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Research article

Influence of detopping practices on green fodder availability, seed yield and economics of fodder maize (*Zea mays* L.) in central and southern plateau regions of India

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Abstract

The unavailability of adequate quality seeds and green fodder during the lean period together affects livestock productivity in the country. Hence, it is necessary to assure the availability of quality seeds for sowing and green fodder to feed the livestock. To study this, field experiments were conducted on fodder maize at two locations in the country. Treatments included four detopping (DT) practices *viz*., T_1: no DT, T_2: DT at 10 days after (DA) 50% silking, T_3: DT at 20 DA 50% silking and T_4: DT at 30 DA 50% silking. Results demonstrated that DT at 10, and 20 DA 50% silking is not advisable in fodder maize for seed production as it considerably reduced the biomass accumulation (252.4-254.5 g/plant) and leaf relative water content (44.79-63.95%). However, no DT produced the highest growth attributes and green fodder yield followed by DT at 30 DA 50% silking which was at par with no DT regarding 100 seed weight (23.01 g) and seed yield (2725 kg/ha) with an additional green fodder yield (3245 kg/ha). Thus, no DT followed by DT at 30 DA 50% silking favored the economics of fodder maize seed production (gross return, net return, and benefit-cost ratio). Regarding locations, Dharwad (Karnataka) outperformed Jhansi (Uttar Pradesh) regarding growth, seed yield attributes, and the economics of fodder maize. Therefore, DT at 30 DA 50% silking could supply additional green fodder (3245 kg/ha) with a 14% compromise in the seed yield of fodder maize.

Keywords: Detopping, Economics, Fodder maize, Green fodder, Seed yield

Introduction

India is the world's largest milk-producing country and livestock contributes 18.6% to the Gross Value Added of Agriculture and allied sectors (NAS, 2021). The sector is however facing a major challenge of poor per-animal milk yield, which is 20-60% lower than the global average especially in the Indian sub-continent. Deficiency of feed and fodder is the major constraints affecting livestock productivity to an extent of 50% (Raju, 2013; Halli *et al.,* 2018; Mahanta *et al*., 2020; Kumar *et al*., 2023). Furthermore, Indian livestock sector is facing a net deficit of green fodder (35.6%), dry crop residues (10.95%) and concentrate feed ingredients (44%) due to insufficient and poor-quality forages (IGFRI, 2013; Halli and Angadi, 2020). Therefore, efforts should move towards the production and supply of sufficient good quality green fodder. Among forage crops, fodder maize is an ideal crop with wider adaptability and acceptability due to its quick growth, and nutritious green forage. The average proximate composition of green fodder harvested at milk to early-dough stage on dry matter basis consists of crude protein (9-10%), neutral detergent fibre (60-64%), acid detergent fibre (38-41%), cellulose (28-30%) and hemi-cellulose (23-25%) (Kumar *et al.,* 2012).

Despite tremendous benefits and demand, the area under fodder maize is still negligible in the country due to many reasons. The unavailability of good quality seeds is still the main constraint, and it is hardly 25-30% of the total demand in the case of cultivated forage crops and is < 20% in range grasses (Vijay *et al.,* 2018; Singh *et al.,* 2021). Prominent fodder crops such as maize, sorghum, berseem, lucerne, bajra, fodder cowpea, and oats are being grown in more than 50% of the area under fodder crops (Roy *et al.,* 2019; Rathore *et al.,* 2020). In supplementation to best crop management, practices like detopping is one of the possible solutions to promote both seed production and green fodder supply. Detopping refers to the removal of the terminal portion of the plant with active leaves to improve the yield through greater functioning of the remaining leaves. The important objectives of the detopping include decreasing mutual shading of leaves, enhancing light interception, control of unnecessary vegetative growth, and decreasing competition between the tassel and cob for assimilated photosynthates and available plant nutrients, which aids in a better source-sink relationship (Esechie and Al-Alawi, 2002). Farmers practice detopping in maize to avoid lodging problems in fertile soils and especially in areas of coastal districts. Thus, proper time of detopping seems to be very important for controlling lodging and obtaining enough forage without sacrificing the seed yield to a greater extent. It was reported in grain maize that detopping of 2-6 top leaves at 10 and 20 days after silking reduced the plant height by 20-23%, leaf area index by 26-27%, and dry matter production by 13% (Bhargavi *et al.,* 2017). However, detopping at 30 days after silking produced comparable grain yield (7204 kg/ha) as that of no detopping (7226 kg/ha) in maize (Bhargavi *et al.,* 2016). However, the information on the effect of detopping in fodder maize seed production is sparse. Thus, we hypothesized that detopping practice could supplement the green fodder supply without much reduction in the seed yield. Therefore, the experiments were conducted for two years (2019 and 2020) at two different locations in the country to determine the effects of detopping on the growth, seed yield, additional fodder yield, and economics of fodder maize grown for seed production.

Materials and Methods

Weather and soils of the experimental locations: Field experiments were conducted at two locations in the country representing distinct soil and climatic features during *Kharif* 2019 and 2020. The first location represents the Southern part of India (ICAR-IGFRI-Southern Regional Research Station, Dharwad, Karnataka, 678 m above the mean sea level) and the second location represents the Central part of India (ICAR-India Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, 270 m above mean sea level). Average maximum temperature recorded was higher (Table 1) at Jhansi (32.8-34.3°C) as compared to Dharwad (27.13-27.72°C), while average minimum temperature recorded was relatively higher (23.6-23.7°C) at Jhansi compared to Dharwad (20.47-20.51°C). The soil type of experimental site was silty loam with a bulk density of 1.32 g/cm^3 at Dharwad, whereas it was sandy loam with a bulk density of 1.35 g/cm^3 at Jhansi (Table 2). Silty loam soil of Dharwad was comparatively more fertile with higher organic carbon (0.47%), available nitrogen (211.4 kg/ha), phosphorus (23.5 kg/ha) and potassium (305.8 kg/ha) content compared to sandy loam soil of Jhansi (organic carbon: 0.27%, available N: 200 kg/ha, P: 5.90 kg/ha and K: 111.4 kg/ha; Table 2).

Experimental setup and crop management: The field study was conducted in a randomized complete block design and treatment consisted of four detopping DT practices (T_1: no DT, T_2: DT at 10 days after (DA) 50% silking, T_3: DT at 20 DA 50% silking and T_4: DT at 30 DA 50% silking), which were replicated three times at two locations. Uniform and

Table 1. Mean temperature of the study locations during cropping period (*kharif* 2019 and 2020)

Std. Met. week	Month	Maximum temperature (°C)				Minimum temperature (°C)			
		Dharwad		Jhansi		Dharwad		Jhansi	
		2019	2020	2019	2020	2019	2020	2019	2020
27-30	2-29th July	27.45	27.38	34.6	34.9	20.30	20.83	25.9	26.1
31-34	30th July to 26th Aug.	26.08	26.20	32.3	32.2	20.33	20.65	25.2	25.0
35-39	27th Aug. to 30th Sept.	26.26	28.22	32.4	34.5	20.84	20.38	24.5	24.6
40-43	1-28th Oct.	28.75	29.08	32.0	35.5	20.40	20.20	19.2	18.8
Total*/average		27.13	27.72	32.8	34.3	20.47	20.51	23.7	23.6

well-leveled plots (4.2 m × 3.8 m) with gentle slopes were prepared by performing one disc ploughing followed by harrowing. Sowings of popular fodder maize variety (African Tall) was done during the first fortnight of July for both years at a spacing of 60 × 20 cm. Nutrients (N, P_2O_5 and K_2O) were applied to the crop at the rate of 100, 50, 50 kg/ha through urea, diammonium phosphate, and muriate of potash respectively. The 50% of N and 100% of P_2O_5 and K_2O were applied as basal doses, and the remaining 50% of N was applied at the knee-high stage. Weeds were economically managed by applying post-emergent herbicide (Topramazone @ 33.6 g a.i ha^{-1} + adjuvant; MSO 2 ml/ l water) at 20 DAS. Curative measures against fall armyworm, *Spodoptera frugiperda* (J. E. Smith, Lepidoptera, *Noctuidae*) was taken by spraying Emamectin benzoate @ 0.4 g/l water at knee-high and cob formation stage. According to treatments, detopping of maize was carried out manually by removing the top four leaves above the cob (Bhargavi *et al.,* 2016; 2017).

Growth and yield attributes of fodder maize: Growth attributes such as plant height and leaf area were recorded at the time of harvest by selecting ten representative plants per treatment. Five representative plants from each plot were uprooted and shade dried, followed by oven drying at 70°C, to determine the plant's biomass. The relative water content (RWC) of the fully opened top three leaves was computed following the standard formula (Halli *et al.,* 2021). Additional green fodder yield (AGFY) of maize was weighed after detopping as per the treatments and expressed in kilograms per hectare. At the grain filling stage, total soluble solids (°brix) content of the seeds was measured using the Labart hand refractometer (Hand Brix Refractometer, 0-18%, RHB 32 ATC, New Delhi, India) and expressed in percentage (Halli *et al.,* 2021). The crop was harvested at physiological maturity as indicated by drying of silk on the cob and old leaves followed by hardening of grains. After harvest of the crop, cob yield from twenty representative plants from each plot was collected, air-dried, and recorded the cob yield per plant. Further grains were separated from the cobs, weighed, and expressed as g/cob and kg/ha. Similarly, the weight of 100 seeds was also recorded (g) and finally, harvest index was calculated using formula of seed yield (kg/ha)/ stover yield (kg/ha) of maize.

Economics: The economics of the fodder maize in response to detopping and other management practices in two locations was calculated by considering the different variable costs and expressed in terms of gross return, net return, and benefit-cost ratio.

***Statistical analysis*:** The experimental data were checked for normality before conducting analysis of variance. Mixed Model (proc GLIMMMIX, SAS v 9.3. SAS Institute, Inc, NC, USA) was used to perform Analysis of Variance (ANOVA) in Statistical Software. Detopping and locations were considered fixed effects and replications and years as random effects. The overall ANOVA for all the parameters was recorded (Table 3). The mean separation for each of the variables was performed using Fisher's least significant difference (LSD) test ($\alpha = 0.05$).

Results and Discussion

Detopping and growth attributes: Important growth determining traits of fodder maize such as plant height, leaf area, biomass production, and RWC were significantly ($p < 0.05$) influenced by the DT practice at both the locations (Fig 1, Table 3-4). Across locations, the highest plant height (250.2 cm) and leaf area (227.0 cm/plant) were recorded in plots with no DT, whereas DT practice at 10, 20, and 30 DA 50% silking proportionately reduced the plant height and leaf area of fodder maize by 90.2 to 99.7 cm and 16.6 to 34.4 cm^2/plant, respectively at the harvest (Fig 1a-1b). Similarly, total plant biomass and RWC content of leaves were notably decreased due to detopping. The lowest biomass (252.4 and 254.5 g/plant, respectively) and RWC (44.79% and 63.95%, respectively) were observed in detopping at 10, and 20 DA 50% silking. The plants under no DT produced the highest total biomass (314.3 g/plant) and RWC (67.49%). Interestingly, DT at 30 DA 50% silking maintained similar RWC (65.25%) to that of no DT at the tasseling stage (Table 4). Plants grown at the Dharwad location were superior for plant height (193.1 cm), leaf area (231.6 cm^2/plant), total biomass (285.3 g/ plant), and RWC (63.60%) over Jhansi (Fig 1a-1b; Table 4). In this study, decreased photosynthetic or functional leaf area due to removal of apical dominance (removing 20-30 cm tops) notably reduced the plant height of fodder maize (37-39.8%) and leaf area (7.31-15.15%). Thus plants could not extract much soil moisture and nutrients due to reduced photosynthetic area (leaves). We also presumed that the removal of maize tassel might affect light interception in the canopy. The C_4 nature of maize requires high light intensity for optimum photosynthesis, therefore, total biomass production was reduced by 14.98-19.69% due to DT, and consequently, the RWC of leaves declined. Our findings corroborated with the results of Bhargavi *et al.* (2017) and Srisailam (2010). Likewise, Usman *et al.* (2007) reported a greater plant height (125 cm) and number of productive tillers per hill (9) in no DT, whereas DT adversely affected the growth contributing characteristics of rice in Pakistan. Reduced size of the leaf or canopy might limit the production of assimilates and accumulation in stem and roots which have an important role in determining the overall growth of the crop. Notably, detopping at 10, 20, and 30 days after 50% silking delayed the physiological maturity of fodder maize by 5, 4 and 3 days, respectively (Table 4). In this line, Khan *et al.* (2007) reported that DT significantly delayed the maturity of wheat and mustard by 3-50 days and reduced the grain yield by 2.5 fold over no DT. Therefore, the DT of top active leaves affects the growth and biomass accumulation in fodder maize grown for seed production.

***Seed yield parameters and additional green fodder yield (AGFY)*:** The combined analysis of the two-years results at two locations exhibited that DT had a significant effect ($P < 0.05$) on yield parameters, seed yield, and AGFY of fodder maize (Table 3 and 5). Detopping decreased the cob weight by 12.3-31.6% over no DT. Likewise, no DT maintained the maximum 100 seed weight (23.68 g) over DT at 10 and 20 DA 50% silking (18.85 and 20.43 g, respectively). Interestingly, DT at 30 DA 50% silking maintained the comparable cob weight (256.7 g) and 100 seed weight (23.01 g) as that of no DT (Table 5). Consequently, seed and stover yields of fodder maize were substantially reduced due to DT. Seed and stover yields were recorded in the decreasing order of no DT > DT at 30 DA 50% silking > DT at 20 DA 50% silking > DT at 10 DA 50% silking across the locations. Distinctly, DT at 30 DA 50% silking produced at par seed yield (2725 kg/ha) and harvest index (0.36) as that of no DT. Interestingly, DT at 30 DA 50% silking supplied an AGFY of 3245 kg/ha followed by DT at 20 DA 50% silking (3012 kg/ha) and 10 DA 50% silking (2854 kg/ha). Among locations, the Southern Plateau region (Dharwad) exhibited higher yield attributes such as cob weight (282.3 g), 100 seed weight (24.40 g), seed yield (3311 kg/ha), stover yield (5962 kg/ha), harvest index (0.37) and AGFY (2815 kg/ha) of fodder maize as compared to Central Plateau region (Jhansi).

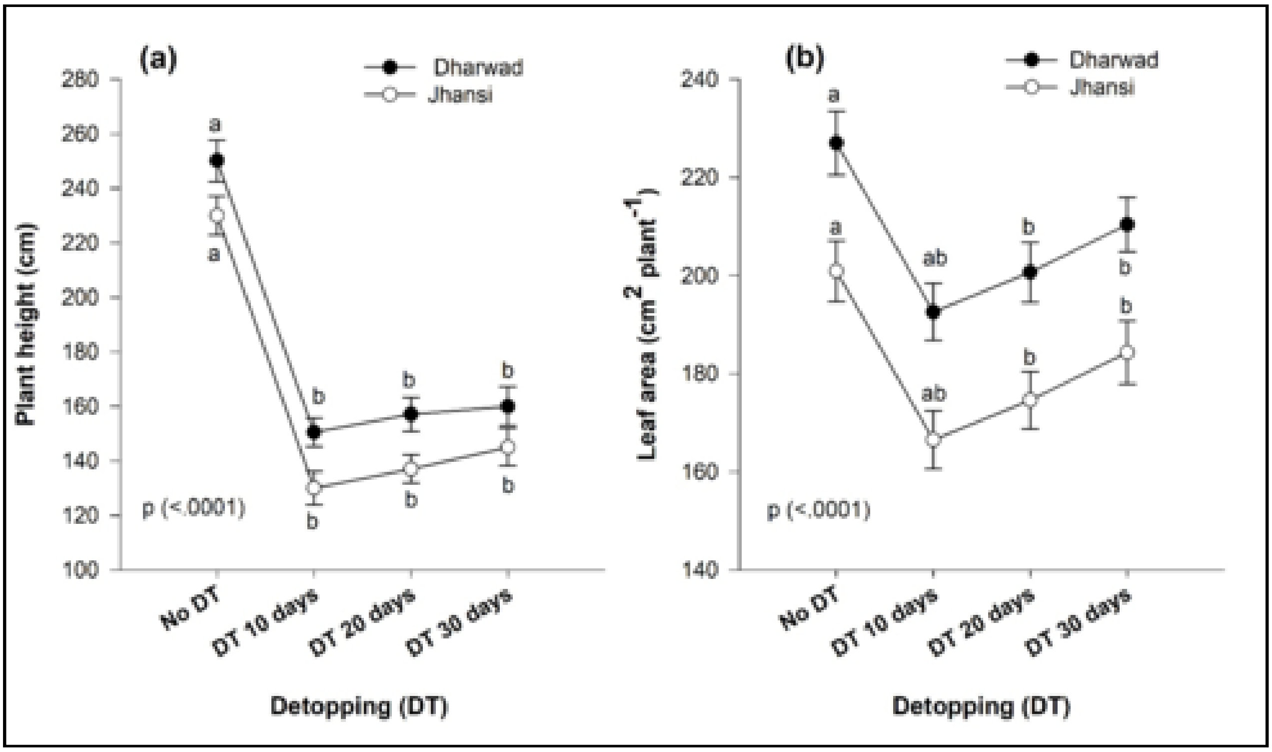

Fig 1. Plant height and leaf area of fodder maize (for seed production) at harvest as influenced by detopping practice (after 50% silking); Means with similar lower-case letter did not differ significantly

Table 2. Initial soil properties of the experimental locations

Locations	Texture	BD (g/cm^3)	pH	EC (dS /m)	Organic carbon (%)	Nitrogen (kg/ha)	Phosph-orous (kg/ha)	Potas-sium (kg/ha)
Dharwad	Silty loam	1.32	7.96	0.35	0.47	211.4	23.5	305.8
Jhansi	Sandy loam	1.35	7.52	0.13	0.27	200.0	5.90	111.4

Table 3. Analysis of variance (ANOVA) for the growth, yield attributes, and economics of fodder maize

Variance	DF	PH	LA	TBM	RWC	DPM	CBW	100SW	TSS	SDY	STY	AGFY	HI	GR	NR	BCR
Detopping	3	<.0001	<.0001	<.0001	<.0001	0.0224	0.0027	0.0091	<.0001	<.0001	<.0001	<.0001	0.005	<.0001	<.0001	<.0001
Location	1	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005	NS	NS	0.008

DF: Degree of freedom; PH: Plant height; LA; Leaf area; TBM: Total biomass; RWC: Relative water content; DPM: Days to physiological maturity; CBW: Cob weight; 100SW: 100 seed weight; TSS: Total soluble sugars; SDY: Seed yield; STY: Stover yield; AGFY: Additional green fodder yield; HI: Harvest index; GR: Gross return; NR: Net return; BCR: Benefit-cost ratio, NS: Non-significant at P< 0.05

In the present study, DT at 10 and 20 DA 50% silking severely reduced the seed yield of fodder maize (20.8-32.0%). This decrement in seed yield was possibly due to poor yield governing traits such as cob weight, and 100 seed weight due to DT. Reduction in crop growth in terms of plant height, leaf area, biomass production, and RWC (Table 4) was responsible for yield reduction, which might affect the development of sink and subsequent accumulation. Therefore, the TSS content of seeds at the milky stage (16.43%) was reduced in DT at the early stage (10 DA 50% silking) compared to no DT (16.51%) and DT at 20 and 30 DA 50% silking (16.12% and 16.32%, respectively). The findings of Bhargavi *et al.* (2016) supported our results. The reduced apical dominance due to DT at later stages had a little positive influence on grain yield via diverting energy towards grain filling hence producing the next better cob weight and seed yield with an AGFY, and reduction in crop lodging in case of over vegetative growth or wind prone regions (Khan *et al.,* 2003; Usman *et al.,* 2007). The greater seed yield and yield attributes at Dharwad were possibly due to higher soil fertility and assured rainfall throughout the growing period. Hence, detopping could supply additional green fodder to the livestock during the lean period with compromise in the seed yield (14-36%) of fodder maize.

Table 4. Growth attributes of fodder maize for seed production in response to detopping practice

Treatments	Total biomass (g/ plant)	RWC (%)	DPM
Detopping (DT)			
T_1: No DT	314.3^a	67.49^a	127^b
T_2: DT at 10 DA 50% silking	252.4^b	44.79^c	132^a
T_3: DT at 20 DA 50% silking	254.5^b	63.95^b	131^a
T_4: DT at 30 DA 50% silking	267.2^b	65.25^{ab}	130^{ab}
P value (0.05)	<.0001	<.0001	0.0224
Location			
Dharwad	285.3^a	63.60^a	133^a
Jhansi	262.1^b	57.22^b	126^b
P value (0.05)	<.0001	<.0001	<.0001

DA: Days after; RWC: Relative water content; DPM: Days to physiological maturity; Means followed by the same letter (s) within a column did not differ significantly (P = 0.05)

Table 5. Yield attributes, seed yield and economics of fodder maize for seed production as influenced by detopping practice

Treatments	Cob weight (g)	100 seed weight (g)	TSS* content (%)	Seed yield (kg/ ha)	Stover yield (kg/ha)	AGFY (kg/ha)	Harvest index	Gross return (Rs. /ha)	Net return (Rs./ha)	BC ratio
				Detopping (DT)						
T_1: No DT	262.9^{a}	23.68^{a}	16.51^{a}	2966^{a}	5672^{a}	0.00	0.36^{a}	243122^{a}	195549^{a}	4.16^{a}
T_2: DT at 10 DA* 50% silking	200.4^{bc}	18.85^{bc}	16.12^{b}	2015^{d}	4258^{c}	2854^{bc}	0.35^{b}	175866^{d}	125422^{d}	2.52^{d}
T_3: DT at 20 DA 50% silking	218.2^{b}	20.43^{b}	16.34^{ab}	2348^{c}	4693^{b}	3012^{b}	0.35^{b}	191212^{c}	146560^{c}	3.31^{c}
T_4: DT at 30 DA 50% silking	256.7^{ab}	23.01^{a}	16.43^{ab}	2725^{ab}	4845^{b}	3245^{a}	0.36^{a}	213581^{b}	169477^{b}	3.94^{b}
P value (0.05)	<.0001	0.0017	<.0001	<.0001	<.0001	<.0001	0.005	0.001	0.012	0.015
				Location						
Dharwad	282.3^{a}	24.40^{a}	16.61^{a}	3311^{a}	5962^{a}	2815a	0.37^{a}	216551^{a}	171624^{a}	3.87^{a}
Jhansi	229.6^{b}	20.38^{b}	16.16^{b}	2182^{b}	4177^{b}	2345b	0.36^{b}	195453^{b}	169433^{a}	3.74^{b}
P value (0.05)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005	0.0004	NS	0.008

*DA; Days after; 1000 kg = 10 q = 1 ton; Means followed by the same letter (s) within a column did not differ significantly (P = 0.05)

Economics in response to detopping: Economic indicators of the fodder maize grown for seed production were influenced (P<0.05) by the DT treatments across the locations (Table 5). Improved gross return (Rs. 243122 /ha), net return (Rs. 195549 /ha), and BCR (4.16) were obtained with no DT in maize followed by DT at 30 DA 50% silking and 20 DA 50% silking. The lowest gross return (Rs. 175866 /ha), net return (Rs. 125422 /ha), and BCR (2.52) were documented with DT at 10 DA 50% silking. Among locations, Dharwad reported a higher gross return (Rs. 216551/ha), followed by Jhansi (Rs. 185453 /ha), in converse, both locations recorded at par net return of maize due to detopping (Table 5). Higher seed and stover yield in no DT were mainly responsible for the better gross return, net return, and BCR of fodder maize. The compromise in the seed yield (36%, 25% and 14%, respectively) due to DT at 10, 20, and at 30 DA 50% silking reduced the economic benefits. Moreover, the additional cost for DT (~5 man-days /ha) and lesser green fodder prices (Rs. 3000 /t) might be the reasons for the lower gross return and net returns (Table 5). The greater BCR of fodder maize grown for seed production (2.52-4.16) was mainly due to the higher seed prices (Rs. 60 /kg) compared to the price of grain maize (Rs. 18-20 /kg). Though the Dharwad location recorded a higher gross return, but the extra cost incurred on repeated use of insecticides, and herbicides to control insects and weeds because of continuous rainfall possibly minimized the net profit. It was reported in harmony with these findings that DT of maize (grain purpose) at 20 DA silking up to 4 leaves was found to be economical to obtain higher gross returns (Rs. 103234 /ha), net returns (Rs. 70513 /ha) and BCR of 3.15 (Bhargavi *et al.,* 2016). Similarly Rahmat *et al.* (2007) found that DT of rapeseed leaves and sold as vegetables resulted in a higher net return and obtained comparative seed yield with an economic advantage (20%) compared to no DT. In the present study, DT of the top four active leaves at 10 and 20 DA 50% silking drastically reduced the seed yield. Therefore, there was a clear trade-off between seed yield and AGF supply in fodder maize due to DT. However, AGF supply (2.8-3.2 t /ha) with DT makes it more remunerative under fodder-scarce situations, especially during the lean period to supplement the livestock feeding.

Conclusion

Based on the results, it was concluded that detopping significantly influenced the growth, yield (seed + green fodder), and economics of fodder maize seed production. Detopping of the top four active leaves at an early stage (at 10 days after 50% silking) adversely affected the growth and yield attributes. The detopping at 30 days after 50% silking produced an additional green fodder yield (3.2 t/ha) with 14% compromise in the seed yield. Dharwad location (southern part) recorded 34% higher seed yield compared to Jhansi (central part). Therefore, farmers could practice detopping in fodder maize grown for seed production at 30 days after 50% silking in acute green fodder shortage situations.

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