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P Bhuvanaswri
Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Dr. V Geethalakshmi
Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Dr. T Ragavan
Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Dr. V Krishnamoorthy
Department of Horticulture, Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Dr. T Sivakumar
Department of Crop Physiology, TNAU, Coimbatore, Tamil Nadu, India

Correspondence
P Bhuvanaswri
Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Impact of planting window and N levels on tomato productivity and quality

P Bhuvanaswri, Dr. V Geethalakshmi, Dr. T Ragavan, Dr. V Krishnamoorthy and Dr. T Sivakumar

Abstract
Tomato (*Lycopersicum esculentum*.) is one of the ubiquitous and widely consumed vegetable crops. High quality yield is an essential pre-requisite for its efficient and economical production. Here, we aimed to evaluate the effects of different nitrogen doses on physical and chemical quality of tomato fruit. The experiment was conducted at Ponnaniyar, Trichy. The experimental setup included a factorial randomized block design with three replications. The treatments comprised of four dates of sowing (22nd, 24th, 26th and 28th Meteorological Standard Week), applied in three doses of N [RDN-75kg ha^{-1}, RDN (-25%) and RDN (+25%)]. The fruit shape index, pericarp thickness, pH, titratable acidity, total soluble solid, sugar acid ratio and ascorbic acid were analyzed. However, increasing concentrations of N increases the acidity, SAR and TSS, but the ascorbic acid and the fruit firmness declines

Keywords: RDN, pH, TSS, ascorbic acid, titratable acidity

Introduction

Tomato (*Lycopersicum esculentum* Mill.), an herbaceous sprawling vegetable crop with wide usage in Indian culinary tradition. It is the world's largest vegetable crop after potato and sweet potato, but it tops the list of canned vegetables with the total global coverage of 46.16 lakh ha and production of 1279.93 lakh tonnes. As far as India is concerned, it occupies the third position in the production of tomato in the world. Tamil Nadu, one of the southern Indian states grow tomato in around 23 thousand hectare with a production of three lakh tonnes of fruits which is nearly 3.4 per cent of India's total production (State of Indian Agriculture 2015-16, GOI).

Tomato consumption and widespread adoption as an important food commodity has regularly increased over recent years due to its flexibility in usage as fresh or processed form. However, consumers are very much concerned with the fruit quality (Hobson and Kilby, 2000) [11]. Fruit quality for consumption is determined by physical (size, colour, pericarp thickness) and chemical properties (pH, acidity, TSS, ascorbic acid) of the fruit. Tomatoes are heavy feeders because of their rapid growth and long production season and are highly responsive to nitrogen (N) application. Nitrogen is the key component of enzymes, vitamins and other cell constituents, all of which are essential for crop growth and yield. Commercial tomato production requires optimal fertilizer for high yield and maximum profits. In many cases, N is the element that most limits tomato crop growth (Scholberg *et al.*, 2000) [14]. The limited nitrogen fertilization affects yield and quality traits such as total soluble solids, reducing sugars and acidity (Colla *et al*., 2003) [6]. Soils all over the world are universally deficient in nitrogen (N) to varying degrees. Nitrogen is the nutrient applied in most quantities from external sources. As a result, modern agricultural systems depend heavily on large inputs of N fertilizer to maintain soil productivity. Adequate N availability during crop growth and development must be ensured to obtain high yield and quality produce. (Elia and Conversa, 2012) [8]. Scarce N availability leads to both reduced growth and yield, that also leads to early senescence of leaves. In contrast, exceeding N may increase plant vigour, extend plant cycle causing delayed harvest and may also influence the quality traits of fruits. Nitrogen Use Efficiency (NUE), a derived parameter depicting the relationship between the applied N and the yield is currently serving as an indicator for optimizing the fertilizer requirement. Effective N management strategies should include many critical factors that are interrelated, of which the correct rate of N application and efficiency of genotypes are considered as the most important factor in improving N use efficiency (Widowati *et al.*, 2011) [17].

Concerning the above facts, an experiment was designed to understand the influence of N doses on fruit quality parameters

Materials and Methods

The field experiment was conducted with tomato (Variety PKM-1) in a farmer's field, near Ponnaniyar dam area of Thiruchirapalli district, Tamil Nadu during *kharif* and *rabi* seasons of 2016-2017. The experimental site is situated at 10.51° N latitude and 78.21° E longitude at an altitude of 78.17 m above Mean Sea Level (MSL). The place enjoys a moderate climate and receives a normal rainfall of 850.6 mm in a year with mean maximum and minimum temperature of 37.4° C and 29.2° C respectively. The field soil is taxonomically '*Ustic*', sandy loam in texture. The pre-plant soil of the experimental site was analyzed and compared with the ratings. The data indicated that the soil of Ponnaniyar has a pH of 7.98, which is mildly alkaline in reaction and a normal in electrical conductivity (0.24 dSm^{-1}), low in available N (66.4 kg ha^{-1}), low in organic carbon content (0.46%), medium in P content (19 kg ha^{-1}) and high in potassium content (585 kg ha^{-1}).

The trial was conducted in factorial Randomized Block Design (RBD) with three replications at a plot size of 4.0 m x 3.0 m. The first factors being the date of planting (D_1: Sowing in 22nd Meteorological Standard Week (MSW), D_2: Sowing in 24th MSW, D_3: Sowing in 26th MSW, D_4: Sowing in 28th MSW) and the second factor being the nitrogen doses (N_1: Application of N at recommended dose (RDN-75kg ha^{-1}), N_2: RDN (-25%) and N_3: RDN (+25%)). The combination of factors comprises of twelve treatments. Tomato seedlings were raised in protray cells and twenty eight days old seedlings were transplanted to the main field with a spacing of 60 cm X 40 cm. The N doses in the form of urea (46% N) was applied as per the treatments on 25 days after transplanting (DAT). Crop was irrigated uniformly using bore well water as and when required by the crop.

The biometric observations on growth attributes was recorded on 45 and 90 DAT and the yield attributes were recorded at the time harvest. The physical quality attributes *viz.*,mean pericarp thickness, fruit shape index and the chemical quality attributes like Total soluble solids (TSS), pH, titratable acidity, sugar to acid ratio (SAR) and ascorbic acid content of the fruit was analyzed after harvest.

Physical quality attribute such as mean pericarp thickness (mm) was recorded by taking cross section and measuring the pericarp thickness. The length and width of the fruit was measured using measuring tape and fruit shape index was calculated by the ratio of fruit length to width. pH was measured using a digital pH meter, TSS content was determined using a hand refractometer at 26 °C.

Chemical quality attributes like titratable acidity was quantified by neutralizing the acidity in known volume of juice using alkali (NaOH). Sugar to acid ratio (SAR) was calculated by dividing the value of total soluble solids to the value of titratable acidity. Ascorbic acid content in the fruit was also estimated by titrating against 2,6 dichloroindophenol dye and comparing with the titration value for standard ascorbic acid solution (100 mg ascorbic acid in 100 ml of 4% oxalic acid).

Result and Discussion

Impact of planting time and N doses on tomato productivity

The present investigation revealed that the individual effects of date of planting (DOP) as well as levels of N had significant influence over fruit yield, however, the interaction effect between the two factors was not significant. Among different planting dates, 10th July planted crop recorded the highest fruit yield of 30317 kg ha^{-1}, which was at par with 15st June planted crop (29817 kg ha^{-1}). When the planting of tomato is delayed beyond July 10th, the yield got reduced considerably, which was evident from 25th July and 15th August planting that recorded 23044 and 20668 kg ha^{-1} respectively.

Tomato yields are highly responsive to nitrogen application (Anderson *et al.*, 1999). Among the levels of Nitrogen tried, RDN (75 kg ha^{-1}) recorded higher yield of 30174 kg ha^{-1} (Table 1) which was at par with 125% of RDN (28501 kg ha^{-1}). The lower doses of N (75% RDN) yielded only 19209 kg ha^{-1} of fruits. Application of higher doses of N (125% RDN) increased the plant vegetative growth due to development cell division and cell expansion. Average number of fruits per cluster in RDF was three, while it was six in 125% RDF resulting in more number of fruits with reduced size and weight. Similar results of more number of smaller fruits for enhanced N levels was also reported by Adams *et al.*, (1978).

Table 1: Impact of planting time and nitrogen doses on yield and physical quality of tomato

Treatments	Yield	Fruit Shape Index	Pericarp thickness (mm)	pH of juice
Dates of planting (DOP)				
D_1	29817	0.48	4.83	4.17
D_2	30317	0.47	4.14	4.61
D_3	23044	0.47	4.11	4.62
D_4	20668	0.48	4.46	4.42
S Ed	1632	0.006	0.10	0.13
CD	3385	NS	0.21	0.27
Nitrogen levels (N)				
N_1	30174	0.47	4.66	4.35
N_2	19209	0.47	4.34	4.38
N_3	28501	0.49	4.16	4.63
S Ed	1413	0.005	0.09	0.11
CD	2931	0.011	0.19	0.24
Interaction (D x N)				
S Ed	2827	0.011	0.18	0.23
CD	NS	NS	NS	NS

Impact of planting time and N doses on physical fruit quality of tomato

Nutrient requirement of tomato is an important factor if large quantities of high quality fruits are to be produced. (Wien and Minotti, 1988) [18]. In the current study, nitrogen levels had significant impacts on fruit quality.

Fruit shape index

Dates of planting had no significant influence on the fruit shape index, however, levels of N application had significant influence. It was interesting to note that the increased N levels increased the number of fruits per plant but reduced the size and weight of individual fruit. The lower mean fruit shape index of 0.47 (Table 1) was observed from RDN and higher value of 0.49 was recorded with 25% higher RDN. Reduction in yield in the higher dose of N might be due to reduction in partitioning efficiency that has resulted in more translocation of photosynthates to leaves and stem instead of fruits. Similar results were confirmed by Akanbi *et al.*, (2007) [4] stating that the fruit size is genetically and environmentally controlled through successive phases of fruit development and is positively correlated with amount of N available for plant during fertilization of flower, cell mitotic activity and enlargement. N availability affect sink function of the fruit and these play a role in the control of carbohydrate accumulation in tomato. Nitrogen availability also determined the size and chemical components of fruits. According to Acedo *et al.* (2002) [1], fruits having flat shape with length less than the width (<1 length to width ratio) are considered as large fruit; on the other hand, oblong shape fruits with length greater than width (>1 length to width ratio) are considered as small fruits. Correct dose of N resulted in more number of larger fruits, that yielded maximum fruit productivity.

Pericarp thickness

Thick pericarp is a useful character as far as post-harvest handling is concerned in transportation. So it could be an added advantage to have a denser pericarp. Firmness of pericarp tissue is a key factor for long storability (Lemma Deselagne, 2002) [13]. Pectic substances present in the cell walls of plants are structures that contribute to the firmness of fruit and are found in different forms. Nitrogen element initiates the cell activity at a faster rate. The proto-pectin, a water insoluble form of pectic substances, undergoes transformation to pectin during fruit maturation, which by enzymatic action, is first solubilized and then completely degraded when the fruit is ripened, leading to formation of weak pericarp. Higher doses of nitrogen application reduced the fruit pericarp thickness of early planted crops. Application of RDN formed a thicker pericarp of 4.66 mm whereas 25% higher RDN treatments formed comparatively weak pericarp (4.16 mm). The similar result was noticed by Schwartz *et al.*, (2010).

PH

Tomato is classified as acid fruit vegetable with acid I class which pH ranges between 3.7 to 4.6 (Gloud, 1978). In the present investigation, increased doses of N resulted in lowering the pH and resulted tartness. The observed pH values are in the range of 3.74 to 4.77 (Table 1). Increasing rate of N fertilizer increased the potential acidity (pH) in fruits which was confirmed by Winsor and Massey (1978). It is possible that larger amounts of reserve carbohydrates transformed into organic acids and concentrated in fruit tissues might have lead to a reduction of NO^{3-} which ultimately affected the pH.

Table 2: Impact of planting time and nitrogen doses on chemical quality of tomato

Treatments	Total Soluble Solids (TSS) %	Titratable Acidity (TA) %	Sugar Acid Ratio (SAR)	Ascorbic acid (mg $100g^{-1}$)
Dates of planting (DOP)				
D_1	4.58	0.49	9.85	20.05
D_2	4.60	0.47	9.80	20.05
D_3	4.70	0.55	8.82	20.33
D_4	4.61	0.50	9.63	21.85
S Ed	0.09	0.04	0.83	1.02
CD	NS	NS	NS	NS
Nitrogen levels (N)				
N_1	4.63	0.48	8.43	20.60
N_2	4.55	0.46	10.11	21.40
N_3	4.69	0.56	10.04	19.71
S Ed	0.08	0.03	0.72	0.88
CD	0.16	0.07	NS	1.83
Interaction (D x N)				
S Ed	0.16	0.07	1.44	1.76
CD	NS	NS	NS	NS

The study results indicated that the dates of planting had no influence on any of the chemical quality parameters of the fruit. Levels of nitrogen significantly influenced Total Soluble Solids, Titrable acidity and Ascorbic acid. However, the sugar acid ratio that is responsible for good flavour used to be between 10 and 18 (Gloud 1978) [10] remained unaffected by N rate. All the parameters showed no interaction effect between dates of planting and N levels.

Total Soluble Solids (TSS)

Total soluble solid contents is an indicator of mineral nutrient concentration in fruit. The total soluble solids increased during the maturation stage due to degradation of polysaccharides to simple sugars, thereby causing a rise in total soluble solids in tomato. The observed trend showed that TSS and the applied N rates had a direct relationship and the TSS values increased with increase in N fertilization (Table 2). This could be attributed to the reason that nitrogen, which is a constituent of protein and amino acids that directly affects TSS (Ahmed *et al*., 2012) [3]. Erdal *et al* (2007) [9] also indicated that TSS was highest with fruits that received higher N doses. Similarly, Huett and Dettmann (1988) [12] also confirmed that per cent dry matter and total soluble solids increased with N application.

Titratable acidity and sugar acid ratio

Titratable acidity was influenced positively by N application and 125% RDN recorded the highest value of 0.56 per cent. The results of Erdal *et al.* (2007) [9] agree with the results of the present study who reported that titratable acidity increased with increasing N rate of application. Likewise, Adams *et al.* (1978) also found that titratable acidity increased with N levels.

Ascorbic acid

The ascorbic acid content decreased with increased N concentration. Among the treatments, RDN and -25% RDN recorded an ascorbic content of 20.6 and 21.6 mg per 100 g (Table 2) which is higher when compared to +25% RDN (19.71 mg $100g^{-1}$), this is because the exposure of fruits to sunlight favored the accumulation of ascorbic acid content in the pulp. However, high doses of N leads to shoot biomass production, thus, the leaves shaded the fruits and reduce the ascorbic acid content. This was also supported by Dumas *et al.*, (2003).

Conclusion

Based on the findings, it could be observed that the early-planted before first fortnight of July (25th June and 10th July planted crops) recorded higher yield compared to later planting. With respect to N levels, recommended dose of nitrogen (75 kg ha^{-1}) yield more with improved fruit physical and chemical quality compared to decreased or increased doses of N. Application of excess amount of nitrogen (+25% RDN) resulted in enhanced vegetative growth but reduced the fruit size and quality. Hence, to achieve more productivity and profitability, tomato crop should be planted before first fortnight of July and applied with recommended dose (75 kg ha^{-1}) of N.

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