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Effect of Source Manipulation with Defoliation and Nitrogen on Maize

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Abstract

Maize is one of the most important grains in the world. The leaves play an important role in providing grain reserves in cereals by performing photosynthesis. The leaf is known as the source and the seed is known as the sink. Removing part of the leaf can decrease the amount of photosynthetic material produced by the plant. A C4 plant, maize has been widely cultivated as a summer plant in western of Iran in recent years. Utilizing maize for both grain and forage can reduce the amount of the woody residues left by this plant in the soil while providing part of the forage for livestock. Field and laboratory experiments were conducted to investigate the effect of defoliation and nitrogen on seed yield and germination characteristics of seeds derived from the maternal plant. Defoliation intensities (removing none, half of the leaves, or all of the leaves per plant) and nitrogen rates (zero and 100 kg ha^{-1}) were among the variables examined. Nitrogen and defoliation as two source manipulations were used. The results demonstrated a significant decrease in the number of seeds per ear row and column, cob length and weight, and seed yield upon complete defoliation during the tasselling stage. Germination features of generated seeds were also affected by the maternal plant environment. Under removal of all leaves per plant, seed germination percentage, seed vigor, and seedling weight were reduced. Harvesting of the half-green leaves prior to the ripening of the seeds did not result in a decrease in seed yield or germination characteristics of the generated seeds. Nitrogen had less application of an impact on the analyzed maize features than defoliation. In conclusion, half of the green leaves in maize can be harvested before seed maturity without reducing seed yield and seed germination.

Keywords: Defoliation, Maternal plant environment, Seed vigour, Sink-source, Tasselling stage

Introduction

The leaves play an important role in providing grain reserves in cereals by performing photosynthesis. The leaf is known as the source and the seed is known as the sink. The amount of photosynthetic material produced by the plant may decrease if a portion of the leaf is removed. In recent years, Maize is a C4 plant that has been widely cultivated as a summer plant in western of Iran. The dual-purpose utilization of maize grain and forage severe to diminish

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the accumulation of woody residues in the soil while simultaneously supplying forage for livestock. Determining the appropriate stage of harvest, leaf harvest rate, nitrogen consumption in dual-purpose cultivation, etc. are some of the key factors that are critical in this regard. Numerous researches have been investigated the impact of defoliation (Cavagnaro et al., 2021; Császár et al*.,* 2021; Ferretti et al*.,* 2021; Waterman and Vermeire, 2021). Fasae et al. (2009) reported that maize defoliation yields the highest grain and leaf production approximately12 weeks post-planting, demonstrating its viability for dual-purpose forage and grain cultivation. In the case of sunflower (*Helianthus annuus*), grain yield was found to decrease with increased defoliation intensity before flowering (Erbas and Baydar, 2007). The position of leaves also plays a significant role in determining the effect of leaf removal on grain yield. Khan et al. (2001) noted that the removal of the upper leaves in the sunflower significantly affects grain yield more than the removal of lower leaves, as the upper leaves are closer to the seed sources. In sugarcane (*Saccharum* spp.), the removal and harvesting of leaves for animal feed did not alter sucrose content and agronomic characteristics (Gutie´Rrez-Miceli et al*.,* 2004). Nitrogen is a crucial nutrient that facilitate rapid crop growth, and since plant leaves contain nitrogen, the removal results in a loss of this essential nutrient. A study simulating hail damage on wheat (*Triticum aestivum* L.) through leaf removal revealed that nitrogen consumption maintained the grain yield of damaged plants at levels comparable to the control group (Heidari et al*.,* 2013).

The conditions surrounding the mother plant significantly affect the germination characteristics of the seeds it produces. For instance, the application of nitrogen in the environment of mother plant was found to reduce the germination rate of seeds from garden cornflowers (*Centaurea cyanus*) (Mohammaddoust et al. 2008). Conversely, a separate investigation revealed that nitrogen application did not impact the germination characteristics of rapeseed seeds (Oskouie, 2012). Additionally, excessive nitrogen consumption in the mother plant environment led to a reduction in the germination percentage of wheat seeds (*Triticum aestivum*) due to increased salinity in the growing medium (Fallahi and Khajeh-Hosseini, 2011).

Research on the impact of the mother plant environment on the germination traits of crop seeds is limited, and this study aims to provide valuable insights for both public and private seed producers. On the other hand, maize serves as a dual purpose, providing seeds for poultry feed and fodder for livestock. Consequently, this experiment investigated the effects of nitrogen levels and defoliation intensity on the seed yield and germination characteristics of maize.

Materials and methods

Field experiment

A field experiment was carried out in Kashantoo village, Chamchamal plain, Kermanshah (34 ° N, 47 ° E, an altitude of 1300 m) in 2013. The region experiences an average annual rainfall of 442 mm (IMO, 2023). Situated in western Iran, this plain is the main source of maize production in Kermanshah. The high groundwater levels in the area render for irrigated agriculture. The field experiment was conducted as a factorial experiment within a randomized complete block framework, comprising three replications. The factors examined included varying levels of defoliation (no leaf removal, removal of half of the leaves, and complete leaf) and nitrogen application rates (no nitrogen application and 100 kg of nitrogen per hectare). Nitrogen and defoliation served as the primary manipulative variables. Treatments were applied on July 5, 2013, coinciding with the onset of tasselling. Before sowing, the soil was prepared using a mouldboard plough, followed by the incorporation of triple superphosphate fertilizer at a rate of 300 kg per hectare. Seeds of Single Cross 704 Maize cultivar (*Zea mays* L.) were planted on April 12, 2013, utilizing a pneumatic seedling machine. The seeding rate was set at 20 kg per hectare, with a row spacing of 0.75 meters. A top dressing of urea fertilizer was applied at the rate of 367 kg per hectare at the onset of the stem elongation stage. Irrigation was conducted every 10 days, commencing on 15 June, with three irrigations performed prior to the application of treatment. Plants were irrigated a total of seven times at the end of the growing season. Maize ears were harvested once the plants exhibited yellowing and a reduction in moisture content. In each experimental plot, three representative plants were selected for analysis. The samples were air-dried before being transported to the Agronomy Laboratory of Razi University. Firstly, the weight of the ear husk was recorded, followed by the enumeration of seeds per row and column on the ear. After separating the seeds from the cob, the length and weight of the cob were measured. At the next step, seed yield and the weight of 200 seeds were calculated, with all measurements derived from three selected plants

Laboratory experiment

In the laboratory experiment, the initial step involved the extraction of seeds from the ear, followed by their preparation seeds for cultivation in the Petri dishes. This study aimed to examine the influence of field treatment applied to the parent plant on the germination characteristics of maize seeds through a standard germination experiment. The seeds were surface disinfected using sodium hypochlorite solution for a duration of five minutes and then transferred to sterile Petri dishes lined with two layers of filter paper. Each Petri dish contained 20 maize seeds, to which 8 ml of sterile distilled water was subsequently added to each Petri dish. To prevent evaporation of distilled water, all three replicates of a single treatment were enclosed within a plastic bag. The petri dishes were then incubated in a germinator set at 22 °C for a period of seven days, after which measurements were taken for germination percentage, as well as the length of caulicle and radicle, and the weight of seedling. The seedlings were dried in the oven at 75 °C, maintaining the temperature for 24 hours. Germination was determined based on a growth of two mm in both the caulicle and radicle. Seed vigour was obtained with the following equations (Heidari et al*.,* 2013).

(1)

Seed vigour based on length (% cm) = (Radicle length (cm) + Caulicle length (cm)) (Germination (%))

(2)

Seed vigour based on weight (% mg) = (Radicle weight (mg) + Caulicle weight (mg)) (Germination (%))

Data analysis

Data were initially analyzed by variance, followed by the means were compared using Duncan's test at the 5% probability level. The normality of the data was evaluated, and appropriate transformations were applied when normality was not achieved. Additionally, correlations among the traits were calculated. The statistical analysis was conducted using MINITAB (Ver. 14.0), SAS (Ver. 9.1), and SPSS (Ver. 16.0).

Results and discussion

Field experiment

Ear husk weight

The application of nitrogen application coupled with the removal of half of the leaves, resulted in a greater ear husk weight compared to the treatment that involved no nitrogen application and no leaf removal, as well as the treatments that entailed complete leaf removal with or without nitrogen application. The total removal of leaves led to a significant decrease in the weight of ear husk so that nitrogen consumption could not compensate for the damage caused by complete defoliation of leaves at the stage of tasselling (Table 1). The application of 100 kg of nitrogen per hectare during the tasselling stage resulted in an increased weight of ear husk in plants from which half of the leaves were removed, in comparison to the control group that did not receive nitrogen and was not foliated. A positive and significant correlation was observed between ear husk weight and both the number of seeds per row and overall seed yield (Table 2). In oats, the plant recovered faster from defoliation damage when nitrogen was available (Cook and Lovett, 1974). Additionally, Pinkard et al. (2007) also reported a positive effect of nitrogen on plant shoot renewal, which is consistent with the results of this study.

Seed number per column and row of the ear

Regarding the number of seeds per column and row of the ear, treatment without defoliation, both with and without nitrogen application, exhibited a greater number of seeds per column than those subjected to complete defoliation, regardless of nitrogen application, as well as those with half of the leaves removed and nitrogen applied. The application of nitrogen was insufficient to compensate the damage caused by the severe reduction in the number of seeds per column with complete defoliation (Table 1). In the case of nitrogen consumption, removing half of the leaves reduced the number of seeds per column compared to not removing the leaves. No leaf removal with a consumption of 100 kg N per hectare at the tasselling stage had the highest number of seeds per row. The number of seeds per row and column had a positive and significant correlation with each other and with the length and weight of the cob (Table 2). The length and weight of the cob provide the basis for the development of the number of seeds per row and column of the ear, so their correlation was not unexpected. Barimavandi et al. (2010) reported that only complete defoliation affected the number of rows on the ear.

Cob length and weight

The treatment of no-defoliation combined with nitrogen application resulted in a greater cob length compared to the complete defoliation treatment without nitrogen, the complete defoliation treatment with nitrogen, and the treatment involving the removal of half the leaves without nitrogen (Table 1). The combination of no defoliation and the application of 100 kg of nitrogen per hectare during the tasselling stage yielded the maximum cob weight. Additionally, the application of nitrogen at two different cutting heights in *Phalaris tuberosa* led to a decrease in plant mortality, with the highest nitrogen rate contributing to the greatest biomass production (Grimmett, 1967).

Seed yield and 200-seed weight

The removal of fifty percent of the leaves without the application of nitrogen resulted in a greater seed yield compared to other treatments, with the exception of no leaves removal with nitrogen and the removal of half of the leaves with nitrogen (Table 1). This phenomenon can be attributed to the fact that the lower leaves of the plant typically exist in the shaded area and consist of older foliage, where the respiration may exceed photosynthesis. Therefore, the removal of these leaves can increase seed yield. A positive and significant correlation was observed between seed yield and factors such as a 200-seed weight, the number of seeds per row, and ear husk weight (Table 2). Some of the results of this study are consistent with the findings of other researchers (Barimavandi et al., 2010). The weight of 200 seeds of maize was not affected by defoliation and nitrogen application (Table 1). Generally, seed weight is less affected by environmental conditions and is predominantly determined by genetic factors. However, due to the incomplete formation of seeds on the ear in the complete leaf removal treatment, it can be said that seed weight is not affected by defoliation.

Table 1. Effect of nitrogen rate and defoliation intensity on maize traits

Treatments	Ear husk weight (g plant^{-1})[b]	Seed number per column	Seed number per row	Cob length (cm)	Cob weight (g plant^{-1})	Seed yield (g plant^{-1})	200-Seed weight (g)
N1D1[a]	6.367 bc	39.57 a	12.0 b	17.1 ab	10.033 b	36.11 b	54. 7 a
N1D2	9.503 ab	32.50 ab	11.5 b	11.5 b	8.495 b	70.56 a	58.0 a
N1D3	4.195 c	0.00 c	0.0 c	0.9 c	0.013 c	0.00 c	------
N2D1	9.145 ab	37.35 a	18.0 a	17.8 a	18.500 a	52.07 ab	55.5 a
N2D2	10.620 a	23.00 b	11.3 b	12.9 ab	7.760 c	62.13 ab	56.3 a
N2D3	3.873 c	0.43 c	0. 6 c	1.2 c	0.077 c	0.54 c	------

[a] N1 and N2 are nitrogen rates of 0 and 100 kg ha^{-1}, respectively. D1= no leaf removal, D2= removal of ½ leaves, D3= removal of all leaves.

[b] Means followed by the same letter within each column are not significantly different according to Duncan's Test ($P < 0.05$).

Table 2. Correlation coefficients among maize traits under nitrogen rate and defoliation intensity

	Ear Husk Weight	Seed Number Per Column	Seed Number Per Row	Cob Length	Cob Weight	Seed Yield	200-Seed Weight
Ear Husk Weight	1	.700	.816*	.731	.698	.965**	.738
Seed Number Per Column	.700	1	.940**	.971**	.885*	.800	-.525
Seed Number Per Row	.816*	.940**	1	.966**	.972**	.839*	-.247
Cob Length	.731	.971**	.966**	1	.922**	.776	-.857
Cob Weight	.698	.885*	.972**	.922**	1	.709	-.313
Seed Yield	.965**	.800	.839*	.776	.709	1	.980*
200-Seed Weight	.738	-.525	-.247	-.857	-.313	.980*	1

*. Significant at the probability level of 0.05

**. Significant at the probability level of 0.01

Umashankara (2007) reported that among various defoliation levels, total defoliation of maize resulted in the lowest grain weight.

Laboratory experiment

Seed germination percentage

The treatment of removing half of the leaves without using nitrogen, the treatment of not removing the leaves with nitrogen application, and the removal of half of the leaves with nitrogen application exhibited higher percentage of seed germination compared to the treatments involving complete leaf removal without nitrogen and complete leaf removal with nitrogen application (Table 3). The percentage of seed germination showed a significant positive correlation with all germination characteristics, with the exception of caulicle length (Table 4). The removal of the leaves leads to a reduction in the current photosynthesis of the plant, thereby diminishing the production of the photosynthetic material necessary for seed development. This is further evidenced by a notable decrease in the number of seeds per ear. Seeds that are exposed to insufficient photosynthetic material are likely to be poorly developed, resulting in weak seedlings (Table 3). In contrast, *Vicia sativa* demonstrated similar germination percentages across various defoliation intensities as noted by Koptur et al. (1996), which diverges from the results of this study.

Caulicle and radicle length

The length of the caulicle was unaffected by both defoliation and nitrogen treatment (Table 3). The treatment involving the retention of leaves with nitrogen application resulted in a greater radicle length compared to the treatment included complete leaf removal without nitrogen and the treatment involved complete leaf removal with nitrogen (Table 3). Radicle length exhibited a positive and significant correlation with all germination traits, with the exception of caulicle length (Table 4). These results show that the caulicle length of the seeds produced, which is shorter than the radicle length, is affected by the environmental conditions of the mother plant. This may be attributed to the fact that the radicle is the first structure to emerge from the seed, leading the seedling to prioritize the elongation of the radicle for the rapid establishment in the soil. Consequently, the radicle is more likely to reflect the internal characteristics of the seed and serves as a more effective criterion for assessing the impact of maternal environmental conditions on the offspring (Jadia and Fulekar, 2008).

Seedling weight and seed vigour

Non-removal of leaves or removal of half of the leaves, regardless of nitrogen application, resulted in greater seedling weight and seed vigour based on weight, compared to complete defoliation. At each nitrogen level, both no defoliation and removal of half the leaves exhibited superior seed vigour based on length when contrasted with complete defoliation (Table 3). Furthermore, seedling weight and seed vigour demonstrated a positive and significant correlation with all seed germination characteristics, with the exception of caulicle length (Table 4). Radicle length, germination percentage, and seedling weight are the components of seed vigour, so their correlation was not far from expectation. In *Potentilla tanacetifolia*, the nitrogen uptake by the mother plant was found to diminish the biomass of the seedling produced (Li et al*.,* 2011). As previously mentioned, the photosynthetic resources necessary for seed development become limited when the plant completely sheds its leaves. Therefore, the resulting seeds are expected to shrink and produce weak seedlings, which has happened in this study. On the other hand, the loss of half of the plant leaves in the lower part of the canopy did not affect the seed germination traits. This may be attributed to the lower leaves inadequate photosynthetic efficiency due to their age and shaded position, which may even lead to them acting parasitically in terms of nutrition consumption. Notably, the application of nitrogen to enhance the radicle length of the seeds produced by the plant and to increase the seed vigour based on length proved beneficial. It was observed that the radicle length and vigour based on length of seeds produced under complete defoliation conditions that received nitrogen were not significantly differ from the control group (which had no nitrogen application and no defoliation). While, the treatment involving complete defoliation without nitrogen application exhibited a significant decrease compared to the control. Therefore, it is suggested that if the production of seed maize is considered, it is better not to neglect the consumption of nitrogen even at the tasselling stage. In addition, the producer need not be concerned about the loss of the lower leaves of the maize plant during the later stage of tasselling because, as these leaves do not significantly contribute to enhancing the germination characteristics of the seeds produced.

Conclusion

Complete defoliation of maize at the tasselling stage caused a severe reduction in seed yield, its components, and germination characteristics of the produced seeds. Loss of lower leaves of the plant did not

Table 3. Effect of nitrogen rate and defoliation intensity on maize seed traits

[a]Treatments	Germination (%)	Caulicle length (cm)	Radicle length (cm)	Seedling weight (mg)	Vigour (% mg)	Vigour (% cm)
N1D1 [a]	71. 7 ab	4.97 a	11.83 ab	38.2 a	28.89 a	11.99 ab
N1D2	91. 7 a	3.33 a	10.87 ab	45.5 a	41.75 a	13.09 ab
N1D3	35.0 b	3.70 a	2.70 c	10.4 b	3.64 b	2.23 c
N2D1	97.5 a	3.55 a	14.70 a	53.7 a	52.37 a	17.74 a
N2D2	91. 7 a	4.30 a	12.27 ab	49.5 a	45.20 a	14.78 a
N2D3	50.0 b	4.70 a	4.40 bc	14.0 b	7.00 b	4.55 bc

[a]N1 and N2 are nitrogen rates of 0 and 100 kg ha^{-1}, respectively. D1= no leaf removal, D2= removal of ½ leaves, D3= removal of all leaves.

[b]Means followed by the same letter within each column are not significantly different according to Duncan's Test ($P < 0.05$).

Table 4. Correlation coefficients among maize seed traits under nitrogen rate and defoliation intensity

	Germination percent	Caulicle length	Radicle length	Seedling weight	Vigour (based on weight)	Vigour (based on length)
Germination percent	1	-.285	.944**	.983**	.987**	.976**
Caulicle length	-.285	1	-.105	-.250	-.331	-.202
Radicle length	.944**	-.105	1	.976**	.958**	.990**
Seedling weight	.983**	-.250	.976**	1	.994**	.992**
Vigour (based on weight)	.987**	-.331	.958**	.994**	1	.986**
Vigour (based on length)	.976**	-.202	.990**	.992**	.986**	1

*. Significant at the probability level of 0.05

**. Significant at the probability level of 0.01

affect seed yield, its components, and germination characteristics of produced seeds. It is recommended to utilize nitrogen to improve the seed vigour at the tasselling stage. Furthermore, it is suggested to study the effect of defoliation at the pre- and post-tasselling stages on the germination characteristics of maize seed.

Conflict of interest

The authors declare that they have no conflict of interest with any organization concerning the subject of the manuscript.

References

Barimavandi AR, Sedaghathoor S, Ansari R. (2010). Effect of different defoliation treatments on yield and yield components in maize (*Zea mays* L.) cultivar of S.C704. Australian Journal of Crop Science. 4: 9-15.

Cavagnaro RA, Oyarzabal M, Oesterheld M, Grimoldi AA. (2021). Species-specific trade-offs between regrowth and mycorrhizas in the face of defoliation and phosphorus addition. Fungal Ecology. 51: 101058. DOI:10.1016/j.funeco.2021.101058.

Cook LJ and Lovett JV (1974). Response of oats to nitrogen and defoliation. Australian Journal of Experimental Agriculture and Animal Husbandry. 14: 373-379. DOI:10.1071/EA9740373

Császár O, Tóth F, Lajos K. (2021). Estimation of the expected maximal defoliation and yield loss caused by cereal leaf beetle (*Oulema melanopus* L.) larvae in winter wheat (*Triticum aestivum* L.). Crop Protection. 145: 105644. DOI:10.1016/j.cropro.2021.105644.

Erbas S and Baydar H. (2007). Defoliation effects on sunflower (*Helianthus annuus* L.) seed yield and oil quality. Turkish Journal of Biology. 31: 115-118.

Fallahi J, Khajeh-Hosseini M. (2011). Effects of applying various levels of nitrogen on parent plants on the resistance to salinity stress in achieved seeds in *Triticum aestivum* L. cv. Gaskojen at germination period. Journal of Agricultural Technology. 7: 1743-1754.

Fasae OA, Adu FI, Aina ABJ, Elemo KA. (2009). Effects of defoliation time of maize on leaf yield, quality and storage of maize leafs as dry season forage for ruminant production. Revista Brasileira de Ciencias Agrárias. 4: 353-357. DOI:10.5039/agraria.v4i3a19

Ferretti M, Bacaro G, Brunialti G, Calderisi M, Croisé L, Frati L, Nicolas M. (2021). Tree canopy defoliation can reveal growth decline in mid-latitude temperate forests. Ecological Indicators. 127: 107749. DOI:10.1016/j.ecolind.2021.107749

Grimmett SG. (1967). The effect of severity of defoliation and nitrogen fertilizer on the growth of *Phalaris tuberosa* L. Grass and Forage Science. 22: 42-45. Doi:10.1111/j.1365-2494.1967.tb00500.x

Gutie´rrez-Miceli FA, Morales-Torres R, de Jesu´ s Espinosa-Castan˜ eda Y, Rinco´ n-Rosales R, Montes-Molina J, Oliva-Llaven MA, Dendooven L. (2004). Effects of partial defoliation on sucrose accumulation, enzyme activity and agronomic parameters in sugar cane (*Saccharum* spp.). Journal of Agronomy

& Crop Science. 190: 256-261. Doi:10.1111/j.1439-037X.2004.00103.x

Heidari H, Fatahi A, Saeedi M, Khoramivafa M. (2013). Study of defoliation intensity and nitrogen rate effects on yield, yield components and germination traits of produced seed in wheat (*Triticum aestivum*). Agricultura – Ştiinţă şi practică. 1-2: 11-17.

IMO. (2023). Iran Meteorological Organization, Meteorological data. http://www.weather.ir (Accessed on 22 3 2023).

Jadia CD and Fulekar MH. (2008). Phytoremediation: The application of vermicompost to remove zinc, cadmium, copper, nickel and lead by sunflower plant. Environmental Engineering and Management Journal. 7: 547-558. DOI:10.30638/eemj.2008.078

Khan ShMA, Poswal MA, Rana MA, Baitullah. (2001). Simulation of leaf damage by artificial defoliation and its effect on sunflower (*Helianthus annuus* L.) performance. HELIA. 24: 145-154. DOI:10.1515/helia.2001.24.34.145

Koptur S, Smith CL, Lawton JH. (1996). Effects of artificial defoliation on reproductive allocation in the common vetch *Vicia sativa* (fabaceae; papilionoideae). American Journal of Botany. 83: 886-889. DOI:10.1002/j.1537-2197.1996.tb12780.x

Li Y, Yang H, Xia J, Zhang W, Wan S, Li L. (2011). Effects of increased nitrogen deposition and precipitation on seed and seedling production of *Potentilla tanacetifolia* in a temperate steppe ecosystem. PLoS ONE. 6: 1-8. DOI:10.1371/journal.pone.0028601

Mohammaddoust HR, Asghari A, Tulikov AM, Hasanzadeh M, Saidi MR. (2008). Effect of fertilizer application on density, dry matter and seed characteristics of garden *cornflower (Centaurea cyanus L.) and corn spurrey (Spergula vulgaris L.).* Pakistan Journal of Weed Science Research. 14: 73-80.

Oskouie B. (2012). Effect of mother plant nitrogen application on seed establishment of rapeseed. International Journal of AgriScience. 2: 444-450.

Pinkard EA, Battaglia M, Mohammed C. (2007). Defoliation and nitrogen effects on photosynthesis and growth of *Eucalyptus globulus*. Tree Physiology. 27: 1053-1063. DOI:10.1093/treephys/27.7.1053.

Umashankara KB. (2007). Influence of stage and levels of defoliation on seed yield and quality of fodder maize (c.v. South African Tall). Department of seed science and technology, M. Sc. thesis, University of Agricultural Sciences, Dharwad, 77 p.

Waterman RC and Vermeire LT. (2021). Annual bromes decrease with increasing fall defoliation intensity. Global Ecology and Conservation. 28: e01652. DOI:10.1016/j.gecco.2021.e01652.