

# Dual-purpose production of forage and seeds in maize by detopping and defoliation

## Producción doble propósito de forraje y semillas en maíz mediante una poda apical y defoliación

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### ABSTRACT

Maize is one of the most productive crops whose seeds are used in the poultry sector as one of the main ingredients in the diet; it is also important forage for ruminants as silage. The aim of this research was to assess the effect of defoliation and detopping on dual-purpose maize production in field (Kermanshah, Iran, Mediterranean climate conditions) and laboratory experiments. The study included a control (intact plant), removal of leaves at the top of the ear, removal of leaves under the ear, removal of all leaves, detopping (stem removal at the top of the ear), and detopping including removal of leaves under the ear. In the laboratory experiment, germination traits were assessed in seeds obtained from the mother plants in the field experiment. The field and laboratory experiments were conducted with a randomized complete block design and completely randomized design, respectively. The data were analyzed using a general linear model. The removal of leaves under the ear produced an increased seed number per row compared to the removal of leaves at the top of the ear. Intact plants (control) and the plants defoliated under the ear had a higher 100-seed weight than other treatments. There was no difference between detopping and control plants in seed yield. Removal of leaves under the ear of mother plants produced a lower seed germination percentage (83%), radicle length (11.3 cm), and seed vigor than in other treatments. The results show that maize can be cultivated as a dual-purpose crop for forage and seed production.

**Key words:** dual-purpose crop, germination, mother plant.

### RESUMEN

El maíz es uno de los cultivos más productivos cuyas semillas se utilizan en el sector avícola como uno de los principales ingredientes de la dieta; además, es un forraje importante para la alimentación de rumiantes en forma de silo. El objetivo del estudio fue evaluar el efecto de la defoliación y poda apical en la producción de maíz de doble propósito en campo (Kermanshah, Irán, condiciones de clima mediterráneo) y laboratorio. El estudio incluyó un control (planta intacta), eliminación de hojas en la parte superior de la mazorca, eliminación de hojas debajo de la mazorca, eliminación de todas las hojas, poda apical (eliminación del tallo en la parte superior de la mazorca), y poda apical más eliminación de hojas debajo de la mazorca. En el experimento de laboratorio, se evaluaron parámetros de germinación de las semillas producidas de plantas madre del experimento en campo. El experimento de campo y de laboratorio se llevaron a cabo con un diseño en bloques completos al azar y un diseño completamente al azar, respectivamente. Los datos se analizaron utilizando un modelo lineal generalizado. La remoción de hojas debajo de la mazorca produjo un mayor número de semillas por fila que la remoción de hojas en la parte superior de la mazorca. Las plantas intactas (control) y las plantas defoliadas debajo de la mazorca tuvieron un peso de 100 semillas más alto que otros tratamientos. No hubo diferencia entre la poda apical y el control en el rendimiento de semillas. La eliminación de las hojas debajo de la mazorca de las plantas madre produjo un porcentaje de germinación de semillas (83%), longitud de radícula (11.3 cm) y vigor de semilla más bajos que otros tratamientos. Los resultados muestran que el maíz puede ser cultivado como un cultivo de doble propósito, con producción de forraje y de semillas.

**Palabras clave:** cultivo de doble propósito, germinación, planta madre.

## Introduction

One of the major problems of agriculture is insufficient nutrition of livestock and poultry. Maize is one of the most productive crops whose seeds are used in the poultry

industry as one of the main ingredients in the diet (Singh & Ravindran, 2019). Also, it is an important fodder for ruminant nutrition in the form of silage (Horst *et al.*, 2020). In maize for grain, plant residues are usually dried and are not suitable for livestock. In maize crops, defoliation is a

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removal of plant leaves, and detopping is the removal of the plant stem just above the maize ear.

Defoliation is the subject of much research (Rua *et al.*, 2020; Song *et al.*, 2020; Donovan *et al.*, 2021; Sánchez-Cuesta *et al.*, 2021; Wang *et al.*, 2021; Yang *et al.*, 2021). In maize with increasing defoliation at the ear initiation stage, the grain yield decreases (Iledun & Rufus, 2017). Removal of two leaves from the top of maize plants increases the biomass in maize and soybeans in a maize-soybean intercropping system (Raza *et al.*, 2019). In intercropping of maize and legume forage as the following crops, the appropriate rate of maize defoliation is 25% to 50% without a negative effect on dry matter production of maize (Hassen & Chauhan, 2003). In a study on maize, the treatments consisted of four stages of source restriction: including defoliation at the middle of silking and three consecutive 10 d intervals from the middle of the silking as well as three defoliation intensities (zero, half, and total leaf removal) (Emam *et al.*, 2013). Delay in source restriction was found to be associated with reduced grain weight (Emam *et al.*, 2013). The highest mean grain weight was obtained by defoliation at the middle of silking, which also resulted in the lowest reduction in grain yield compared to the non-defoliation treatment. Increased defoliation intensity was associated with decreased grain yield. However, delay in defoliation after the middle of silking had no significant effect on grain yield (Emam *et al.*, 2013). Defoliation reduces stem biomass, grain yield, and the maize harvest index. Decreasing the height of the maize plants increases the stability of grain yield by reducing lodging and increasing stress tolerance during the flowering stage (Edmeades & Lafitte, 1993).

Removal of the tassel increases maize yield by 11% to 32% (Mashingaidze *et al.*, 2010). Defoliation at the anthesis (50% tasselling) increases yield by 16% to 28%, while defoliation three to four weeks before or after anthesis has no significant effect on yield. Removal of the tassel increases solar radiation absorption by leaves below the tassel and ear leaves. In addition, removal of the tassel may reduce the terminal dominance that aids in grain filling (Mashingaidze *et al.*, 2010). Among detopping (removal of the upper ear stem) of maize at 10, 20, and 30 d after silking, detopping at 20 d after silking results in the higher grain yield (Amanullah, 2020). Detopping 30 d after silking, removal of the top 6 leaves after physiological maturity, removal of all leaves above the ear, or detopping above the tenth internode produces the highest forage yield and net yield with partial or no reduction in grain yield (Rajkumara *et al.*, 2020). In a study of three detopping levels including complete removal of the shoot from above the ear, leaving one or two leaves

above the ear, and four detopping times (different times after pollination) in maize, detopping reduces grain yield by 18% and lowers the 1000-seed weight. Complete removal of shoots from above the ear produces the highest forage yield and leaving two leaves above the ear produces the least forage. Detopping is not recommended if the purpose of the crop is seed production, but if the purpose is forage plus seed production, the best detopping time is at the end of pollination or 10 d after pollination (Afarinesh, 2005). In maize, detopping at different stages does not produce a significant effect on the studied parameters; however, the highest dry matter yield is with detopping 30 d after silking, and the lowest dry matter yield is 10 d after silking. The highest plant height, leaf number, leaf area index, dry matter, and yield are by detopping up to two upper leaves and the lowest of these traits is found by detopping up to six upper leaves (Bhargavi *et al.*, 2017).

The environment of the mother plant affects the germination traits of the produced seeds. Different levels of defoliation in vetch (*Vicia sativa*) produce seeds with the same germination percentage and germination time (Koptur *et al.*, 1996). Artificial defoliation of wheat (*Triticum aestivum* L.) has little effect on the germination traits of produced seeds (Heidari *et al.*, 2013). Defoliation caused by *Cameraria ohridella* (Lepidoptera: Gracillariidae) in *Aesculus hippocastanum* L. causes a decrease in shoot weight, root weight, total biomass, root length, and root diameter; the seeds from infested trees have higher germination than non-infested ones (Takov *et al.*, 2008). We studied the effect of defoliation and detopping (removal of the upper ear stem) in the mother plant and their effect on the germination traits of the produced seeds. Therefore, this study was designed to determine the best defoliation or detopping treatment for dual-purpose production of maize as fresh forage and seeds in the field conditions of Kermanshah, Iran.

## Materials and methods

### Site description

A field experiment was conducted in the arable lands of the Chamchamal plain (34° N, 47° E, and altitude 1300 m a.s.l.) with an average annual rainfall of 442 mm (IMO, 2012) located 47 km from Kermanshah, Iran. The Chamchamal plain has fertile agricultural lands and is one of the production areas in the west of the country. The average monthly temperature, relative humidity and rainfall of the region are shown in Figure 1. Soil texture was silty clay loam, and pH and electrical conductivity were 7.2, and 1.6 dS m<sup>-1</sup>, respectively.

To evaluate the effect of field treatments on germination traits of produced seeds, a laboratory experiment was conducted in the Crop Physiology Laboratory, Faculty of Agricultural Science and Engineering, Razi University (Iran).

### Treatments and experimental design

We conducted a field experiment in a randomized complete block design with three replicates. The plots were 3 m x 3 m. The distance between the plots was 2 m. Treatments included the control (intact plants), removal of leaves above the ear, removal of leaves below the ear, removal of all leaves, detopping (removal of stem above the ear), and detopping in addition to removal of leaves below the ear. In the defoliation treatments, the leaf blade was cut with a sharp cutter from the point where it was attached to the stem. In the detopping treatment, the plant stem was cut from the top of the ear. In order to evaluate the effect of field treatments on germination of produced seeds, a laboratory experiment was conducted in a completely randomized design with three replicates.

### Plant management in field and laboratory

At the beginning of March 2014, the land was plowed using a moldboard plow. Triple superphosphate fertilizer was mixed with soil at the rate of 333 kg ha<sup>-1</sup>. On April 7, 2014, maize (cv. single cross 704) seeds were sown at a rate of 27 kg ha<sup>-1</sup> using a maize pneumatic machine. Planting row spacing was 75 cm. The most important weeds were *Amaranthus retroflexus* L., *Chenopodium album* L., *Setaria viridis* L., *Sorghum halepense* L., *Phragmites australis* Cav., and *Cynodon dactylon* L.. The 2,4-D (2,4-dichlorophenoxyacetic acid) and nicosulfuron (2-[(4,6-dimethoxypyrimidin-2-yl) carbamoylsulfamoyl]-N,N-dimethylpyridine-3-carboxamide) herbicides were used to control the weeds. The cultivator was used to earth

up and open irrigation ditches. Urea fertilizer at the rate of 367 kg ha<sup>-1</sup> was applied at two moments (May 31 and June 22). The plants were irrigated eight times by the surface method until the end of the growth season.

After field measurements, a laboratory study was developed. The seeds of each treatment were first sterilized with sodium hypochlorite (1% active chlorine) for 10 min and then 10 seeds were placed on filter paper in sterile Petri dishes. Eight ml of distilled water was added to each Petri dish to prevent evaporation, and the Petri dishes were placed in a plastic bag. The Petri dishes were stored in a germination chamber at 25°C for one week.

### Sampling and measurements

Due to the size of the plot, which was 3 x 3 m<sup>2</sup>, there were four planting lines at a distance of 75 cm in each plot. At the time of harvest (August 29, 2014), three plants were randomly selected from the two middle lines of the plot and the desired ears were harvested. The selection criteria were plants that represented the plot. Sampling was not performed from the two side lines of the plot to remove the margin effect. After drying the ears, the ear husks were first separated from the ears and the ear husks were weighed. Each ear was then weighed without husk. Seed numbers per column and row of ear, length and weight of cobs, seed yield, and weights per 100 seeds were determined.

One week after the seed germination test, seed germination percentages, coleoptile and radicle lengths, and seed vigor were measured. Two millimeters of coleoptile growth was the germination criterion. The seed vigor estimate was calculated by multiplying the germination percentage by the seedling length (coleoptile length plus radicle length) (Heidari, 2013).

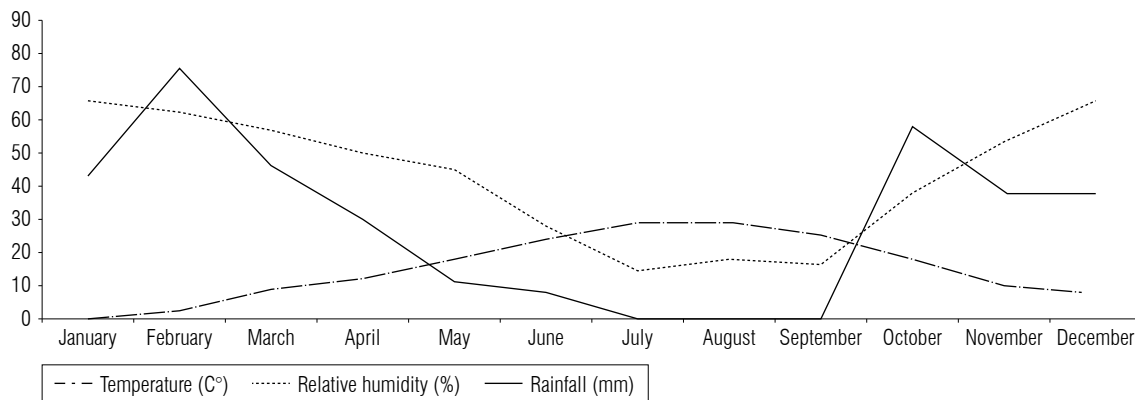


FIGURE 1. The average monthly temperature, relative air humidity, and rainfall of the region in 2014 (IMO, 2014).

## Data analysis

Before analyzing the data, normality was checked and the data were analyzed by variance. Data were then compared by Duncan's multiple range test at a 5% probability level. Correlation between traits was also calculated. SAS, MINITAB, and SPSS statistical software were used (Soltani, 2007).

## Results and discussion

### Field experiment

#### Ear husk weight and ear weight

Analysis of variance showed that detopping and defoliation did not affect maize ear husk weight (Tab. 1). A mean comparison with Duncan's test also showed that there was no difference between detopping and defoliation treatments in ear husk weight (Tab. 2). The ear husk weight was, probably, relatively complete by the beginning of the seed filling period (milking stage). Maize ear husks contain chloroplasts and can photosynthesize as leaves. The ear husk begins to develop earlier than the seeds and due to its proximity to the seeds has an effective role in seed filling (Koocheki & Sarmadnia, 2011). Data analysis of variance showed that detopping and defoliation had no significant effect on maize ear weight (Tab. 1). The mean comparison showed that the detopping with the removal of the lower leaves of the ear had a lower ear weight than the control (no leaf removal and no detopping) (Tab. 2). But there was no difference between

detopping and the control. These results indicated that the upper leaves and stem of the ear could be harvested at the seed milking stage for livestock use, without affecting the ear weight. The lack of weight loss of the ear at the milking stage is, probably, due to the compensatory properties of other photosynthetic organs such as the lower leaves of the ear (Sun *et al.*, 2021). Because in these conditions the lower leaves of the ear are not shaded by the upper leaves, they receive more light and their photosynthesis increases (Liu *et al.*, 2020). The removal of all leaves from the plants was no different from the control in terms of ear weight. But detopping is easier than removing all leaves from the plants because it can be mechanized. However, during the milking stage the leaves and stems of the plants are still green and palatable to livestock, while less residue remains on the soil surface that interferes with the tillage operation for the next crop. Ear weight had a positive and significant correlation with all studied traits except the seed number per column (Tab. 3).

#### Seed number per column and row of the ear

Analysis of variance showed that detopping and defoliation did not affect seed number per ear column (Tab. 1). The mean comparison revealed no differences between the studied treatments in terms of seed number per ear column (Tab. 2). Considering that the time of application of treatments was at the seed milking stage, it is clear that if the treatments were applied at the pollination stage, it would have a greater effect on the seed number per column.

TABLE 1. Analysis of variance of the effect of detopping and defoliation on maize traits.

Source of variation	df	Ear husk weight		Ear weight		Seed number per column		Seed number per row		Cob length		Cob weight		Seed yield		100-seed weight	
		MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F
Block	2	0.82 <sup>ns</sup>	0.97	68.8 <sup>ns</sup>	0.89	17.9 <sup>ns</sup>	0.64	0.819 <sup>ns</sup>	0.10	0.862 <sup>ns</sup>	0.72	23.5 <sup>ns</sup>	0.28	39.8 <sup>ns</sup>	0.91	13.4 <sup>ns</sup>	0.138
Treatment	5	6.07 <sup>ns</sup>	0.49	1293.7 <sup>ns</sup>	0.15	16.3 <sup>ns</sup>	0.82	0.659 <sup>ns</sup>	0.12	0.755 <sup>ns</sup>	0.90	18.7 <sup>ns</sup>	0.40	1164.7 <sup>ns</sup>	0.09	53.9 <sup>**</sup>	0.001
Error	9	6.39		610.4		37.9		0.286		2.577		16.2		444.6		5.5	

<sup>ns</sup> and (<sup>\*\*</sup>) are non-significant and significant at the probability level of 1%, respectively. df= degree of freedom, MS= mean square, and Pr>F= the P-value to determine whether to reject the null hypothesis.

TABLE 2. Mean comparison of effect of detopping and defoliation on maize traits.

Treatments	Ear husk weight (g/plant)	Ear weight (g/plant)	Seed number per column	Seed number per row	Cob length (cm)	Cob weight (g m <sup>2</sup> )	Seed yield (g m <sup>2</sup> )	100-seed weight (g)
T1	8.0a	123.3a	36a	13ab	17.5a	16.6a	105.9a	22.0a
T2	10.3a	87.9ab	39a	12b	17.3a	15.5a	72.3ab	15.6b
T3	5.7a	99.5ab	42a	14a	17.8a	18.5a	84.9ab	21.0a
T4	9.5a	83.1ab	43a	13ab	18.1a	19.9a	65.2ab	12.3b
T5	9.5a	98.9ab	40a	13ab	17.4a	17.4a	81.2ab	15.6b
T6	8.3a	60.6b	39.4a	12.8ab	16.6a	13.2a	47.3b	12.0b

T1, T2, T3, T4, T5, and T6 are control (intact plants), removal of leaves above the ear, removal of leaves below the ear, removal of all leaves, detopping (removal of stem above the ear), and detopping plus removal of leaves below the ear, respectively. Means followed by a different lowercase letter in the column are different at a 5% probability level by the Duncan test.

At this stage, the seed number is fixed and only the weight of the seeds changes, *i.e.*, the seeds remain small (Tollenaar & Daynard, 1987). Analysis of variance showed that detopping and defoliation did not affect seed number per ear row (Tab. 1). The mean comparison showed that removal of leaves below the ear produced more seeds per row than removal of leaves above the ear and there was no difference between other treatments (Tab. 2). The importance of upper leaves of the ear in grain filling is known (Xue *et al.*, 2017). Because the lower leaves of the ear are older and in the shade, they may even act as a sink for photosynthetic compounds. Therefore, removing the lower leaves of the ear can eliminate the respiration of this part and provide the plant with more photosynthetic substances for seed filling.

### **Weight and length of cob**

Analysis of variance showed that detopping and defoliation had no significant effect on weight and length of cob (Tab. 1). The mean comparison showed that there was no difference between defoliation and detopping treatments in cob length and weight (Tab. 2). The cob, which is the necessary element for seed growth, must be formed before seed formation. Apparently, at the seed milking stage, the cob reaches relatively full growth. Therefore, this trait should have fewer changes than other studied traits. Defoliation at the ear initiation stage reduced the weight and length of maize cob so that the highest defoliation intensity provides the lowest cob weight and length (Iledun & Rufus, 2017). The difference between the results of the present study and the results of Iledun and Rufus (2017) is related to the time of defoliation.

### **One hundred seed weight and seed yield**

Analysis of variance of data showed that detopping and defoliation had a significant effect on the 100-seed weight of maize (Tab. 1). The mean comparison showed that intact plants (control) and plants with lower leaves removed had higher 100-seed weight than other treatments (Tab. 2). These results indicated the importance of the upper leaves of the ear in production of coarse grains. The lower leaves of the ear were of little importance in the production of photosynthetic materials at the seed milking stage due to their age and being in the shade, and even their removal at this stage does not have an adverse effect on the seed weight. But the upper leaves of the ear had a great effect

on the seed filling because they are younger and exposed to more light. Maize is a C4 plant and its light requirement is high. The data of this study showed that the current photosynthesis of the leaf at the seed milking stage was still very important in seed filling. Grain weight loss due to the removal of upper leaves of the ear is shown in previous studies (Umashankara, 2007). Analysis of variance showed that detopping and defoliation had no significant effect on maize seed yield (Tab. 1). Mean comparisons showed that the detopping treatment with removal of lower leaves of the ear had lower seed yields than the control treatment and no difference was obtained between the other treatments (Tab. 2). These results showed that maize can be grown for both seed and forage production. In other words, harvesting green forage of the upper stem and leaves of the ear is possible without reducing the seed yield of maize. This can also be mechanized because removing the stem along with the upper leaves of the ear is easier than removing the leaves alone and produces less damage to the plants. Maize leaves and stems are green and palatable to livestock during the milking stage. At the same time, less maize residue remains on the field, which hinders tilling for the next crop. Considering that the detopping treatment with the removal of the lower leaves of the ear had lower seed yield than the control, it can be inferred that in a situation where only the upper leaves of the cob are removed during detopping, photosynthesis of other photosynthetic organs such as the lower leaves of the cob increases. On the other hand, by removing the upper stem and leaves of the ear, more light reaches the lower leaves of the ear, and these leaves increase photosynthesis. Therefore, detopping with removal of lower leaves of the ear had lower seed yield than the control, but the removal of lower leaves alone was not different from the control. The timing of the treatment is very important: if these treatments were applied at the time of pollination or earlier, detopping may also reduce the seed yield of the plants. Therefore, in areas that are faced with a shortage of forage at the milking stage, the upper stem and leaves of the ear can be harvested for livestock; and the dry seed can be harvested later with a combine. Studies show a more severe decrease in grain yield with defoliation at the early stages of plant growth than at the late stages (Ibrahim *et al.*, 2010). Seed yield had a positive and significant correlation with all studied traits except seed number per row and ear husk weight (Tab. 3).

**TABLE 3.** Pearson correlation coefficients between studied traits in maize under detopping and defoliation.

	Ear husk weight (EHW)	Ear weight (EW)	Seed number per column (SNC)	Seed number per row (SNR)	Cob length (CL)	Cob weight (CW)	Seed yield (SY)	100-seed weight (100-SW)
EHW	1							
EW	0.485*	1						
SNC	0.677**	0.584*	1					
SNR	-0.150	0.295	0.021	1				
CL	0.833**	0.726**	0.817**	0.006	1			
CW	0.774**	0.827**	0.745**	0.167	0.905**	1		
SY	0.438	0.998**	0.548*	0.289	0.688**	0.792**	1	
100-SW	0.164	0.886**	0.204	0.316	0.393	0.544*	0.91**	1

\* and \*\* are significant correlations at the probability level of 5% and 1%, respectively.

### Laboratory experiment

Analysis of variance showed that detopping and defoliation had a significant effect on the germination percentage, radicle length, and vigor of maize seeds (Tab. 4). Mean comparisons showed that removal of leaves under the ear of mother plants produced lower seed germination percentages, radicle lengths, and seed vigor than other treatments (Tab. 5). Analysis of variance showed that leaf removal and detopping had no significant effect on coleoptile length (Tab. 4). Mean comparisons also showed that there was no difference between detopping and leaf removal treatments in terms of coleoptile length (Tab. 5). The results of the field experiment showed that the removal of the lower leaves of the ear had a 100 seed weight equal to 100 seed weight of control and more than other treatments. Therefore, in proportion to seed weight, these large seeds may not have received the nutrients or hormones necessary for

germination on the mother plant through the lower leaves of the plant. The lower leaves usually mature earlier and send their nutrients to the seeds through re-mobilization. Because the only difference between removing the lower leaves of the ear to complete removal of the leaves or removing the lower leaves of the ear with detopping is the same difference in the 100 seed weight. The last two treatments have lost their lower leaves, but their 100-seed weight is less than that of removing the lower leaves of the plant. Although the treatment of removing the lower leaves of the ear had larger seeds than other treatments except for the control, its radicle was shorter. Therefore, the seeds of this treatment probably have dormancy, which may be due to hormonal imbalance. Seed germination is influenced by the relationship between stimulants and inhibitors of germination (Koocheki & Sarmadnia, 2011). Defoliation stress may have increased the production of seed germination

**TABLE 4.** Analysis of variance of the effect of detopping and defoliation of the mother plants on maize seed traits.

Source of variation	df	Germination		Coleoptile length		Radicle length		Seed vigor	
		MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F
Treatment	5	133.3*	0.049	0.905 <sup>ns</sup>	0.49	26.5*	0.02	61.04**	0.002
Error	12	44.4		0.981		6.8		7.61	

\*, \*\* and <sup>ns</sup> are significant at the probability level of 5% and 1% and non-significant, respectively. df= degree of freedom, MS= mean square, and Pr>F= the P-value to determine whether to reject the null hypothesis.

**TABLE 5.** Mean comparison of effect of detopping and defoliation of the mother plants on maize seed traits.

<sup>a</sup> Treatments	Germination (%)	Coleoptile length (cm)	Radicle length (cm)	Seed vigor (% cm)
T1	100 a	7.2a	16.8a	2400a
T2	100 a	8.4a	19.9a	2830a
T3	83 b	7.6a	11.3b	1540b
T4	100 a	7.8a	16.1a	2390a
T5	100 a	8.4a	17.7a	2610a
T6	96 a	8.5a	18.7a	2630a

<sup>a</sup> T1, T2, T3, T4, T5, and T6 are control (intact plant), removal of leaves above the ear, removal of leaves below the ear, removal of all leaves, detopping (removal of stem above the ear), and detopping plus removal of leaves below the ear, respectively. <sup>b</sup> Means followed by a different lowercase letter in the column are different at a 5% probability level by the Duncan test.

stimulants during seed development on the mother plant, but because in most treatments the seed weight has also decreased, the proportion of these substances decreased. However, when removing the lower leaves of the ear, the seed weight did not decrease, so the ratio of germination stimulants to germination inhibitors decreased and seed dormancy increased. Some studies indicate that the defoliation of the mother plant does not affect the germination percentage of produced seeds (Koptur *et al.*, 1996; Heidari *et al.*, 2013). Part of the difference between the results of others and our results can be attributed to the application time of the treatments. Maize seed vigor had a positive and significant correlation with coleoptile and radicle length and germination percentages (Tab. 6). Coleoptile length, radicle length, and germination percentages could be regarded as the components of seed vigor.

**TABLE 6.** Pearson correlation coefficients between studied traits in maize seeds after detopping and defoliation of the mother plants.

	Germination percent (GP)	Radicle length (RL)	Coleoptile length (CL)	Seed vigor (SV)
GP	1			
RL	0.333	1		
CL	-0.068	0.489*	1	
SV	0.616**	0.925**	0.526*	1

\* and \*\* are significant correlations at the probability level of 5% and 1%, respectively.

## Conclusion

Maize detopping at the milking stage of the seed formation to produce green forage from the upper stem and leaves of the ear was not different in seed yield from intact plants. Therefore, the plants can be allowed to reach physiological maturity and also produce seeds, and the farmer can benefit from the seed production. Therefore, a suitable device could be designed to harvest the upper parts of the maize ear without damaging the plant. However, this could also be done manually. This type of dual-purpose crop can be a good way to feed livestock in times of critical need for fodder. At the same time, less maize residue remains on the soil surface, hindering the tillage operation for the next crop.

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## Conflict of interest statement

The authors declare that there is no conflict of interest regarding the publication of this article.

## Author's contributions

MA conducted the experiment. HH designed and conducted the experiment and wrote the manuscript. All authors reviewed the manuscript.

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