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Significance of nutrient application on growth, yield and quality of Guava: A review

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Abstract
Macro and micronutrient play a vital role in the growth and productivity of fruit trees. A well-nourished fruit tree not only produces good yield but also improves quality and remains for longer period in healthy and productive condition. Application of higher fertilizers resulted in more uptake of nitrogen, phosphorus and potassium from soil which ultimately led to better plant growth, yield and leaf nutrient status. Nitrogen, phosphorus and potassium, being the essential major elements and required by plants in relatively large quantities for building their infrastructure. These are especially responsible for maximising physiological activities of the plant and for plant, water and soil relationships, which ultimately affect fruiting and quality but excess amount of application can result deteriorate fruit quality. Foliar spray of zinc sulphate, boric acid and manganese sulphate alone and there combinations showed positive impact mainly fruit yield and quality of guava. Similarly, these foliar application of micronutrients improved leaf nutrient status of guava.

Keywords: Boric acid, fruit yield, guava, nitrogen, quality, zinc sulphate

Introduction
Guava (*Psidium guajava* L.) is an important tropical and commercial fruit rich in dietary fibre, calcium, phosphorus and iron. In India, guava occupies an area of 2.55 lakh hectares with annual production of 40.48 lakh tonnes and productivity 15.9 MT/ha (Anonymous, 2017) [1]. In Haryana, the area under guava crop is 11.21 thousand hectares with total production of 1.52 lakh tonnes (Anonymous, 2017) [1]. Guava is very popular among poor people due to moderate price, good taste and easy availability. The fruits are used for table and processing purposes. Guava bears crop two to three times a year. The economic returns are also higher with few inputs. Judicious management is required to produce a profitable crop and that includes optimum fertilization of the orchard. Else, fruiting, yield and fruit quality are all affected adversely. It can tolerate high temperature and drought conditions in summer but it is susceptible to severe frost, particularly during initial years of plantation. An annual rainfall of about 100 cm is sufficient during rainy season (July-September). Its cultivation require little care and minimal inputs. It can be grown on a wide variety of soil from heavy clay to light sandy soil of pH 4.5 to 8.5 (Arshad, 2015) [2]. Nitrogen, phosphorus and potassium are the major and essential nutrients for plant growth and development. Nitrogen is an essential component of amino acid, proteins, nucleic acids, porphyrins, purines and pyrimidine nucleotides, flavin nucleotides, enzyme, co-enzyme and alkaloids. Being a constituent of nucleic acids viz. Ribo Nucleic Acids (RNA) and Deoxyribo Nucleic Acids (DNA), it is responsible for the transfer of genetic code to the off-springs. Phosphorus is involved in energy transfer, photosynthesis, transformation of sugars and starch, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next (Rattan and Goswami, 2009) [3]. Potassium plays a major role in transport of water and nutrient throughout the plant in xylem. It increase root growth and improves drought tolerance. Potassium is responsible for activation and synthesis of protein-forming nitrate reductase enzyme (Rattan and Goswami, 2009) [3]. Nitrogen, phosphorus and potassium are most indispensable of all mineral nutrients for growth and development of the plant as these are the basis of fundamental constituents of all living matter (Throughton *et al*., 1974) [4]. Foliar application of fertilizer is advantageous over soil application. It helps in uniform distribution of fertilizers, low application rates and quick response to applied nutrients (Kumar *et al*., 2015) [5].

Boron is mainly considered for reproduction, germination of pollen tube, fertilization and improving fruit quality (Ganie *et al*., 2013) [6]. Foliar application of micronutrients like zinc sulphate and boric acid plays a crucial role in growth, development and improving quality of fruit (Dixit *et al*., 2004) [7].

Manganese is an integral component of the water-splitting enzyme associated with photosynthesis. Because of this role, Mn deficiency is associated with adverse effects in photosynthesis and O2 evolution. It is a constituent of superoxide dismutase (Mn-SOD). Role of Mn assumes critically because Mn-SOD (present in mitochondria and peroxisomes) protects cell against the deleterious effects of superoxide free radicals (Rattan and Goswami, 2009) [3]. In Hisar district of Haryana about 83 per cent orchards were found deficient in nitrogen, 75 per cent in phosphorus and 91 per cent in case of potassium (Baloda *et al*., 2014) [8]. The deficiency of zinc (15.3%), boron (6.10%) and manganese (3.30%) varied in Haryana soils (Shukla *et al*., 2015) [9]. Zinc act as metal activator in enzymes like dehydrogenase and is also involved in the synthesis of tryptophan and act as precursor of IAA (Noggle and Fritz, 1980) [10]. It influences translocation and transport of P in plants. Under Zn-deficiency, excessive translocation of P occurs, resulting in P toxicity (Rattan and Goswami, 2009) [3]. Guava suffers zinc deficiency, which is characterized by reduction in leaf size, interventional chlorosis and suppression of growth and dieback. As micronutrient deficiency is major constraint in fruit production as well as in fruit quality. Even small variations from the optimum level required for plant growth can be damaging. Therefore, it is very important for growers to have a clear understanding about micronutrient management to maintain a proper balance of micronutrients in the production systems. A small investment in supplementing the deficient micronutrients benefits in terms of both yield and marketable quality of fruit. Micronutrients increases fruit yield, encourage fruit set on lower part of tree and increases physico-chemical characteristics of guava fruits (Sarkar *et al*., 2005; Shukla *et al*., 2008) [11-12]. Zinc, boron, and manganese are essential component of enzyme responsible for carbohydrates and nitrogen metabolism, thereby resulting in to increased uptake of nitrogen by plants (Shukla *et al*., 2009) [13]. The foliar application of micronutrient reduced fruit drop and increased fruit retention, this might be due to role of biosynthesis of IAA (El-Sherif *et al*., 2000) [14]. The deficiency of micronutrients in soil leads to lower micronutrient in edible part and thereby causing health problem in human population (Shukla *et al*., 2015) [9]. Horticultural crops can play a vital role in solving the micronutrients crisis in human health. Fruits are the most sustainable and affordable source of micronutrients in diets. Imbalances in micronutrient management may lead to reduced yield and poor fruit quality. There is an urgent need to re-look into the problems of micronutrients in horticulture to overcome the hidden hunger.

Effect of nitrogen, phosphorus and potassium fertilizers on Growth parameters

Nitrogen, phosphorus, and potassium are most indispensable of all mineral nutrients for growth of the plant as these are the basis of fundamental constituents of all living matter. Wagh and Mahajan (1985) [15] reported good tree growth with application of NPK (900:300:300) along with 25 kg FYM in guava. Kumar *et al*. (1996) [16] reported that application of nitrogen and phosphorus 400 g/tree significantly increased stem girth and tree height of guava cv. Allahabad Safeda. Khattak *et al*. (2005) [17] reported that 4 kg NPK/tree gave the maximum plant height (19.26 cm), plant spread (19.22 cm) in guava. Bhobia *et al*. (2006) [18] obtained maximum increase in plant height (15.55%), plant spread [East-West (25.00%) and North-South (24.38%)] in treatment where 100 per cent N was applied through urea in guava cv. Hisar Surkha. Kaur and Chahil (2006) [19] recorded the maximum stem girth (1.90 cm) with the application of NPK (400:200:100 g/tree) in guava. Baksh *et al*. (2008) [20] observed significantly increase in plant height (0.32 m), plant spread (0.33 m) and trunk girth (1.10 cm) with the application of NPK (900:600:900 g/tree) as compared to control in guava. Kumar *et al*. (2009) [21] evaluated the effects of nitrogen, phosphorus and potassium on vegetative growth of guava cv. Allahabad Safeda. It was reported that significantly higher plant height, stem diameter and canopy spread was obtained with application of NPK (600:300:600 g/tree) as compared to control. Kumar *et al*. (2010) [22] recorded significantly higher plant growth characteristics viz., plant height, plant spread and stem girth with application of NPK (800:600:600 g/tree) along with 25.0 kg FYM doses as compared to control in guava.

Goswami *et al*. (2012) [23] observed that trees growth with application of NPK (225:195:150 g) + 50 kg FYM enriched with 250 g Azospirillum tree/year was found most effective to increase maximum tree height, plant spread and trunk diameter in guava. Ramniwas *et al*. (2012) [24] observed maximum plant height (1.96 m), plant spread [E-W (1.89 m) and N-S (1.80 m)] with the application of NPK (60:30:30 g/tree) in guava. Chandra *et al*. (2015) [25] found that application of NPK (450:225:225 g/tree) with Cowdung slurry @ 10 litre/tree and Azospirillum 100 g/tree significantly increase tree height, trunk girth and canopy spread of tree as compared to control in guava plant. Dhakar *et al*. (2016) [26] studied the effect of phosphorus on vegetative growth of guava. It was found that application of phosphorus @ 600 g/tree significantly increases the growth of guava.

Effect of nitrogen, phosphorus and potassium fertilizers on Yield parameters

Bhobia *et al*. (2006) [18] obtained maximum number of fruits (300), fruit weight (284 g) and yield (85 kg/plant) with 40% nitrogen application through urea + 60% through FYM sources in guava cv. Hisar Surkha. Kumar *et al*. (2008) [27] evaluated the response of various combination of NPK on fruit set and yield of guava and reported that maximum fruit yield (69.64 kg/plant) and fruit set (73.23%) of guava was obtained with the application of NPK (150:50:75 g/tree) during rainy season crop. Kumar *et al*. (2009) [21] observed that NPK (600:300:600 g/tree) is the most appropriate and sustainable dose for getting good fruit yield. Baksh *et al*. (2008) [20] reported that application of NPK (900:600:900g/tree/year) significantly increased fruit yield (32.68 kg/tree and 31.00 kg/tree) as compared to control (22.06 kg/tee and 20.72 kg/tree) during both the year in rainy season guava. Ramniwas *et al*. (2012) [24] recorded maximum fruit weight (162.43 g) with the application of NPK (60:30:30 g/tree) as compared to control (150.25 g) in guava. Similarly, maximum fruit yield (6.01 kg/trees) was obtained as compared to control (5.12 kg/tree) in guava. Brar *et al*. (2015) [28] reported that application of 50% higher recommended dose of fertilizer (RDF) exhibited significantly higher fruit yield and fruit weight as compared to lower doses in guava cv. L-49. Goswami *et al*. (2015) [29] observed that application of NPK (225:195:150 g) + 50 kg FYM per tree recorded maximum number of flower buds per branch (60.28), fruit set (83.33%), number of fruits/tree (599.20) and yield (78.68 kg/tree) during rainy season guava cv. Pant Prabhat. Sahu *et al*. (2015) [30] achieved significantly higher fruit yield (8.33 t/ha) with the application of NPK (600:300:300 g/tree) as compared to control (4.47 t/ha) in guava.

Effect of nitrogen, phosphorus and potassium fertilizers on quality parameters

Optimum nutrition is the most important factor governing sweetness of fruits. Kumar *et al*. (2009) [21] evaluated the effect of three levels of nitrogen and potassium (300, 600 and 900 g/tree/year) and two levels of phosphorus (300 and 600 g/tree/year) of guava. It was reported that higher doses of nitrogen and phosphorus application have no influence on TSS however, application of potassium significantly increase TSS of guava. Sharma *et al*. (2013) [31] studied the effect of nitrogen on fruit TSS of guava and reported that higher total soluble solids (12.35 ºBrix) were obtained with the application of 100% N through inorganic fertilizer as compared to control (11.58 ºBrix). Brar *et al*. (2015) [28] reported that 50% higher fertilizers than RDF did not influence fruit TSS in guava cv. Sardar. Goswami *et al*. (2015) [29] studied that trees grown with fertilizers (500 N_2: 200 P_2O_5: 500 K_2O g/tree) along with organic mulching 10 cm thick increased TSS significantly during rainy season in guava cv. Pant Prabhat. Acidity in fruits present in reasonable limit imparts desirable taste and its absence in optimum concentration gives an insipid taste. However, in excess, it may make the fruits unpalatable even if other components are optimum. Kumar *et al*. (1996) [16] reported that increasing levels of nitrogen significantly reduced the fruit acidity as compared to control in guava. Brar *et al*. (2015) [28] reported that acidity of fruits was not significantly decrease beyond NPK application (345:320:658 g/tree) in guava. Chandra *et al*. (2016) [32] conducted an experiment to find out the effect of chemical fertilizers, organic manure, and bio fertilizer on fruit quality of guava. They observed that minimum acidity was obtained with the treatment receiving 75% RDF + cow dung slurry @10 litre/tree + PSB 100 g/tree and maximum acidity was obtained in the control.

Gupta and Nijjar (1978) [33] obtained the maximum ascorbic acid in guava with application of NPK (400:100:200g/tree) in guava. Tassar *et al*. (1989) [34] reported that highest ascorbic acid in guava trees with application of nitrogen 400 g/tree/year. Walling and Sanyal (1995) [35] observed maximum ascorbic acid contents (190 mg/100g) with the application of nitrogen 250 g/tree + potassium 100 g/tree as compared to (168.2 mg/100g) with nitrogen 250 g/tree in guava cv. Allahabad Safeda. Kumar *et al*. (2008) [27] reported that nitrogen application along with higher doses of potassium gave higher ascorbic acid contents. However, Baksh *et al*. (2008) [20] observed no significant changes in ascorbic acid content of fruit with higher doses of NPK (900:600:900 g/tree) as compared to control in guava. Sharma *et al*. (2013) [30] reported 100% of nitrogen through inorganic fertilizer significantly improved ascorbic acid (194.78 mg/100 g pulp) of guava fruit as compared (184.94 mg/100 g pulp) to control. Sharma *et al*. (2014) [36] studied the effect of nitrogen and phosphorus on guava and observed that combination of (600 g N + 400 g P_2O_5) significantly increased ascorbic acid content (206.433 mg/100 g pulp) as compared to control. The sugar contents of fruit increased with the application of higher doses of nitrogen in guava (Tassar *et al*., 1989; Tomar *et al*., 1998) [34, 37]. Kumar *et al*. (1996) [16] observed significant increase in reducing sugar of fruits with the application of nitrogen up to 600 g/plant/year, but further, the changes were marginal in guava. However, Baksh *et al*. (2008) [20] observed no significant changes in reducing sugar and non-reducing sugar with the application of NPK (900:600:900 g/tree) in guava. Sharma *et al*. (2013) [31] observed significant variation on total sugars, reducing sugar and non-reducing sugars with higher dose of nitrogen as compared to control in guava. Sharma *et al*. (2014) [36] reported that nitrogen and phosphorus improved the total sugars of guava. The maximum total sugars (7.98%) were recorded with the application of 300 g nitrogen and 400 g phosphorus as compared to control.

Singh and Rajput (1977) [38] reported significantly improved pectin content of fruit with the application of higher dose of nitrogen in guava. Sharma *et al*. (2013) [31] observed that application of nitrogen (572 g/tree) through inorganic fertilizer significantly improved pectin content (0.66%) as compared to control (0.50%) in guava. Jat and Kacha (2014) [39] reported that pectin content of guava was significantly increased by higher level of urea. Sharma *et al*. (2014) [36] reported that higher doses of nitrogen and phosphorus fertilizers increased pectin content of guava. The maximum pectin content (0.83%) was observed with the application of (600 g N + 400 P_2O_5) as compared to other treatments in guava.

Effect of nitrogen, phosphorus and potassium fertilizers on Leaf NPK content

The leaf analysis offers the most accurate and reliable diagnostic tool for examining the nutritional status of trees (Srivastava *et al*., 1993) [40]. Tassar *et al*. (1989) [34] observed leaf nitrogen content (2.08%) with the application of nitrogen 600 g/tree in guava trees. Lal *et al*. (2000) [41] observed maximum N content in guava leaves with the application of nitrogen @ 600 g/plant/year. Kotur *et al*. (1997) [42] reported increment in leaf NPK content with higher NPK application in guava. Bhobia *et al*. (2005) [43] noted the maximum leaf N content when 100% nitrogen supplied through urea sources, whereas, the content of phosphorus and potassium were maximum when whole nitrogen was added organically in guava. Kaur and Chahil (2006) [19] recorded the maximum leaf NPK content (2.24, 0.34 and 1.48%) with the application of NPK (400:200:100 g/tree) in guava cv. Sardar.

Kumar *et al*. (2009) [21] observed that application of nitrogen, phosphorus, and potassium at different levels influenced the leaf nutrient status of guava leaf. Goswami *et al*. (2012) [23] reported that guava tree grown with NPK (225:195:150 g) + 50 kg FYM enriched with 250 g Azospirillum/year was found most effective to increased leaf N and K content. Shukla *et al*. (2009) [13] observed significant variation on leaf nutrient content of guava with higher doses of NPK fertilizers. It was reported that significantly higher leaf N (1.33%), P (0.39%) and K (1.10%) was observed with the application of NPK (500:200:500 g/tree) as compared to control.

Effect of foliar application of zinc, boron and manganese alone and their combinations on Growth parameters

Balakrishnan (2000) [44] studied the effect of micronutrient application alone and their combinations of 0.5% Zn and 0.2% borax on growth of guava and reported that, foliar application individually or in combinations significantly increased the growth as compared to control in guava. Tomar (2010) [45] reported that foliar application of Zn (0.6%) and Mn (0.2%) were effective in growth of guava. Kumawat *et al*. (2012) [46] reported that foliar application of micronutrients Zn

(0.5%) + B (0.2%) + Mn (0.1%) in month of August and October significantly increased plant growth of guava. Goswami *et al*. (2015) [29] reported that foliar application of Zn (0.5%) + B (0.2%) + Mn (1%) significantly increased plant height, plant spread and trunk diameter as compared to control in guava. Kumar *et al*. (2017) [47] observed that foliar application of Zn (0.03%) significantly increased canopy spread (9.93%) as compared to control in guava.

Effect of foliar application of zinc, boron and manganese alone and their combinations on Yield parameters

Sharma and Bhattacharya (1994) [48] reported that foliar application of Zn (0.4%) increased fruit set per cent and number of fruits per plant in guava. Yadav *et al*. (2011) [49] investigated the foliar application of micronutrient on guava and found that application of borax (0.4%) increased fruit retention (57.27%), fruit weight (98.48 g) and fruit yield (48.63 kg/tree) as compared than control. Kumawat *et al*. (2012) [46] reported that double spray of micronutrients Zn (0.5%) + B (0.2%) + Mn (0.1%) significantly increased fruit retention (67.30%), fruit weight (102.46 g) and fruit yield (12.63 kg/plant) as compared to control in guava. Trivedi *et al*. (2012) [50] studied the effect of zinc and boron fertilizers on yield of guava and found that combined foliar application of zinc sulphate (0.6%) and boric acid (0.5%) produced higher yield and fruit weight.

Rajkumar *et al*. (2014) [51] investigate the feasibility of foliar application of zinc and boron on fruit yield of guava cv. Pant Prabhat and reported that foliar application of zinc and boron (1%) have significantly increased fruit set, fruit retention (72.55%) and yield (135.10 kg/tree) over control. Gaur *et al*. (2014) [52] reported that foliar application of Borax (0.4%) influenced significantly the fruit retention and yield of guava as compared to control in guava cv. L-49. Goswami *et al*. (2014) [53] reported that foliar application of H_3BO_3 (0.4%) achieved maximum fruit weight (120.87g), while minimum fruit weight (98.10 g) in control. Goswami *et al*. (2015) [29] reported that foliar application of Zn (0.5%) + B (0.2%) + Mn (1%) resulted in higher number of flower buds, fruit set, number of fruits per tree and yield as compared to control in guava cv. Pant Prabhat. Kumar *et al*. (2017) [47] observed that foliar application of borax (0.03%) significantly increased fruit yield (21.50 kg/tree) as compared to control (16.50 kg/tree) in guava. Yadav *et al*. (2017) [54] shows the significant response on fruit set (58.54%), fruit retention (49.82%), fruit weight (120.2 g) and yield (149.27 q/ha) with the foliar application of zinc sulphate (0.5%) + Borax (0.5%) as compared to control in guava.

Effect of foliar application of zinc, boron and manganese alone and their combinations on Quality parameters

Singh and Brahmachari (1999) [55] found that total soluble solids of guava were enhanced significantly by the foliar application of borax. Lal and Sen (2001) [56] conducted an experiment on N, Zn and Mn fertilization on fruit quality of guava and observed that total soluble solids of guava were linearly increased with increasing application of N, Zn and Mn fertilizers. Prasad *et al*. (2005) [57] studied the effect of various fertilizers on quality of rainy season guava cv. Allahabad Safeda and found that foliar spraying of (0.8%) borax give maximum TSS while, minimum was obtained under control. Rawat *et al*. (2010) [58] studied the effect of foliar application of micronutrients on rainy season guava and found that application of $ZnSO_4$ (0.4%) and H_3BO_3 (0.4%) improves TSS significantly over control.

Kumawat *et al*. (2012) [46] reported that foliar application of micronutrients $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (0.1%) significantly increased TSS (13.20 ºBrix) as compared to control (12.65 ºBrix) in guava cv. Sardar. Jat and Kacha (2014) [38] reported that application of $ZnSO_4$ (0.6%) treatment gave significantly higher TSS as compared to control. Goswami *et al*. (2015) [29] studied that foliar application of $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (1%) has higher TSS (8.74 ºBrix and 9.41 ºBrix) during both the rainy season in guava cv. Pant Prabhat. Lal and Sen (2001) [56] studied the effect of nitrogen, zinc and manganese application on guava and observed that fruit acidity linearly decreased with increasing rates of N, Zn and Mn. Prasad *et al*. (2005) [57] studied the effect of borax on quality of rainy season guava and reported that borax (0.8%) application achieved minimum acidity while, maximum was obtained under control. Rawat *et al*. (2010) [58] studied the effect of foliar application of micronutrients on the quality of guava and found that application of $ZnSO_4$ (0.4%) and H_3BO_3 (0.4%) decreases fruit acidity significantly over control. Kumawat *et al*. (2012) [46] reported that foliar application of micronutrients $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (0.1%) significantly decreased acidity of guava. The minimum acidity (0.45%) was recorded with $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (0.1%), while maximum acidity was recorded under control. Jat and Kacha (2014) [38] reported that foliar application of $ZnSO_4$ (0.6%) significantly decreased acidity over $ZnSO_4$ (0.2%) in guava. Goswami *et al*. (2014) [53] reported that foliar application of $ZnSO_4$ (0.4%) significantly decrease acidity of fruits in guava cv. L-49.

Lal and Sen (2001) [56] studied the effect of N, Zn and Mn fertilization on ascorbic acid contents of guava. It was observed that ascorbic acid was linearly increased with increase rates of N, Zn and Mn application. Prasad *et al*. (2005) [57] evaluate the various micronutrients application on ascorbic acid content of guava and reported that maximum ascorbic acid content was obtained with application of borax (0.8%) while, minimum was recorded under control. Rawat *et al*. (2010) [58] studied the effect of micronutrients application on rainy season guava and reported that application of $ZnSO_4$ (0.4%) and H_3BO_3 (0.4%) improved the ascorbic acid significantly over control. The maximum ascorbic acid (161.64 mg/100g) was obtained with the foliar application of $ZnSO_4$ (0.4%) and H_3BO_3 (0.4%) and while, minimum ascorbic acid (143.27 mg/100g) under control.

Kumawat *et al*. (2012) [46] reported that foliar application of $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (0.1%) significantly increased the ascorbic acid content of guava. The maximum ascorbic acid (239.0 mg/100g) was obtained with double spray of $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (0.1%) and minimum (215.50 mg/100g) in control. Goswami *et al*. (2015) [29] reported that foliar application of micronutrients Zn (0.5%) + B (0.2%) + Mn (1%) had higher ascorbic acid as compared to control during both the years in guava. Jat and Kacha (2014) [38] reported that application of $ZnSO_4$ (0.6%) gave significantly higher ascorbic acid content (219.21 mg/100g) than $ZnSO_4$ (0.2%) in guava. Goswami *et al*. (2014) [53] studied the effect of nutrient application on quality of guava and observed that H_3BO_3 (0.4%) increased the ascorbic acid of fruit significantly as compared to control. Kumar *et al*. (2017) [47] observed that foliar application of borax (0.03%) significantly increased ascorbic acid content (125 mg/100g) of fruit as compared to control in guava.

Singh and Brahmachari (1999) [55] found that sugar contents of guava were enhanced significantly by the foliar application of borax. Lal and Sen (2001) [56] studied the effect of N, Zn and Mn fertilization on fruit quality of guava and observed that total sugars, reducing sugar and non-reducing sugars of guava fruit linearly increased with increase rates of N, Zn and Mn. Prasad *et al*. (2005) [57] studied the effect of various foliar application of micronutrient on rainy season guava cv. Allahabad Safeda. It was reported that foliar spray of (borax 0.8%) give maximum total sugars, non-reducing sugar while minimum was obtained in control.

Rawat *et al*. (2010) [58] evaluated the effect of micronutrients application of rainy season guava and found that $ZnSO_4$ (0.4%) and H_3BO_3 (0.4%) alone and their combinations significantly improved total sugars content of guava than control. Kumawat *et al*. (2012) [46] reported that foliar spray of micronutrients increased total sugars of guava fruit. The maximum total sugars (6.98%) were obtained with the application of $ZnSO_4$ (0.5%) + B (0.2%) + $MnSO_4$ (0.1%) and minimum total sugars (6.79%) under control. Goswami *et al*. (2014) [53] reported that foliar application of $ZnSO_4$ (0.4%) significantly improved reducing, non-reducing and total sugars of guava fruits. Jat and Kacha (2014) [38] reported that foliar application of $ZnSO_4$ (0.6%) significantly increased total sugars, reducing sugar and non-reducing sugars as compared to $ZnSO_4$ (0.2%). Goswami *et al*. (2015) [29] studied that foliar application of Zn (0.5%) + B (0.2%) + Mn (1%) has significantly increased total sugars (8.55% and 7.72%) as compared to control (7.01% and 5.68%) in both the years in guava.

Lal and Sen (2001) [56] studied the effect of Zn and Mn fertilizers on pectin content of guava. It was concluded that pectin content of guava fruit linearly increased with increasing rates of Zn and Mn. Rawat *et al*. (2010) [58] studied the foliar application of micronutrients on pectin content of guava. It was observed that foliar application of $ZnSO_4$ (0.4%) and H_3BO_3 (0.4%) alone and their combinations significantly improved pectin content of fruit as compared to control. The higher pectin content was observed in H_3BO_3 (0.4%) as compared to $ZnSO_4$ (0.4%). Waskela *et al*. (2013) [59] observed significantly higher pectin content (0.82%) as compared to control (0.68%) in guava cv. Dharidar.

Jat and Kacha (2014) [38] reported that application of $ZnSO_4$ (0.6%) obtained significantly higher pectin content as compared to lower level in guava. Goswami *et al*. (2015) [29] studied that foliar application of Zn (0.5%) + B (0.2%) + Mn (1%) recorded higher pectin content as compared to control during both the years in guava. Kumar *et al*. (2017) [47] observed foliar application of H_3BO_3 (0.03%) significantly improved pectin content (0.60%) of fruit as compared to control (0.33%) in guava.

Effect of foliar application of zinc, boron and manganese alone and their combinations on Leaf micronutrient content (Zn, B and Mn)

Lal *et al*. (2000) [41] studied the effect on N, Zn and Mn fertilizers on leaf nutrient content of guava and reported that foliar spray of Zn at 4 g/tree increased Zn content of leaves. However, it significantly reduced the Mn content of leaves. Similarly, foliar application of Mn @ 4 g/tree significantly increased Mn content of leaves. Prakash *et al*. (2006) [60] studied the effects of N, Zn and B on the leaf nutrient composition of guava. The guava tree was treated with application of zinc (0, 3, 6 g/plant) and boron (0, 2, 4 g/plant). It was observed that significantly higher concentration of Zn and B in guava leaf.

Conclusion

The perusal of the literature suggests that nutrient application of macro and micronutrients fertilization rate are the two most pivotal agro-inputs which describe the guava yield and fruit quality to a major extent. Nitrogen, phosphorus and potassium, being the essential major elements, are required by plants in relatively large quantities for building their infrastructure. These are especially responsible for maximising physiological activities of the plant, water and soil relationships, which ultimately affect fruiting and quality but excess amount of application can result deteriorate fruit quality. In conclusion, foliar application of zinc sulphate, boric acid and manganese sulphate either singly or there combinations showed positive effect on vegetative and reproductive growth, fruit yield and ultimately fruit quality of guava. Application of macro and micronutrients application improved leaf nutrient status of guava plant.

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