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Effect of integrated nutrient management on yield and quality of acid lime (*Citrus aurantifolia* Swingle)

G. Lal[1]* and H. Dayal[2]

[1]National Research Centre on Seed Spices, Ajmer-305206, Rajasthan, India.
[2]Krishi Vigyan Kendra (Central Arid Zone Research Institute), Pali, Rajasthan, India.

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Integrated nutrient management refers to maintenance of the soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrient in an integrated manner. Therefore, it is a holistic approach, where we first know what exactly is required by the plant for an optimum level of production, in what different forms these nutrients should be applied in soil and at what different timings in the best possible method and how best these form should be integrated to obtain highest productive efficiency on the economically acceptable limits in an environment friendly manner. To identify suitable integration of different sources of nutrients in different ratios with respect to vegetative growth, fruit yield and quality, a field investigation was carried out on integrated nutrient management in acid lime (*Citrus aurantifolia* Swingle) in randomized block design with three replications. There were nine treatments, T_1- Control (500 : 300 : 300 g NPK per tree through fertilizers), T_2- 2/3 RDF + 1/3 through Goat manure, T_3- 2/3 RDF + 1/3 through *Neem* Cake, T_4- 1/3 RDF + 2/3 through Goat manure, T_5- 1/3 RDF + 2/3 through *Neem* Cake, T_6- 50% RDF + 50% through Goat manure, T_7- 50% RDF + 50% through *Neem* Cake, T_8- 100% RDF as Goat manure, T_9- 100% RDF as Neem Cake. The observation on growth parameters of acid lime tree, fruit yield and yield attributes and fruit quality were recorded to study the effect of treatments and their interpretation. Results of the investigation revealed that treatment T_6 (50% RDF + 50% through goat manure) performed best among all treatments. The maximum vegetative growth and yield (7.58 kg tree^{-1}) of fruits having highest fruit length (4.43 cm), fruit diameter (3.99 cm) and fruit weight (35.71 g) was recorded under T_6 treatment. Similarly best quality fruits were also produced with maximum juice (43.37%), TSS (10.42%) and Ascorbic acid (86.33 mg/100 g juice) content and minimum seed (1.15%) and acidity (6.06%) content under the same treatment.

Key words: Integrated nutrient management, acid lime, vegetative growth, fruit yield, fruit quality.

INTRODUCTION

Citrus fruits are popular in subtropical regions of north India mainly due to their hardy nature and good nutritional values. India produced 10,09,000 (Ten lakh nine thousand) tonnes of citrus fruit annually from 1,04,200 (One lakh four thousand two hundred) ha area with the productivity of 9.70 tones ha^{-1} (Tiwari et al., 2013). Rajasthan produces about 1.80 million tones of horticultural produce from an area of 0.95 million hectare

*Corresponding author. E-mail: glal67@yahoo.co.in

and accounts for about 1% of total horticulture production of the country. The major of horticulture produce comes from vegetable (40.82%), spices (28.28%) and fruits (26.85%). It is the eighth largest producer state of citrus in the country and forms 3.6% of total production of citrus in the country. The State produces 0.31 million tones of citrus from an area of 0.02 million hectare with productivity of 18.1 tones ha^{-1} (Anonymous, 2011).

Acid lime (*Citrus aurantiifolia* Swingle*)* is a shrubby tree, to 5 m (16 ft), with many thorns. Its trunk rarely grows straight, with many branches, often originating quite far down on the trunk. The leaves are ovate, 2.5 to 9 cm long, resembling orange leaves (the scientific name *aurantiifolia* refers to this resemblance to the leaves of the orange, *C. aurantium*). The flowers are 2.5 cm in diameter, are yellowish white with a light purple tinge on the margins. Flowers and fruit appear throughout the year, but are most abundant from May to September in the Northern Hemisphere. The method of cultivation greatly affects the size and quality of the harvest. Trees cultivated from seedlings take 4 to 8 years before producing a harvest. They attain their maximal yield at about 10 years of age.

Citrus occupies an important place in the fruit industry, but yield levels of citrus orchards are still very low. Out of many factors, poor nutrient status of the soil as well as malnutrition is considered to be the major factors responsible for citrus decline and low yield. Chemical fertilizers are mostly in use for their cultivation, which have some deleterious effects on fruit quality besides adverse effect on soil, water and environmental pollution. An integrated use of organic manures, biofertilizers and chemical fertilizers could help in achieving the goal of obtaining safer food and environment for the people.

Nutrient refers to all those compounds, which are required by the plant as a source of body building material and for the energy, without which, it will not be able to complete its life cycle. The fruit tree nutrition is concerned with the provision of plant with nutrients as well as nutrient uptake and their distribution in the plant nutrition is fertilizer and/ or nutrient application. Fertilizer is one of the major inputs accounting for nearly one-third of the cost of cultivation and its production consumes a lot of energy used in agriculture. Consequent to the global energy crisis, efficient and judicious use of the fertilizers is imperative not only for obtaining more yields per unit area on a sustainable basis, but also to conserve the energy and to avoid the problem of environment quality. These have become key components for the fruit industry growth. The protection of natural resources base for which the intensification of integrated nutrient management in fruit production has become important, because it is directly related to soil and water resources. The land and water are the bases for any sustainable system of agriculture and the improvement should lay the foundation of a production, economically viable, environment friendly and socially acceptable crop production system.

Therefore, we must adopt the most appropriate land investment practices. The new thinking about the soil management technologies needed for the continuous enhancement of the productivity, sustainability of land, arresting the process of land degradation, accelerating the process of land degradation, accelerating the rate of reclamation and restoration of the productivity of lands which have degraded in the past. Therefore, integrated nutrient management is the most appropriate approach for managing the nutrient input. Integrated nutrient management refers to maintenance of the soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrient in an integrated manner. Therefore, it is a holistic approach, where we first know what exactly is required by the plant for an optimum level of production in what different forms these nutrients should be applied in soil and at what different timings in the best possible method; and how best these forms should be integrated to obtain highest productive efficiency on the economically acceptable limits in an environment friendly manner.

Increased chemical fertilizer cost and awareness of environmental pollution have necessitated the use of organic fertilizers for the development of more efficient fertility management program (Bhattarai and Tomar, 2009). Organic fertilizers are apparently environment and farmer friendly renewable source of non-bulky, low cost organic agricultural inputs for improving soil fertility status. Organic manures are fairly good source of nutrients which has direct influence on plant growth like other commercial fertilizers. Mukherjee et al. (1991) and Prasad and Singhania (1989) also reported that application of organic manures with NKP increased the leaf nutrient status of *Khasi* mandarin, which consequently increased the fruit size, weight and yield. Owing to increasing cost of fertilizers, their short supply and sustainability issues gaining importance, it felt essential to reduce the dependence on chemical fertilizers. Therefore, different sources of plant nutrient, viz., chemical fertilizers, organic manures, Vesicular-arbuscular mycorrhiza (VAM) and biofertilizers have to be tried for working out their suitable integration (Singh et al., 2004).

Keeping the above facts into consideration, an investigation on integrated nutrient management in acid lime (*Citrus aurantifolia* Swingle) was carried out to identify the suitable integration of different sources of nutrients with respect to plant growth, yield and quality of acid lime fruits.

MATERIALS AND METHODS

Investigation locale

The investigation was conducted during 2007 to 2008 and 2008 to

Table 1. Properties of experimental soil before experimentation.

Particulars	Value obtained	Reference to the method employed
Mechanical analysis		
Coarse sand	16.10%	International pipette method (Piper, 1950)
Fine sand	25.43%	
Silt	35.78%	
Clay	22.69%	
Chemical analysis		
Available nitrogen (N)	133.10 $kgha^{-1}$	Subbiah and Asija (1956)
Available phosphorus (P)	18.37 $kgha^{-1}$	Olsen et al. *(*1954)
Available potassium (K)	290.63 $kgha^{-1}$	Metson (1956)
Soil pH	8.2	Richard (1954)
Bulk density	1.39 gm^{-3}	Singh (1980)

2009 at Regional Research Station (Central Arid Zone Research Institute), Pali, Rajasthan, India. The study area represents the transitional climatic conditions between the sub-tropical arid and semi-arid regions and falls in upper Luni basin agro-climatic zone of the arid Rajasthan. It is situated at 25° 47' 13" north altitudes and 73° 18' 42" east longitudes, at an elevation of 220.46 m above the mean sea level. This location received annual average rainfall of 465 mm. Of the total precipitation, 90% was received during July to September.

Experimental details

Six years old acid lime trees having uniform size and vigour were selected. The trees were planted at a spacing of 6 m × 6 m. The water was applied to the trees through ring system of surface irrigation method. About 150 L water $tree^{-1}$ was given per irrigation at an interval of 20 days. An experiment was laid out in a randomized block design with three replications. There were nine treatments, T_1- Control (500 : 300 : 300 g NPK per tree through fertilizers), T_2- 2/3 RDF (Recommended Dose of Fertilizers) + 1/3 through Goat manure, T_3- 2/3 RDF + 1/3 through *Neem* Cake, T_4- 1/3 RDF + 2/3 through Goat manure, T_5- 1/3 RDF + 2/3 through *Neem* Cake, T_6- 50% RDF + 50% through Goat manure, T_7- 50% RDF + 50% through *Neem* Cake, T_8- 100% RDF as Goat manure, T_9- 100% RDF as *Neem* Cake.

Method of application of nutrients

The required quantity of manures (goat manure and *Neem* cake) were weighed by weighing balance separately and applied by broadcasting in the tree basin area, then mixed in the soil properly. Among fertilizers, the total quantity of nitrogen was supplied through urea (46%). Phosphorus and potassium were applied through single super phosphate (16%) and potassium chloride (60%), respectively. Soil application of half dose of nitrogen and full dose of phosphorus and potassium were supplied in July and the remaining half dose of nitrogen was given as top dressing at the time of fruiting in the month of November.

Experimental soil

Experimental soil was loamy sand in nature having low nitrogen, medium phosphorus and high potassium content with 8.2 pH (Table 1).

Vegetative growth parameters

Vegetative growth parameter viz., tree height, spread and stem girth was measured with the help of measuring tape each year just after harvesting of fruits and expressed the pooled values of both the years in cm (tree height and stem girth) and M^2 (tree spread).

Fruit sampling procedure and recording of data

Fruit samples were taken from the plants under different treatments at the time of maturity and analyzed for various physical characteristics. At the time of harvest, ten fully developed fruits were selected randomly from each tree. Length of these fruits was measured longitudinally, fruit diameter transversely with the help of vernier callipers, mean value per fruit calculated and expressed in cm. Weight of the selected fruits was also recorded with the help of physical balance, mean value per fruit calculated and expressed in g $fruit^{-1}$. For computing the yield of fruits per plant, the matured fruits were harvested and weighed periodically and yield was expressed in kg $tree^{-1}$.

Juice and seed content in fruits

Juice of the fruits was extracted with the help of juice extractor, from ten randomly selected fruits of each tree, which were washed, dried and weighed. Then filtered through clean muslin cloth, which separated the juice from fruit sacs and seeds. Filtered juice was measured with the help of measuring cylinder in milliliters and expressed as percentage juice content in the fruits on the basis of fruit weight. Similarly, the weight of seeds was recorded with the help of physical balance in grams and expressed as percentage seed content in fruits on the basis of fruit weight. Juice seed ratio was calculated by dividing the values seed (g) by the values of juice (ml).

Chemical composition of fruits

The mature fruits were selected for the study of their chemical composition in the second picking.

(a) T.S.S.: Ten fruits were randomly selected for juice extraction and total soluble solids of the juice were determined by using a 'Zeiss' hand refractometer of 0 to 30% range. The values were corrected at 20°C and expressed as per cent total soluble solids of

Table 2. Effect of integrated nutrient management on vegetative growth of acid lime trees.

Treatment	Tree height (cm)	Tree spread (m^2)	Stem girth (cm)
T_1- Control (500 : 300 : 300 g NPK per tree through fertilizers)	245.28	7.17	36.92
T_2- 2/3 RDF + 1/3 through Goat manure	275.81	9.07	39.25
T_3- 2/3 RDF + 1/3 through *Neem* Cake	291.56	8.51	38.48
T_4- 1/3 RDF + 2/3 through Goat manure	286.83	9.10	41.01
nrrT_5- 1/3 RDF + 2/3 through Neem Cake	289.22	9.54	40.77
T_6- 50% RDF + 50% through Goat manure	319.28	11.37	45.24
T_7- 50% RDF + 50% through *Neem* Cake	287.06	8.54	39.58
T_8- 100% RDF as Goat manure	287.66	8.29	39.23
T_9- 100% RDF as *Neem* Cake	289.22	8.44	39.77
SEm$\pm$	**4.28**	**0.26**	**9.59**
CD at 5%	**12.33**	**0.76**	**3.20**

the fruit juice (A.O.A.C., 1990).

(b) Acidity: The acidity was determined by diluting the known volume of clean juice, filtered through muslin cloth with distilled water and titrated against standard N/10 sodium hydroxide (NaOH) solution, using phenolphthalein as an indicator. The appearance of light pink colour was marked as the end point. The result was expressed in terms of per cent acidity of the fruit juice (A.O.A.C., 1990).

Total acid =

$$\frac{Titre \times Normality\ of\ alkali \times Volume\ made\ up \times Eq\ wt\ of\ acid \times 100}{Volume\ of\ sample\ for\ estimate \times Wt.\ or\ volume\ of\ sample\ taken \times 1000}$$

(c) Ascorbic acid: The ascorbic acid of fruit juice was determined by diluting the known volume of juice with 3% metaphosphoric acid and titrating with 2, 6 dichlorophenol indophenol dye solution. The result was expressed as mg of ascorbic acid per 100 g of fruit juice (A.O.A.C., 1990).

(d) Standardization of dye: Standardization of 2, 6 dichlorophenol indophenols dye solution was done. For this purpose, 100 mg pure ascorbic acid was dissolved in 3% metaphosphoric acid and volume was made up to 100 ml. From this, 1 ml ascorbic acid solution was used for titration.

Ascorbic acid (mg/100 g p) =

$$\frac{Titre \times Dye\ factor \times Volume\ made\ up}{Aliquot \times Wt.\ or\ volume\ of\ sample\ taken} \times 100$$

Statistical analysis

The data for two successive years (2007 to 2008 and 2008 to 2009) were pooled together and subjected to statistical analysis. To test the significance of data, the analysis of variance technique was adopted as suggested by Gomez and Gomez (1984). Significance of the difference in the treatment effect was tested by 'F' test. Critical difference value (*p=0.05*) was calculated whereever the 'F' test was significant.

RESULTS AND DISCUSSION

Application of nutrients to acid lime trees through different sources as integrated nutrient management improved vegetative growth, fruit yield and its attributes, juice content and its chemical composition.

Vegetative growth

Results of the investigation (Table 2) revealed that vegetative growth parameters like height, spread, and stem girth of acid lime trees influenced significantly with the application of recommended doses of nutrients through different combinations of organic and inorganic sources. Maximum tree height (319.28 cm), tree spread (11.37 m^2) and stem girth (45.24 cm) was recorded with the application of T_6 (50% RDF + 50% through goat manure). These values were minimum (245.28 cm, 7.17 m^2 and 36.92 cm, respectively) under control (100% NPK nutrients through fertilizers). The tree height, spread and stem girth were taken as indicators for the growth of acid lime tree. The maximum values of these parameters were recorded under treatment T_6, which was superior over rest of all the treatments. It might be due to high nutrient and mineral content present in the combination of inorganic fertilizers (50%) with organic fertilizer, that is, goat manure (50%) in comparison to other sources and treatment combinations. This might also be attributed to the improved nutrient use efficiency with the balanced use of organic and inorganic sources of nutrients. Application of goat manure with NPK fertilizers improved the soil texture and porosity due to bulkiness in nature, which might have helped the plant root development and enhanced the uptake of available nutrients resulting into faster cell division and cell elongation; and consequently increased the tree height, spread and stem girth. These observations were corroborated with the findings of Villasurda (1990) and Yadav et al. (2012) in guava.

Yield and yield attributes

Data presented in Table 3 revealed that integrated nutrient management practices influenced significantly

Table 3. Effect of integrated nutrient management on yield and yield attributes.

Treatment	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Yield (kg/tree)
T_1- Control (500 : 300 : 300 g NPK per tree through fertilizers)	3.66	3.16	23.40	5.54
T_2- 2/3 RDF + 1/3 through Goat manure	3.75	3.24	24.74	5.69
T_3- 2/3 RDF + 1/3 through *Neem* Cake	3.77	3.53	28.42	5.62
T_4- 1/3 RDF + 2/3 through Goat manure	4.13	3.76	33.55	5.73
T_5- 1/3 RDF + 2/3 through *Neem* Cake	4.16	3.69	30.66	5.93
T_6- 50% RDF + 50% through Goat manure	4.43	3.99	41.26	7.58
T_7- 50% RDF + 50% through *Neem* Cake	4.17	3.90	35.71	6.89
T_8- 100% RDF as Goat manure	3.86	3.72	30.81	6.85
T_9- 100% RDF as *Neem* Cake	3.77	3.75	29.24	6.64
SEm±	0.04	0.04	0.94	0.18
CD at 5%	0.12	0.11	2.70	0.52

Table 4. Effect of integrated nutrient management on chemical constituents of fruits.

Treatment	Juice content (%)	Seed content (%)	Juice: Seed ratio
T_1- Control (500 : 300 : 300 g NPK per tree through fertilizers)	39.17	1.72	0.044
T_2- 2/3 RDF + 1/3 through Goat manure	38.33	1.19	0.031
T_3- 2/3 RDF + 1/3 through Neem Cake	40.17	1.45	0.028
T_4- 1/3 RDF + 2/3 through Goat manure	41.07	1.28	0.031
T_5- 1/3 RDF + 2/3 through Neem Cake	43.12	1.15	0.027
T_6- 50% RDF + 50% through Goat manure	43.73	1.15	0.026
T_7- 50% RDF + 50% through Neem Cake	40.44	1.20	0.030
T_8- 100% RDF as Goat manure	34.90	1.21	0.035
T_9- 100% RDF as Neem Cake	34.71	1.24	0.036
SEm±	0.37	0.04	0.0012
CD at 5%	1.07	0.11	0.0036

the physical characters of fruits (fruit length, fruit diameter and fruit weight) and fruit yield. Highest fruit yield (7.58 $kgha^{-1}$) with maximum fruit length (4.43 cm), fruit diameter (3.99 cm) and fruit weight (41.26 g) was recorded in the acid lime trees fed by treatment T_6 (50% RDF + 50% through goat manure). However, the lowest yield (5.54 $kgha^{-1}$) with minimum fruit length (3.66 cm), fruit diameter (3.16 cm) and fruit weight 23.40 g) were recorded under T_1 treatment (control) where 100% NPK nutrients was applied through fertilizers.

Increase in yield and yield attributing characters with 50% NPK fertilizer doses in association with 50% nutrients through goat manure was due to the optimum supply of plant nutrients and growth hormones at desired amount during entire period of fruit growth, ultimately resulting in accumulation of more photosynthates leading to more length, diameter, fruit weight and yield of fruits. The increase in both number and weight bases might be attributed to the fact that, there was increasing levels of nutrients in assimilating area of crop due to which the rate of dry matter production was enhanced. Similarly, due to rational partitioning of dry matter to economic sink, the yield attributes were improved. The above results are in conformity with the findings of Dalal et al. (2004). Fruit weight and fruit size are highly correlated with dry matter content and balanced level of hormones. Superior physical fruit quality may be due to the fact that, goat manure combined with fertilizers enhances the nutrient availability by enhancing the capability of plants to better solute uptake from rhizosphere; also these are known for accumulation of dry matter and their translocation as well as favour synthesis of different growth regulators. The findings are in accordance with Gawande et al. (1998) and Patel and Naik (2010) in sapota.

Juice and seed content in fruits

Findings of the investigation (Table 4) exhibited that integrated nutrient management influenced significantly the juice and seed content in acid lime fruits and their juice: seed ratio. Maximum juice content (43.73%) with minimum seed content (1.15%) and minimum juice: seed ratio (0.026) was recorded in the fruits produced with the

Table 5. Effect of integrated nutrient management on chemical constituents of fruits.

Treatment	TSS (%)	Acidity (%)	Ascorbic acid (mg/ 100 g juice)
T_1- Control (500 : 300 : 300 g NPK per tree through fertilizers)	10.12	7.02	75.67
T_2- 2/3 RDF + 1/3 through Goat manure	10.20	6.53	78.00
T_3- 2/3 RDF + 1/3 through Neem Cake	10.23	6.77	79.17
T_4- 1/3 RDF + 2/3 through Goat manure	10.22	6.98	80.33
T_5- 1/3 RDF + 2/3 through Neem Cake	10.17	7.07	79.83
T_6- 50% RDF + 50% through Goat manure	10.42	6.06	86.33
T_7- 50% RDF + 50% through Neem Cake	10.13	7.12	82.50
T_8- 100% RDF as Goat manure	10.13	7.10	78.50
T_9- 100% RDF as Neem Cake	10.20	6.76	77.67
SEm±	0.04	0.06	0.81
CD at 5%	0.10	0.18	2.33
CV%	1.47	3.98	4.30

application of treatment T_6 (50% RDF + 50% through goat manure). However, the values of juice content (43.12%), seed content (1.15%) and juice: seed ratio (0.027) recorded in the fruits produced with treatment T_5 (1/3 RDF + 2/3 through *Neem* Cake) were at par with the values obtained under T_6. The minimum juice content (34.71%) was recorded in the fruits produced with application of treatment T_9 (100% RDF as *Neem* cake), while maximum seed content (1.72%) and juice: seed ratio was recorded in the fruits produced under treatment T_1 (control), that is, chemical fertilization. Improvement in physical characters of fruits with respect to fruit size (fruit length and diameter), fruit weight, juice content, seed weight and juice seed ratio in response to integrated nutrient management including organic and inorganic sources of nutrients can be related to assimilate accumulation of the plant. Similar results have been reported by Verma (2010) in phalsa, Yadav et al. (2007) in aonla and Madhvi et al. (2008) in mango.

Chemical composition of fruits

It is inferred from the data presented in Table 5 that chemical composition of acid lime fruits with respect to TSS, acidity and ascorbic acid content was significantly affected with integrated nutrient management. The highest TSS (10.42%) and ascorbic acid (86.33 mg/100 ml juice) with minimum acidity (6.06%) were recorded in the fruits produced with the application of treatment T_6 (50% RDF + 50% through goat manure). However, the minimum TSS (10.12%) and ascorbic acid (75.67 mg/100 g juice) were recorded in the fruits produced under control (T_1 treatment).

These findings are in accordance with the results of Mahendra et al. (2009) in ber. The quality improvement in fruits may be due to proper supply of nutrients and induction of growth hormones, which stimulated cell division, cell elongation, increase in number and weight of fruits, better root development and better translocation of water uptake and deposition of nutrients. This might be attributed due to the improved fertilizer use efficiency with the application of organic source of nutrients (Ranjan and Gosh, 2006) in sweet orange and Ram et al. (2007) in guava.

Conclusion

On the basis of obtained experimental findings, it can be concluded that among different treatments of integrated nutrient management, application of T_6 (50% RDF + 50% through goat manure) gave best results with respect to vegetative growth, yield, fruiting and quality of fruits of acid lime. Hence, application of treatment T_6 (50% RDF + 50% through goat manure) is highly recommended to enhance growth of trees and consequently produce high yield of good quality fruits.

Conflict of Interest

The authors have not declared any conflict of interest.

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