International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 208-211

Received: 22-01-2020
Accepted: 24-02-2020

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Effect of foliar spray of urea and micro-nutrients on yield and quality of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi lime

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2c.8769

Abstract
An experiment was conducted on healthy, uniform 12-year-old trees of Acid lime (*Citrus aurantifolia* swingle) cv. Kagzi lime at Fruit Research Farm, Department of Fruit Science at KNK College of Horticulture, and Mandsaur during 2016-2017. The experiment was conducted in Randomized Block Design with three replications. There were three levels of Urea, Zinc Sulphate and Borax *i.e*., Urea (0.5%, 1.0% and 1.5%), $ZnSO_4$ (0.3%, 0.4% and 0.5%) and Borax (0.4%, 0.5% and 0.6%) and with three levels of combination (Urea, Borax and $ZnSO_4$) Urea 0.5% +Borax 0.4% +$ZnSO_4$ 0.3%, Urea 1.5% +Borax 0.5% +$ZnSO_4$ 0.4% and Urea 1.5% +Borax 0.6% +$ZnSO_4$ 0.5% were applied and compared with control. Maximum Number of fruits per plant, fruit weight and fruit yield was recorded with foliar spray of T_{12} (Urea 1.5% +Borax 0.6% +$ZnSO_4$ 0.5). Further significantly increased quality characteristics like Maximum TSS, ascorbic acid, TSS: acid ratio were also recorded with foliar spray of T_{12} (Urea 1.5% +Borax 0.6% + $ZnSO_4$ 0.5%).

Keywords: Foliar spray, kagzi lime, macro and micro nutrients, fruit quality

Introduction
Acid lime *(Citrus aurantifolia* Swingle) belongs to the family *Rutaceae* and widely grown in tropical and sub-tropical region of India. Acid lime (*Citrus aurantifolia* swingle) is the third important citrus fruit crop in India next to mandarins and sweet oranges. It is polyembryonic in nature and the fruits are very small and round to oval. Flesh is greenish yellow, juicy, highly acidic with distinctive aroma. The fruit juice mainly contains sugar and fruit acids, mainly citric acid. (Prasad and Kumar, 2012) [18]. Fruits of acid lime possess great medicinal and nutritional value. It is an appetizer, stomachic, antiscorbutic and antihelmintic. It is a rich source of vitamin "C" and has good antioxidant properties (Thirugnanavel *et al*., 2007) [28].
Nutrients play an important role in keeping up the growth, yield and quality of fruit crops through improving flowering, fruit set, fruit drop control, fruit shape and size etc. Its attractive appearance, penetrating aroma of peel and excellent taste gives a remarkable position to acid lime which is grown widely throughout the world (Babu, 2001) [4]. Nutritional deficiencies are closely associated with the poor plant growth and fruit set, heavy fruit drop, inferior quality of produce and also make the tree vulnerable to diseases, pests and other disorders (Vasure *et al.*, 2018) [29]. It is well established that urea significantly improve the yield and quality characteristics as compared to the control. Total carbohydrates and C: N ratio of leaves are decreased by the application of urea showed good results for most of the fruit characters of acid lime (Carpenter *et al.*,2018) [5]. Among the different essential mineral nutrients, zinc (Zn) is an important micronutrient involved in enzymatic systems essential for protein synthesis, seed production and rate of maturity in plants (Swietlik, 1999, 2002) [25]. Boron (B) as a micronutrient plays significant role in growth and productivity of citrus. It increases pollen grain germination, pollen tube elongation, consequently fruit set percentage and finally the yield (Abd-Allah, 2006) [2]. Micronutrients like Zn, Fe and B, play a vital role in plants. Foliar application of micronutrients is more successful than soil application. Among the several factors responsible for poor yield and declining health in citrus, deficiency of micronutrients is considered to be the major one (Edward raja, 2009) [8]. Foliar application of the nutrients is obviously an ideal way of evading the problems of nutrient availability. This method is highly

helpful for the correction of trace element deficiencies to restore disrupted nutrient supply to overcome stress factors limiting their availability and it is commercialized in a number of fruits, like Citrus, pineapple, guava etc. (Sharma, 2000) [21]. The present study was therefore undertaken to investigate the effect of combinations of macro and micro nutrients viz; urea, zinc sulphate and borax on yield and fruiting quality of acid lime cv. Kagzi lime, which may help in increasing the yield and quality of the fruit.

Materials and Methods

Twelve years old uniform trees of acid lime (*Citrus aurantifolia* Swingle) were selected for the study at *Instructional cum Research Fruit Orchard*, Department of Fruit Science, College of Horticulture, and Mandsaur (M.P.). The experiment was laid out in randomized block design with thirteen treatments replicated thrice and each treatment was applied singly with spray of plain tap water in control. The treatments were marked as T_0 (control; water spray), T_1 (urea 0.5%), T_2 (urea 1.0%), T_3 (urea 1.5%), T_4 (Borax 0.4%), T_5 (Borax 0.5%), T_6 (Borax 0.6%), T_7 ($Znso_4$ 0.3%), T_8 ($Znso_4$ 0.4%), T_9 ($Znso_4$ 0.5%), T_{10} (urea 0.5%+ Borax 0.4%+ $Znso_4$ 0.3%), T_{11} (Urea 1.0%+ Borax0.5%+ $Znso_4$ 0.4%), T_{12} (Urea 1.5%+ Borax 0.6%+ $Znso_4$ 0.5%). Thirty nine trees of uniform size and vigour with a spacing of 5 x 5m were selected and the uniform cultural practices were performed throughout the experiment period. Observations were recorded on different aspects to yield characteristics like number of fruits, fruit weight (gm), fruit yield (kg) per plant and quality characteristics like TSS by hand refractometer, acidity by pH indicator and ascorbic acid contents were determined by (AOAC 1970) taking the samples from extracted juice of acid lime fruits.

Result and Discussion

Yield Parameters

The maximum fruit weight (47.00g) was achieved with application of $ZnSO_4$ (0.5%) when applied without combinations (T_1 to T_9). Among the lower to higher combination of all components i.e. urea, zinc sulphate and borax (T_{10} and T_{12}), Higher combination (T_{12}) did significant effect on increasing the fruit weight (52.50g) followed by (T_{11}) (51.86g). The minimum value among all the treatments of fruit weight (39.30g) was found with control (T_0). Combined application of zinc and boron might be due to increased rate of cell division and cell enlargement leading to more accumulation of metabolites in the citrus fruit (Gurjar *et al.*, 2015) [10]. Urea increase in fruit weight due to accumulation of sugars and high pulp percentage (Debaje *et al*., 2011) [7]. Similar results were also obtained by Mazumdar and Bhatt (1976) [16] in sweet orange.

The maximum fruits per plant (935.00) was observed with application of $ZnSO_4$ (0.5%) over all the single treatments. Different level of urea, borax and $znso_4$ when spray in combinations (T_{10} to T_{12}), higher combination (T_{12}) significantly increased fruits per plant (985.00) which is followed by the treatment (T_{11}) (960.00). The minimum number of fruits per plant (765.00) was found with control (T_o). The number of fruits per plant was significantly increased due to different levels of urea in combination treatments. The urea has helped in more fruit retention per shoot, which resulted in increasing number of fruits per plant (Syamal *et al*., 2008) [27]. Zinc assists the translocation of metabolites from source to sink, which leads to retention of more number of fruits on tree (Gurjar and Rana, 2004). Boron reduce fruit drop because it play an important role in translocation of carbohydrate, synthesis of auxin and enhancing pollen viability and fertilization, ultimately increase the number of fruit per plant (Wet *et al*.,1989) [30].

When urea, zinc sulphate and borax applied singly without combination (T_1 to T_9), the maximum yield per plant (41.94 kg) was observed with application of $ZnSO_4$ (0.5%) over all the single treatments. Different level of urea, borax and $ZnSO_4$ when sprayed in combinations (T_{10} to T_{12}), higher combination (T_{12}) significantly increased yield per plant (45.40kg), which is followed by the treatment (T_{11}) (44.75 kg). The minimum yield per plant found with control T_0 (30.06kg). The cumulative effect of nitrogen on photosynthetic as well metabolic activities has helped to increase the fruit size and fruit weight and thereby increase the fruit yield (Jat and Kacha 2014) [12]. Similar results are also found by Labanauskas *et al*., (1963) [14]. and Singh *et al*., (2002) [23] in grapes.

Quality Parameters

The maximum TSS (7.94 ^{0}Brix) was observed with the application of $ZnSO_4$ (0.5%) applied as singly or without combinations (T_1 to T_9). Different levels of urea, zinc sulphate and borax when sprayed in combinations (T_{10} and T_{12}), treatment (T_{12}) did significantly to increase the TSS (8.20 ^{0}Brix) followed by treatments T_{11} (8.18 ^{0}Brix). The minimum TSS (6.93 ^{0}Brix) was found with control (T_0). Urea helped to increased TSS due to its action on converting complex substances into simple ones, which enhances the metabolic activity in fruits and it results in increased TSS of fruit (Parmar *et al*. 2014) [17]. Boron increase in T.S.S was due to rapid translocation of sugar from leaves to developing fruits and synthesis of cell wall material (Ali *et al*., 2014) [3] These are in accordance with the findings in Lahore local (Singh and Randhawa, 1961) [24] and Kinnow mandarins (Chundawat *et al*., 1975) [6]. Malik *et al*., (2000) [15] found the significant increase in total soluble solids with receiving 1% urea spray and 0.8% zinc sulphate separately or in combination in mandarin hybrid trees.

When urea, zinc sulphate and borax applied singly or without combinations (T_1 to T_9), the minimum fruit acidity (6.50%) was observed with application of $ZnSO_4$ (0.5%) in over all the single treatments. Different level of urea, borax and $ZnSO_4$ sprayed in combinations (T_{10} to T_{12}), higher combination (T_{12}) significantly reduced fruit acidity (6.40%) which is followed by the treatment T_{11} (6.42%), T_{10} (6.47%). The maximum fruit acidity found with control T_0 (7.20%). The maximum reduction in acid content was also obtained under zinc sulphate treatment. It is reported that zinc sulphate being a major substrate of respiration, its decline the mallic acid during fruit ripening might be the results of an increase in membrane permeability which allows acids to be stored in the respiring cells results in decreasing acidity of fruits (Rawat *et al*., 2010) [20]. The decrease in the titrable acidity was mainly due to the increase in total soluble solids. These results are in accordance with the findings of Jagtap *et al*., (2013) [11].

The maximum TSS/acid ratio (1.24) was observed with application of $ZnSO_4$ (0.5%), when urea, $ZnSO_4$ and borax applied as alone without combinations (T_1 to T_9). Among the lower to higher combination of all components i.e. urea, $ZnSO_4$ and borax (T_{10} and T_{12}), higher combination of treatment (T_{12}) did significant effect on increasing the TSS/acid ratio (1.29). However, this treatment was also found significantly at par with treatment T_{11} (1.28) and T_{10} (1.26). The minimum TSS/Acid ratio (0.96) was observed with

control (T_0). This may be due to rapid translocation of sugar from leaves to developing fruits and synthesis of cell wall material. Boron facilitates sugar transport within the plant and it was also reported that borate reacted with sugar to form of sugar-borate complex with more easily to transverse membrane (Ali *et al*., 2014) [3]. The increase in sugars ultimately reduces the acidity of fruit (Khan *et al*., 2012) [13].

The maximum ascorbic acid (29.24 mg/100g) was observed with application of $ZnSO_4$ (0.5%) in over all the single treatments. Different levels of urea, zinc sulphate, and borax when spray in combination (T_{10} and T_{12}), treatment (T_{12}) did significantly to increase the ascorbic acid (31.21mg/100g) followed by treatments T_{11} (30.60 mg/100g). The minimum ascorbic acid (24.38 mg/100g) was found with control T_0. The increase in ascorbic acid content might have resulted owing to biosynthesis of ascorbic acid from sugar or inhibition of oxidative enzymes or both due to favorable metabolic activity involving certain enzymes and metabolic ions under the influence of plant growth regulators and micro-nutrients (Rajput *et al*., 2015) [19]. An increase in vitamin C content of fruits with boron spray. Similar results were obtained by Singh *et al*., (2001) [22] and Yadav *et al*., (2011) [31] in guava.

Table 1: Effect of foliar spray of Urea and micro-nutrients on yield and quality characteristics of Acid lime

	Fruit weight (gm)	Number of fruits per plant	Yield (kg/plant)	TSS (°Brix)	Acidity	TSS: Acid ratio	Ascorbic acid
(T_0)-Control (Water spray)	39.30	765.00	30.06	6.93	7.20	0.96	24.38
(T_1)-Urea (0.5%)	43.07	855.00	34.82	7.30	6.98	1.07	25.07
(T_2)-Urea (1.0%)	45.50	880.33	38.05	7.52	6.80	1.12	25.73
(T_3)-Urea (1.5%)	46.50	890.00	39.38	7.62	6.80	1.14	26.33
(T_4)-Borax (0.4%)	43.43	866.67	35.63	7.77	6.76	1.17	26.00
(T_5)-Borax (0.5%)	44.80	892.00	37.96	7.80	6.72	1.19	26.40
(T_6)-Borax (0.6%)	46.03	870.67	38.07	7.82	6.71	1.20	26.80
(T_7)-$ZnSo_4$ (0.3%)	45.10	885.00	37.91	7.84	6.76	1.21	27.77
(T8)-$ZnSo_4$ (0.4%)	46.23	915.33	40.31	7.93	6.56	1.23	28.68
(T9)-$ZnSo_4$ (0.5%)	47.00	935.00	41.94	7.94	6.50	1.24	29.24
(T10)-Urea (0.5%) +Borax (0.4%) +$ZnSo_4$ (0.3%)	49.67	942.00	43.50	7.95	6.47	1.26	29.39
(T11)-Urea (1.0%) +Borax (0.5%) +$ZnSo_4$ (0.4%)	51.86	960.00	44.75	8.18	6.42	1.28	30.60
(T12)-Urea (1.5%) +Borax (0.6%) +$ZnSo_4$ (0.5%)	52.50	985.00	45.40	8.20	6.40	1.29	31.21
S. Em.±	0.21	14.97	0.32	0.08	0.10	0.01	0.55
C.D. at 5%	0.63	43.71	0.93	0.23	0.30	0.05	1.63

Conclusion

The foliar spray of urea, zinc sulphate and borax was found beneficial for yield and quality of acid lime cv. Kagzi lime, especially under Malwa plateau condition of India i.e. in mandsaur condition. However, among different interaction treatments, T_{12} treatment (Urea 1.5% +Borax 0.6% +$ZnSo_4$ 0.5%) has given significantly maximum number of fruits per plant, fruit weight (gm), fruit yield per plant (kg/tree), ascorbic acid (mg/100gm), maximum TSS (°Brix), acidity (%) and TSS: acid ratio of Kagzi lime fruit.

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