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DEFOLIATION IMPACTS ON MORPHO-PHYSIOLOGICAL ATTRIBUTES AND YIELD OF TOMATO

M.M.A. Mondal[*]

Adaptive Research and Extension Division
Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

ABSTRACT

The experiment was conducted under sub-tropical condition during two successive seasons (November-March) of 2017-18 and 2018-19 to investigate the effect of defoliations on morpho- physiological attributes and yield of tomato. The experiment comprised of five levels of defoliation *viz*., 0 (control), 3, 6, 9 and 12 leaves defoliation from the base out of 17 leaves at the beginning of flowering stage and two widely cultivated varieties *viz*., TM-110 and TM-135. The plant characters such as leaf area, plant height, number of leaves plant^{-1}, straw weight plant^{-1}, absolute growth rate, number of fruits plant^{-1}, individual fruit weight and fruit yield were not affected up to 6 leaves defoliation irrespective of seasons and genotypes. Interestingly, photosynthesis, nitrate reductase and reproductive efficiency increased with increasing defoliation levels. Morpho-physiological parameters and yield attributes were better in 3 and 6 leaves defoliated plants over the control with being the highest in 6 leaves defoliated plant, which resulting the highest fruit yield. Heavy defoliation not only reduced source sizes but also decreased total sink (fruits) causing lower fruit yields. The lowest morpho-physiological attributes and fruit yield was recorded in 12 leaves defoliated plants. These results indicate that tomato plants can tolerate one-third leaf loss during reproductive stage and the knowledge of which might be essential for maintaining better quality tomato production.

Keywords: Defoliation; Dry matter production; Reproductive characters; Fruit yield; Tomato

INTRODUCTION

Traditional varieties of tomato (*Lycopersicon esculentum* Mill.) possess greater sources than sink because they are leafy. Greater source capacity leads to poor crop performance as fertilization and other cultural practices result in greater foliage and poor productivity (Mondal et al., 2011a). It means instead of large physical

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[*] Corresponding author: mmamomdal@gmail.com

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dimensions of the sources, optimum and more stable functional efficiency at moderate source size are more advantageous to realize the potential sink size under field conditions. Even increased LAI is not associated with increased fruit production but reaches a plateau (Heuvelink et al., 2005). Heuvelink (2005) further opined that lower leaves of tomato in most cases are utilizing resources more than assimilated production which inturn act as burden leaves on the others (leaves in the upper canopy). Defoliation up to certain limit may, therefore, be useful to overcome this problem of excessive vegetative growth. Greater light penetration in the canopy due to defoliation may reduce the abortion of flowers and increase fruit yield (Heuvelink et al., 2005; Verheul, 2012).

The effect of manipulation of source (leaf) size in field crops has been studied and reported both advantageous and disadvantageous effect of defoliation in many crops (Leonard et al., 2004; Mondal et al., 2011a,b; Liu et al., 2019). For example, one-third leaf removal from basal portion of the canopy in tomato increased fruit yield over control and severe defoliation decreased fruit yield (Heuvelink et al., 2005; Silva et al., 2011). Similarly, mild defoliations (16.6-33%) during reproductive phase do not adversely affect the seed yield in mungbean (Mondal et al., 2011a) and in soybean (Ali et al., 2013). On the other hand, reverse results due to defoliation was also reported in maize (Liu et al., 2019) and in soybean (Borras et al., 2004). It is reported that partial defoliation appeared to stimulate an increase (10-18%) of net photosynthesis rate, stomatal conductance and nitrate reductase activity of the remaining leaves of crop plant (Chanishviti et al., 2005; Iqbal et al., 2012). No detail information is available about source-sink relationships under discriminated levels in tomato during early reproductive growth stage. These aspects need investigation in tomato genotypes to develop the high yielding variety and to assist in the development of practices under Sub-tropical condition.

In our earlier study, we observed that defoliation of lower leaves at flowering stage did not affect the rest of the leaves by *A. solani* (BINA, 2012). Anyway, removal of full-grown leaves from below is common practice in tomato cultivation. The main reasons for leaf removal are prevention of diseases, obtaining faster fruit ripening and easier harvest as trusses are no longer hidden by leaves. Old leaves are also believed not to contribute to the crop photosynthesis anymore (Hauvelink et al., 2005). This favours dry matter partitioning towards the fruits (Leonard et al., 2004).

The purpose of this study was to investigate the extent to which and what portion of leaf removal during the beginning of reproductive phase affects morpho-physiological and biochemical parameters thereby fruit yield of tomato plant under field condition.

MATERIALS AND METHODS

Two experiments were carried out at the farm of Bangladesh Institute of Nuclear Agriculture, Mymensingh ($24^0$75´N and $90^0$50´E), Bangladesh, during two successive seasons (November-March) of 2017-18 and 2018-19. The experimental field was under subtropical climates characterized by heavy rainfall from April to September and scanty rainfall from October to March. The soil of the experimental site was sandy loam having a total nitrogen 0.065%, organic matter 1.07%, available phosphorus 18.5 ppm, exchangeable potassium 0.30 meq 100 g^{-1}, sulphur 20 ppm and pH 6.8.

The experiment comprised of two factors: five defoliation levels of 0 (control), 3, 6, 9 and 12 leaves were removed from base of the plant out of 16 or 17 leaves at the beginning of flowering. Two recently released tomato cultivars (TM-110 and TM-135) were used as planting material. The experimental design was split-plot with three replicates by maintaining varieties as main plot and the defoliation levels as sub-plot. The sub-plot consisted of 6 rows including two borderlines on either side. The unit plot size was 3 m × 4 m.

For the first experiment (2017-2018), seeds were sown in seedbed on 29 October 2017 and 27-day old seedlings were transplanted in the experimental field with spacing of 50 cm × 50 cm. In the second experiment (2018-2019), seeds were sown in seedbed on 26 October 2018 and 25-day old seedlings were transplanted in the experimental field with same spacing. The plants were grown by maintaining proper fertilization, irrigation, and other intercultural operations.

To study of growth characteristics, a total of two harvests were made in 2017-18. The second rows from the border of each plot were used for sampling. The first and second crop sampling was done at 40 and 60 DAT. Five plants were randomly selected from each plot during each sampling date and uprooted for collecting necessary parameters. The plants were separated into roots, stems, leaves and fruits, and the corresponding dry weight were recorded after oven drying at 80 ± 2^0C for 72 hours. The leaf area was measured using an automatic leaf area meter (Model: LICOR 3000, USA) at 80 DAT, just before harvesting the fruits. Absolute growth rate (AGR) was determined following the formula of Hunt (1978). All biochemical parameters and photosynthesis were recorded at 50-60 DAT (fruiting stage) from the second experiment of the year 2018-19. Nitrate reductase (NR) activity was determined by following the method of Stewart and Orebamjo (1979). Total sugar and chlorophyll were determined at 55 DAT following the method of Yoshida et al. (1976). Photosynthesis was measured at flowering and fruit development stage using a portable photosynthesis meter (LI- 6400XT, USA).

At harvest, ten plants from each plot were selected randomly for data recording on morpho-physiological, reproductive, yield and yield related traits. Fruit yield was collected from each plot excluding border line and converted into tonnes per hectare. Harvesting was done at different dates depending on fruit ripening.

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan’s Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell, 1986).

RESULTS AND DISCUSSION

Morphological parameters

Variety and defoliation significantly influenced on plant height and number of leaves plant^{-1} (Table 1). Defoliation up to six leaves out of 17 showed similar plant height and leaves plant^{-1} with that of control. This means that 36% leaf removal from bottom of the canopy does not affect plant height and number of leaves plant^{-1}. In contrast, defoliation beyond 36% caused significant reduction in plant height and leaves plant^{-1} with being the lowest in 12 leaves removal. Anyway, removal up to six leaves (36% of control) compensated the loss fully at harvest, even some times greater than control, whereas leaf loss of 9 and 12 leaves plant^{-1} compensated up to 90 and 82%, respectively, due to regrowth of leaves. This result indicates that tomato plant has high compensatory capacity of leaf loss during flowering start phase. The result is consistent with the findings of Iqbal et al. (2012), who opined that at early growth stages, generally leaf loss by pest appeared to stimulate regrowth of shoot and leaves nearby node of damaged leaf to compensate photoassimilate production for normal growth and development. Between the two varieties, plant height, leaf number plant^{-1} and percent leaf compensation were greater in TM-135 than in TM-110.

Interaction of variety and defoliation revealed that the reduction trend in plant height and leaves plant^{-1}due to defoliation was not similar in both the varieties (Table 1). The reduction in plant height and number of leaves was greater in TM-110 than in TM-135. Similarly, percent compensation of leaves loss due to defoliation was also higher in TM-135 than in TM-110.

Morpho-physiological and biochemical parameters

The effect of defoliation on physiological and biochemical characters was significant except chlorophyll content in leaves (Table 2). Results indicated that defoliation up to six leaves did not significantly affect straw weight and leaf area (LA) plant^{-1} as compared to control. This means 36% leaf removal from bottom of the canopy does not affect leaf area as well as straw weight. In contrast, defoliation beyond 36% caused significant reduction in straw weight and LA plant^{-1} with being the lowest by 12 leaves removal. Absolute growth rate (AGR) increased with increasing degree of defoliation till 6 leaves removal followed by a decline. The highest AGR was recorded in 6 leaves removal plants (1.49 g plant^{-1} day^{-1}) and the lowest was recorded in 12 leaves removal plants (0.81 g plant^{-1} day^{-1}). Photosynthesis (Pn) rate, nitrate reductase (NR) activity and total sugar (TS) content in leaves were greater in defoliated plants than in control plants. Results showed that Pn rate and NR activity increased with increasing degree of defoliation. It is possible because of leaf photosynthesis or whole canopy gas exchange per unit leaf area was positively related to crop load. In the experiment, fruit number did not decrease proportional to the leaf loss. In heavy defoliated plant, fruit bearing lost only 14% against 71% leaf reduction. It means to fulfill the assimilate demand by the sink, the remaining leaves

Table 1. Effect of different levels of defoliation, variety and interaction of variety and defoliation on morphological characters in tomato

Treatment		Plant height (cm)		Leaves plant^{-1} at first fruit harvest (no.)		Leaves plant^{-1} just after treatment imposed (no.)		%compensation of leaf loss at harvest over control	
		2017	2018	2017	2018	2017	2018	2017	2018
No. of removed leaves									
Control		89 a	78.8 ab	56.93 a	36.4 a	16.5 a	16.8 a	---	---
3		89 a	79.5 a	56.75 a	37.6 a	13.5 b *(18.2)*	13.8 b *(17.9)*	100 a	100 a
6		85.2 ab	80 a	53.42 ab	38.3 a	10.5 c *(36.4)*	10.8 c *(35.7)*	94.06 b	100 a
9		79.6 cd	73.9 c	47.25 c	32.5 b	7.5 d *(54.5)*	7.75 d *(53.6)*	81.87 c	89.8 b
12		76.3 d	67.7 d	43.05 d	30 c	4.5 e *(72.7)*	4.75 e *(71.4)*	74.96 d	82.4 c
Level of significance		**	**	**	**	**	**	**	**
Variety									
TM-110		80.2 b	66.3 b	43.33 b	33.3 b	10 b	10 b	67.71 b	73.9
TM-135		87.5 a	85.7 a	59.63 a	36.7 a	11 a	11.5 a	72.65 a	75
Level of significance		**	**	**	*	**	**	**	NS
Interaction of variety and defoliation									
Variety	*No. of removed leaves*								
TM-110	Control	86.0 b	69 e	49.6 cd	34.8 cd	16 b	16	---	---
	3	85.5 b	69.2 e	48.8 cd	35.2 bc	13 d	13	100 a	100
	6	83.8 bc	71.8 d	47.5 d	37 ab	10 f	10	95.8 ab	100
	9	73.8 d	65.5 f	36.2 e	31 de	7 h	7	73 e	89.1
	12	72 d	55.7 g	34.6 e	28 e	4 j	4	69.8 e	80.5
TM-135	Control	92 a	88.5 a	64.2 a	38 ab	17 a	17.5	---	---
	3	92.5 a	89.7 a	64.8 a	40 a	14 c	14.5	100 a	100
	6	86.7 b	88.3 a	59.3 b	39.7 ab	11 e	11.5	92.3 bc	100
	9	85.5 b	82.3 b	58.3 b	34 cd	8 g	8.5	90.7 c	89.5
	12	80.7 c	79.8 c	51.5 c	32 de	5 i	5.5	80.2 d	84.2
Level of significance		*	**	**	*	**	NS	**	NS
CV %)		3.68	2.42	4.9	6.4	4.55	5.29	4.92	5.64

In a column, within treatment, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * and ** indicate significance at 5% and 1% level of probability, respectively; NS, not significant; The figures in parenthesis indicate percent leaf loss over control increase Pn rate and NR activity. These results suggest that under normal condition, assimilate accumulation is operating below its maximum potential. When source-sink ratios of whole plants were lowered experimentally, net photosynthetic and net assimilation rates of the remaining leaves increased 10-20% in soybean (Raza et al., 2019) and 18% in maize (Liu et al., 2014). Other authors have found that partial defoliation of plants stimulated the photosynthetic rates of the remaining leaves (Silva et al., 2011; Verhuel, 2012). Further, moderate defoliation may improve light penetration and distribution within the canopy, thereby improving whole plant CO_2 assimilation. This indicates involvement of an effective compensatory mechanism, which helps in production of more assimilate in the remaining leaves. This could be the reason that fruit yield did not reduce proportionally to the degree of defoliation.

Between the two varieties, the physiological and biochemical parameters were higher in TM-135 than in TM-110. The interaction between variety and defoliation on physiological and biochemical parameters was significant except chlorophyll content and NR activity in leaves (Table 2). Results revealed that the reduction trend in straw weight, AGR and LA due to defoliation were not similar in both varieties (Table 2). Leaf area decreased with increasing defoliation in TM-110 whereas in TM-135, the leaf area increased compared to control up to 6 leaves defoliation followed by a decline. The reduction in straw weight and LA was greater in TM-110 than in TM-135. Similarly, percent compensation of leaf loss due to defoliation was also higher in TM-135 than in TM-110 and vice-versa for Pn rate.

Table 2. Effect of different levels of defoliation, variety and interaction of variety and defoliation on morpho-physiological and biochemical parameters in tomato

Treatment	Straw weight plant^{-1} at harvest (g)		Absolute growth rate (g p^{-1} d^{-1}) at 45-60 DAT	Leaf area plant^{-1} (cm^2) at 80 DAT	Chloro-phyll (mg g^{-1} fw)	Photo-synthesis (µ mol CO_2 s^{-1} dm^{-2})	Nitrate reduc-tase (µmol NO_2^- g^{-1} fw)	Total sugar (mg g^{-1} fw)
	2017	2018	2018	2018	2018	2018	2018	2018
No. of removed leaves								
Control	41.3 a	31.5 a	1.31 c	4894 b	2.14	23.20 c	5.67 b	72.8 b
3	40.0 a	32.6 a	1.37 b	5406 a	2.19	23.60 c	5.82 ab	73.0 ab
6	41.4 a	31.9 a	1.49 a	4809 b	2.19	24.63 bc	5.83 ab	74.7 a
9	34.0 b	28.3 b	1.16 d	4258 c	2.17	26.41 ab	6.11 a	75.6 a
12	27.6 c	25.4 c	0.81 e	2903 d	2.18	27.12 a	6.13 a	73.5 ab
Level of significance	**	**	**	**	NS	**	*	*
Variety								
TM-110	33.3 b	24.8 b	1.11 b	3584 b	2.13 b	24.08 b	5.62 b	73.2

Treatment		Straw weight plant^{-1} at harvest (g)		Absolute growth rate (g p^{-1} d^{-1}) at 45-60 DAT	Leaf area plant^{-1} (cm^2) at 80 DAT	Chloro-phyll (mg g^{-1} fw)	Photo-synthesis (μ mol CO$_2$ s^{-1} dm^{-2})	Nitrate reduc-tase (μmol NO$_2^-$ g^{-1} fw)	Total sugar (mg g^{-1} fw)
		2017	2018	2018	2018	2018	2018	2018	2018
TM-135		40.4 a	35.1 a	1.34 a	5324 a	2.21 a	25.90 a	6.2 a	74.3
Level of significance		**	**	**	**	*	**	**	NS
Interaction of variety and defoliation									
Variety	*No. of removed leaves*								
TM-110	Control	37.3 b	27.1 c	1.14 de	4205 e	2.09	22.3 e	5.41	72.3 bc
	3	36.3 b	29.0 c	1.21 de	3932 f	2.13	22.50 e	5.34	72.7 bc
	6	36.6 b	27.5 c	1.37 bc	3925 f	2.18	24.25 bc	5.68	73.8 ab
	9	29.8 c	21.8 d	1.08 e	3626 g	2.14	25.11 b	5.8	74.4 ab
	12	26.3 d	18.3 e	0.76 f	2234 h	2.13	26.23 ab	5.88	73 ab
TM-135	Control	45.3 a	35.8 a	1.47 ab	5583 b	2.19	24.1 de	5.93	73.2 ab
	3	43.7 a	36.2 a	1.52 a	6880 a	2.24	24.7 cd	6.3	71.9 c
	6	46.2 a	36.2 a	1.61 a	5693 b	2.19	25 cd	5.98	75.6 a
	9	38.2 b	34.9ab	1.24 cd	4891 c	2.2	27.7 ab	6.42	76.7 a
	12	28.9cd	32.5 b	0.85 f	3571 d	2.22	28 a	6.38	73.9 ab
Level of significance		*	**	*	**	NS	*	NS	*
CV(%)		5.94	5.51	7.89	4.15	3.18	6.45	7	6.65

In a column, within treatment, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * and ** indicate significance at 5% and 1% level of probability, respectively; NS, not significant; DAT, days after transplanting

Yield attributes and yield

The effect of defoliation on yield and yield attributes was significant (Table 3). Results revealed that number of fruits plant^{-1}, single fruit weight and fruit yield both per plant and per unit area were greater in 3 and 6 leaves defoliated plant than the control. Defoliation beyond 6 leaves decreased yield contributing characters, thereby fruit yield. The highest number of fruits plant^{-1}, single fruit weight and fruit yield were recorded in 6 leaves defoliated plants followed by 3 leaves defoliated plant and had no significant different between 3 and 6 leaves defoliated plant. The lowest number of fruits plant^{-1}, single fruit weight and fruit yield were recorded in 12 leaves defoliated plants. However, fruit yield was not proportional to the degree of

Table 3. Effect of different levels of defoliation, variety and interaction of variety and defoliation on yield contributing characters and yield in tomato

Treatment		Fruits plant^{-1} (no)		Weight fruit^{-1} (g)		Fruit yield plant^{-1} (kg)		Fruit yield (ton ha^{-1})	
		2017	2018	2017	2018	2017	2018	2017	2018
No. of removed leaves									
Control		33.3 c	45.3 b	40.5 a	37.6 a	1.34 c	1.63 a	47.0 bc	57.1 b
3		34.1 bc	47.6 a	41.2 a	37.9 a	1.39 b	1.71 a	49.1 ab	60.5 a
6		35.8 a	45.4 ab	42.1 a	38.2 a	1.49 a	1.70 a	52.7 a	60.7 a
9		35.0 ab	41.2 c	37.6 b	33.7 b	1.31 c	1.43 b	45.7 c	50.4 c
12		31.1 d	35.2 d	34.5 c	30.9 c	1.05 d	1.19 c	37.0 d	41.5 d
Level of significance		**	**	**	**	**	**	**	**
Variety									
TM-110		29.8 b	39.8 b	42.1 a	38.3 a	1.25 b	1.62	44.0 b	57.4 a
TM-135		37.9 a	46.2 a	36.3 b	33.0 b	1.38 a	1.43	48.6 a	50.7 b
Level of significance		**	**	**	**	*	NS	**	**
Interaction of variety and defoliation									
Variety	*No. of removed leaves*								
TM-110	Control	29.0	41.6	43.7	41.6 a	1.27	1.71 a	44.5	59.9
	3	30.2	44.0	44.2a	41.2 a	1.33	1.80 a	46.6	63.0
	6	30.8	43.8	45.6	39.7 ab	1.40	1.76 a	49.7	63.4
	9	32.0	37.2	40.1	35.8 bc	1.28	1.59 a	44.8	55.7
	12	27.0	32.2	36.9	33.3 cd	0.97	1.28 bc	34.4	44.8
TM-135	Control	37.6	49.0	37.4	33.6 c	1.41	1.55 ab	49.4	54.3
	3	38.0	51.2	38.2	34.6 c	1.45	1.61 a	51.5	57.9
	6	40.8	47.0	38.5	36.7 b	1.57	1.63 a	55.7	57.9
	9	38.0	45.2	35.1	31.6 cd	1.33	1.27 bc	46.6	45.1
	12	35.2	38.2	32.1	28.5 d	1.13	1.09 c	39.6	38.2
Level of significance		NS	NS	NS	*	NS	*	NS	NS
CV(%)		7.21	7.68	6.80	6.94	7.44	9.19	8.76	8.32

In a column, within treatment, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * and ** indicate significance at 5% and 1% level of probability, respectively; NS, not significant defoliation. For example, 71% leaf reduction (removed 12 leaves out of 17) caused only a 27.3% less yield over control in 2017. Fruit yield plant^{-1} increased under 3 and 6 leaves defoliated plants was due to greater number of fruits plant^{-1} and larger fruit size compared to control. This result is consistent with the findings of Verheul (2012) in tomato who observed that fruit yields were not affect under mild or partial defoliation in tomato. Again, lower fruit yield per plant under heavy defoliated condition was due to fewer numbers of fruit and smaller size fruits. Reduction in the number of fruits plant^{-1} under high defoliated condition might be due to lesser leaf area plant^{-1} which consequence production of lower amount of assimilate that is not sufficient for bearing maximum fruits. Similar result was also reported by many workers in tomato and soybean (Valdes et al., 2010; Silva et al., 2012; Raza et al., 2019)). They observed that fruits plant^{-1} decreased under heavy defoliated condition in tomato. Again, the fruit size was lower in higher defoliated plants. It might be due to lower amount of assimilate translocation from leaf to fruits which consequence smaller size fruits. Under heavy defoliated condition, less number of leaves unavailable to supply sufficient assimilates to the fruits, thereby produced small size fruits. The number of fruits plant^{-1} was greater in TM-135 than in TM-110 and vice-versa for fruit size (single fruit weight). However, fruit yield was higher in TM-135 than TM110 in 2017 and vice-versa in 2018.

Interaction effect of genotype and defoliation on yield attributes and fruit yield was non-significant in both years except single fruit weight and fruit weight plant^{-1} in 2017. It means trend of increase/decrease in yield attributes and fruit yield was almost similar in both the varieties. The reduction in fruit yield due to high degree of defoliation was greater in TM-135 than in TM-110. Reverse trend was observed in case of fruit size. The reduction in fruit size due to high defoliation was greater in TM-110 than in TM-135.

CONCLUSION

Severe defoliation in tomato not only decreased source size but also sink production resulting in lesser fruits and yield. However, the fruit yield of tomato increased over the control until 6 leaves (36% leaf loss) defoliated plant due to superiority in yield contributing traits. Further experimentation is needed for confirmation of the result.

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