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Effect of organic and inorganic nutrient sources on growth, yield and quality of Acid lime *(Citrus aurantifolia* Swingle)

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Abstract
An experiment was carried out at the Instructional cum research fruit orchard, College of Horticulture, Mandsaur, during 2016-17 on 10 years old Kagzi lime. Different doses of inorganic sources of NPK *viz*., 900:400:400 g NPK (100% NPK), 675:300:300 g NPK (75% NPK), 450:200:200 g NPK (50% NPK), 225:100:100 g NPK (25% NPK) and organic source through FYM *i.e*., 20 Kg, 15 Kg, 10Kg, vermicompost *i.e*., 10 Kg, 7 Kg, 3 Kg including 150 g VAM and 25 g Azotobactor inoculation were applied to the plants. Results revealed that the application of 75 % RDF + 3 kg vermicompost + 10 kg FYM + 150 g VAM + 25 g Azotobactor (T_{11}) significantly influence the vegetative growth and quality parameters of acid lime. Maximum plant height (3.93 m), canopy spread in E-W direction (4.74 m), canopy spread in N-S direction (4.66 m), canopy volume (75.75 m^3) leaf area (39.61 cm^2), maximum TSS (7.93^{0}Brix), minimum acidity (6.11%), maximum TSS/acid ratio (1.29), ascorbic acid (32.27 mg/100g pulp) and chlorophyll content in leaves (64.40) were recorded with T_{11}. Whereas, the application of 50 % RDF + 7 kg vermicompost + 15 kg FYM + 150 g VAM + 25 g Azotobactor had been found the most appropriate for physical and yield characteristics of the acid lime fruit. Maximum fruit length (4.86 cm), fruit diameter (4.70 cm), fruit volume (51.50 ml), specific gravity (1.05), juice (51.82%), maximum fruit weight (54.14 g), number of fruits per plant (967.06) and yield per plant (52.35 kg) were obtained with T_{12}, while minimum seed weight (1.28 g) and maximum peel thickness (1.78 cm) was recorded in T_{11}. The number of seed per fruit observed were non significant.

Keywords: Acid lime, Azotobactor, VAM, vermicompost, FYM, NPK

Introduction

Acid lime (*Citrus aurantifolia* Swingle) is known as Kagzi lime or Neebu belongs to the family Rutaceae. It is a profusely branched thorny shrubs or small tree. The leaves are small with narrowly winged petioles. The flowers are small, pure white and are borne in clusters. The fruits are more or less round to oval, smooth having thin rind (papery) attached lightly. The immature fruits are dark green in colour which changes to light yellow when ripe. The colour of the pulp is light greenish-yellow; taste is acid, aromatic; cells fine and shiny. The numbers of segments and seeds per fruit varies from 9-11 and 9-10 respectively. Fruit of acid lime possess great medicinal and nutritional value. It is a rich source of vitamin “C".

Conventional (chemical based) farming is non-sustainable because of many problems such as loss of soil health and productivity due to excessive erosion and low farm income from high production costs etc. In view of these, there is an urgent need to increasing awareness about alternate agriculture system known as integrated plant nutrient management. The main objective of integrated nutrient management (INM) is the adjustment of plant nutrient supply with proper combination of chemical fertilizers, organic manure and biofertilizers suitable to social, economical and ecological system. Vermicompost is an eco-friendly natural fertilizer prepared from biodegradable organic wastes, rich in micro and macronutrients, vital plant promoting substances, humus farming substances, N-fixers and humus forming microorganism. Biofertilizers are microbial preparations containing living cells of different microorganisms which have the ability to mobilize plant nutrients in soil from unusable to usable form through biological process. They are environmental friendly and play significant role in crop production. The use of organic manure along with biofertilizers and inorganic fertilizers, a cheap source of available nutrient to plants, has resulted in beneficial effects on growth, yield and quality of various fruit crops under normal spacing.

Materials and methods

The experiment was conducted during 2016-17 at the Instructional cum research fruit orchard Department of Fruit Science, College of Horticulture, Mandsaur (M.P.) on ten-year-old acid lime tree cv. Kagzi lime. Initial proportion of the soil were pH-7.38, EC-0.48, OC-0.94, available nitrogen (485.26 kg/ha), available phosphorus (14.7 kg/ha) and available potassium (521 kg/ha). There were different doses of inorganic sources of NPK *i.e*., 900:400:400 g NPK (100% NPK), 675:300:300 g NPK (75% NPK), 450:200:200 g NPK (50% NPK), 225:100:100 g NPK (25% NPK) and organic sources of FYM *i.e*., 20 Kg, 15 Kg, 10Kg, vermicompost *i.e*., 10 Kg, 7 Kg, 3 Kg including 150 g VAM and 25 g Azotobactor inoculation were applied to the plants having uniform growth and vigour while the control plants received no fertilizer, inoculation and manure treatment.

The experiment was laid out in Randomized Block Design (RBD) with three replications. The whole of the organic manure were applied as a basal dose on the onset of monsoon. Then required doses of fertilizers were applied in two split doses in the month of July and August and then bio-fertilizers were applied one week after each application of inorganic fertilizers. Thus, there were 14 treatments, keeping each treatment on one plant, providing total forty-two plants. For recording various growth parameters viz., plant height, canopy spread, canopy volume, leaf area. The height of the plant and canopy spread was measured with the help of measuring device at the time of fertilizer application and at harvest and calculated. Canopy volume was calculated as per the Westwood *et al.* (1963) [17], [canopy volume (m^3) = $4/3\pi a^2 b$, where: π = 22/7, a= ½ of the plant height, b= average of east-west and north-south spread] and leaf area was measured with Systronics Leaf Area Meter Licor 211.

For determination of chemical parameters of fruit viz., acidity, total soluble solids (TSS), TSS/acid ratio and ascorbic acid, four healthy fruits were selected randomly from each tree at full maturity stage. Hand refractometer was used for determination of TSS in ^{0}Brix. Acidity was estimated by simple acid-alkali titration method as described in A.O.A.C. (1970) [1]. Assay method of ascorbic acid was followed given by Ranganna (1977) [12]. Chlorophyll content in leaves was estimated by using instrument SPAD-505 chlorophyll meter. Fruit length and diameter were noted using the vernier caliper, volume of fruit was recorded by water displacement method and weight of fruit was recorded using electronic weight balance, number of fruits per plant was recorded separately for each plant at each picking. Average yield per plant was calculated by the following formula: Yield per plant (kg) = no. of fruit per plant x fruit weight.

Results and discussion

Growth parameters

The result of the present investigation revealed that influence of organic and inorganic fertilizers on different growth attributes *viz.*, plant height, canopy spread E-W and N-S, canopy volume, leaf area at harvesting stage observed significant responses. It is clear from the results (Table 1) that higher plant height (3.93 m), canopy spread E-W (4.74 m), canopy spread N-S (4.66 m), canopy volume (75.75 m^3) and maximum leaf area (39.61cm^2) were recorded with plant received 75 % RDF + 3 kg vermicompost + 10 kg FYM + 150 g VAM + 25 g Azotobactor (T_{11}).

The positive influence of organic and inorganic fertilizers on growth performance might be due to fact that application of NPK, vermicompost and FYM along with Azotobacter and VAM. The useful effect of nitrogen is certainly the results of an increase in growth attributes. As nitrogen is the major constituent of fertilizers applied and as it is constituent of the protein which is essential for formation of protoplasm thus affecting the cell division and cell elongation and there by more vegetative growth. Higher supply of N made more rapid synthesis of carbohydrate, which was converted into protein and protoplasm increasing the size of cells. Inoculation with Azotobacter a biological nitrogen fixer improves the nitrogen use efficiency of the plant (Dutta *et al*., 2009) [5]. In addition to this, phosphorus plays an important role in energy transformation and potassium plays an important role in maintenance of cellular organization by regulating the permeability of cellular membrane (Godage *et al*., 2013) [7].

Vermicompost improves microbial distribution and moisture retention capacity in soil that results in greater enzymatic (phosphatase and urease) activities which improves the growth parameters. The association of mycorrhiza with roots of higher plants is known for its exploration of more soil volume especially for higher uptake of phosphorus by extending the area of absorption through fungal hyphae or by the formation of arbuscules (absorptive structure or false roots) which ultimately increases the availability of nutrients specially phosphorus to plants. Its inoculation showed significantly higher shoot and root dry weight and phosphorus in grape root stock. These results are in conformity with the findings of Derbew *et al*. (2007) [3] and Binepal *et al*. (2013) [2].

Chemical parameters

The data presented in Table 1 reveal that the application of organic and inorganic nutrient improved the fruit quality of acid lime. Their application significantly influenced the chemical constituent's of the fruit. The maximum TSS (7.93 ^{0}Brix), minimum acidity (6.11%), TSS/acid ratio (1.29), ascorbic acid (32.27 mg/100g pulp) and chlorophyll content in leaves (64.40) were recorded with application of 75 % RDF + 3 kg vermicompost + 10 kg FYM + 150 g VAM + 25 g Azotobactor (T_{11}) which were superior to the rest of treatment.

The improvement in various chemical characteristics by application of optimum dose of NPK may be explained by the fact that phosphorus enters into the composition of phospholipids and nucleic acids, the latter combines with proteins and result in the formation of nucleo-proteins which are important constituents of the nuclei of the cells. Potassium acts as a catalyst in the formation of more complex substances and in the acceleration of enzyme activity. These carbohydrates and coenzymes are beneficial in the improvement of fruit quality and nitrogen enhances the uptake of phosphorus and potassium. The higher ascorbic acid content with increased N application in form of organic and inorganic nutrient sources might be due to the catalytic activity of several enzymes, which participate in biosynthesis of ascorbic acid and its precursor. These results are in line with the findings of Dudi *et al*. (2005) [4] in Kinnow, Binepal *et al*. (2013) [2] in guava and Savreet Khehra (2014) [13] in lemon.

Whereas FYM increased TSS and total sugars due to gradual supply of nutrients and organic manures throughout the growth period which increased the metabolites in improvement in soil moisture availability, soil pH, organic carbon and nutrient status of the soil and decrease acidity of fruits may be attributed to their conversion into sugars and their derivatives by the reactions involving reversal of

glycolytic pathway or might be used in respiration or both. Similar findings were also reported by Dwivedi (2013) [6].

Vadak *et al.* (2014) [16] reported that VAM converts the unavailable nutrient from rhizosphere soil to available forms resulting increased uptake of nutrient. Besides increased nutrient absorbing area of root, so increase in the chemical quality of fruits may be due to beneficial and stimulatory effect of nitrogen and other nutrient.

Physical parameters

The physical characteristics of kagzi lime fruit are an expression of a plant's vegetative activity which was also significantly influenced by various organic and inorganic nutrients treatments. Result (Table 2) showed that maximum fruit length (4.86 cm), diameter (4.70 cm), volume of fruit (51.50 ml), specific gravity (1.05) and juice (51.82%) were recorded with application of 50 % RDF + 7 kg vermicompost + 15 kg FYM + 150 g VAM + 25 g Azotobactor (T_{12}) while minimum seed weight (1.28 g) and maximum peel thickness (1.78 cm) was recorded under T_{11} (75 % RDF + 3 kg vermicompost + 10 kg FYM + 150 g VAM + 25 g Azotobactor) over the rest of treatments. Numbers of seeds per fruit were not influenced by organic and inorganic nutrient sources.

The increase in average fruit weight due to the integration of organic and inorganic sources of nutrients occurred due to accelerated mobility of photosynthates from source to sink as influenced by the growth hormones, released or synthesized due to organic sources of nutrients. The increase in fruit volume was attributed to the corresponding increase in length and diameter. Similar results were also observed by Sharma *et al*., 2013 [14]. The ample increase in the juice content in case of combination of organic and inorganic sources of nitrogen appears to be due to the added benefits of organic matter which improves the soil structure, penetration, retention of moisture etc. and root proliferation by biofertilizer. Since water is the chief constituent of fruit juice, its increased availability within certain limits was apt to affect the juice percentage favourably. There is enough evidence in literature to support these findings. Singh *et al*. (2000) [15] also elaborated similar results in sweet orange. Organic manures and biofertilizers have direct role in nitrogen fixation, production of phytohormones like substances and increased uptake of nutrients hence quality improvement reflected in fruit character.

The higher uptake of nutrients in the tissues of Nagpur mandarin with recommended dose of NPK might have occurred due to stimulation of the rates of various physiological and metabolic processes resulting in better size, weight and fruit yield of Nagpur mandarin. These results are in accordance with the findings of Hadole *et al.*, 2015 [8]. The potassium is known to be a vital element for the development of fruit, movement of sugar and indirectly photosynthesis (Pawar *et al*., 2014) [10] in acid lime.

Yield parameters

The data presented in Table 2 reveal that the yield characters of plant were significantly influenced by the organic and inorganic nutrients. The maximum fruit weight (54.14 g), number of fruits per plant (967.06) and yield per plant (52.35 kg) were obtained with T_{12} (50 % RDF + 7 kg vermicompost + 15 kg FYM + 150 g VAM + 25 g Azotobactor). Whereas, the least value for yield characters were recorded with control. The application of optimum dose of inorganic fertilizers along with organic manures like farmyard manure and vermicompost which might have increased the activity of beneficial microbial population helped to initiate various growth promoting processes resulting in vigorous growth of plants. Besides promoting growth, these manures imparted beneficial effects on soil environment, especially on soil physical properties, thus making rhizosphere most congenial for growth and development resulting in increased availability of nutrient status of NPK in both soil and leaf of acid lime which lead to higher yield and yield attributing traits. These results are in conformity with findings of Marathe and Bharambe (2007) [9] and Rajendra *et al.* (2013) [11].

Table 1: Effect of organic and inorganic nutrient sources on morphological and chemical parameters of acid lime.

Treatments		Plant height (m)	Canopy spread (m)		Canopy volume (m^3)	Leaf area (cm^2)	TSS (^{0}Brix)	Acidity (%)	TSS/acid ratio	Ascorbic acid (mg/100g pulp)	Chlorophyll content in leaves (SPAD value)
			E-W	N-S							
T_0	Control	3.22	3.86	3.72	41.10	22.19	7.10	7.06	1.00	24.20	49.65
T_1	RDF (Recommended dose of fertilizers- 900:400:400 N:P:K g/plant)	3.72	4.51	4.46	64.92	35.31	7.22	6.90	1.04	26.33	59.43
T_2	75 % RDF + 3 Kg VC + 10 Kg FYM	3.77	4.57	4.49	67.47	36.17	7.42	6.71	1.10	27.68	60.51
T_3	50 % RDF + 7 Kg VC + 15Kg FYM	3.46	4.31	4.27	53.78	30.71	7.29	6.83	1.06	26.82	55.62
T_4	25 % RDF + 10 Kg VC+ 20 Kg FYM	3.31	4.13	4.11	47.19	27.57	7.16	6.94	1.03	25.58	51.65
T_5	75 % RDF + 3 Kg VC + 10 Kg FYM + 150 g VAM	3.82	4.64	4.55	70.58	37.30	7.80	6.29	1.24	30.95	61.36
T_6	50 % RDF + 7 Kg VC+ 15 Kg FYM + 150 g VAM	3.53	4.36	4.30	56.47	31.44	7.75	6.38	1.21	30.55	56.72
T_7	25 % RDF + 10 Kg VC+ 20 Kg FYM+ 150 g VAM	3.36	4.18	4.14	49.10	28.52	7.49	6.68	1.12	28.21	53.21
T_8	75 % RDF+ 3 Kg VC+ 10 Kg FYM + 25 g Azotobactor	3.88	4.69	4.60	73.33	38.27	7.67	6.47	1.18	29.73	62.72
T_9	50 % RDF + 7 Kg VC + 15 Kg FYM + 25 g Azotobactor	3.61	4.40	4.36	59.97	32.58	7.61	6.55	1.16	29.14	57.25
T_{10}	25 % RDF + 10 Kg VC + 20 Kg FYM + 25 g Azotobactor	3.40	4.25	4.19	50.96	29.48	7.35	6.76	1.08	27.41	54.52
T_{11}	75 % RDF + 3 Kg VC+ 10 Kg FYM + 150 g VAM + 25 g Azotobactor	3.93	4.74	4.66	75.75	39.61	7.93	6.11	1.29	32.27	64.40
T_{12}	50 % RDF + 7 Kg VC + 15 Kg FYM + 150 g VAM + 25 g Azotobactor	3.68	4.46	4.40	63.11	34.48	7.87	6.20	1.24	31.44	58.20
T_{13}	25 % RDF + 10 Kg VC+ 20 Kg FYM + 150 g VAM + 25 g Azotobactor	3.44	4.26	4.25	52.89	30.34	7.54	6.61	1.14	28.86	55.62
S.Em. ±		0.02	0.02	0.02	0.64	0.46	0.02	0.03	0.02	0.19	0.62
C.D. at 5%		0.05	0.04	0.05	1.87	1.34	0.07	0.08	0.04	0.56	1.79

Table 2: Effect of organic and inorganic nutrient sources on physical and yield parameters of acid lime.

Treatments		Fruit length (cm)	Fruit diameter (cm)	Fruit volume (ml)	Specific gravity	Juice (%)	Number of seed per fruit	Seed weight (g)	Peel thickness (mm)	Fruit weight (g)	Number of fruit/plant	Yield per plant (kg)
T_0	Control	3.74	3.65	31.18	1.00	36.07	9.74	3.19	1.20	31.22	711.12	22.20
T_1	RDF (Recommended dose of fertilizers- 900:400:400 N:P:K g/plant)	4.43	4.30	41.12	1.03	39.46	9.10	2.31	1.42	42.33	821.66	34.78
T_2	75 % RDF + 3 Kg VC + 10 Kg FYM	4.46	4.35	45.13	1.01	43.78	8.84	2.11	1.53	46.13	840.11	38.77
T_3	50 % RDF + 7 Kg VC + 15Kg FYM	4.53	4.43	46.42	1.01	45.10	8.87	2.17	1.47	47.59	855.12	40.69
T_4	25 % RDF + 10 Kg VC+ 20 Kg FYM	4.26	4.13	41.56	1.02	37.12	9.65	2.92	1.28	42.67	779.14	33.24
T_5	75 % RDF + 3 Kg VC + 10 Kg FYM + 150 g VAM	4.59	4.46	47.64	1.03	46.62	8.73	2.04	1.61	49.49	877.59	43.42
T_6	50 % RDF + 7 Kg VC+ 15 Kg FYM + 150 g VAM	4.64	4.50	48.55	1.04	47.48	8.79	2.08	1.56	50.88	890.57	45.31
T_7	25 % RDF + 10 Kg VC+ 20 Kg FYM+ 150 g VAM	4.30	4.18	42.99	1.03	38.70	9.62	2.81	1.33	44.66	788.61	35.23
T_8	75 % RDF+ 3 Kg VC+ 10 Kg FYM + 25 g Azotobactor	4.71	4.56	48.62	1.05	48.12	8.53	1.84	1.68	50.95	909.16	46.23
T_9	50 % RDF + 7 Kg VC + 15 Kg FYM + 25 g Azotobactor	4.77	4.61	49.90	1.05	49.21	8.61	1.90	1.65	52.58	930.41	48.92
T_{10}	25 % RDF + 10 Kg VC + 20 Kg FYM + 25 g Azotobactor	4.37	4.20	43.68	1.04	41.48	9.45	2.56	1.35	45.38	809.45	36.73
T_{11}	75 % RDF + 3 Kg VC+ 10 Kg FYM + 150 g VAM + 25 g Azotobactor	4.81	4.63	50.66	1.05	49.86	8.20	1.28	1.78	53.61	959.88	50.48
T_{12}	50 % RDF + 7 Kg VC + 15 Kg FYM + 150 g VAM + 25 g Azotobactor	4.86	4.70	51.50	1.05	51.82	8.41	1.75	1.71	54.14	967.06	52.35
T_{13}	25 % RDF + 10 Kg VC+ 20 Kg FYM + 150 g VAM + 25 g Azotobactor	4.40	4.25	43.78	1.05	42.49	9.37	2.46	1.39	46.18	822.36	37.97
S.Em. ±		0.02	0.02	0.36	0.01	0.28	0.22	0.16	0.01	0.41	3.30	0.43
C.D. at 5%		0.05	0.06	1.05	0.01	0.80	NS	0.45	0.03	1.18	9.59	1.24

Conclusion

On the basis of result obtained from present experiment showed that the application of 75 % RDF + 3 kg vermicompost + 10 kg FYM + 150 g VAM + 25 g Azotobactor (T_{11}) proved to be best in term of maximum vegetative growth and quality. When, T_{12} (50 % RDF + 7 kg vermicompost + 15 kg FYM + 150 g VAM + 25 g Azotobactor) had been most appropriate organic and inorganic nutrient dose under agro-climatic conditions of Malwa Plateau for physical and yield characteristics of the acid lime fruit.

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