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Integrated effects of irrigation interval and calcium nutrient on growth and yield of tomato in pot cultivation

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Abstract: The study cultivating tomato in noncalcareous soil using pots was undertaken to investigate the combined effects of irrigation interval and calcium on growth and yield of different tomato varieties during the period from November, 2012 to March, 2013 at Kazla, Motihar, Rajshahi, Bangladesh. Three factors following a split-split plot design with three replications were involved in this experiment. The factors were composed of four tomato varieties viz., Raton (V_1), Unnoyn F_1 (V_2), Tomy gold F_1 (V_3) and USO_4 F_1 (V_4); three levels of calcium treatment as control (T_0), 60ppm (T_1) and 120ppm (T_2); and three times irrigation with 1 day interval (I_1), 2 day interval (I_2) and 3 day interval (I_3). Results exposed that calcium treatment with irrigation interval had significant influences on varietal performances of tomato. Tomy gold F_1 variety receiving 60ppm calcium treatment with 2 day irrigation interval gave the highest growth parameters as well as total yield of tomato followed by Raton which showed the second highest performances regarding the same parameter with the same dose of calcium and irrigation interval. Alternatively, USO_4 F_1 variety without calcium treatment applying 3 day irrigation interval showed the poorest yield and yield contributing characters of tomato. The lowest number of defective fruits with economic value was found with the interaction treatment of T_1I_2 with the variety V_2 (Unnoyn F_1). However, results suggested that Tomy gold F_1 variety at the combination of 60ppm calcium with 2 day irrigation interval would be the best choice for the farmer's practice for it's ability to produce the highest yield and fruit quality, though the variety Unnoyn F_1 produced less defective fruits.
Key words: Tomato varieties, calcium treatment, irrigation interval, pot culture.

Introduction

Tomato is one of the most important vegetable crops grown throughout the world. It is the most consumable vegetable crop after potato and sweet potato (Chowdhury, 1989). In Bangladesh congenial atmosphere remains for tomato production during low temperature in winter season that is early November is the best time for tomato planting in our country. It is the most popular as salad in the raw state and is made into soups, juice, ketchup, pickles, sauces, conserves, puree, paste, powder and other products. The positive role of tomato on human health has been ascribed principally to its vitamin C content.

Higher production of tomato depends upon adoption of high yielding varieties, appropriate crop management practices and balanced fertilization, timely irrigation and mulching, control of diseases and insect pests. Now-a-days the rooftop cultivation in pots is increasing with the increasing demand of increased people. Pot gardening is the practice of growing plants in pots or containers instead of planting them in the ground (Mills, 2013). This type of gardening is highly suitable for people who want to try gardening but have limited space or limited time. It is also useful for gardeners who live in areas where the soil isn't suitable for a particular plant. Transplanting gardens to the rooftop can be beneficial gardeners who have bushes, shrubs, or other plants that are prone to attacks from pests and small animals.

A significant decrease in water-soluble Ca in fruits and an increase in BER incidence with a decrease in Ca concentration in the supplied solutions, and the decrease in water-soluble, but not total, Ca available for physiological processes was supposed to be a major cause or risk indicative parameter of BER incidence in tomato (Yoshida et al., 2014). Likewise, manipulation of growth conditions such as increasing air humidity that decrease leaf transpiration rate may promote fruit Ca uptake and reduce the risk of BER development (Li et al., 2001). Irrigation frequencies or different irrigation intervals have beneficial effects on fruit production. Increasing irrigation frequency caused significant increases in plant water consumption and yield, whereas, an excessive irrigation level had a negative effect on irrigation use efficiency.

Materials and Methods

The experiment was conducted on the roof of a building at Kazla, Motihar, Rajshahi city corporation Bangladesh during the period from November 2013 to March 2014 to evaluate the integrated effects of calcium nutrient and irrigation intervals on growth and yield of tomato varieties. The experimental site was located at 24°21′41.85″N latitude and 88°37′42.34″E longitude. The area prevails with moderately high temperature and heavy rainfall during the kharif season and scanty rainfall with moderately low temperature during the Rabi season. Godagari terrace area, Rajshahi, Bangladesh was selected for collecting soil which was characterized as noncalcareous gray terrace soil. The experimental soil was silty clay loam in texture (sand 10%, silt 60%, clay 30%) with pH 6.7, and the calcium content was 21.08ppm. It was well drained with moderately high permeability. For making samples soils were collected from a depth of 0 to 15cm to analyze for determining physical and chemical characteristics before setting the experiment. Soil samples were analyzed at the soil resource development institute (SRDI), Regional station, Shyampur, Rajshahi Bangladesh.

Four tomato varieties viz., Raton, Unnoyan F_1, Tomy gold F_1 and USO_4 F_1 were used as plant material. Calcium nitrate tetrahydrate [$Ca(NO_3)_2.4H_2O$] compound was applied for supplying the nutrient calcium (Ca). Two doses of it for Ca treatment as 60ppm (T_1) and 120ppm (T_2) were applied and compared with control. Same doses of Ca compound were applied for three times interval during the whole experiment. Firstly, the dose of calcium was mixed up with pot soil before one day of transplanting, secondly the dose was applied at 20 days after transplanting (DAT) and finally at 40 DAT. Irrigation intervals were used as a treatment factor in this experiment. Each block was divided into three main plots in which irrigation intervals were applied. Three irrigation intervals were marked as I_1, I_2 and I_3.

The study was laid out in a split-split plot design assigning the irrigation interval on the main plot, variety to the sub-plots, calcium (Ca) to the sub-sub plots. The treatments were replicated in triplicate. Each block was divided into three main plots in which irrigation intervals were applied. Each main plot was further divided into four sub-plots and varieties were allocated to these plots. Then each sub plot was again divided into three sub-sub plots

where calcium (Ca) treatments were assigned at random. However, the total number of unit plots in the entire experiment was 3×4×3×3= 108. Each plot was treated with an individual earthen pot using 10 kg experimental soil in each. All data were analyzed statistically and the mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT). The following notations have been used to specify statistical significance. NS=Non-significant, **=Significant at 1% level, *= Significant at 5% level.

Results and Discussion

Effect of calcium: Calcium has an important effect on plant growth due to its function as a second messenger in the signal conduction among environmental factors and responses in plant growth and development. Large number of researchers showed that poor supplementation or uptake of Ca as well as low transport of Ca to fruits can cause BER in tomato (Bradfield & Guttridge, 1984; Ho *et al.* 1995; Marcelis & Ho, 1998; Grattan & Grive, 1999) therefore BER is also referred as a Ca- related disorder. In our study, calcium treatments at different doses affected significantly on their yield parameters of tomato (Table 1). The experiment showed that 60ppm calcium treatment (T_1) was suitable for the highest yield of tomato. The treatment T_1 (60 ppm) gave the highest number of total and fresh fruit, and lower incidence of blossom end rot (BER) in comparison to other treatments. Yoshida *et al.* (2014) reported the same as BER is believed to result from a lack of Ca^{2+} in the fruits or parts of fruits, because of poor Ca uptake by the roots, deficient Ca translocation in vascular vessels and/or inadequate Ca partitioning in fruits. Calcium treatment with 60ppm (T_1) also showed the highest fresh yield (1.61kg/plant or 79.51t/ha) due to higher concentration of calcium into the soil solution. Similar results were in agreement with the findings of Hao and Papadopoulos (2003). They found that increasing Ca^{2+} concentration in the nutrient solution increased fruit fresh weight, number of fruits, total yields, and marketable fruit yields. Control treatment showed highest defective fruits for insufficient calcium supply to the plant (Table 1). Similar results were supported by Tonetto de Freitas *et al.* (2011) as they found that low levels of Ca in fruit tissues can also cause blossom end rot, which is a physiological disorder that reduces the yield of many vegetables such as tomato. Calcium had significant difference with single fruit weight. Calcium treatment with 120ppm showed the highest single fruit weight and the lowest was in control treatment (Table 1). Calcium is well known for its role in maintaining the cell wall, particularly the middle lamella structure, through its binding to pectin substances. This property has long been used in maintaining tissue integrity of processed tomato products and increase individual fruit weight.

Table 1. Effect of calcium (Ca), irrigation interval and variety on yield and yield contributing characters of tomato

Treatments	No. of total fruits/plant	No. of defective fruits/plant	No. of fresh fruits/plant	Av. single fruit weight (g)	Total yield (kg)/plant	Wt. of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
T0	32.28b	7.22a	24.86b	47.19c	1.55b	0.47a	1.21b	59.75a
T1	36.72a	2.92b	32.14a	49.14b	1.75a	0.14b	1.61a	79.51b
T2	33.78ab	3.53b	30.56a	51.28a	1.77a	0.17b	1.60a	79.01a
LS	*	**	**	**	**	**	**	**
I1	40.11a	2.11b	38.00a	50.00b	1.99b	0.14	1.89b	93.33b
I2	41.31a	1.78b	39.83a	52.81a	2.20a	0.15	2.10a	103.70c
I3	21.36b	9.78a	9.72b	44.81c	0.88c	0.48	0.43c	21.23a
LS	**	**	**	**	**	**	**	**
V1	34.33b	4.89b	28.07b	47.48c	1.60b	0.22b	1.38b	68.15b
V2	37.22b	2.96c	34.26a	30.22d	1.14c	0.21b	1.06c	52.35a
V3	42.30a	6.52a	36.19a	62.70a	2.75a	0.39a	2.38a	117.53c
V4	23.19c	3.85bc	18.22c	56.41b	1.27c	0.21b	1.07c	52.84c
LS	**	**	**	**	**	*	**	**

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. T_0 = Control treatment, T_1 = 60 ppm Ca, T_2 = 120 ppm Ca; I_1 = 1 day irrigation interval, I_2 = 2 day irrigation interval, I_3 = 3 day irrigation interval; V_1 = Raton, V_2 = Unnoyn F_1, V_3 = Tomy gold F_1, V_4 = USO_4 F_1 ;NS = Non significant, LS = Level of significance, **=Significant at 1% level, *= Significant at 5% level.

Effect of irrigation: Irrigation interval had significant effect on yield of tomato. Table 1 showed that 2 day irrigation interval (I_2) showed the highest number of fruits up to harvest, the lowest number of defective fruits which were ultimately produced the highest number of fresh fruits (39.83) and fresh yield due to most favorable moisture condition. Similar observations were reported by May (1993); Shinohara *et al.* (1995); Candido *et al.* (2000); Yavuz *et al.* (2007); Pervez *et al.* (2009). Most favorable moisture condition means slightly moisture stress condition. In this experiment, 2 day irrigation interval (I_2) had slightly moisture stress but 1 day irrigation interval (I_1) had no moisture stress and sometimes it created anaerobic condition of soil which reduced yield compare to those of 2 day irrigation interval (I_2). Such findings were demonstrated that optimum water supply for tomato was an important factor for maximizing its production. In contrast, 3 day irrigation interval (I_3) showed the lowest number of total fruits (21.36) and the highest number of defective fruits (9.78) which were ultimately produced the lowest number of fresh fruits (9.72) and fresh yield due to moisture stress (Table 1). The similar result was reported by Candido *et al.* (2001) and Yaza *et al.* (2002). Moisture stress reduce photosynthesis by decreasing chlorophyll content, reduction in leaf area, closure of stomata and decrease in the efficiency of carbon fixation.

Another possible reason for the reduction in yield was reduced nutrient uptake by crops during moisture stress. The lowest number of fruits were obtained by applying 3

day irrigation interval (I_3) compare to other irrigation treatments due to flower abortion at flowering stage caused by water stress. The obtained results were agreement with that of Mahendran and Bandara (2000) who assessed with another crop of solanaceae family, chili. The different irrigation intervals had significant effect on the weight of single fruit. The single fruit weight was decreased with the increase of moisture stress. The highest single fruit weight was found in 2 day irrigation interval due to available moisture and was the lowest in 3 day irrigation interval due to moisture stress (Table 1). The results were supported by Ubaidullah *et al.* (2002).

Effect of variety: Different varieties showed significant differences on yield components of tomato. Table 1 represents total number of fruits, number of defective fruits, number of fresh fruits and fresh yield per plant of different tomato varieties. The highest number of total fruits, number of fresh fruits per plant and fresh yield were produced with the variety Tomy gold F_1 variety (V_3). Genetic constituents may be the causes for this occurence. Internal differences in genetic compositions among the varieties were the factors due to the variation in the yield of tomato as they were produced in the similar external situation. The yield variation could be related to genetic differences among the varieties since they were grown under the same environmental conditions (Hussain et al., 2002). Rehman et al. obtained significant differences amongst different tomato varieties. The results were also similar to those of Olaniyi and Fagbayide (1999). The highest defective fruits were observed in Tomy gold F_1 variety (V_3) with the same environmental condition. The defectiveness was occurred due to blossom end rot (BER), fruit cracking etc. The varietal differences to defectiveness of tomato fruits were occurred due to susceptibility to BER, fruit cracking. The obtained results were in partially supported by Adams and Ho (1992). Individual fruit weight was significantly influenced by different varieties. Maximum individual fruit weight was found in Tomy gold F_1 variety (V_3) followed by V_4, V_1 and V_2 respectively (Table 1). The variations among the varieties in respect of individual fruit weight per plant due to the varietal and genetic characteristics. Varietal influence on individual fruit weight was also reported by Biswas *et al.,* (2015).

Table 2. Interaction effect of variety and calcium on yield and yield contributing characters of Tomato

Treatments	No. of total fruits/plant	No. of defective fruits/plant	No. of fresh fruits/plant	Av. single fruit weight (g)	Total yield (kg)/plant	Wt. of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
V_1T_0	32.89	8.00b	24.11	45.33	1.52	0.36bc	1.72	84.94
V_1T_1	36.33	3.00de	30.00	47.56	1.58	0.14ef	1.44	71.11
V_1T_2	33.78	3.67de	30.11	49.56	1.70	0.17def	1.53	75.56
V_2T_0	35.22	4.22cde	31.00	28.67	1.03	0.50b	0.91	44.94
V_2T_1	38.67	2.33e	36.33	30.44	1.20	0.07f	1.13	55.80
V_2T_2	37.78	2.33e	35.44	31.56	1.21	0.07f	1.14	56.30
V_3T_0	41.00	10.67a	30.33	60.22	2.55	0.67a	1.94	95.80
V_3T_1	44.78	4.00de	40.78	62.44	2.86	0.22cdef	2.64	130.37
V_3T_2	41.11	4.89cd	37.44	65.44	2.85	0.29cde	2.56	126.42
V_4T_0	20.00	6.00c	14.00	54.56	1.11	0.33bcd	0.82	40.49
V_4T_1	27.11	2.33e	21.44	56.11	1.36	0.12ef	1.24	61.23
V_4T_2	22.44	3.22de	19.22	58.56	1.33	0.17def	1.16	57.28
LS	NS	**	NS	NS	NS	**	NS	NS

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. V_1 = Raton, V_2 = Unnoyn F_1, V_3 = Tomy gold F_1, V_4 = USO_4 F_1 ;T_0 = Control treatment, T_1 = 60 ppm Ca, T_2 = 120 ppm Ca; NS = Non significant, LS = Level of significance

Interaction Effects

Variety and calcium (V×T): With the combination of V_3×T_1, Tomy gold F_1 (V_3) gave the highest number of total fruits, number of fresh fruits and yield per plant as well as per hectare (Table 2). Fletcher *et al.* (2000) found the similar findings treating with 60ppm calcium for tomato cultivation. The highest number of defective fruits and the weight of defective fruits were found in treatment combination of V_3×T_0 due to calcium deficiency (Table 2). This result showed partially conformity with the agreement of Bangerth (1979).

Variety and irrigation (V×I): The interaction of irrigation interval and variety significantly influenced on yield parameters of tomato, presented in Table 3. The highest number of total fruits, fresh fruits, total yield and fresh yield per plant was found in the interaction of V_3×I_2 due to most favorable moisture condition. Similar observations were reported by Yavuz *et al.* (2007). Alternatively, highest number of defective fruits and defective fruit weight were observed in the interaction of V_3×I_3 due to moisture stress. Similar observation was found by Yaza *et al.* (2002).

Calcium and irrigation interval (T×I): The interaction effect of calcium and irrigation interval had significant effect on number of defective fruits per plant, weight of defective fruits per plant and fresh yield per plant and per hectare of tomato, presented in Table 4. The highest defective fruits were observed in the interaction of T_2×I_3 which was followed by T_0×I_3 and the highest defective fruit weight was observed in the interaction of T_2×I_3 which was followed by T_0×I_3 due to poor movement of calcium to the plant. Similar observation found by Adams and Holder (1990). The highest fresh yield was observed in the interaction of T_2×I_2 due to optimum moisture level.

Maintaining an optimum soil moisture level (i, e, not too wet and not too dry) helps to promote an adequate movement of calcium to the roots and then into the plant. Similar observation was found by Pervez *et al.* (2009). The lowest number of fresh yield was observed in interaction of T_0×I_3 which was followed by T_2×I_3 due to

moisture stress. Though calcium was available in $T_2 \times I_3$ but soil dryness could not allow calcium translocation to the fruits. Dryness of the growing substrate encourage BER in tomato which reduced fresh yield. Similar observation was found by Adams and Holder (1990).

Table 3. Interaction effect of variety and irrigation interval on yield and yield contributing characters of tomato

Treatments	No. of total fruits/plant	No. of defective fruits/plant	No. of fresh fruits/plant	Av. single fruit weight (g)	Total yield (kg)/plant	Wt. of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
V_1I_1	41.67c	2.33d	39.33cd	47.78ef	1.99c	0.11d	1.90c	93.83a
V_1I_2	40.56c	2.22d	38.33d	50.00de	2.03c	0.11d	1.92c	94.81c
V_1I_3	20.78ef	10.11b	6.57gh	44.67f	0.78f	0.45b	0.31f	15.30c
V_2I_1	44.56bc	1.33d	43.22bc	30.44gh	1.36e	0.13d	1.32d	65.19f
V_2I_2	45.44bc	0.79d	44.67b	32.22g	1.47de	0.23cd	1.44d	71.11d
V_2I_3	21.67def	6.78c	14.89f	28.00h	0.61f	0.27cd	0.42ef	20.74ef
V_3I_1	49.33ab	2.67d	46.67ab	65.00a	3.21b	0.22d	3.04b	150.12b
V_3I_2	51.89a	2.33d	50.78a	68.11a	3.62a	0.16d	3.46a	170.86a
V_3I_3	25.67de	14.56a	11.11fg	55.00c	1.43de	0.80a	0.62e	30.62c
V_4I_1	24.89de	2.11d	22.79e	56.78c	1.42de	0.12d	1.30d	64.120b
V_4I_2	27.33d	1.78d	25.56e	60.89b	1.67d	0.11d	1.56d	77.04d
V_4I_3	17.33f	7.67c	6.33h	51.56d	0.72f	0.40bc	0.36ef	17.78ef
LS	**	**	**	**	**	**	**	**

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. V_1 = Raton, V_2 = Unnoyn F_1, V_3 = Tomy gold F_1, V_4 = USO_4 F_1; I_1 = 1 day irrigation interval, I_2 = 2 day irrigation interval, I_3 = 3 day irrigation interval; NS = Non significant, LS = Level of significance

Table 4: Interaction effect of calcium and irrigation interval on yield and yield contributing characters of tomato

Treatments	No. of total fruits/plant	No. of defective fruits/plant	No. of fresh fruits/plant	Av. single fruit weight (g)	Total yield (kg)/plant	Wt. of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
T_0I_1	39.92	6.33c	33.58	48.00	1.90	0.43a	1.59c	78.52c
T_0I_2	39.67	5.33c	33.33	51.00	2.01	0.45a	1.71c	84.44c
T_0I_3	17.25	10.00ab	6.67	42.58	0.75	0.51a	0.33d	16.30a
T_1I_1	41.42	0.00d	41.42	49.50	2.05	0.00b	2.05b	101.23b
T_1I_2	42.83	0.00d	42.83	52.75	2.26	0.00b	2.26ab	111.60bc
T_1I_3	25.92	8.75b	12.17	45.17	0.94	0.41a	0.53d	26.17d
T_2I_1	39.00	0.00d	39.00	52.50	2.03	0.00b	2.03b	100.25b
T_2I_2	41.42	0.00d	42.33	54.67	2.32	0.00b	2.32a	114.57a
T_2I_3	20.92	10.58a	10.33	46.67	0.96	0.52a	0.44d	21.73b
LS	**NS**	**	**NS**	**NS**	**NS**	**	**	**

In a column, figures bearing similar letter(s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. T_0 = Control treatment, T_1 = 60 ppm Ca, T_2 = 120 ppm Ca; I_1 = 1 day irrigation interval, I_2 = 2 day irrigation interval, I_3 = 3 day irrigation interval,NS = Non significant, LS = Level of significance

It can be concluded that Tomy gold F1 variety with 2 day irrigation interval applying 60ppm calcium treatment exposed the highest yield, while USO4 F1 variety with 3 day irrigation interval with control treatment gave poor yield of tomato. However, Tomy gold F1 variety would be considered as better for pot experiment applying the combination of 60ppm calcium treatment with 2 day irrigation interval.

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