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DEBRANCHING IMPROVES MORPHO-PHYSIOLOGICAL CHARACTERS, FRUIT QUALITY AND YIELD OF TOMATO

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Abstract

Farmers are commercially cultivated tomato with different levels of shoot pruning but this production practice has not been defined clearly. The experiment was conducted under sub-tropical condition to assess the effect of different levels of debranching on morpho-physiological, reproductive and yield contributing characters in determinate tomato cultivar *cv*. Binatomato-5. The debranching levels were: i) control, ii) only mainstem (MS), iii) MS with 2 branches, iv) MS with 3 branches and v) MS with 4 branches. Based on recommended spacing (50 cm × 50 cm), the higher fruit yield plant^{-1} as well as fruit yield per hectare were observed in more branch bearing plants of the treatment control (MS with 5-6 branches), MS with 3 branches and MS with 4 branches due to production of higher number of fruits plant^{-1} with being the highest in MS with 3 branches due to increase fruit size. The lowest fruit yield per plant as well as per hectare was observed in uniculm plants due to lower number of fruits per plant. This study suggests that plants that have MS with three branches may be recommended for commercial cultivation of tomato under sub-tropical condition.

Key words: Branch removal, Physiological and reproductive characters; Fruit yield; *Lycopersicon esculentum*.

Introduction

Traditional varieties of tomato (*Lycopersicon esculentum* Mill.) possess greater sources than sink because they have capacity to produce profuse branching, thereby are leafy. In some situations, physical leaf area is adequate and even more than required, but the functional efficiency is far lower due to utilizing resources as a respiratory burden of those parasitic leaves (leaves in the lower canopy) on the other (Heuvelink, 2005). Debranching up to certain limit may, therefore, be useful to overcome this problem of excessive vegetative growth. Greater light penetration in the canopy through debranching and defoliation may reduce the abortion of flowers and increase fruit yield (Navarrete &Jeannequin, 2000; Martinez *et al*., 2001; Andriolo *et al*., 2004; Mondal *et al*., 2011a; Hesami *et al*., 2012). Andriolo *et al.* (2001) suggested that for commercial purposes, should practice branch and leaf pruning simultaneously to maximize light interception and fruit yield in tomato. Although pruning increases costs in tomato production, it improves light penetration inside the plant canopy and increases photosynthesis efficiency and so fruit yield (Ambroszczyk *et al*., 2008). Since vegetative growth, as a powerful sink, consumes produced assimilates, limitation of vegetative growth enhances assimilate transport to fruits. Thus, proper balance between vegetative and reproductive growth could improve fruit quantity and quality (Arzani *et al*., 2009). Many researches have done on the effect of pruning on qualitative and quantitative characteristics of tomato show that pruning limits vegetative growth and allows more light penetration and so improves qualitative and quantitative characteristics of tomato fruits (Preece & Read, 2005). There are some evidences that pruning not only improve fruit quality but also increases plant health against pests and disease (Kanyomeka & Shivute, 2005).

The effect of debranching of field crops and fruit tree has been studied and reported advantageous effect of debranching in many crops (Kanyomeka & Shivute, 2005; Ambroszczyk *et al*., 2008; Hesami *et al*., 2012). Proper pruning method gives the best quality and early fruit in tomato (Hesami *et al*., 2012). Although pruning needs extra cost, the practice could increase the economic return by increasing marketable fruit yield and improvement of the quality of fruits (Davis & Estes, 1993). Therefore, in accordance with recent agricultural policy to increase yield vertically and to get better quality fruits of tomato, an attempt was made to study the effects of different levels of debranching on growth and yield of widely cultivated tomato variety (Binatomato-5) in Bangladesh, thereby to assess the plant architecture which plant canopy is suitable for increase yield and to assist in the development of practices under Sub-tropical condition.

Materials and Methods

Experimental site: The two experiments were carried out under sub-tropical condition ($24^0 75'$ N and $90^0 50'$ E), Bangladesh during the three successive seasons (November-March) of 2011-12 and 2012-13. The experimental field was under subtropical climates characterized by heavy rainfall during the month of May to September and scanty rainfall during October to April. The soil of 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/100g, sulphur 20 ppm and pH 6.8.

Treatments and experimental design: The experiment comprised of one factor randomized complete block design with three replications. The widely cultivated variety, Binatomato-5 was used as plant material. The debranching levels were: i) control, ii) only mainstem (MS), iii) MS with 2 branches, iv) MS with 3 branches and v) MS with 4 branches. Control plants had 5-6 branches plant^{-1}. The treatments were maintained until harvest by frequently removing the new born shoots when necessary. The unit plot size was 4 m × 3 m.

Management practices: For the first experiment, seeds were sown in seedbed on 29 October 2011 and 27-day old seedlings were transplanted in the experimental field with recommended spacing of 50 cm × 50 cm. In the second experiment, seeds were sown in seedbed on 26 October 2012 and 25-day old seedlings were transplanted in the experimental field with same spacing. Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and cowdung were applied at the rate of 280, 250, 180, 80 and 10000 kg ha^{-1}, respectively (Anon., 2005). Whole amount of TSP, gypsum and cowdung, and half of MP were applied as basal dose during final land preparation. The remaining half of MP was applied as top dress at 45 days after transplanting (DAT). Half of urea was applied as top dress at 21 DAT and remaining half was applied at 45 DAT. Irrigation, weeding, pruning, staking, pesticides spray and other intercultural operations were done when required.

Parameters measured

Morpho-physiological and reproductive characters: The morpho-physiological parameters such as number of leaves $plant^{-1}$, leaf area $plant^{-1}$, straw weight and leaf area index, reproductive characters such as number of effective and non-effective flower cluster $plant^{-1}$, number of flowers $plant^{-1}$ and number of flowers $cluster^{-1}$ were recorded at first harvest of tomato in 2011-12. The second rows from the border of each plot were used for sampling. Five plants were randomly selected from each plot and uprooted for collecting leaf area and straw weight. The plants were separated into roots, stems, leaves and fruits, and the corresponding dry weight were recorded after oven drying at 80 ± 2 ^{0}C for 72 hours. The leaf area was measured using automatic leaf area meter (Model: LICOR 3000, USA) at 80 days after transplanting (DAT), just before harvesting the fruits. The leaf area index was measured using canopy analyzer (Model: LICOR 2000, USA) at 80 DAT. The canopy area was measured using Ceptometer (Decagon Devices Inc., Pullman, WA, USA) at noon of sunny day at 81 DAT. Percent fruit set to opened flowers, reproductive efficiency (RE) was estimated as:

$$\% \text{ Fruit set} = \frac{\text{Number of fruits plant}^{-1}}{\text{Number of flowers plant}^{-1}} \times 100$$

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. The non-effective flower cluster denotes as when it bears no fruits.

Biochemical parameters: All biochemical parameters were recorded at 50-60 DAT, the fruiting stage. Nitrate reductase (NR) activity was determined by following the method of Stewart & Orebamjo (1979). Total sugar and chlorophyll content in leaves were determined at 55 DAT following the method of Yoshida *et al*. (1976). Photosynthesis was measured at flowering and fruit development stage using portable photosynthesis meter (LI- 6400XT, USA). Vitamin C content was estimated by titration using iodate solution (Aminuddin *et al.*, 2003). It has been considered fruit ripening when the fruit was firm and red in color. Total soluble solid was measured using a portable refractometer (Model: 2WAJ-China).

Fruit yield and yield contributing parameters: At harvest, ten plants from each plot were selected randomly for data recording on 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.

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

Results

Morpho-physiological and phenological parameters: The effect of different levels of debranching on number of leaves, leaf area (LA) and straw weight $plant^{-1}$, leaf area index (LAI), days to flowering and harvesting duration was significant (Table 1). Result showed that number of leaves and LA $plant^{-1}$, straw weight $plant^{-1}$ and LAI decreased with increasing debranching levels over control. The highest number of leaves (71.0) and LA $plant^{-1}$ (6556 cm^2in 2011 and 5250 cm^2 in 2012), LAI (4.32) and straw weight $plant^{-1}$ (97.0 g) was recorded in control plants followed by the plants having mainstem (MS) with 4 branches. In contrast, the lowest above parameters was recorded in the plants having MS only. However, days to flowering and harvesting duration had no significant differences in the plants having any number of branches. Only the uniculm plants (No branch bearing plant) showed the significant shortest days to flowering and harvesting duration over other treatments.

Biochemical parameters: For biochemical parameters, results indicated that there had no significant different in chlorophyll content, photosynthesis (Pn) rate, total sugar (TS) content in leaves, Vit-C and total soluble solid (TSS) in fruits due to different levels of debranching (Table 2). On the other hand, nitrate reductase (NR) activity was significantly influenced by debranching levels. However, Pn rate and TSS were apparently higher in uniculm plant or low branch bearing plants (MS only and MS with 2 branches) than high branch bearing plants (Control plant, 5-6 branches and MS with 4 branches). NR activity was significantly higher in uniculm and low branch bearing plants (MS only and MS with 2-3 branches) than high branch bearing plants (Control plant, 5-6 branches and MS with 4 branches). Anyway, Vit-C content in fruits was apparently lower in debranched plants than control plants.

Table 1. Effect of different levels of debranching on morpho-pysiological and phenological parameters in tomato *cv.* Binatomato-5.

Debranching levels	Leaves/plant (no)	Leaf area/ plant (cm^2)		Straw weight/ plant (g)	Leaf area index	Days to flowering†	Harvesting duration†† (days)
	2012	2011	2012	2011	2011	2011	2011
Control	71.0 a	6556 a	5250 a	97.0 a	4.32 a	41.5 a	22 a
MS only	32.4 e	3261 d	3018 e	51.7 d	2.34 d	36.2 b	18 b
MS + 2 br.	45.2 d	4528 c	4390 d	73.2 c	3.26 c	39.7 ab	20 ab
MS + 3 br.	55.2 c	5760 b	4784 c	75.9 bc	3.82 b	40.1 a	21 a
MS + 4 br.	62.4 b	6294 ab	4980 b	80.9 b	4.21ab	40.1 a	21 a
Level of sig.	**	**	**	**	**	**	*
CV (%)	7.26	4.55	3.88	6.93	5.94	3.33	4.93

In a column, same letter (s) do not differ significantly at $p \leq 0.05$ by DMRT; MS = Main stem; Br. = Branches; *, ** significant at 5% and 1% level of probability, respectively; †, Days count from transplanting; ††, harvesting duration counts from first to final fruit harvest

Table 2. Effect of debranching on biochemical parameters in tomato cv. Binatomato-5.

Debranching levels	Chloro-phyll (mg g^{-1}fw)	Photo-synthesis (μ mol CO_2 $m^{-2}s^{-1}$)	Nitrate reductase (μmol NO_2^- g^{-1}fw)	Total sugar (mg g^{-1}fw)	Vit-C (mg/100g)	Total soluble solid (% w/w)
Control	2.24	21.29	5.57 b	72.2	2.22	4.35
MS only	2.29	23.55	6.02 a	74.4	1.98	4.65
MS + 2 br.	2.19	23.63 21.91 22.12	5.93 a	74.7	2.00	4.69
MS + 3 br.	2.27		6.01 a	72.6	2.11	4.50
MS + 4 br.	2.18		5.39 b	73.1	2.17	4.31
Level of sig.	NS	NS	*	NS	NS	NS
CV (%)	4.11	6.45	6.56	6.65	5.48	3.43

In a column, same letter (s) do not differ significantly at $p \leq 0.05$ by DMRT; NS = Not significant; MS = Main stem; Br. = Branches; * significant at 5% level of probability

Table 3. Effect of different levels of debranching on reproductive characters in tomato *cv.* Binatomato-5.

Debranching levels	Effective flower clusters/plant (no)	Non-effective flower cluster/plant (no)	Flowers/plant (no)	Flowers/cluster (no)	Reproductive efficiency (%)
Control	16.3 a	8.86 ab	189.3 a	6.27 c	36.0 b
MS only	12.5 c	5.80 c	106.7 c	7.76 a	38.9 ab
MS + 2 br.	14.9 ab	7.77 b	146.5 b	7.09 ab	38.8 ab
MS + 3 br.	15.8 a	8.66 ab	162.9 b	6.70 b	41.1 a
MS + 4 br.	15.1 ab	9.34 a	182.0 a	6.52 bc	35.6 b
Level of sig.	**	**	**	*	**
CV (%)	7.61	9.09	9.48	6.51	6.31

In a column, same letter (s) do not differ significantly at $p \leq 0.05$ by DMRT; MS = Main stem; Br. = Branches; *, ** significant at %% and 1% level of probability, respectively

Reproductive characters: The effect of different levels of debranching on reproductive characters such as number of effective and non-effective flower clusters $plant^{-1}$, flowers $plant^{-1}$, flowers $cluster^{-1}$ and reproductive efficiency (RE) was statistically significant (Table 3). Results indicated that number of effective and non-effective flower clusters $plant^{-1}$, and number of flowers $plant^{-1}$ decreased with increasing debranching levels, whereas reverse trend was observed in case of number of flowers $cluster^{-1}$ and RE. But decrease of effective flower clusters $plant^{-1}$ over control was not significant in plants having any number of branches. The lowest number of effective (12.5) and non-effective flower clusters (5.80) $plant^{-1}$, and flowers $plant^{-1}$ (106.7) was recorded in uniculm plants (having MS only). In contrast, the highest and higher flowers $cluster^{-1}$ and RE was recorded in uniculm plants followed by the plants having MS with two branches with same statistical rank. The lower number of flowers $cluster^{-1}$ and RE was recorded in control plants and plants having MS with 4 branches.

Fruit yield and yield contributing parameters: The effect of different levels of debranching on yield and yield contributing characters was significant (Table 4). Results revealed that higher fruit yield $plant^{-1}$ as well as higher fruit yield per hectare were observed in more branch bearing plants of the treatment, control and MS with 3-4 branches due to production of higher number of fruits $plant^{-1}$. Results indicated that plants having MS with 3 or 4 branches had no significant differences with control plants (having 6 branches) in fruit yield of tomato. However, single fruit weight was increased with increasing debranching levels. The highest single fruit weight was recorded in uniculm plants (having MS only) which was statistically similar to the plants having MS with 2 branches. The lowest single fruit weight was recorded in control plants followed by the plants having MS with 4 branches with same statistical rank. Although the uniculm plants had larger fruit size than branch bearing plants, the fruit yield was the lowest in uniculm plant due to fewer fruits $plant^{-1}$. The highest fruit yield was recorded in the plants having MS with 3 branches followed by plants having MS with 4 branches and control plants with same statistical rank.

Table 4. Effect of different levels of debranching on yield attributes and yield in tomato cv. Binatomato-5.

Debranching levels	Fruits/plant (no)		Single fruit weight (g)		Fruit weight/plant (kg)		Fruit yield (t/ha)	
	2011	2012	2011	2012	2011	2012	2011	2012
Control	70.0 a	55.6 a	31.0 c	42.5 c	1.74 ab	1.89 ab	62.64ab	68.04ab
MS only	40.5 d	35.5 c	38.8 a	47.8 a	1.26 d	1.36 b	45.36 c	49.96 c
MS + 2 br.	53.5 c	46.7 b	37.9 a	46.9 a	1.62 b	1.76 ab	58.32 b	63.36 b
MS + 3 br.	67.0 ab	54.4 a	33.6 b	45.0 ab	1.80 a	1.96 a	64.80 a	70.56 a
MS + 4 br.	64.8 b	55.4 a	30.4 c	44.4 b	1.58 b	1.97 a	56.88 b	72.12 a
Level of sig.	**	**	**	**	**	**	**	**
CV (%)	5.23	6.66	6.19	4.02	9.00	8.86	7.79	5.82

In a column, same letter (s) do not differ significantly at $p \leq 0.05$ by DMRT; MS = Main stem;
Br. = Branches; ** significant at 1% level of probability

Discussion

Although pruning increases costs in tomato production, it improves light penetration inside the plant canopy and increases photosynthesis efficiency and so fruit yield (Ambroszczyk *et al*., 2008). Since vegetative growth, as a powerful sink, consumes produced assimilates, limitation of vegetative growth enhances assimilate transport to fruits. Thus, proper balance between vegetative and reproductive growth could improve fruit quantity and quality (Arzani *et al*., 2009). In the experiment, improved biochemical parameters, reproductive efficiency and assimilates translocation to the sink (fruit) thereby produced larger and good quality fruits in debranched plants compared to unbranched plants. Muhammad & Singh (2007) reported that pruning is used to increase weight of marketable fruits and fruit yield in tomato that supported the present findings. Non-pruned plants (control plant) produced smaller size of fruits might be due to nonpruned plants continued to partition carbohydrates to vegetative growth, instead of reproductive growth. This result is consistent with Davis & Estes (1993) who reported that larger fruits produced in pruned plants than in nonpruned plants in tomato. In other words, debranching plants produced fewer fruits than non-debranching plants (Table 4) that might be helped less competition for assimilates amongst the fruits and this has certainly facilitated increase fruit size (Mondal *et al*., 2011a).Therefore in double branch or less, there is an appropriate proportion between leaves and light penetration into the canopy. In severe pruning treatments, there is high ventilation around the plants and on the other hand more light penetrates into the plant canopy so leaf fungal disease growth under this condition is reduced (Kanyomeka & Shivute, 2005) thereby produced more assimilates which efficiently partitioned to the sink, the fruits and produced more number of marketable fruits.

Pn rate apparently increased and NR activity significantly increased in debranched plant. However, Pn was greater in fewer branch bearing plants than high branch bearing plants. It is possible because of leaf photosynthesis or whole canopy gas exchange per unit leaf area was positively related to crop load. It means to fulfill the assimilate demand by the sink, the remaining leaves 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 rate of the remaining leaves increased 20- 38% in okra (Bhatt & Rao, 2003). Further, debranching may improve light penetration and distribution within the canopy, thereby improving whole plant CO_2 assimilation.

In general, heavy pruning decreased the number of flowers but RE did not affect by heavy pruning, 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 fruits to flowers and vice versa (Mondal *et al*., 2011b). However, pruning decreases fruit yield plant^{-1} but it does not mean that lack of pruning lead to the highest yield, and in order to the highest yield it is need to balance source and sink relations. In this experiment, plants having MS with 3 branches produced the highest fruit yield both per plant and per hectare.

Conclusion

Debranching of tomato could be practiced to increase the fruit quality and yield of tomato**.** MS with 3 branches might be the best treatment for increased fruit yield under recommended plant spacing (50 cm × 50 cm) for determinate cultivars of tomato in the sub-tropical area.

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