EFFECT OF DEFOLIATION ON REPRODUCTIVE CHARACTERS AND YIELD OF TOMATO

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Abstract

The experiment was conducted under sub-tropical condition during 2017-18 and 2018-19 (November-March) to investigate the effect of defoliations on reproductive characters and yield of tomato. The experimental treatments were five levels of leaves defoliation *viz*., 0 (control), 3, 6, 9 and 12 from the base out of 17 leaves treated on and two tomato advanced lines *viz*., TM-110 and TM-135. The leaves defoliations were started at the beginning of flowering stage. The experiment was laid out in two factors split-plot design with three replicates by maintaining varieties as main plot and the defoliation levels as sub-plot. The reproductive characters and yield related characters such as number of effective flower clusters and flowers plant^{-1}, number of fruits plant^{-1}, individual fruit weight and fruit yield were not affected up to six leaves defoliation irrespective of seasons and genotypes. Reproductive parameters and yield attributes were better in three and six leaves defoliated plants over the control with being the highest in six leaves defoliated plant. Heavy defoliation not only reduced source sizes but also decreased total sink (flower and fruits) causing lower fruit yields. The lowest reproductive characters and fruit yield was recorded from twelve leaves defoliated plants. Interaction effects of genotype and defoliation on reproductive characters, 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. 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; 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 resulted on greater foliage production (Mondal *et al*., 2011a). It means instead of large physical 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 plant in most cases utilizing resources more than assimilate production which intern act as burden leaves on the

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others (leaves in the upper canopy). Defoliation up to certain limit therefore, may be useful to overcome this problem of excessive vegetative growth. Greater light penetration in the canopy through defoliation may reduce the abortion of flowers and increase fruit yield (Heuvelink *et al*., 2005; Valdes *et al*., 2010; 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 (Bhatt and Rao, 2003; 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; Valdes *et al*., 2010; 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). No detail information is available about source-sink relationships under discriminated levels in tomato during early reproductive growth stage. These aspects need specific investigation on tomato genotypes to assist the development of management practices under Sub-tropical condition.

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 reproductive characters 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 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 with two advanced lines of tomato (TM-110 and TM-135) 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 six rows including two borderlines on either side. The unit plot size was 3m × 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.

At harvest, ten plants from each plot were selected randomly for data recording on reproductive, yield and yield related traits. Per cent fruit set to opened flowers, reproductive efficiency (RE) was estimated as: % fruit set = (Number of fruits plant^{-1}/Number of flowers plant^{-1}) × 100. The number of effective and non-effective flower clusters plant^{-1} was counted of the sampled plant at 80 DAT. The effective flower cluster denotes as when it bears at least one fruit whereas the non-effective flower cluster denotes as when it bears no fruits. 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 New Range Test (DMNRT) using the statistical computer package program, MSTAT-C.

Results and discussion

Reproductive characters

The effect of genotype and defoliation on number of effective and non-effective clusters plant^{-1}, number of flowers plant^{-1} and per cent fruit set to flowers (reproductive efficiency, RE) was significant in both years (Table 1). Results revealed that the number of effective flower clusters plant^{-1} increased over control up to six leaves defoliation followed by a decline. However, there was a significant difference in number of effective flower cluster between the control and nine leaves defoliation plant in both years. The greater number of effective flower cluster plant^{-1} was recorded in three and six leaves defoliated plants than control with being the highest in three leaves defoliated plants in 2017-18 (12.0 plant^{-1}) and 6 leaves defoliated plants in 2018-19 (14.5 plant^{-1}). The lowest number of effective flower cluster plant^{-1} in both years was recorded in twelve leaves defoliated plants (9.88 plant^{-1} in 2017-18 and 11.1 plant^{-1} in 2018-19). The non-effective flower clusters plant^{-1} increased in three leaves defoliation over control and then further increased of defoliation, decreased the non-effective flower clusters plant^{-1}. The highest number of non-effective flower clusters plant^{-1} of both years was recorded in three leaves defoliated plants (4.46 plant^{-1} in 2017-18 and 3.63 plant^{-1} in 2018-19). The lowest number of non-effective flower cluster was recorded in twelve leaves defoliated plant in both the years (2.13 plant^{-1} in 2017-18 and 2.04 plant^{-1} in 2018-19). In 2017-18, number of flowers plant^{-1} did not significantly affected until 6 leaves defoliation and further increase in degree of defoliation, also significantly decreased the flower number. In 2017-18, the lowest number of flowers plant^{-1} was recorded in twelve leaves defoliated plants (65.4). In 2018-19, flower number increased with increasing defoliation levels till six leaves defoliation followed by a decline. The highest number of flowers plant^{-1} (90.0) was recorded in six leaves defoliated plants followed by 3 leaves defoliated plants (78.6 plant^{-1}). In contrast, the lowest number of flowers plant^{-1} (64.9) was observed in twelve leaves defoliated plants. However, the number of decreased flowers was not proportional to the degree of defoliation. For example, 71% leaf reduction (removed 12 leaves out of 17) caused only a 13.4% fewer flower production in 2017-18. RE increased with increasing defoliation in 2017-18 and the highest RE was recorded in twelve leaves defoliated plants (47.6%) followed by nine leaves defoliated plants (47.1%) with same statistical rank, whereas the lowest was recorded in control plant (40.1%). In 2018-19, RE significantly decreased after six leaves defoliation in tomato. The highest RE in 2018-19 was recorded in three leaves defoliated plants (61.3%) followed by control plants (60.5%) with same statistical rank. The lowest RE in 2018-19 was recorded in nine leaves defoliated plants (50.8%). The number of flowers plant^{-1} was greater in TM-110 (85.8 in 2017-18 and 78.0 in 2018-19) than in TM-135 (72.1 in 2017-18 and 73.8 in 2018-19) and vice-versa for RE. In general, heavy pruning decreased the number of flowers but RE was not affected by heavy defoliation, even increased over control. This could be explained in a way that less competition for assimilates by being their fewer flowers and this has certainly facilitated to produce maximum number of pods to flowers and vice versa (Mondal *et al*., 2013). Positive and significant correlation of yield with flowers, but number of flowers was negatively and significantly correlated with RE suggests that it might be difficult to get higher flower production with increased RE simultaneously. Similar results were also reported by Fakir *et al*. (2011) in mungbean and Saitoh *et al.* (2004) in soybean that it would be difficult to incorporate high flower production capacity and low flower abortion (FA) into one strain because of a positive correlation between FA and flower number, which also support the present result.

Interaction effect between genotype and defoliation on reproductive parameters was significant except number of effective flower clusters plant^{-1} (Table 1). Results indicated that number of non-effective flower clusters plant^{-1} followed no sequence in regard to defoliation levels. However, the lowest number of non-effective flower clusters plant^{-1} in both the varieties was the lowest in twelve leaves defoliated plants in both years. The number of flowers plant^{-1} in TM-110 increased in three leaves defoliated plants and further increased in degree of defoliation also decreased flower number in both years whereas in TM-135, flower number increased with increasing degree of defoliation till six leaves defoliation followed by a decline. RE was greater in defoliated plants of both varieties in 2017-18 and the variety TM-135 only in 2018-19, whereas RE was lower in defoliated plants as compared to control plants of the variety TM-110 in 2018-19.

Fruit yield and yield attributes

The effect of defoliation on yield and yield attributes was significant (Table 2). Results revealed that number of fruits plant^{-1}, single fruit weight and fruit yield per plant & per unit area were greater in three and six leaves defoliated plant than the control. Defoliation beyond six leaves decreased yield contributing characters, thereby fruit yield. In 2017-18, the highest number of fruits plant^{-1} (35.8), single fruit weight (42.1 g) and fruit yield (1.49 kg plant^{-1} and 52.7 t ha^{-1}) were recorded in six leaves defoliated plants followed by three leaves defoliated plant and had no significant different between three and six leaves defoliated plant. In 2018-19, the highest number of fruits plant^{-1} (47.6) was recorded in three leaves defoliated plants but single fruit weight (38.2 g) and fruit yield (60.7 t ha^{-1}) were the highest in six leaves defoliated plants, The lowest number of fruits plant^{-1} (31.1 in 2017-18

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

Treatment		Effective clusters plant^{-1} (no.)		Non-effective clusters plant^{-1} (no.)		Flowers plant^{-1} (no.)		Reproductive efficiency (%)	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
No. of removed leaves									
Control		11.6 ab	13.1 bc	3.88 b	3.12 b	85.8 a	74.7 c	40.1 b	60.5 a
3		12.0 a	14.0 ab	4.46 a	3.63 a	86.3 a	78.6 b	41.2 b	61.3 a
6		11.7 ab	14.5 a	2.88 c	3.50 a	83.0 a	90.0 a	44.1 ab	55.4 b
9		11.4 b	12.8 c	3.75 b	2.50 c	74.5 b	76.1 bc	47.2 a	50.8 c
12		9.88 c	11.1 d	2.13 d	2.04 d	65.4 c	64.9 d	47.6 a	55.0 b
Level of significance		**	**	**	**	**	**	**	**
Variety									
TM-110		12.1 a	12.9	3.10 b	3.22 a	85.8 a	78.0 a	35.5 b	51.0 b
TM-135		10.4 b	13.3	3.73 a	2.70 b	72.1 b	73.8 b	52,6 a	63.7 a
Level of significance		**	NS	**	**	**	**	**	**
Interaction of variety and defoliation									
Variety	No. of removed leaves								
TM-110	Control	12.8	12.8	4.25 b	2.75 cd	96.5 a	72.2 f	30.1 e	57.6 b
	3	13.0	13.2	4.25 b	4.25 a	99.5 a	84.2 a	30.4 e	52.4 bc
	6	12.5	14.5	2.25 e	4.50 a	91.0 b	82.5 ab	33.8 d	53.1 b
	9	12.0	13.0	3.24 c	2.25 e	77.0 c	80.7 cd	41.6 c	46.3 d
	12	10.5	11.0	1.50 f	2.33 de	65.2 d	70.3 f	41.4 c	45.8 d
TM-135	Control	10.5	13.5	3.50 c	3.50 b	75.0 d	77.2 de	50.1 b	63.2 b
	3	11.0	14.7	4.66 a	3.00 c	73.1 d	75.0 e	52.0 ab	70.1 a
	6	10.6	14.5	3.50 c	2.50 de	75.3 d	81.5 ab	54.4 a	57.7 c
	9	10.8	12.5	4.25 b	2.75 cd	72.0 d	71.5 f	52.8 ab	63.5 b
	12	9.25	11.3	2.75 d	1.75 f	65.5 e	59.5 g	53.7 a	64.2 b
Level of significance		NS	NS	**	**	**	**	**	**
CV(%)		5.14	6.64	6.70	7.41	5.04	4.23	6.51	6.91

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

and 35.2 in 2018-19) single fruit weight (34.5 g in 2017-18 and 30.9 g in 2018-19) and fruit yield (1.05 kg plant^{-1} in 2017-18 and 1.19 kg plant^{-1} in 2018-19) were recorded in twelve leaves defoliated plants in both years. However, fruit yield was not proportional to the degree of defoliation. For example, 71% leaf reduction (removed twelve leaves out of seventeen) caused only a 27.3% less yield over control in 2017-18. Fruit yield plant^{-1} increased under three and six leaves defoliated plants was due to greater number of fruits plant^{-1} and larger fruit size compared to control (Table 2). This result is consistent with the findings of Verheul, (2012) and Islam *et al.,* (2016) in tomato. They observed that fruit yields were not affect under mild or partial defoliation in tomato. Xiao *et al*. (2004) found that removing one in every three young leaves did not result in any significant loss in yield of 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 2017-18 and vice-versa in 2018-19.

Table 2. 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 (t ha^{-1})	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
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 abc	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	44.2	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.

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 2017-18. 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 the sink production resulting in lesser fruits and finally affect the fruit yield. However, the fruit yield of tomato increased over the control until six leaves (36% leaf loss) defoliated plant due to superiority in reproductive characters and yield contributing traits. Further experimentation is needed for confirmation of the result.

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