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Effect of Different Defoliation Treatments on Yield and Yield Components in maize (*Zea mays* L.) Cultivar of S.C704

Barimavandi A. R.[1], Sedaghathoor S.[1*] and Ansari R[2]

[1]Agriculture College, Islamic Azad University, Rasht Branch, Rasht, Iran
[2]Former Horticultural Science MSc Student, Agriculture College, Guilan University, Rasht, Iran
***Email: sedaghathoor@yahoo.com**

Abstract

Plant leaves are major source of photosynthesis and obtain assimilates for growing parts. Effects of different levels of defoliation studied on maize's growth and yield. The study was conducted as completely randomized block design with 8 treatments in 4 replications. The treatments were: $T_{1=}$ control (without leaf removal), T_2= removing of ear leaf, T_3= defoliating leaves on top of the ear, T_4= defoliating leaves under the ear, T_5= defoliating just two leaves under ear, T_6= defoliating two leaves on top of ear, T_7= defoliation whole leaves (complete defoliation) and T_8= defoliating just tassel leaf. Effects of these treatments were evaluated on the major traits of yield components. Results showed that leaves defoliation had significantly effect on grain yield, rows number on cob, grains number on cob, grain dry weight and cob length (P<1%). Leaf defoliation intensity and leaf position affected total dry matter. Complete defoliation reduced severely grains on cob. While defoliation on top of ear and underneath leaves of ear caused to reduce grains on row. The maximum LAI belonged to control and the least amount was connected to T_4. The results suggest that the top leaves should not defoliate, because this treatment has negative effect on the yield.

Key words: *Zea mays*, Assimilate, Growth, Photosynthesis

Introduction

Throughout plants growth and development, photosynthetic materials are transferred from sources to sinks. If the rate of transfer be slight, photosynthates would be stored as starch in different parts of plants (Hashemi *et al*., 1995). As soon as grains are formed in a plant, the greater amount of photosynthetic materials moves to the grains. Grain stored photosynthates are obtained via three main resources including current photosynthesis in the leaves; photosynthesis in green parts of plants excluding the leaves and transferring from the storing parts. But interfere amount of the resources depends on species and environmental conditions (Hashemi and Maraashi, 1993). Field trials on wheat (*Triticum aestivum)* and barley (*Hordeum vulgare)* revealed that photosynthesis in the nearest source to the grain such as flag leaf, stem and spike supply the main part of grains weight (Sarmadnia and Kocheki, 1993). Andrew and Peterson (1984) reported that distance of leaves to the ear and their photosynthetic efficiency are important in a slight defoliation. They showed that leaves on top of the ear transfer about 23 to 91 percent of photosynthates to the cob and the greatest amount of transferred materials belongs to the nearest leaf on top of the ear (Andrew and Peterson, 1984).

A study on sunflower (*Helianthus annus)* demonstrated that defoliation could not affect stem diameter and plant height, but disk flower diameter, filled grains percentage, one thousand seed weight, harvesting index and grain yield affected by the every defoliation treatments. Middle leaves of the stem have most important role than the other leaves because of greater surface and active participation in the photosynthesis. 100 percent defoliation was lead to minimum yield of seeds compared to control because of decrease in grain weight and filled grain percent (Abbaspour *et al*., 2001). Results of many studies about effects of defoliation on seed yield of sunflower showed that increase of defoliation intensity and defoliation near flowering stage was lead to decrease in seed yield because of decreasing in the photosynthetic surface (Abdi *et al*., 2007; De beer, 1983; and Kene and Charjan, 1998). Complete defoliation was the most effective on the ear diameter, dry grain weight, one hundred grain weight and grain yield. There was no significant difference between removing of the whole leaves on the top of ear and the whole leaves under ear (Remison, 1978).

Tilahun (1993) demonstrated that removing of above three leaves has considerable effect on total dry weight of grains (Tilahun, 1993). Below leaves of maize transferred a greater part of their photosynthates to the roots, but above leaves transferred their production to the upper plant organs (Hashemi *et al.*, 1995*)*. Usually, photosynthetic products of above leaves of the ear and below five leaves move to the grains (Barzegari, 1996). The aim of this research was to determine the effects of different levels of defoliation on the yield and yield components of maize (cultivar S.C704).

Materials and methods

This study was conducted in the experimental field of agricultural research center of Kermanshah province, Iran. Experimental design was arranged completely randomized block with eight treatments and four replications. Treatments included: T_1 = without leaf removal (control), T_2 = ear leaves removal, T_3 = defoliating leaves on top of the ear, T_4 = defoliating leaves under the ear, T_5 = defoliating just two leaves under the ear, T_6 = removing of two leaves on top of the ear, T_7 = complete defoliation, T_8 = removing of tassel leaf. Removing of the leaves was performed at anthesis and after opening of tassel. Removing of the leaves did from ligules and then cutting layer was covered with paraffin. In this experiment, maize (*Zea mays* L.) cultivar SC704 was sown with density 64000 plants per hectare in furrow and ridge form. SC704 is very popular maize in the Kermanshah province. Plants planted with 75×20 cm^2 distance. The whole of cultural practices including irrigation, fertilization (based on soil analyze), weed and pests management were performed equally in the entire experimental plots. The last harvesting date was on the base of receiving grains to 65 percent dry weight, so harvesting dates was different for every treatment. Sampling was done to evaluate growth process and dry matters of the every parts of plant; sampling was carried out 25 days after planting and was replicated every 15 days. After exercitation of treatments in anthesis, sampling was performed every 10 days. To determine dry weight and dry matter percent, 5 plants were cut from their collar in each sampling. Drying of different organs (leaf, stem, husk, tassel, shank, grain and cob) depended on kind of organ and growth stage and was done in oven with 60°C during 48-72 hours. In this experiment many factors including leaf area index (LAI), leaf dry weight, dry biomass, grain dry weight, length cob, single grain weight, number of row on a cob, number of grain in row, number of grain on each cob, dry weight of cob, duration of grain filling, rate of grain filling, dry weight of maize stalk and dry weight of cob skin were examined (Kabiri, 1996). In order to determine of leaf area index, we selected 5 plants from each plot and after measuring of length and biggest width of leaf, LAI obtained by use of this formula: (S= length × width× 0.75) (Hashemi et al., 1995).

Results and Discussions

Investigation on growth pathway of maize cultivar S.C704 in climates of Kermanshah province (West of Iran) showed that accumulation of dry matter was slow since 40 days after planting and then fast growth began

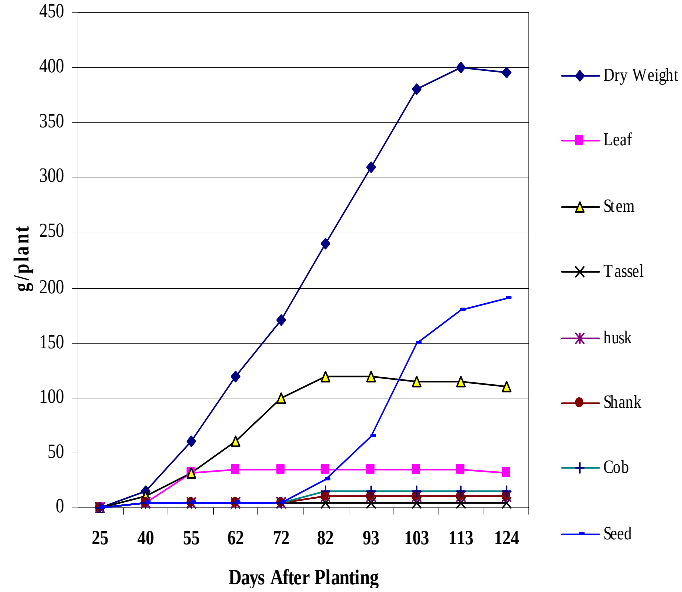
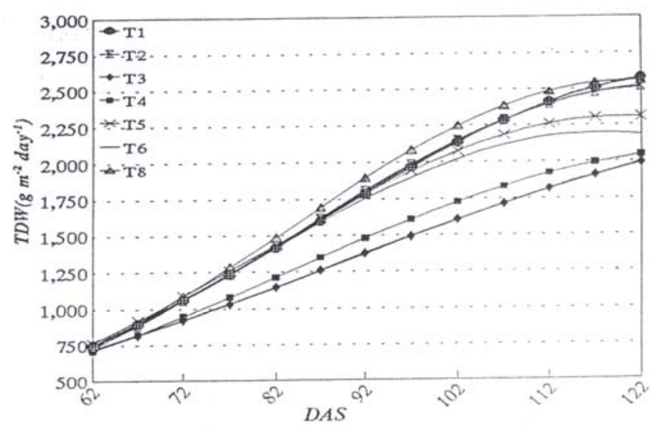


Fig 1. Growth stages of maize CV. S.C.704 based on days after planting



$T1 = exp(3.21 + 0.072DAS - 0.000282DAS^2)$ $R^2 = 0.956$
$T2 = exp(2.94 + 0.078DAS - 0.000316DAS^2)$ $R^2 = 0.984$
$T3 = exp(4.38 + 0.045DAS - 0.000152DAS^2)$ $R^2 = 0.969$
$T4 = exp(3.74 + 0.059DAS - 0.000229DAS^2)$ $R^2 = 0.956$
$T5 = exp(3.02 + 0.079DAS - 0.000328DAS^2)$ $R^2 = 0.990$
$T6 = exp(2.89 + 0.081DAS - 0.000347DAS^2)$ $R^2 = 0.988$
$T8 = exp(2.63 + 0.086DAS - 0.000357DAS^2)$ $R^2 = 0.979$

Fig 2. Dry matter changes under different treatments (TDW; total dry weight and DAS; Day after Sown)

and continued to 103 days after planting (Fig 1). So, the first slow growth phase, the fast growth phase and finally third stage of the maize growth (ultimate slow growth phase) took long 40, 63 and 15 days respectively. Ultimate slow growth phase accompanied with decreasing of stem dry weight. It signs utilization and transmission of stem reserved matters to grains (Fig 1). Three growth stages of grain filling are completely clear; the first phase or slow growth stage took 10-20 days that increasing of grain weight is very little in this period. The second phase, fast stage, was 35 days period and 90 percent of grain dry weight was supplied from photosynt-

Table 1. Analysis results of defoliation treatments effect on yield and yield components of grain maize cv. SC704

Variables	df	Mean Square													
		Grain yield	number of row on cob	Grain number on row	Grain weight	number of grain on cob	length cob	Biological yield	stalk and shield	cob wood	cob skin	cob stalk	Harvest index	grain filling period	grain filling speed
Replication	3	619.4 ^{ns}	0.06^{ns}	2.54^{ns}	174.6^{ns}	475.7^{ns}	0.09 ^{ns}	2031.5 ^{ns}	587.06^{ns}	123.5 ^{ns}	100.21 ^{ns}	7.05 ^{ns}	5.19^{ns}	4.69^{ns}	0.22^{ns}
Treatment	7	546230.7**	6.14**	412.4**	8598.2**	118710.5**	31.8**	1193511.4**	5633**	9046.22**	1939.55 **	103.8**	474.5**	387.56**	1.51**
Error	21	3053	0.27	2.8	115.6	326.10	0.98	4538.5	1098.21	63.59	1111.11	10.52	13.4	1.94	0.82
CV (%)	-	5.38	15.2	4.32	4.06	3.08	5.03	13.23	8.12	5.69	10.30	5.03	7.25	10.25	8.52

ns: non-significant and **: Significant at 1%

Table 2. Mean values of examined parameters

Treatments	Grain yield (g/m^2)	number of grain on cob	number of row on cob	Grain weight (mg)	Grain number on row	length cob (cm)	Biological yield (g/m^2)	stalk and shield (g/m^2)	cob wood (g/m^2)	cob skin (g/m^2)	cob stalk (g/m^2)	Harvest index **(%)**
T1; control	1272 a	692.25 a	15.88 a	296.2 a	44.25 ab	21.75 ab	2565.22 a	664.5 a	121.6 a	174.1 b	25.21 ab	49.59 ab
T_2; removing of ear leaf	1230 a	675.5 a	15.40 ab	289.2 a	43.90 ab	22.42 a	2436.52 b	622 ab	118.1 a	177.3 b	22.35 bc	50.47 a
T_3; defoliating upper leaves of ear	944 c	589.56	15.35 ab	265.3 b	38.33 c	18.54 c	1925.18 f	552.5 c	98.34 ab	110.5 e	20.17 cd	49.02 ab
T_4; defoliating leaves lower the ear	1035 b	620 b	15.20 ab	257.8 b	41 b	19.87 bc	2039.85 e	584.1 bc	115.7 a	143.1 c	16.76 d	50.78 a
T_5; defoliating two leaves under ear	1202 a	625 b	14.98 b	281.3 a	42 b	20.31 b	2263.97 c	625.2 ab	107.5 ab	152.8 c	18.83 cd	49.88 ab
T_6;defoliating 2 leaves on top of ear	1100 b	623.25 b	15.80 ab	291.4 a	39.20 c	18.56 c	2151 d	570.6 bc	87.33 b	129 d	19.23 cd	51.15 a
T_7; complete defoliation	159.9 d	170.5 d	12 c	154.7 c	14.22 d	13.81 d	552.24 g	571.8 bc	55.6 c	42.55 f	11.62 e	18.75 c
T_8; defoliating just tassel leaf	1271 a	694.5 a	15.15 ab	282.5 a	45.64 a	22.21 a	2474.76 ab	620.40 ab	114.3 a	191.2 a	28.1 a	51.38 a

*: Values followed by the same letters are not significantly different according to Tukey Test (*p*<0.05).

hesis of leaves and other secondary sources of photosynthesis including maize stem and cob. The last slow growth stage or physiological maturation of grains was last stage accompanied with slowly increasing dry matter in about 15 days. The results of this study showed that (Table 1), defoliation treatments have significant effect ($p<1\%$) on grain yield, number of grain row on cob, number of grain in row, grain weight, number of grain on cob and length cob. Based on results, removing of some leaves caused to decrease in grain yield, and complete defoliation decreased 87% of grain yield compared to control (Table 2). Defoliating leaves on top of the ear had greater effect on grain yield compared to below leaves. Removing of above two leaves decreased grain yield compared to control, but removal two leaves under the ear did not have significant effect on grain yield (Table 2). The superior effect of top leaves on the yield depends on their well sun light absorb. It is reported that apex leaves of ear could transfer about 23-91% of photosynthetic matters to the cobs (Anderew and Peterson, 1984). In delayed intercropping of maize and *Eragrostis tef* Zucc, defoliating leaves under the ear did not significantly decrease corn yield (Worku, 2004).

Based on data mean comparison (Table 3), the yield of grains in complete defoliation (T_7) was 1599 kg/ha that this dry matters could be obtained from 2 resources including 1) retransmission of matters from stem and other storing organs to grains and 2) photosynthesis of other parts of plants exception of leaves (Tilahun, 1993). In this study removing of tassel leaf and stuck leaf to the cob did not have significant effect on the grain yield (Table 3). Tilahun (1993) found that there is direct relation between grain yield and the number of removed leaves. The greatest yield diminishing is obtained under complete defoliation after anthesis stage (Tilahun, 1993).

The number of grain strongly affected by defoliation, likewise complete removing of leaves (full defoliation) caused to 75% decreasing grain number on cob compared to control, but removing of above leaves decreased about 14.8% of the number of grains on cob (Table 3). Removing of ear leaf and tassel leaf did not have significant effect on the number of grains. The results revealed that above leaves of cob were most effective than below leaves. Complete defoliation caused to decrease in yield and yield components. This treatment caused to produce immature grains. Tollenaar and Daynard (1978) believed that difference in plant yield after photosynthesis decreasing treatments, generally is consequent difference in the number of grain on cob (Tollenaar and Daynard, 1978). Decreasing in grain number on cob probably is a result of partial number of flower primordia or slight pollination because of dichogamy (Dhopte, 1984). Defoliation in swelling stage of flag leaf and anthesis of grain sorghum showed that there is a decreasing in yield as a result defoliation. It is noteworthy that top leaves of plant have more effect on yield than below leaves (Stickler and Pauli, 1960).

The result of this experiment (Table 1 and 2) showed that the complete removing of leaves caused to severe decreasing of grain number in rows, but removing of above and below leaves of cob decreased this item about 7% and 13%. It is found that above leaves of ear have considerable effects on the number of grain in row character. It is certain that the removing of leaves causes to restriction of carbohydrates in cob and finally to decrease yield. Kabiri (1996) found that removing of above leaves of ear could decrease the number of grain in row; since this type of defoliation causes to produce immature grains in the tip of ear (Kabiri, 1996). In this trial, the effect of defoliation treatments on the weight of single grain was significant (Table 1) and the most decreasing in yield was belonged to the complete defoliation treatment (T_7 with 48% decreasing), removing of upper leaves (T_3 with 10% decreasing) and removing of lower leaves (T_4 with 13% decreasing). Only aged leaves with little photosynthetic potential remained after removing of upper leaves. Consequently, upper leaves (T_3) especially near to the ear have been more effective on grain weight than other treatments. Full defoliation (T_7) caused to increase the rate of grains filling, but the effective period of filling decreased strangely (Table 3).

The third treatment (defoliating leaves on top of the ear) caused to more decreasing in the rate of grain filling because of inability of remained leaves in supplying of required assimilate for plant. The effective period of grain filling affected more increasingly by defoliation than the rate of grain filling (Table 3). Minimum period of grain filling (22 days) was related to complete defoliation (T_7); this period was less than control about 26 days (Table 3). Frey (1981) found that decrease of planting density increases the rate of plant growth in silk growth stage; nevertheless defoliation treatment in this stage decreases the rate of plant growth. But effect of these treatments was insignificant on the rate of grain filling (Frey, 1981). Study on grain maize showed that complete defoliation caused to diminish of the yield about 95% (19).

The results (Table 1 and 2) demonstrated that the row numbers on ear only affected by complete defoliation, while removing of one or more leaf has no effect on this character. The maximum stem dry weight was linked to control (664.5 kg/m^2) and the minimum amount was connected to removing of above leaves (552.5 kg/m^2). Whereas treating was at anthesis stage and stem has stored maximum dry weight in this phase, so probably difference of weight among treatments depended on transmission of accumulated materials from stem to other parts of plants. In conclusion, stem is important secondary resource in maize and this source acts efficiently in stress conditions. All treatments caused to decrease stem weight (Table 3) that could be declared two reasons for it. The first is the least use of stored assimilate of stem under control (without defoliation) because a sufficient amount photosynthesis via leaves. The second is the amount of retransmission stored assimilates from stem to grain depends on intensity of defoliation and position of remained leaves. So that the

Table 3. Means values of grain filling, speed, grain filling period and final grain weight under treatments

Treatments	grain filling speed (mg/day)	grain filling period (day)	final grain weight (mg)
T1; control	6.08 ab	48.77 c	296.2 a
T_2; removing of ear leaf	6.02 ab	48 bc	289.2 a
T_3; defoliating upper leaves of ear	5 d	53 a	265.3 b
T_4; defoliating leaves lower the ear	5.14 d	50 b	257.8 b
T_5; defoliating two leaves under ear	5.85 c	48 bc	281.3 a
T_6; defoliating two leaves on top of ear	5.80 bc	50.24 b	291.4 a
T_7; complete defoliation	7 a	22 d	154.7 c
T_8; defoliating just tassel leaf	5.90 c	47.88 c	282.5 a

*: Values followed by the same letters are not significantly different according to Tukey Test ($p<0.05$).

removing of above leaves causes to exceed retrans-mission of assimilates from stem to grain. On the other hand, study with the radioactive carbon showed that assimilate retransferring from stem to grain is done in grain filling period (Hashemi et al.,1995). But the amount of retransferring assimilates in different crops is not same. For instance this quantity is 2-5% in wheat, 20% in maize and 40% in rice (Hosseinzade 1996). In developmental stages of maize, the stem is a temporary storing site of carbohydrates and soluble solid. This accumulation continues until the ear changes to the main sink to store (Dungan *et al*., 1965).

The highest cob dry weight related to defoliating just tassel leaf (T_8) and the least cob dry weight belonged to complete defoliation (T_7) (table 2). So there is a reverse relation between intensity of leaf removing in anthesis stage and cob dry weight. Following T_7, T_4 (removing of lower leaves of ear) caused to the most decreasing in cob dry weight. Based on results, the most effect on growth of shank is related to the nearest leaves of ear. But decreasing of ear length were 36% in T_7 (removing of whole leaves), 15% in T_3 (removing of above leaves) and 9% in T_4 (removing of below leaves). While T_8 (defoliating just tassel leaf) showed about 1.6 % increasing in ear length. The intensities of defoliation, position of leaves on the plant and defoliation time are the most effective factors on the ear length (Thomison and Nafziger, 2003; Tilahun, 1993).

Nearly all treatments had not significant effect on harvesting index (Table 3) and allocation of dry matter to grain was the minimum (18%) merely under T_7 (removing of whole leaves), which was consequence of deficit in photosynthetic matters and shortage of assimilate retransferring. On the base of results, the effects of defoliation intensity and position of defoliated leaves on the plant is completely clear on total dry matter. So maximum yield of dry matter allocated to control and the least amount belonged to full defoliation (T_7), removing of lower leaves of ear (T_4) and removing of upper leaves of ear (T_3). A trial on maize demonstrated that dry weight of straw would be decreased with increasing of defoliation intensity (Chauhan and Halima, 2003).

In full defoliation (T_7), production of 552.2 kg/m^2 dry matter could be consequent of leaves photosynthesis before anthesis (doing treatment time) and other parts photosynthesis (excluding leaves) after anthesis.

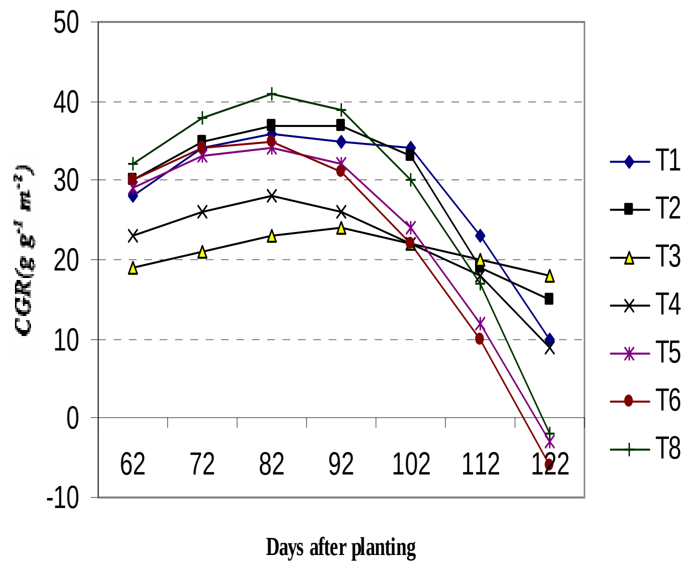


Fig 3. Crop growth rate (CGR) changes under different treatments

Following T_7, removing upper leaves of ear (T_3) caused to the maximum reduction in dry weight of plant. 82 days after planting, all treatments had no significant difference on the rate dry matter increasing. But 92 day after sowing, dry matter increasing found descent lane under t_6 (defoliating two leaves on top of ear). Probably reason of this incident is suitable position of upper leaves for perfect absorption of sun light and superior photosynthesis. Consequently, removing of these leaves is lead to decrease in photosynthetic materials and little production of dry matters. Finally, the reasons of dry matters declining under different treatments are:

- Elimination of young leaves at anthesis stage would be diminished the amounts of dry matters in plant.
- The upper leaves in a plant are more effective than other ones because of best absorption of sun light.
- The leaves located in vicinity of the ear are broad and have broad surface for more photosynthesis. Removing of these leaves have intensive effects on dry weight diminishing.

In addition, crop growth rate (CGR) is a main growth factor that was investigated. The maximum CGR belonged to defoliating just tassel leaf (T_8) and the minimum amount was interrelated to removing of upper and lower leaves of ear (T_3 and T_4) (Fig 3). These results revealed that the near leaves to ear are main factor of

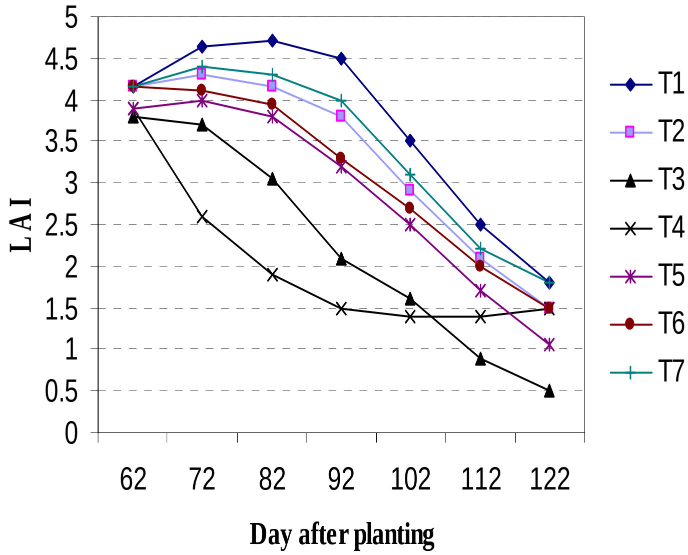


Fig 4. Leaf area index (LAI) changes under different treatments

increasing dry matters and growth rate in the development duration (sampling stages). It was considerable result that the amount of CGR increased under T_8 (removing just tassel) rather than control, which could be explained that the tassel is an unnecessary organ after anthesis and with shading on plant and use of photosynthetic compounds causes to decrease CGR.

The leaf area index (LAI) was similar in all treatments before treating time. Effects of leaf removing on LAI were different according to the intensity of defoliation and leaf position. LAI at treating time under various treatments were T_2=0.46, T_3=1.42, T_4= 3.14, T_5= 0.85, T_6= 0.73, T_7= 4.65. But finally the maximum LAI belonged to control and the least amount was connected to T_4 (removing of lower leaves). LAI variation showed that the main factor of LAI reduction is aging of leaves in this cultivar. Kabiri (1996) reported that the lower leaves are able to supply necessity photosynthates after removing of upper leaves of ear. Results of this study show that removing of upper leaves of ear decreases yield because of diminishing of number and weight of grains. In addition, some factors including stem dry weight, ear length, shank dry weight, husk and cob weight are decreased under defoliation treatments. If the utmost of photosynthetic area has been removed, the quantity of retransferring of assimilate from stem to grain would be increased. Finally, removing of upper leaves of ear was more effective on the all investigated characteristics. The results suggest that the upper leaves should not defoliate, because this treatment has negative effect on the yield.

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