economic efficiency of Rainfall Water (₹/ha/mm)} = \frac{\text{Net Returns (₹/ha)}}{\text{Rainfall received during crop season (mm)}}$$

For working out average factor productivity for physical and economic returns, the following formulae were used;

$$\text{Average factor productivity (kg grain/ha/day/)} = \frac{\text{Grain Yield (kg/ha)}}{\text{Crop Duration (days)}}$$

$$\text{Average economic productivity (₹/ha/day/)} = \frac{\text{Net Returns (₹/ha)}}{\text{Crop Duration (days)}}$$

Sustainability of treatments was worked out for grain yield and economic value by following standard statistical procedures, utilizing data of three years for grain yield (kg/ha) and net returns (₹/ha) and expressed as Sustainability Yield Index (SYI) and Sustainability Value Index (SVI), respectively.

Table 1 Details of rainfall situation and growing period of crop during 2010-2012 (3 years)

Particular	Years		
	2010	2011	2012
Rainfall details			
Total Rainfall during rainy season (mm)	792.8	722.0	625.3
Total rainfall during crop season (mm)	592.0	712.0	518.2
Deficit of rainfall than normal during season	17 days (9 July 2010 to 25 July 2010)	Nil	Nil
Dry spells of >10 days during crop season	18 days (12 September 2010 to harvest)		
Date of sowing	26.06.2010	28.06.2011	15.07.2012
Date of harvesting	05.10.2010	07.10.2011	08.10.2012
Effective cropping season (days)	102	106	86
Crop variety	Navjot (Composite)	Navjot (Composite)	Maize – PEHM 2

Rainfall normal =657.7 mm

RESULTS AND DISCUSSION

Yield attributes and yield: Detasseling had significant positive effect on number of cobs per plant, number of grain in line per cob, number of grains per cob and 1000 grain weight (Table 2). Moreira *et al.* (2010) also reported that detasseling improved growth and yield characters of maize.

Timing of tassel removal was more effective in improving yield contributing characters. Cobs per plant increased significantly up to 3 DAE (1.11, 1.19 and 1.21 cobs per plant) that was 4.71, 14.42 and 3.41 % higher over JAE during three years and the 3 DAE and 7 DAE were at par. The number of grains per line also followed the similar trend and 3 DAE produced 25.5, 15 and 15% higher grains as compared with JAE during respective years. Significant improvement in number of grains per cob was also found (22 and 15% higher) where tassel were removed 3 DAE, compared to JAE, remaining at par with 7 DAE during 2010 and 2011, however, during 2012, 7 DAE was significant to JAE but again this was at par with 3 DAE. The highest grain yield per plant was with 7 DAE followed by 3 DAE, both of these remaining at par were significantly better to JAE during first two years, however, during third year, all were at par. During 2012, the crop season was the smallest due to delayed rainfall and the highest impact was observed on single plant grain yield. Various intensities of tassel removal did not have any significant variation for single plant grain yield. During 2010, the test weight was the highest with 3 DAE followed by 7 DAE and JAE and all three were significantly different. Detasseling probably,

Table 2 Performance of yield characters (at harvest) and yields (kg /ha) as influenced by time and intensity of de-tasseling of maize

Treatment	Cobs/plant			No. of grains/line			Grains/cob			Grain yield (g)/ plant			Test weight-1000 seed		Grain			Stover			Biological		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2010	2011	2012	2010	2011	2012	2010	2011	2012
											Control v/s Rest												
Control	1.00	0.93	1.00	33.00	28.00	23.33	440	379	321	87.50	83.75	49.33	197.24	182.68	3409	3721	2704	5942	8594	6093	9352	12315	8796
Rest	1.09	1.15	1.18	31.44	32.92	30.58	460	452	434	94.78	100.29	63.84	202.35	184.82	4193	4540	3321	8067	9546	7466	12260	14086	10787
	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	NS	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
											Time of tassel removal												
JAE	1.06	1.04	1.17	26.50	29.83	27.83	390	404	399	84.79	87.29	58.85	191.89	183.66	3731	4319	3087	7709	8853	6844	11441	13171	9931
3 DAE	1.11	1.19	1.21	33.25	34.33	32.00	477	466	442	98.81	103.40	65.67	209.30	184.72	4280	4574	3399	8467	9373	7666	12747	13947	11065
7 DAE	1.11	1.23	1.17	34.58	34.58	31.92	513	485	462	100.73	110.17	67.00	205.87	186.08	4568	4726	3476	8023	10413	7890	12592	15139	11366
SEm+	0.01	0.05	0.05	1.95	1.00	1.15	19	20	17	4.12	3.20	2.72	3.88	2.87	140	79	92	339	219	186	385	268	267
CD (P=0.05)	0.04	0.13	0.14	5.68	2.93	3.36	55	60	49	12.03	9.34	NS	11.33	NS	409	231	270	NS	638	542	1123	782	778
											Intensity of removal (%)												
25	1.08	1.14	1.11	32.00	31.89	29.67	459	443	426	92.28	96.33	58.22	192.36	185.03	3756	4173	2991	7487	8821	6793	11243	12994	9784
50	1.12	1.17	1.25	31.33	33.78	30.22	471	470	422	98.89	102.32	67.03	210.32	184.24	4407	4715	3534	8351	9823	7948	12758	14537	11482
75	1.09	1.19	1.17	31.00	33.22	32.11	448	444	443	94.14	102.24	66.33	203.17	186.56	4331	4562	3440	8203	9821	7702	12534	14383	11142
100	1.07	1.11	1.19	31.44	32.78	30.33	461	450	445	93.81	100.25	63.78	203.55	183.44	4279	4709	3318	8225	9720	7423	12504	14429	10741
SEm+	0.02	0.05	0.06	2.25	1.16	1.33	22	24	20	4.76	3.70	3.14	4.48	3.31	162	91	107	391	253	214	444	309	308
CD (P=0.05)	0.05	NS	0.16	6.56	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	473	267	311	NS	737	625	NS	903	899

JAE, Just After Emergence; DAE, Days After Emergence.

increases the hormones disponibility for cob growth and development and the tassel can dominate the cobs and thus limit grain yield by modifying the supply of growth regulators. Velma (2013) also observed that detasseled young maize significantly produced more cobs per plant, longer cob and heavier cob of maize than tassled control. The beneficial impact of detassling on yield contributing characters has also been reported by Barbieri (2000). The intensity of tassel removal did not have much effect on various yield contributing characters except cobs per plant observed during 2010 and 2012 and number of grains per line during 2010. The 50% tassel removal produced greater number of cobs per plant and grains per line in cobs.

The effect of detassling improved the biomass accumulation that reflected in the increased biological yield to the tune of 31, 14.4 and 22.6% during respective years in comparison to untasseled control. During 2011, the situation was highly favourable getting more than normal rainfall, well distributed across the crop season with no dry spell, having the longest crop season giving the highest biological yield. However, during 2011 detassling could bring only 14.4% increase than control against the corresponding increase observed during 2010 and 2012 those were not as favourable years in terms of onset, amount and distribution of rainfall. During 2010, detassling increased biomass accumulation by 31.1% as compared to control while during 2012 such increase was 22.6%. During 2010, though amount of rainfall received was more and it also witnessed much longer crop duration in comparison to year 2012. However, during 2010 two dry spells of 17 and 18 days were experienced during early growth phase and terminal phase of crop, respectively coinciding with early growth and reproduction and grain development stages. During 2012, aberration was in form of late onset of rains that partly offset by substituting the variety with shorter duration. Thus, it is quite evident that detassling has positive effect on biomass accumulation and such positive effect becomes stronger as the incidence and magnitude of moisture stress increases. During each year of 2010 and 2012, detasseling improved the grain yield by 23% against 22% increase during year of 2011 as compared with control, suggesting that detasseling is beneficial during all the three years. Detasseling also improved the stover yield of crop, that increased by 35, 11 and 23% over control during respective years. Singoi *et al.* (2006) and Heidari (2013) also reported that tassel removal increase the seed yield and the seed quality of maize.

Detasseling of maize 7 DAE increased grain yield by 22, 9.0 and 12%, and stover yield by 4, 17 and 15% in comparison to JAE during respective years (Table 2). The respective figures for these three years for 3 DAE were 15, 6 and 10% for grain and 9, 5 and 12% for stover, respectively in comparison to JAE. Increased accumulation of biomass received as biological yield and its proportionate distributed among grain and stover yield improved the productivity (Choudhary and Rahi 2018, Prasad *et al.* 2016). The 7 DAE not only dispersed their pollen but it also restricted the utilization of energy only up to dispersion of pollens and soon after they were removed. Thus, tassel removal at this stage catered both the requirements, viz. adequate pollen dispersion and saving of energy. It is also demonstrated that maize grain yield was positively correlated to the amount of radiation intercepted by the maize canopy during critical period bracketing flowering (Andrade *et al.* 2002 and Barbieri *et al.* 2000).

The improvement in grain and stover yield due to detasseling was recorded up to only 50% removal of tassels producing the highest grain yield that was significantly better over 25% and remained at par with 75 and 100% during every year. The response for stover yield observed during the years of 2011 and 2012 was in the same line as that of grain yield, however, during, 2010, the stover yield was non-significantly affected. The harvest index was not affected thus increased grain yield probably was the effect of increased accumulation of photosynthates those converted in to biomass and not due to any favourable effect on partitioning of photosynthates towards sink (Pooniya *et al.* 2017). It is suggested that maize tassel removal may affect light penetration in the canopy of maize, especially if the crop is a C4 plant and has a high light requirement and tassel removal may increase the seed yield and the seed quality of maize and maize grain yield was found positively correlated to the amount of radiation intercepted by the maize canopy during critical period, i.e. flowering in maize (Suri and Choudhary 2012, Heidari 2013, Rana *et al.* 2018). In this study, detasseling probably increased the proportion of total incoming PAR that penetrated into the canopy from anthesis onwards, well within the same critical period as identified by Andrade *et al.* (2002) and Barbieri *et al.* (2000) for the grain yield response to increased radiation interception. Therefore, an increased amount of PAR reaching the upper and middle leaf strata constitutes a likely contributing factor to the observed increase in maize biomass upon detasseling (Andrade 2002).

Economics and rainfall water use efficiency: During each year tassel removal was profitable and improved productivity (kg grain/ha/mm) along with improved returns (₹/ha/mm), compared to untassled control (Table 3), giving higher net return (₹61311/ha) and B:C ratio (5.6). The highest net return (₹65513/ha) and B: C ratio (6.0) were recorded with 7 DAE over JAE (₹57075/ha and 5.3). The 50 % tassels removal gave the highest net return (₹64295/ha) and B:C ratio (6.0). The interesting observation here was the fact that net returns and rainfall water use efficiency (RWUE) for physical production and economic returns were appreciably higher during 2012, considering the shortest crop season with no dry spells in comparison to 2010. However, stress free longer crop season during 2011, proved the best on these parameters.

Factor productivity and sustainability: Physical and economic factor productivity was in increasing trend during all three years (Table 3). The highest values for both the categories were obtained with tassel removal 7 DAE followed by 3 DAE and JAE. Among the intensities, the best treatment was 50% under both the categories followed

Table 3 Economics, rainwater use efficiency, average factor productivity and sustainability as influenced by time and intensity of de-tasseling of maize

Treatment	Net returns (000 ₹/ha)			B:C ratio			Rainfall water use efficiency						Average factor productivity						Sustainability (Based on 3 year data)	
							kg grain/ha/mm			₹/ha/mm			Kg grain /day			₹/day				
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	SYI	SVI
Control v/s Rest																				
Control	28.00	50.63	37.96	4.68	5.19	4.14	5.8	6.3	5.2	47.30	71.11	73.26	33.42	35.10	31.44	274.54	477.61	441.42	0.583	0.420
Rest	33.93	61.31	48.21	4.26	5.64	4.65	7.1	7.7	6.4	57.32	86.11	93.04	41.11	42.83	38.62	332.65	578.41	560.59	0.717	0.521
Time of tassel removal																				
JAE	28.82	57.08	43.56	3.60	5.28	4.27	6.3	6.1	6.0	48.69	80.16	73.59	36.58	40.75	35.90	282.58	538.44	506.55	0.655	0.443
3 DAE	35.15	61.35	49.70	4.37	5.64	4.76	7.2	6.4	6.6	59.38	86.16	83.95	41.96	43.15	39.52	344.62	578.73	577.90	0.735	0.544
7 DAE	37.82	65.51	51.37	4.82	6.01	4.93	7.7	6.6	6.7	63.88	92.01	86.77	44.79	44.58	40.42	370.76	618.05	597.33	0.757	0.576
Intensity of removal (%)																				
25	31.29	56.05	42.91	4.54	5.47	4.42	6.3	5.9	5.8	52.86	78.73	82.81	36.82	39.37	34.78	306.80	528.81	498.95	0.643	0.474
50	36.49	64.30	52.46	4.60	5.98	5.06	7.4	6.6	6.8	61.64	90.30	101.24	43.20	44.48	41.09	357.75	606.56	610.03	0.763	0.567
75	34.78	61.90	50.09	4.16	5.60	4.72	7.3	6.4	6.6	58.76	86.94	96.67	42.46	43.04	40.00	341.01	583.94	582.47	0.745	0.539
100	33.15	63.00	47.38	3.75	5.53	4.40	7.2	6.6	6.4	56.00	88.48	91.43	41.95	44.42	38.58	325.04	594.31	550.90	0.717	0.502

JAE, Just after emergence; DAE, Days after emergence; SYI, Sustainability yield Index; SVI, Sustainability value Index.

by 75 and 100%. For SYI, 7 DAE followed by 3 DAE was highly sustainable and JAE was moderate, however, for SVI all these were moderately sustainable. Among intensities, 50% followed by 75 and 100% were highly sustainable but 25% was moderately sustainable for SYI and all intensities were moderately sustainable for SVI.

The detassling of maize under rainfed conditions is highly desirable under moisture stress situations and 50% tassel removal at 7 DAE is highly effective in harnessing higher grain yield, economics and improving RWUE.

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