International Journal of Plant & Soil Science

28(4): 1-9, 2019; Article no.IJPSS.49708
ISSN: 2320-7035

Effect of Artificial Detasseling and Defoliation on Maize Seed Production

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MPC, MK, AGBZ and GPS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors VSO and ERS managed the analyses of the study. Authors OS, RNA, LMBJ, KTHS and JSHS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2019/v28i430114
Editor(s):
(1) Dr. Davide Neri, Professor, Polytechnic University of Marche - Via Brecce White, Ancona, Italy.
Reviewers:
(1) Benjawan Chutichudet, Mahasarakham University, Thailand.
(2) Sirengo Peter Nyongesa, University of Eldoret, Kenya.
Complete Peer review History: http://www.sdiarticle3.com/review-history/49708

Received 30 March 2019
Accepted 14 June 2019
Published 20 June 2019

Original Research Article

ABSTRACT

The objective of this work was to evaluate the effect of artificial detasseling and defoliation on the production of Pioneer 30F90 simple hybrid corn (*Zea mays* L.) seeds. The experiment was set up in a randomized complete block design, consisting of seven treatments (Control; detasseling; detasseling + defoliation of the top leaf; detasseling + defoliation of the two upper leaves; detasseling + defoliation of the three upper leaves; detasseling + defoliation of the upper four leaves; detasseling + defoliation of the upper five leaves), with 4 replicates. The plots were composed of 6 spaced rows of 0.90 cm by 6.00 m in length. At the time of the issue of 50% of the

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tassel were carried out the treatments. For the evaluations the two central lines of each plot were collected, eliminating 1.00 m from each end, totaling a useful area of 7.2 m². At harvest, the crop presented a final stand of 5 plants m² (50000 ha-1). According to the results obtained, it was concluded that the detasseling positively influenced the production components, due to the decrease of the auto-shading. The higher the level of defoliation, the lower the active photosynthetic area of the plant, and consequently the lower the productivity. The most affected production components in defoliation are grain numbers in the row, grain numbers in the ear and weight of 1000 grains. detasseling and defoliation do not interfere with the germination of corn seeds.

Keywords: Zea mays L.; light interception; tassel; grain yield.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most widespread agricultural products in the world. This cereal is an input for the elaboration of products directed to human food, animal feed, fuel production and industrial uses [1]. To meet this growing market demand, there is a large investment in research for hybrid breeding and seed production, with high potential for production. Generally, grain yield is the decisive factor in the choice of the hybrid, since it is directly related to the adaptation to the production environment [2].

Biotic and abiotic factors can cause stress in plants, resulting in reduced productivity. As a biotic factor, one can cite the attack of pests and diseases that cause great changes in the physiological processes of plants. However, the factors that are most related to the reduction of maize crop productivity are the abiotic factors related to the climate (soil water availability, air temperature, relative air humidity and solar irradiation) [3]. Among these factors, it is cited light deficiency or lack of leaf area in the development periods, corresponding to the period of grain filling [4]. There are two characteristics in the corn plant that diminish the efficiency potential of the leaves. The most limiting is the habit of growth, which provides high-shading of the lower leaves. The other is the presence of the tassel, which remains inactive shortly after fertilization, but shade about 19% of the plant, depending on the cultivar [5].

Detasseling in corn is the most commonly used practice in the control of crosses to obtain hybrids, which may favor or impair the plant, depending on the method used. For example, the pure and simple removal of the tassel, which is a strong drain, may favor the plant, since it reduces competition for photoassimilates; and the removal of the cartridge may result in damage to the plant, because it usually occurs a loss of 4 to 5 upper leaves [6,7], which makes the plant less efficient in grain production, because leaf extension above the ear is the most physiologically active [8]. Moreover, the intensity and period of defoliation in the crops are also important factors in grain yield, due to the relationship between leaf area and canopy transpiration [9]. Corn grain filling occurs mainly from photoassimilates produced post anthesis [10].

A number of authors [11,12,13] have reported an increase in grain yield when the tassel is removed shortly before the maydis stigma emission. However, studies show that defoliation of the corn plant [14,15,16,8,17) leads to significant losses in productivity. It is also verified that the detasseling in different hybrids show different behaviors in relation to the production components [18,19,17], thus demonstrating the need for research on other materials, such as 30F90 corn not yet studied.

Considering the above, we can understand that the variation of the production of a crop depends on the genotype of the material, which establishes the level of maximum potential of production; of the production environment, which imposes limits on the development of the expression of crop potential; and the physiological responses of plants to the challenges posed by the environment [3].

The objective of this work was to evaluate the influence of the detasseling and the simulation of several defoliation levels in the production of 30F90 maize seeds.

2. MATERIALS AND METHODS

The experiment was conducted in the field in the municipality of Quatro Pontes in the State of Paraná, Brazil, in an area called rural allotment 91. The climate is of the Subtropical Moist Mesothermal type - Cfa, of hot summers, with rains more concentrated in these months, and without defined dry season. The average temperature in the coldest months is below 18 °C and the average temperature in the warmer months above 22°C, according to Köppen classification [20]. The precipitation values for the period of the survey, which comprises the spring / summer harvest had mean monthly minimum of 125 and maximum of 330 mm of rainfall.

The Pioneer 30F90 simple hybrid corn was used in the experiment. The experimental design was a randomized block design with 7 treatments and four replications, with the following treatments: 1 (Control); 2 (detasseling); 3 (detasseling + defoliation of the top leaf); 4 (detasseling + defoliation of the two upper leaves); 5 (detasseling + defoliation of the three upper leaves); 6 (detasseling + defoliation of the upper four leaves) and 7 (detasseling + defoliation of the upper five leaves).

Seeding was carried out in September, in the no tillage system, having as a previous crop the consortium of black oat and forage turnip, previously desiccated. Each experimental plot consisted of 6 sowing lines of 6.00 m in length, spaced 0.90 m, where the two central lines were harvested, discounting 1.00 m from both ends, totaling a useful area of 7.20 m² per plot. In the context, 5 seeds per linear meter were sown, totaling a population of approximately 55,000 ha^{-1} seeds.

The soil of the experiment site is called Red Eutrophic Latosol [21], whose chemical characteristics are found in Table 1.

Fertilization was carried out according to the soil analysis, following the recommendation of Oliveira [22] for the corn crop.

During the experimental period, the herbicide atrazine 250 g L^{-1} (PRIMATOP) was applied 10 days after emergence (DAE), for the control of weeds at a dose of 4 L ha^{-1}, and 25 DAE the insecticide Lufenuron (MATH) at the dose of 0.7 L ha^{-1} for the control of the caterpillar *Spodoptera frugiperda*.

The corn plants were submitted to the 60 DAE treatments, when 50% of the tassels were exposed, where manual detasseling and defoliation were performed in the four central lines of each plot, leaving the lateral lines intact so that they promoted the release of pollen and consequently fecundation of the lateral lines, which will give rise to the corn seeds. Two days later a pass through was made to certify the efficiency of the treatments.

The characteristics evaluated at 81 DAE were: Leaf area measured on-the-spot, which is a non-destructive method consisting of the sum of the area of the rectangle plus the area of the triangle of each leaf of the plants. To obtain the average leaf area of the plants, five plants were used per plot; Foliar Area Index (LAI) obtained by multiplying the average leaf area of one plant by five (5 plants m²).

The harvest of all useful area of the plot was done manually, and the ears were then threshed, with the help of a manual threshing machine. The characteristics of the production components evaluated after harvesting were as follows: Productivity (kg ha^{-1}) estimated with balance aid, after correction of humidity to 13%; length of ear (cm), measured with the aid of a caliper; number of grains in the ear, obtained by multiplying the count of the average number of grains per row by the average number of rows; grains/row, obtained from the sample of five ears within the useful portion of each treatment and repetition; weight of 1000 seeds, according to the Seed Analysis Rule [23]. In order to carry out this determination, pure seeds were used, where at random eight replicates of 100 seeds each were taken per experimental plot; stand calculated from the number of plants at the end of each treatment; Soluble solids (ºBrix) measured using a portable refractometer on dry thatch. The collection of the thatch was done after the appearance of the black layer (physiological maturation) two between node per plant (between node above the ear and the other just below the ear), of two plants per plot; germination test performed in BOD regulated at 30°C diurnal and 20°C nocturnal, remaining 5 days until the first evaluation, and another 4 days until the second evaluation [23]. 100 seeds of each of the four replications of the seven treatments were used, totaling 400 seeds of each treatment.

The data were submitted to analysis of variance and the means were compared by the Tukey test at 5% probability.

3. RESULTS AND DISCUSSION

3.1 Leaf Area and Leaf Area Index (LAI)

Analyzing the results obtained for the leaf area and leaf area index (LAI), it can be seen that only the control and detasseling treatments do not differ between them (Table 2). However, in the other treatments there was an increasing reduction in both leaf area and LAI, directlyrelated to the number of leaves removed. Simulation of leaf loss and the results found in this work with 30F90 maize for seed production reflect the reality of commercial crops. According to Dias [17], the manual or mechanized detasseling also causes the removal of leaves from the apex, next to the tassel, which can reduce the productivity and the quality of the seeds. This is because leaf area per plant is one of the main factors determining the strength of the source [24], and its reduction affects the photosynthetic activity and consequently the production of photosimilates by the plant [6], mainly because these upper leaves are considered photosynthetically more efficient [8,25].

3.2 Productivity

The yield values did not show a significant difference between control treatments, detasseling, and detasseling + defoliation of a top leaf. However, when only the detasseling was performed, there was an increase in productivity of 4.97% in relation to the control (Table 3). Similarly, Hunter et al. [26] observed an average increase of 6.9% in grain production, when only the tassels were removed. The positive effects of the detasseling on grain yield occur mainly due to the loss of apical dominance and reduction of shading in the upper portions of the plants, as demonstrated by Duncan et al. [27]. Emygdio et al. [2] emphasize that productivity is a decisive factor in the choice of hybrids.

On the other hand, according to the results found in this experiment with 30F90 maize, it is possible to notice the decrease in productivity as the levels of defoliation increase, demonstrating similar behavior to those obtained by other authors, such as Alvim et al. [8] and Vaz et al. [28]. The results obtained are in accordance with Souza and Barbosa [3], who cite as a variation of the production of a crop, the physiological responses of the plants to the challenges imposed by the environment. In the defoliation the plant is less efficient in the production of grains, because the leaf extension above the spike is the most physiologically active [8].

3.3 Number of Grains Per Row and Total Number of Grains Per Tassel

The average results of grains per row and total number of grains per tassel are given in Table 4.

In the use of isolated detasseling, there is an increase in the number of grains per row and consequently the number of grains per tassel.

Table 1. Chemical characteristics of the soil in the period of installation of the experiment, in Quatro Pontes - PR

P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al
mg dm^{-3}			Cmol dm^{-3}		
10.3	0.32	7.04	2.64	0.20	5.44

Table 2. Leaf area and leaf area index (LAI) in function of the artificial defoliation of Pioneer 30F90 maize plants in Quatro Pontes - PR

Treatments	Leaf area (m²)	(%)	LAI	(%)
C	0.90 a	100.00	4.50 a	100.00
D	0.89 a	99.58	4.48 a	99.58
D+1DF	0.88 b	97.69	4.40 b	97.69
D+2DF	0.84 c	93.78	4.22 c	93.78
D+3DF	0.78 d	86.79	3.91 d	86.79
D+4DF	0.72 e	80.22	3.61 e	80.22
D+5DF	0.65 f	72.45	3.26 f	72.45

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

Table 3. Mean productivity values for the pioneer 30F90 maize crop, in quatro pontes – PR

Treatments	Productivity (Kg ha^{-1})	(%)
D	10849 a	104.97
C	10335 ab	100.00
D+1DF	10302 ab	90.68
D+2DF	9800 bc	94.81
D+3DF	9511 bc	92.02
D+4DF	9041 cd	87.48
D+5DF	8602 d	83.23

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

Table 4. Mean values of grains per row and number of grains per ear of corn Pioneer 30F90 in quatro pontes - PR

Treatments	Grains/Row	(%)	Grains/Tassel	(%)
D	41.69 a	103.93	667.04 a	103.93
D+1DF	40.48 ab	100.93	647.80 ab	100.93
C	40.11 ab	100.00	641.85 ab	100.00
D+2DF	39.15 bc	97.60	626.44 bc	97.60
D+3DF	37.69 c	93.95	603.04 c	93.95
D+4DF	34.12 d	85.07	546.00 d	85.07
D+5DF	33.29 d	83.00	532.76 d	83.00

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability.C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

The accumulated photoassimilates reserve during the vegetative phase in the stem and its translocation for the filling of grains in the treatment with defoliation allowed the grain to finish its formation [8], but the withdrawal of leaves reflects in losses, especially of grain per tassel, mass of 1000 seeds and consequently of productivity, which can be explained by the fact that of the total carbohydrates accumulated in the corn grains, 50% are produced by the leaves located in the upper third of the plant, 30% represents the contribution of the leaves of the middle third and the rest of the leaves distributed in the most basal part of the stem [29].

3.4 Ear Length

The average results obtained for the ear length are given in Table 5. In the present work, it is evident that the length of the ear was affected directly by the reduction of the leaf area, in the same way that the number of grains in the tassel was reduced (Table 4), which significantly affects productivity, as previously noted (Table 3). Pereira et al. [30] verified that the defoliation was the major factor influencing the length of the ear, corroborates with the direct relation between the foliar apparatus and the production/growth of the ear. Still, the authors conclude that in the components of maize production, defoliation causes large losses, and there is no means of compensation for maize.

3.5 1000 Seed Mass

The mass production component of 1000 seeds was affected by the leaf reduction, and there was no differentiation of the treatment detasseling, with the control, but of the other treatments (Table 6). Similar results of reduction in the mass of 1000 seeds with the increase of defoliation were also observed by Dias [17] and Vaz et al. [28]. The decrease of the leaf area influences the photosynthetic rate, changes the plant metabolism, reducing the content of sucrose and reducing sugars, as well as the starch content in the seeds, and consequently affects the weight of 1000 seeds [4].

3.6 Stand

There was no difference between treatments for stands (Table 7). The evaluation was performed at the time of harvest, counting the plants to confirm that the results were not affected by the stand. Alvim et al. [8] also found that the final stand of corn plants was not significantly altered by defoliation and reported if they were made in the R_2 stage did not predispose the plants to tipping or stem breakage, probably due to the good resistance of the stem at this.

3.7 Soluble Solids (ºBrix)

The average results for soluble solids (ºBrix) are shown in Table 8. The removal of only the tassel, presented a relative brix greater than the others, except for the treatment detasseling + of the two upper leaves, to which it did not present statistical difference. This higher content of ºBrix is due to the decrease of the interception of light due to the removal of the tassel and consequently the plant "needed" to remove smaller amounts of sugars from the stem for the filling of the grains, agreed with the results found by Vasconcelos et al. [31], where they reported that there was an increase in the residual amounts found in the stalks, sabugos, and ears, taking into account detasseling practices used.

Table 5. Mean values of corn ear length Pioneer 30F90, in Quatro Pontes - PR

Treatments	length of ear (cm)	(%)
D	18.45 a	104.24
D+1DF	17.74 ab	100.24
C	17.70 ab	100.00
D+2DF	16.60 bc	93.77
D+3DF	15.99 cd	90.33
D+4DF	15.22 de	85.99
D+5DF	14.34 e	85.99

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

3.8 Germination Test

In the production of corn seeds, besides the productivity in the formation of new hybrids [2], the physiological quality of the seeds (germination and vigor) is a very important factor. The benefits of a high quality seed include rapid and uniform germination, with seedlings being able to withstand environmental stresses and uniformity in emergence [32].

Table 6. Mean values of the masses of 1000 seeds of maize Pioneer 30F90, in Quatro Pontes – PR

Treatments	1000 seed mass (g)	(%)
D	362.83 a	101.25
C	358.35 ab	100.00
D+1DF	355.44 bc	99.18
D+3DF	351.60 cd	98.11
D+4DF	351.44 cd	98.07
D+2DF	350.19 cd	97.72
D+5DF	346.90 d	96.81

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

Table 7. Mean values of stand of the Pioneer 30F90 maize, in Quadro Pontes – PR

Treatments	Stand	(%)
D	36.25 a	100.69
D+1DF	36.25 a	100.69
C	36.00 a	100.00
D+2DF	35.75 a	99.30
D+5DF	35.75 a	99.30
D+4DF	35.50 a	97.93
D+3DF	35.00 a	97.55

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

According to the results of the statistical analysis for the germination factor, it was observed that there was no statistical difference between the treatments (Table 9). These results are in agreement with some authors who, when studying the effect of defoliation on maize plants on the physiological quality of the seeds, did not detect influence on germination or vigor [33, 34], which is more related to maturity at harvest than to defoliation [4].

Table 8. Mean values of soluble solids (ºBrix) of pioneer 30F90 maize in quatro pontes - PR

Treatments	Soluble solids (ºBrix)	(%)
D	11.42 a	109.07
D+2DF	10.65 ab	101.67
C	10.47 b	100.00
D+1DF	10.47 b	100.00
D+3DF	10.25 b	97.85
D+5DF	10.12 b	96.66
D+4DF	9.97 b	95.25

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

Table 9. Mean values of germination of pioneer 30F90 maize in quatro pontes - PR

Treatments	Germination (%)
D+1DF	98.50 a
D+4DF	98.25 a
D	98.00 a
C	98.00 a
D+2DF	98.00 a
D+3DF	98.00 a
D+5DF	97.50 a

Averages followed by the same letters in the column do not differ from each other by the tukey test at 5% probability. C = control; D= detasseling; D+1DF detasseling + defoliation of the top leaf; D+2DF = detasseling + defoliation of the two upper leaves; D+3DF detasseling + defoliation of the three upper leaves; D+4DF = detasseling + defoliation of the upper four leaves; D+5DF = detasseling + defoliation of the upper five leaves

4. CONCLUSION

The removal of the tassel positively favors the crop with respect to the components of production, due to the reduction of problems with auto-shading.

Defoliation during detasseling negatively influences crop productivity due to the fall in number of grains in the row, number of grains in the ear and weight of 1000 grains, caused by the decrease of the active photosynthetic area of the plant.

Detasseling alone or associated with defoliation does not interfere with the germination of corn seeds.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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