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Responses of Maize (SC704) Yield and Yield Components to Source Restriction

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ABSTRACT- Understanding the relationship between sink and source in maize is of prime importance in maize growing regions. In this study, a field experiment was carried out during spring and summer 2007 in the experimental field of the College of Agriculture, Shiraz University, to examine the effects of source restriction (defoliation) on sink size (yield and its components) of SC704 maize hybrid. A factorial arrangement in a randomized complete block design with four replications was used. Treatments composed of four stages of source restriction including defoliation at half-silking and 3 consecutive 10 day intervals, as well as three defoliation intensities (zero, half and all leaf removal). It was found that delay in source limitation was associated with a lower mean kernel weight achievement. The highest mean kernel weight was attained in defoliation at half-silking (208.14 g), which also resulted in the lowest grain yield reduction, compared to no defoliation treatment. Increase in defoliation intensity was associated with a decrease in grain yield; however, delay in defoliation after mid-silking had no significant effect on grain yield. It was concluded that the grain yield of SC704 maize hybrid was more sensitive to source limitation (i.e. defoliation) intensity than defoliation time.

Keywords: Defoliation, Grain yield, Half- silking, Mean kernel weight

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INTRODUCTION

Maize (*Zea mays* L.) is one of the world's most important cereal crops, grown widely throughout the world in a range of agro-ecological environments. Management practices such as defoliation have been reported to be associated with even higher maize yield and quality (15).

Deciding when to defoliate a crop is an important decision from several points of view. If the crop is defoliated too soon, yield and quality might be negatively affected (25). On the other hand, depending on location and field conditions, delay in defoliation can result in enhanced pest (insect) problems, or delay in harvest (bad weather conditions) which will adversely affect yield and yield components(1 and 6). Defoliation intensity can also exert a dramatic influence on crop yield in several ways; which is why defoliation decisions must be based on the crop and its environmental conditions. (6 and 25).

Reduction of seed yield as a consequence of leaf removal from maize plants when they were in their early reproduction phase has been reported by many researchers (1, 6 and 25). A less marked reduction of the seed yield was found upon the removal of some blades earlier or later in the development of the crop (8 and 15). It has also been reported that if the blades are not removed until the ear has developed, the plant will have the advantage of using photoassimilates produced by the leaves and will therefore, produce more seeds compared to earlier defoliated plants (26).

Studies in crop defoliation have recently received more attention. For instance, a study on maize defoliation by Egharevba et al. (13) showed that huge leaf loss up to at least l0 days after mid-silking decreased grain yield due to reductions in kernel number per plant, whereas grain yield reductions associated with leaf loss 20 days or more after mid-silking has been largely related to a decline in mean kernel weight (15). Leaf removal in maize at or after silking resulted in significant reduction in grain yield (3 and 16). Duncan and Hatfield (10) reported that kernel growth continued at only a slightly lower rate after complete defoliation 12 and 25 days after silking. Walpole and Morgan (29) showed that leaf removal in winter wheat (*Triticum aestivum* L.) 7 days after anthesis did not reduce the rate of grain growth. Aggarwal et al. (2) found that whole plant defoliation treatments had no significant effect on wheat grain yield in most cases. Zhu et al. (30) reported that defoliation of wheat at late tillering increased main shoot grain yield and harvest index and enhanced stomatal conductance and net photosynthesis rate of remaining leaves at anthesis. Detrimental effects of defoliation on yield components might be related directly to reductions in photosynthetic capacity of the remaining tissues (18).

Source restriction effect on crop yield is frequently sought in terms of either photoassimilate production or sink size, the site of the assimilate utilization (14). However, analysis of this system may not always clearly identify the yield limiting process. For example, the conclusion of sink-limited yield, based on seed dry weight response might not be correct, since the photosynthetic activity of the source organs, the source size, might affect sink demand (15). On the other hand, remobilization of the stored carbohydrate might minimize the source limitation (25).

Although there are a number of reports on the effects of leaf removal on maize yield, no detailed study has yet been published on the effects of defoliation time and intensity on the maize hybrid (SC407) which is widely grown in semiarid climate conditions such as Iran. The objective of this investigation was to study the effect of source restriction time and intensity on assimilate partitioning in maize hybrid SC704.

MATERIALS AND METHODS

Field experiment was carried out during the 2007 growing season in the experimental farm of the College of Agriculture, Shiraz University, 18km North of Shiraz, Iran (29°50′N, 52°46′E), approximately 1810 m above sea level. The average annual precipitation of this area is between 350 to 450mm. The soil characteristics of the experimental site, Daneshkadeh soil series (fine, mixed, mesic, Calcixerollic, Xerochrepts), are given in Table 1.

Table 1. Main soil physiochemical characteristics of the experimental site

Physiochemical characteristics	
Classification	**Calcixerollic, Xerochrepts**
Field capacity (%)	**34**
Wilting point (%)	**15**
Silt (%)	**48**
Clay (%)	**30**
Sand (%)	**22**
Soil texture	**Clay**
Chemical characteristics	
Soil pH	**7.7**
Potassium (mg kg $^{-1}$)	**590**
Phosphorus (mg kg $^{-1}$)	**26**
Organic carbon (%)	**1.17**
Organic matter (%)	**1.75**
Total nitrogen (%)	**0.114**
Electrical conductivity (dS m $^{-1}$)	**0.402**

Uniform maize seeds of single cross 704 hybrid were manually planted on June 25 in 75-cm rows. The plants were 12.5 cm apart within each row. Each experimental plot area was 15 m^2 (3×5m). A factorial arrangement of treatments in a randomized complete block design with four replications was used. The treatments consisted of defoliation times at four levels: half silking (when the length of appeared silks was about 2-3 centimeters) and three consecutive 10 day intervals with defoliation intensities of three 0, 50 and 100% leaf removal levels. At 50% defoliation intensity the number of leaves was reduced to half. Defoliation practices started in September 2 by excising leaves using a pair of scissors. A seasonal total of 400 kg ha^{-1} of N and 200 $kgha^{-1}$ of P were given as urea and ammonium phosphate in split applications; half before planting and the rest being top dressed at the six-leaf stage. The plots were irrigated every eleven days by a siphon and weeds appearing in the field were hand- pulled during the experiment. Plants were harvested from Oct. 24 to Nov. 1 at physiological maturity to determine the grain yield and its components.

The leaf area of plants was measured at the beginning of defoliation using a leaf area meter model, the Delta-T Device (Fig. 1). Kernel numbers per ear were estimated by multiplying kernel row numbers by average kernel numbers in each row. After counting one thousand kernels using a seed counter, kernels were weighted by a digital scale.

An analysis of variance was run using SAS software (24), and the means were separated by Duncan multiple range test.

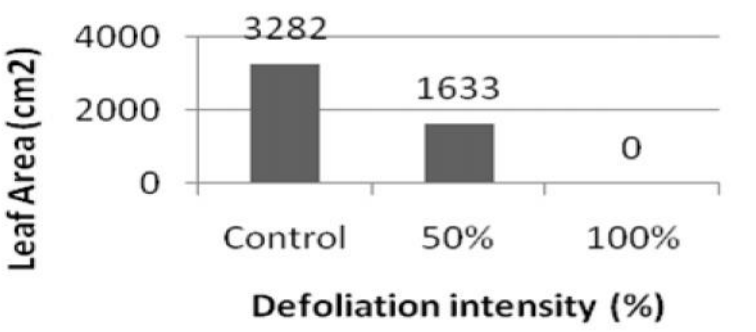

Fig. 1. Leaf area per plant at the onset of defoliation treatments

RESULTS AND DISCUSSION

Number of kernels per ear

Results of the present investigation indicated that more defoliation intensity significantly reduced kernels per ear and kernels per ear row (Table2). These findings were in accordance with Carcova et al. (9) who suggested that the reduced number of kernels per ear was a consequence of reduction in current photosynthesis. Furthermore, the time of defoliation may exert a significant influence on the number of kernels per ear. Tollenar and Daynard (25) showed that defoliation 2 weeks after half- silking affected the number of kernels per ear. Emam and Seghatoleslami (15) also reported similar results.

Table 2. Effect of defoliation intensity and defoliation time on number of kernels per ear

Treatments	number of kernels per ear
Defoliation intensity (%)	
0 (control)	625.50a**
50	511.69b
100	321.63c
Defoliation time	
Half- silking	405.17c
10 days after half-silking	495.25b
20 days after half-silking	485.83b
30 days after half-silking	558.83a

Means within each column with the same letter(s) are not Significantly different using Duncan 0.05

Higher and lower number of kernels per ear was observed in defoliation 30 days after half- silking (Table 2). This finding was in agreement with the results of Borras and Otegui (6). Apparently, the rate of biomass accumulation in ears around the flowering stage is responsible for kernel formation within the ear (4, 11 and 27). The lowest number of kernels per ear was observed in 100% defoliation at half silking and 10 days later (Fig. 2 and 3). Emam and Seghatoleslami (15) also argued that defoliation could reduce the number of kernels per ear as a result of the lack of photoassimilate production.

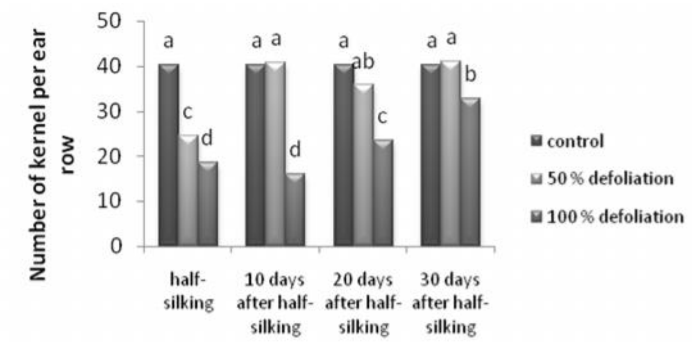

Fig. 2. Interaction between defoliation intensity and defoliation time on number of kernels per ear row of maize plant. Columns with similar letters are not significantly different using Duncan 0.05

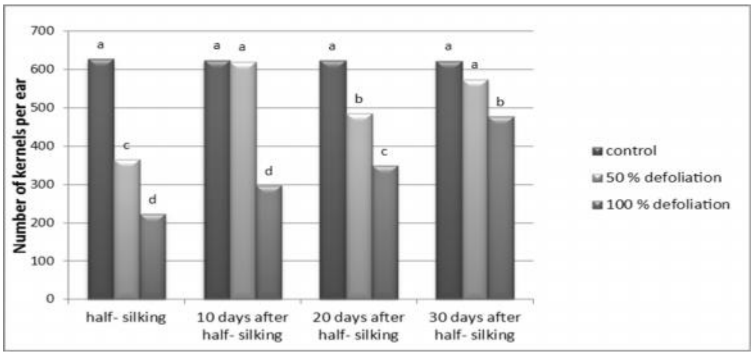

Fig. 3. Interaction between defoliation intensity and defoliation time on number of kernels per ear of maize plant. Columns with similar letters are not significantly different using Duncan 0.05

Mean kernel weight

Results of the present investigation demonstrated that defoliation intensity significantly affected mean kernel weight of maize plants (Table 3**).** Maximum (220.5 g) and minimum (150.15 g) thousand kernel weight were achieved from the control and 100% defoliation treatments, respectively (Table 3). Defoliation times also had a significant effect on mean kernel weight. In addition, higher kernel weight was observed in defoliation at half- silking and 20 days later (Table 3). The post-flowering source–sink ratio determines the mean kernel weight of the maize plants (7). Similar results have also been reported by Mostafavi and Cross (19), who found that complete removal of leaves at the tasseling stage can reduce mean kernel weight, dry matter accumulation rate and grain yield. Roy and Biswas (21) noticed that de-topping after silking leads to a higher mean kernel weight. These researchers (21) also concluded that higher plant density resulted in reduced mean kernel weight.

Table 3. Effect of defoliation intensity and defoliation time on grain yield and thousand kernel weight

Treatments	grain yield (kg/ha)	Thousand kernel weight (g)
Defoliation intensity (%)		
0 (control)	**12730.7a****	**220.50a****
50	**9405.00b**	**203.96b**
100	**4819.8c**	**150.15c**
Defoliation time		
Half- silking	**9617.1a**	**208.14a**
10 days after half-silking	**8931.8a**	**186.08b**
20 days after half-silking	**9312.8a**	**208.05a**
30 days after half-silking	**9418.7a**	**182.92b**

Means within each column with the same letter(s) are not significantly different using Duncan (0.05)

Besides control treatments, 50% defoliation at 20 days after half- silking also showed a higher mean kernel weight (Fig 4). Kernel growth rate during the effective grain-filling period is the main maize kernel weight determinant (8, 22). Minimum mean kernel weight was observed in the complete defoliation treatment (Table 3). Studying the effect of source-sink ratio on mean-kernel weight in corn, Boras et al. (7) found that the seed dry weight sharply reduced by decreased availability of assimilates during the grain filling period, while, increased availability of assimilates per grain had no significant response. Thus, it might be concluded that corn is a sink limited crop under most farming conditions. It was also noted that after defoliation, stem soluble carbohydrates decreased sharply, which is a sign of accelerated consumption of soluble carbohydrates for growing kernels (25).

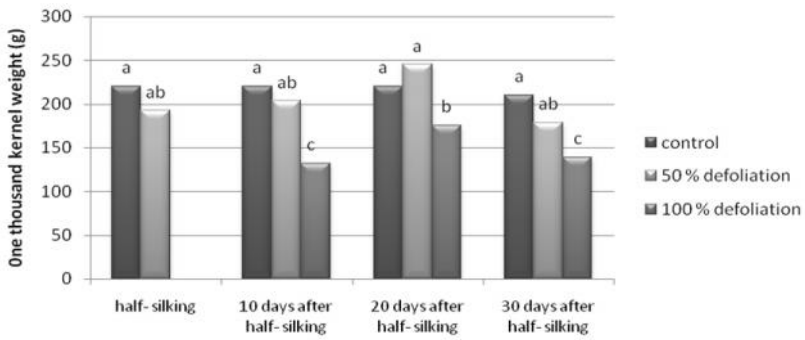

Fig. 4. Interaction between defoliation density and defoliation times on the thousand kernel weight of maize plant. Columns with similar letter are not significantly different. Duncan (0.05). There was no yield formation in 100% defoliation at half silking

Grain yield

Higher defoliation intensity significantly decreased grain yield, the maximum grain yield being achieved in control plants (Table 3). Wilhelm et al (29) examined the effects of leaf removal and de-tasseling on inbred maize and found that grain yield decreased as a consequence of leaf removal. They also concluded that this reduction was a result of diminution in kernel number. Edmeads and Laffite (12) and Hanway (16) also noticed that the highest grain yield reduction was obtained from 100% defoliation treatments. Shapiro et al. (23) and Baldrige (5) found the lowest grain yield from 100% defoliation around the tasseling stage.

Although defoliation time affected the number of kernels and the thousand kernel weight significantly, it did not have any significant effect on grain yield (Table 3). As reported by Jones and Simmons (12) and Edmeads and Lafitte (17), it might be due to the remobilization of assimilates from vegetative organs to ears that could compensate the reduction of photosynthesis. Emam and Seghatoleslami (15) reported that complete defoliation of maize after tasseling was associated with a significant decrease in grain yield. Other researchers also reported that the decrease in grain yield caused by defoliation might be a consequence of reduction in current photosynthesis (9 and 15). The results of the present investigation show that maximum grain yield was achieved from 0% defoliation in half- silking. Grain yield in 100% defoliation at half- silking was low and negligible (Fig. 5). According to our results, delay in defoliation resulted in lower grain yield reduction, however greater defoliation intensity was associated with lower grain yield.

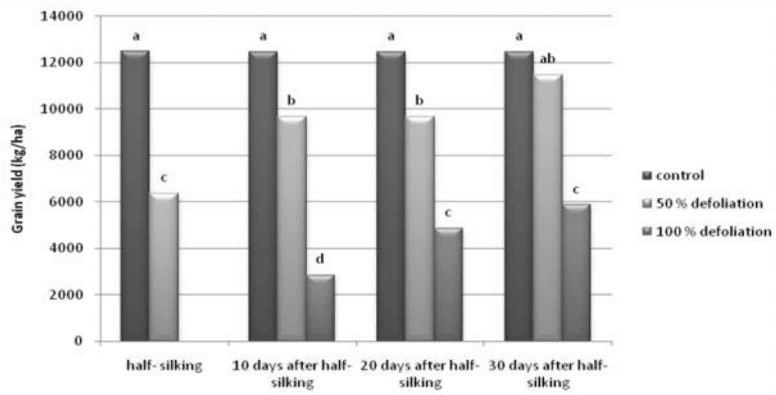

Fig. 5. Interaction between defoliation density and defoliation times on grain yield of maize plant. Columns with similar letter are not significantly different using Duncan 0.05

CONCLUSION

The present investigation demonstrated that delays in defoliation reduced the negative effect of source restriction on yield components. Of course, defoliation at half-silking declined current photosynthesis and consequently reduced yield components. Apparently, half-silking defoliation enhanced remobilization of stem soluble carbohydrates. It seems that the 50% defoliation performed 30 days after half-silking produced similar yield as the control. The results from this study can provide a basis for better understanding of source restriction on grain yield and its components of the SC704 maize hybrid.

REFERENCES

1. Afarinesh, A. 2005. Study of the effect of the intensity and timing of topping on maize (*Zea mays* L.) grain yield under Khuzestan conditions. Iranian J. Agric. Sci. 4: 337-346 (In Farsi)

2. Aggarwal, P. K, R. A. Fischer, and S. D. Liboon. 1990. Source – sink relations and effects of post anthesis canopy defoliation in wheat at low latitudes. J. Agric. Sci. 114: 93-99.

3. Allison, R. C. and D. J. Watson. 1966. The production and distribution of dry matter in maize after flowering. Ann. Bot. 30: 365- 381.

4. Andrade F.H, C. Vega, S. Uhart, A. Cirilo, M. Cantarero and O. Valentinuz. 1999 Kernel number determination in maize. Crop Sci. 39: 453-459.

5. Baldridge, D.E. 1976. The effects of simulated hail injury on the yield of corn grown for silage. Bull. B687. Montana Agric Exp. Stn., Bozeman

6. Borras, L., and M. E. Otegui. 2001. Maize kernel weight response to post flowering source- sink ratio. Crop Sci. 21: 1816-1822.

7. Borras, L., G. A. Slafer, and M. E. Otegui. 2004. Seed dry weight response to source-sink manipulations in wheat, maize and soybean: a quantitative reappraisal. Field Crops Res. 86: 131- 146.

8. Borras, L., M. Y. Westgate, and M, Otegui. 2003. Control of kernel weight and kernel water relations by post-flowering source-sink ratio in maize. Ann. Bot. 91: 857-867.

9. Carcova, J., B. Andrieu, and M. E. Otegui. 2003. Silk elongation in maize relationship with flower development and pollination. Crop Sci.43: 914- 920.

10. Duncan, W.G. and J. L. Hatfild.1965. The daily growth and yield of corn kernels. Agron. J. 57: 221-223.

11. Echarte, L., F.H. Andrade, C.R.C. Vega, and M. Tollenar. 2004. Kernel number determination in Argentinean maize hybrids released between 1965 and 1993. Crop Sci. 44: 1654-1661.

12. Edmeads, G. O., and H. R. Lafitte. 1993. Defoliation and plant density effects on maize selected for reduced plant height. Agron. J. 85: 850- 857.

13. Egharevba , P, N., R. D. Horrocks, and M. S. Zuber. 1976. Dry matter accumulation in maize in response to defoliation. Agron. J. 68: 40-43.

14. Egli, D. B. and W. P. Bruening, 2001. Source- sink relationship, seed sucrose levels and seed growth rates in soybean. Ann. Bot., 88: 235- 242.

15. Emam, Y. and M.J. Seghatoleslami. 2005. Crop Yield, Physiology and Processes. Shiraz University Press. 593p. (In Farsi).

16. Hanway, J. J. 1969. Defoliation effects on different corn (*Zea mays* L.) hybrids as influenced by plant population and stage of development. Agron. J. 61: 534- 538.

17. Jones, R. J. and S. R. Simmons. 1983. Effect of altered source- silk ratio on growth of maize kernels. Crop Sci. 23: 129- 134.

18. Macedo, T. B., R. K. D. Peterson, and D. K. Weaver, 2006. Characterization of the impact of wheat stem sawfly, Cephuscinctus Norton, on pigment composition and photosystem || photochemistry of wheat heads. Environ. Entomol., 35: 1115- 1120.

19. Mostafavi, M. R. and H. Z. Cross. 1990. Defoliation effects on grain filling of RnJ color- selected maize strains. Crop Sci. 30: 385- 362.

20. Reddy, V. M. and T. B. Daynard. 1983. Endosperm characteristics associated with rate of grain filling and kernel size in corn. Mydica.28: 339- 355.

21. Roy, S. K. and P. K. Biswas. 1992. Effect of plant density and detopping following silking on cob growth, fodder and grain yield of maize (*Zea mays* L.). J. Agric. Sci. Camb. 119: 297- 301.

22. Saini, H. S. and M. E. Westga. 2000. Reproductive development in grain crops during drought. Advances in Agronomy. 68: 59- 96.

23. Shapiro, C. A., T. A. Peterson, and A. D. Flowerday. 1986. Yield loss due to simulated hail damage on corn: A comparison of actual and predicted values. Agron. J. 78: 585- 589.

24. SAS, 2000. Statistical analysis software. Version 8, .SAS Institute Inc., Cary, NC. USA.

25. Tollenaar, M. and T. B. Daynard. 1978. Effect of defoliation on kernel development in maize. Can. J. Plant Sci. 58: 207- 212.

26. Umashankara, K.B. 2007. Influence of stages and levels of defoliation on seed yield and quality of fodder maize (cv. South African Tall). M. Sc. Thesis. Department of Seeds Science and Technology, College of Agricultural Sciences, Dharwad. 77p.

27. Vega C.R.C., F.H. Andrade, and V.O. Sadras. 2001. Reproductive partitioning and seed set efficiency in soybean, sunflower and maize. Field Crops Res. 72: 163-175.

28. Walpole, P.R, and Morgan, D. G. 1974. The influence of leaf removal upon the development of the grain of winter wheat. Ann. Bot. 38: 779-782.

29. Wilhelm, W. W., B. E. Johnson, and J. S. Schpers. 1995. Yield, quality, and nitrogen use of inbred corn with varying number of leaves removed during de-tasseling. Crop Sci. 26: 951- 956.

30. Zhu, G. X., D. J. Midmore, B. J. Radford and D. F. Yule. 2004. Effect of timing of defoliation on wheat (*Triticum aestivum*) in central Queensland 1. Crop response and yield. Field Crops Res. 88: 211-226.

عملکرد و اجزای عملکرد ذرت در پاسخ به محدودیت مبدا

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چکیده- درک روابط بین مبدا و مقصد فیزیولوژیک در گیاه ذرت در مناطق عمده کشت این محصول از اهمیت ویژه ای برخوردار است. این آزمایش در بهار و تابستان سال ۱۳۸۶ با هدف بررسی تاثیر محدودیت مبدا بر اندازه مقصد فیزیولوژیک ذرت هیبرید سینگل کراس ۷۰۴ در مزرعه تحقیقاتی دانشکده کشاورزی دانشگاه شیراز انجام شد. آزمایش به صورت فاکتوریل در قالب طرح بلوک های کامل تصادفی با چهار تکرار صورت گرفت. تیمارهای زمان حذف برگ در چهار مرحله: میانه ابریشم دهی و با فواصل ۱۰و ۲۰ و ۳۰ روز پس از میانه ابریشم دهی و تیمارهای شدت حذف برگ در سه تیمار بدون برگ زدایی، ۵۰٪ و ۱۰۰٪ برگ زدایی انجام گردید. نتایج نشان داد که تاخیر در ایجاد محدودیت در اندازه مبدا (برگ زدایی) با کاهش میانگین وزن هر دانه همراه است. بیشترین میانگین وزن هزار دانه (۲۰۸/۱۴ گرم) از تیمار برگ زدایی در میانه ابریشم دهی بدست آمد. برگ زدایی در میانه ابریشم دهی با کمترین افت عملکرد نسبت به شاهد همراه بود. افزایش شدت برگ زدایی باعث کاهش عملکرد دانه شد، اگرچه تاخیر در برگ زدایی تاثیر معنی داری بر عملکرد دانه نداشت. چنین نتیجه‌گیری شد که ذرت هیبرید سینگل کراس ۷۰۴ نسبت به شدت کاهش اندازه مبدا (برگ زدایی) پس از میانه ابریشم دهی در مقایسه بازمان برگ زدایی حساس تر بود.

واژه های کلیدی: برگ زدایی، عملکرد دانه، میانگین وزن دانه، میانه ابریشم دهی

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** مکاتبه کننده