De-topping in Maize for Enhancing Productivity: A Review

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Abstract

Maize is an important staple crop of India and has significant role in both human consumption and as high-quality animal feed. Despite its importance, maize productivity in India remains below the global average due to factors such as poor seed quality, limited technological adoption, reliance on rainfed areas, and diverse climatic conditions. Further, as the world's largest milk producer, India's livestock sector struggles with significant fodder shortage. De-topping is a promising agronomic practice to address these challenges; it involves removing the top portion of the maize plant to enhance light interception and to favor better nutrient assimilation. This practice can significantly improve both grain and fodder yields when executed at the appropriate stage and with proper techniques. By improving maize productivity and fodder availability, de-topping can help alleviate critical feed deficits and enhance the economic viability of India's agricultural sector. Based on previously mentioned focal points, the literature pertaining to the enhancement of maize grain and fodder yields through de-topping has been reviewed.

Abbreviations

GDP: gross domestic product
EEF: ether extractable fats
LAI: leaf area index
TA: total ash
NFE: nitrogen free extract
NPK: nitrogen, phosphorus and potassium

Introduction

Maize is the third most important staple food crop globally, after rice and wheat, and holds significant importance in India. Besides its primary use as grain, maize serves as fodder and is a key raw material for over 3000 consumable products, including starch, oil, protein, alcoholic beverages, food sweeteners, and biofuels. Maize is vital for both human nutrition and high-quality animal feed. In India, maize is utilized for food (13%), processed food (7%), animal feed (13%), poultry feed (47%), industrial products mainly starch (14%), and others (6%) (Agricultural statistics, 2022). Globally, maize is cultivated on an area of about 196 million hectares, yielding approximately 1110 million metric tons annual in production (FAOSTAT, 2021-22). In India, maize is cultivated on an area of about 9.20 million hectares with production of about 27.23 million metric tons (MOA&FW, 2021-22). However, India's maize productivity is significantly below the global average due to challenges like poor seed quality, limited technology adoption, small landholdings, reliance on rainfed areas, and varied climatic conditions (Mehood and Anand, 2020). Further, India being the world's largest milk producer, sees livestock contributing about 18.6% to the Gross Domestic Product (GDP) of agriculture and allied sectors (NAS, 2021). However, livestock sector faces challenges such as below-average per-animal milk yield and deficits in green fodder, dry fodder, and concentrate feed ingredients (Table 1). Therefore, increasing maize production is crucial to ensure a steady supply of grain as well as high-quality green fodder is of utmost importance. Among different crops, maize, with its versatile nature, rapid growth and nutritious green fodder, is an ideal choice containing about 8.62 to 10.32% crude protein, 29.92 to 31.38% crude fiber, 1.27 to 1.35% ether extractable fats (EEF), and 8.45 to 9.24% total ash (TA) (Rajkumara *et al.*, 2020). Hence for enhancing maize productivity and fodder supply in India, de-topping emerges as a promising agronomic practice. De-topping involves removing the top portion of the plant to optimize the function of the remai-

ning leaves. This practice reduces leaf shading, enhances light interception, controls unnecessary vegetative growth, and minimizes competition between the tassel and cob for nutrients, thereby improving the source-sink relationship (Esechie and Al-Alawi, 2002). Farmers also have been noticed to be practicing de-topping to prevent lodging, especially in coastal regions. However, de-topping at proper stage and adopted method are very crucial for enhancing fodder yield without compromising grain yield. De-topping is also essential in hybrid seed production to prevent self-pollination, which can lead to inbreeding depression. Consequently, de-topping has emerged as an economically viable approach to enhance both grain and fodder yield in maize production.

Stage and method of de-topping

Stage and method of de-topping greatly influences the fodder yield and grain yield of maize. Ideal stage selection is very important in order to attain the balance between fodder and grain production. Tasseling and silking are the two important phenological stages in maize crop considered for removal of leaves. Removing the tassel alone or de-topping does not affect the green fodder yield. Silking stage is also an ideal stage for de-topping (Saha, *et al.*, 2001). De-topping either at 20 or 30 days after silking is better for getting higher grain yield over 10 days after silking. Bhargavi *et al.* (2016) reported performance of maize improved with de-topping at 20 days after siking with de-topping upto top four leaves. Similarly, in another experiment at Mandya, Karnataka it was found that de-topping by removing top two leaves at 20 days after silking was better (Amulya, 2018). In a study conducted to identify the best possible stage and method of de-topping it was reported that maize when detopped at 20 days after taselling with top two leaves performed significantly better as compared to other de-topping stages (Badu, 2022). Bhandari *et al.* (2022) reported that de-tasseling with removal of top 3 leaves performs better as compared to other detasseling treatments. However, de-topping with lower leaves when compared to top leaves was found to be better for increasing grain and fodder yields (Umashankara, 2007). Further, performance of Maize was found to be significantly better when detopped at 15 days after silking as compared to other detopped treatments (Nayak. 2023). Similarly, de-topping at 30 days after silking was found to be significantly highest as compared to other de-topping methods (Halli *et al.*, 2023). However, on the contrary study conducted to identify defoliation intensity and defoliation time field experiment in Iran, maize hybrid was not affected by stage/time of defoliation (Emam *et al.*, 2013). Similarly, Bhargavi *et al.* (2017) reported non significant effect on maize due to de-topping at various growth stages (Table 2). The optimal stage and method of de-topping significantly influence maize's grain and fodder yields, with 20 to 30 days after silking and removal of top leaves generally yielding the best results. However, studies show varying outcomes, indicating that the impact of de-topping can be context-specific and may require further research for conclusive recommendations.

Effect of de-topping on growth parameters

De-topping at different growth stages reduced the maize plant height over control (Bhargavi *et al.*, 2017; Amulya, 2018). Similarly, Roy and Biswas (1992) conducted an experiment in Bangladesh on de-topping of maize and reported that this treatment significantly reduced the plant height of maize. This decrease in plant height might be due to the termination of apical dominance (Rajkumara et. al., 2020). Leaf area index of maize is reduced significantly in de-topped plants at different growth stages and methods (Barimavandi *et al.*, 2010; Bhargavi *et al.*, 2017 and Amulya, 2018). Similarly in an experiment to assess the effect of de-topping in maize and it was found that leaf area index reduced significantly in de-topped maize as compared to no de-topping treatment. Safari *et al.* (2013) recorded significant decrease in dry matter production in maize when de-topped at different stages compared

Table 1 - Supply and demand of Fodder and Feed in India

Type of Fodder	Parameters	2015	2020	2025
Dry Fodder	Requirement (Million tonnes)	491	530	550
	Availability (Million tonnes)	387	408	433
	Deficit (%)*	104 (21%)	122 (23%)	117 (23%)
Green Fodder	Requirement (Million tonnes)	840	880	1000
	Availability (Million tonnes)	619	596	600
	Deficit (%)*	221 (26%)	284 (32%)	400 (40%)
Concentrate	Requirement (Million tonnes)	87	96	105
	Availability (Million tonnes)	58	61	65
	Deficit (%)*	29 (34%)	35 (36%)	40 (38%)

Source: (IGFRI, 2023)

Table 2 - Different stages and methods of de-topping

Stage and Method of De-topping	Remarks	Reference
De-topping at 10, 20 and 30 days after silking with removal of lower leaves and top leaves	De-topping at 20 or 30 days after silking with top leaves was found to be better than other de-topping methods	Umashankara, 2007
De-topping at 10, 20 and 30 days after silking with removal of to two leaves	De-topping at different stages had no significant effect on performance of maize.	Emam *et al*., 2013
De-topping at 10, 20 and 30 days after silking with removal of top 4 leaves	No significant effect was found due to de-topping at any stage of growth in maize	Bhargavi *et al*., 2017
De-topping at 10, 15 and 20 days after silking with emoval of top 2 leaves and Removal of lower leaves	De-topping at 20 days after silking with removal of top 2 leaves performed better. However, de-topping at 15 days showed at par results.	Amulya, 2018
De-topping at 10, 15 and 20 days after tussling with removal up to top 6 leaves	De-topping at 20 days of taselling was found to be better than any other methods and stage of de-topping	Bhadu, 2022
De-tasseling with removal of leaves upto 1,2 and 3 leaves from top of ear or under the ear	De-tassseling with 3 top leaves performed better as compared to other de-topping methods	Bhandari *et al*., 2022
De-topping at 15,20,25 and 30 days after silking with removal up to top two leaves	Maize performed better when De-topped at 15 days after silking as compared to other stages of silking	Nayak, 2023
De-topping at 10, 20 and 30 days after silking with removal of top four leaves	De-topping at 30 days after silking was found to be significantly highest as compared to other de-topping methods	Halli *et al*., 2023

to no de-topping. Further, the dry matter accumulation was reduced in de-topped treatments over control (Bhargavi *et al*., 2017; Amulya, 2018; Shesh 2019 and Halli *et al*., 2023). In another experiment Bhadu (2022) reported that all the growth attributes of maize viz plant height, LAI, Dr matter accumulation wasc higher in maize with no de-topping was significantly higher than de-topping treatments. But among de-topping treatments de-topping with 2 leaves at 15 days after silking was better with respect to growth parameters (Table 3). However, Baramavandi *et al*., 2010 and Vishnu, 2019 reported an increase in dry matter production in maize in de-topping treatments as compared to no de-topping. Similarly, Nayak. (2023) revealed that dry matter accumulation with de-topping at 15 days after silking was at par with the no de-topping treatment. In another experiment, de-topping at 20 and 30 days after silking produced on par dry matter accumulation while greater reductions were noticed with early de-topping at 10 days after silking. This might be due to defoliation treatments imposed when the number of grains had been established and reduced the source/sink ratio. This further resulted in a sharp decrease in stem soluble carbohydrates resulting in lesser dry matter (Westgate and Boyer, 1985). Dry matter production was not affected or slightly affected by de-topping of top 2 and 4 leaves, whereas more reduction in dry matter was observed with de-topping of top 6 leaves (Bhargavi, 2017). This reduction in dry matter might be due to loss of photosynthetic area as there were no leaves above the cob when de-topped up to 6 top leaves (Barimavandi *et al*., 2010) (Table 4). The studies collectively indicate that de-topping maize at various growth stages generally leads to reduced plant height, leaf area index (LAI), and dry matter accumulation compared to control (non de-topped) plants. This reduction in growth attributes can primarily be attributed to the termination of apical dominance, which limits vertical growth, and the loss of photosynthetic area, which reduces the plant's ability to produce and accumulate dry matter. However, there are some contradictory findings. While most studies report a decrease in dry matter production with de-topping, some research indicates that de-topping might increase or not significantly affect dry matter production depending on the timing and extent of de-topping.

Effect of de-topping on yield attributes

The different studies on effect of de-topping on yield attributes of maize has various results. Bhadu (2019) reported number of cobs plant^{-1}, length of cob, cob girth, cob weight, number of grain row cob^{-1}, number of grains cob^{-1}, 100 grain weight, grain yield and stover yield was also recorded with control which was found to be statistically at par with the de-topping up to base of the top two leaves after 20 days of tasseling. Similarly, Heidari and Amarani (2022) reported no significant differences with respect to yield attributes viz cob length and seeds per cob row among de-topped and no de-topping treatments However, test weight was significantly higher in no de-topping and treatment with removal of leaves under ear was at par to it (Table 5).

Table 3 - Effect of de-topping on growth attributes of maize

Treatments	No. of Leaves de-topped up to the base of top	Days at which de-topping was done (DAS)	Plant height (cm)	LAI	Dry matter accumulation (g/m^2)
T^1 (No de-topping)	-	-	181.97	4.70	242.20
T_2	2	65	153.17	4.05	205.83
T_3	4	65	128.69	3.14	183.54
T_4	6	65	93.78	2.52	147.36
T_5	2	70	155.35	4.10	216.79
T_6	4	70	130.71	3.18	191.44
T_7	6	70	94.92	2.64	157.50
T_8	2	75	159.34	4.19	224.23
T_9	4	75	132.04	3.32	195.25
T_{10}	6	75	98.08	2.85	163.28
SEm(±)			2.32	0.15	5.81
CD (5%)			6.88	0.45	17.27

While, in another study Shesh *et al.* (2020) reported cob girth and number of cobs were significantly higher in hybrid maize with de-topping over no de-topping. However, the same yield attributes were higher with no de-topping in African tall variety of maize. De-topping up to 2 base leaves up to 20 to 30 days after sowing in comparison to removal up to 6 leaves might have enhances yield attributes due to enhanced plant height, LAI and Dry matter accumulation and better source sink relation.

Grain yield

De-topping significantly affected the grain yield of maize depending on the method and time. Maize grain yield was higher when de-topping was done at 30 days after silking and de-topping of top 2 leaves when compared to early stage with more leaves removal (Bhargavi, *et al.*, 2016) (Table 6). Halli *et al.*, 2023 reported that seed yield of maize was significantly higher in maize with no de-topping however it was at par to the treatment with de-topping at 30 days after silking. Similarly Badhu, 2022 reported that maize with no de-topping recorded significantly higher grain yield however it was at par with treatment receiving de-topping up to 2 leaves at 20 days after tasselling (Table 7). Reduction in grain yield was observed as increase in removal of number of leaves above the cob as there is a direct relationship between number of leaves removed and grain yield (Tilahun, 1993). Degree of yield reduction in de-topped treatment compared to non de-topped treatment was directly proportional to percent of leaf area destroyed. The loss of leaf area resulted in loss of photosynthetic area and reduced the assimilate availability to grain (Walpole and Morgan, 1970). The reduction in yield is also due to reduced rate of dry matter accumulation in the grains (Hanway, 1969). De-topping maize, particularly at later stages such as 20-30 days after silking with minimal leaf removal especially up to leaves, can enhance grain yield compared to early-stage de-topping. The reduction in grain yield with increased

Table 4 - Effect of de-topping stages and heights of de-topping on growth attributes of maize

Treatment	Plant height (cm)				Leaf area index				Dry matter(g/m^2)			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
D_1	194.7	161.9	152.0	169.5	4.17	3.37	2.88	3.47	1484	1469	1368	1440
D_2	193.9	164.0	153.5	171.1	4.14	3.32	2.85	3.43	1639	1636	1607	1627
D_3	190.0	164.7	146.4	165.9	4.16	3.32	2.82	3.43	1642	1639	1641	1641
Mean	192.9	163.5	150.6		4.16	3.34	2.85		1588	1581	1538	
Control		215.2				4.70				52.93		
	SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
Factor(I)	1.56		NS		0.02		NS		1.31		NS	
Factor(II)	1.35		2.85		0.02		0.04		1.31		NS	
Interaction	2.70		NS		0.04		NS		2.27		NS	
Control vs. Treatment	3.31		9.89		0.05		0.15		2.78		NS	

Factor (I): Different stages of de-topping: D_1-10days after silking (70 DAS), D_2-20 days after silking (80 DAS) and D_3-30 days after silking (90 DAS)

Factor (II): Different heights of de-topping: L_1-De-topping up to 2 top leaves, L_2 De-topping up to 4 top leaves, L_3-De-topping up to 6 top leaves, Control - No de-topping

Table 5 - Effect of time of de-topping on maize growth attributes

Treatments	No. of Leaves de-topped up to the base of top	Days at which de-topping was done (DAS)	No. of cobs plant^{-1}	Cob girth (cm)	Cob weight (g)	No. of row cob.$_{-1}$	No. of grains cob^{-1}
T_1	-	-	1.87	16.23	146.73	16.67	574.67
T_2	2	65	1.67	15.07	119.10	15.60	525.53
T_3	4	65	1.60	14.92	109.18	15.47	518.07
T_4	6	65	1.53	14.55	106.86	15.20	505.80
T_5	2	70	1.87	15.49	133.09	16.27	545.67
T_6	4	70	1.73	15.45	129.63	16.00	541.73
T_7	6	70	1.73	15.17	122.03	15.73	530.20
T_8	2	75	1.87	15.79	144.22	16.53	553.40
T_9	4	75	1.87	15.53	137.13	16.40	550.00
T_{10}	6	75	1.73	15.39	124.87	15.87	531.27
	SEm(±)		0.12	0.28	5.44	0.20	9.82
	CD (5%)		NS	0.82	16.16	0.60	29.17

leaf removal suggests a direct relationship between leaf area and yield, as it affects photosynthetic area and assimilate availability to the grains.

Fodder yield

Green fodder yield in maize is significantly influenced by the timing and method of de-topping. Research indicates that maize crops can be effectively de-topped for fodder without significant adverse effects on grain yield (Roy and Biswas, 1992). Fodder yield tends to increase with higher plant density, and optimal results are often achieved when plants are de-topped just above the cob (Roy and Biswas, 1992). Studies have shown that de-topping at various stages after silking can produce comparable green fodder yields, indicating flexibility in timing without sacrificing yield potential (Bhargavi *et al.*, 2017). Similarly, trends in stover yield align with those observed in green fodder yield, suggesting a consistent relationship between de-topping and overall biomass production. Different de-topping methods and timings have been evaluated for their impact on fodder yield. For instance, maintaining the apical ear while removing sub-apical ears and leaves below the apical ear leaf has been shown to result in higher fodder yield, albeit with a slight reduction in grain yield (Ahmed *et al.*, 2007). Furthermore, regardless of the stage of de-topping, removing the top six leaves has consistently led to increased green fodder yield (Bhargavi, 2017). De-topping has been observed to optimize fodder yield and supply, particularly when considering both green fodder at an early stage and dry fodder at harvest (Gaurkar and Bharad, 1998). Additionally, maximum forage yield has been reported when plants are de-topped to leave only one leaf above the ear, particularly when de-topping occurs 10 days after silking (Emran *et al.*, 2014; Emam and Taddayon, 1999). In some cases, de-tasseling alone has shown a numerical increase in green fodder yield, although statistical significance may vary across different de-topping treatments (Rathika, 2014). Moreover, de-topping at specific stages after silking, such as 30 days after 50% silking, has been associated with higher fodder yield compared to other treatments (Shesh *et al.*, 2020; Badhu, 2022; Halli *et al.*, 2023). Notably, de-topping after physiological maturity can provide emergency fodder while also potentially increasing grain yield (Subedi, 1996). Overall, the evidence suggests that de-topping maize for fodder can be a viable practice with minimal impact on grain yield, particularly when carefully timed and executed (Table 8).

Fodder Quality

Fodder quality Maize is an excellent green fodder in terms of quality when it is harvested for fodder at 55-65 days after sowing. This fodder contains 8-11% crude protein and 52-68% in vitro dry matter digestibility (Gupta *et al.*, 2004). Most of the de-topping treatments coincide with this stage. Topping beyond 10th internode recorded higher crude protein (7.30 and 6.98%), crude fiber (40.88 and 42.58%) and NFE content (42.88 and 42.58%) followed by topping beyond 9th internode during two successive years (Rathika, 2014). tasseling + removal of top two leaves at 100 DAS recorded the highest crude protein (12.70%) and oil (6.10%) due to more physiological and biochemical reactions like chlorophyll content, photosynthetic rate and nitrate reductase activity while removal of top 2 leaves at 80 DAS resulted in highest starch content in grains (67.5 %) as compared to other treatments and control (Srisailam, 2010). Nayak (2023) reported significantly higher crude protein, crude fiber and total ash content when de-topped at 15 days after silking and it was at par with de-topping at 20 days after silking. The enhancement in fodder quality could be attributed to increase physio-

Table 6 - Effect of stage and height of de-topping on maize grain yield

Treatment	Grain yield (kg ha^{-1})			
	L_1	L_2	L_3	Mean
D_1	5288	5238	4168	4898
D_2	7197	7195	6872	7088
D_3	7218	7198	7196	7204
Mean	6568	6544	6078	
Control		7226		
	SEm±		CD (P=0.05)	
Factor (I)	55.9		117.6	
Factor (II)	48.4		101.8	
Interaction	96.9		203.7	
Control vs. Treatment	118.7		352.9	

Factor (I): Different heights of de-topping: L_1-De-topping upto 2 top leaves, L_2 De-topping up to 4 top leaves, L_3-De-topping upto 6 top leaves, Control- No de-topping

logical and biochemical reaction leading to increased nutrient uptake which ultimately improved the fodder quality of baby corn (Teyker *et al.*, 1991). De-topping beyond 10th inter node registered higher NPK uptake (Rathika, 2013). The increased uptake of nutrients is possibly due to higher photosynthetic rate and nitrate reductase activity leading to better uptake of N by the crop. De-topping in maize, particularly at optimal stages, significantly enhances fodder quality and nutrient content by improving physiological and biochemical processes, such as photosynthetic rate and nitrate reductase activity. This practice boosts crude protein, fiber, and nutrient uptake, making it a valuable technique for increasing both grain and fodder yields in maize cultivation.

Economics

The economic viability of de-topping in maize varies depending on management practices, nitrogen application, and variety-specific responses. Bhargavi (2017) reported higher gross returns, net returns, and a Benefit-Cost (B:C) ratio with de-topping of the top six leaves at 30 days after silking, attributing this to additional fodder yield with minimal grain yield reduction. Similarly, Shivakumar (2018) observed improved net returns and B:C ratio in fodder maize variety 'African Tall' when de-topping was combined with the application of 150 kg N/ha, highlighting the synergy between nitrogen input and leaf removal for enhancing overall economic performance. Bhadu (2022) further emphasized the benefits of de-topping, reporting the highest B:C ratio with de-topping up to two leaves, as the added fodder yield effectively compensated for grain yield losses seen under no de-topping treatments. However, contradicting these findings, Emran *et al.* (2014) observed the highest gross returns and B:C ratio under no de-topping treatments, possibly due to higher grain yields achieved when maintaining full canopy integrity. In a comparative study, Halli *et al.* (2023) found significantly higher gross returns and B:C ratio under no de-topping treatments; however, results were statistically at par with de-topping at 30 days after silking, indicating that the practice can provide economic advantages without substantial reductions in grain productivity. Overall, while de-topping provides additional fodder yield and improves profitability in fodder-intensive systems, its

Table 7 - Effect of time of de-topping on maize grain yield

Treatments	No. of Leaves de-topped up to the base of top	Days at which de-topping was done (DAS)	Grain Yield (kg ha^{-1})
T_1	-	-	5740
T_2	2	65	4508
T_3	4	65	4199
T_4	6	65	3598
T_5	2	70	5197
T_6	4	70	4810
T_7	6	70	4616
T_8	2	75	5523
T_9	4	75	5316
T_{10}	6	75	4676
	SEm(±)		224.10
	CD (5%)		665.85

success depends on timing (30 days post-silking), variety performance, and nitrogen management to balance grain and fodder yield outputs.

Conclusions

Based on the comprehensive review of studies, it is evident that while de-topping in maize led to slight reduction in plant height and other growth parameters, its benefits prevail over these concerns, particularly with proper timing and methodology de-topping resulted in increase in green fodder yield without imposing substantial reduction in grain yield. Optimal timing for de-topping, around 20 to 30 days after silking or at physiological maturity proves advantageous. Proper timing ensures the availability of green fodder when it is most needed, addressing fodder scarcity while concurrently augmenting maize grain yield. Therefore, de-topping emerges as a strategic agricultural intervention that not only addresses immediate fodder deficiencies but also contributes to sustained maize productivity.

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