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Effect of management practices on the growth and yield of lime and lemon

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Abstract

The present study aimed to evaluate the growth and yield attributes of lime and lemon under different cultural management practices. The experiment consisted of four years old three lemon varieties viz. BAU Lebu-1, BAU Lebu-2, and BAU Lebu-3 and eight management practices such as pruning, manuring, irrigation, pruning + manuring, manuring + irrigation, irrigation + pruning, pruning + manuring + irrigation and control (no treatment). Results revealed that the highest plant height, canopy volume, and yield were found in BAU Lebu-3 (Semi seedless), while lowest was recorded in BAU Lebu-2, though highest number of fruits plant-1 and its percent edible portion were found in BAU Lebu-1 (Kagzi). For interaction effects, pruning together with manuring and irrigation exhibit the highest plant height, canopy volume, and yield in BAU Lebu-3, however, maximum number of fruits and percent edible portion were observed in BAU Lebu-1. The lowest plant height, canopy volume, number of fruits, percent edible portion and yield were obtained in BAU Lebu-2 with control treatment. The results of the present study suggest that BAU Lebu-3 along with treatment combination of pruning + manuring + irrigation can be produced with the highest growth and yield in the off-season.

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Introduction

Bangladesh is blessed with a huge diversity of fruits and circa 70 various kinds of fruits grown all over the country (Hussain *et al.,* 2011). It is crucially needed to meet the mineral requirements of a human body and to strengthen body defense mechanisms against various biotic and abiotic stresses and for proper health per capita fruits requirement is 115 g. (Rahman and Rahman, 2014). Citrus fruits, especially Lemon (*Citrus Limon*) and Lime (*Citrus aurantifolia*) belonging to the family Rutaceae are the most important nutritional fruits in Bangladesh. Lime (*Citrus aurantifolia* L.), popularly known as "Kagzi lebu", mainly grown in tropical rain forests of southern China, Cochin China and certain Islands of the Malay Archipelago. It is a strikingly handsome medium shrub either be sour or sweet taste, whose skin and flesh are green in color and are oval or round shape with a diameter of 2.5 to 5.0 cm. Lemon (*Citrus Limon*) is a fascinatingly attractive medium shrub, originated from tropical regions (Hossain, 2006). In Bangladesh, it can be successfully grown all over the country though profuse production is mainly concentrated in Sylhet, Chittagong, the Chittagong Hill Tracts, Rajshahi and Maulavibazar districts. The leading lemon producing countries of the world are USA, Brazil, Spain, Italy, India, Mexico, Israel, China, and Japan.

Nevertheless, Bangladesh is a country of 168.95 million people and approximately 70% people suffer from malnutrition problem, most importantly different types of vitamins, viz. A, C etc. and other important mineral nutrients like Ca and Fe (Abdullah and Rahman, 2015; Rahman *et al.,* 2016). Reports show that around 93% people of Bangladesh suffer from vitamin C deficiency and unlike other vitamins; it cannot be stored in the body (Mamun *et al.,* 2015). Thus, intake of vitamin C fruits at regular basis is necessary to maintain the supply of vitamin C in the body. Access to vitamin rich fruits and knowledge over the fruits containing these vitamins could play a pivotal role in reducing the malnutrition problem. Citrus fruits are very important in respect of their food values, especially being very rich in vitamin C. These fruits can be eaten as fresh or even used as a salad, which helps in digestion. Furthermore, diverse food items like jam, jelly, pickles and drinks also prepared from these. For the above reasons, citrus fruits are so much popular throughout the world.

Despite enormous health benefits of citrus, Bangladesh stands in a very low position in respect of the production of citrus fruits in comparison to other citrus producing countries of the world. According to the available statistics, the total area under these fruits is 4567 acres while total production is 5594 M. tons in the year 2008-09 (BBS, 2009). Experiences from other citrus growing countries and research findings on the production technology of citrus, however, indicate that some areas of Bangladesh are very much suitable for the production of different types of citrus fruits like lime and lemon. It is, therefore, necessary to give proper attention to increasing the production of lime and lemon fruits and to improve their qualities to meet the increasing demand of the people of Bangladesh. The growth and yield of lemon and lime largely depend on the soil quality and it requires an ample supply of plant nutrient. The judicious fertilization, regular application of nutrients or alternatively use of nutrient enriched organic or inorganic manures and bio fertilizers in an effective manner can only drive a lemon orchard into a profitable venture in a sustainable way (Khehra and Bal, 2014). Manures like cow dung, paragon compost, farm compost etc. help in improving soil texture, structure, aeration, humus content, moisture holding capacity and microbial activities of soil (Sgroi *et al.,* 2015). Microbial biomass accelerate the decomposition of organic matter, to speed up the release of minerals for plants and soil system and the plants absorb these substances, to improve growth and better performance is achieved. Together with manuring, pruning also plays pivotal role for successful citrus fruit production as well as to augment yield. Pruning usually done by judicious removal of any plant parts to establish and to maintain desired shape, facilitate various cultural operations and to distribute proper amount of bearing by encouraging the growth of new shoots,

which ultimately triggers higher yield. Insect pest attack in addition to disease spreading from infectious plant parts can also be reduced if pruning is done regularly after fruits are ripened and harvested. Moreover, pruning is the essential management practice because unproductive branches uptake nutrient without giving fruits. Irrigation is another important management practice for getting quality fruits. Water is needed for photosynthesis, nutrient acquisition and uptake. It is crucial for successful bud initiation, flowering, fruit set and fruit growth. In spite of large water demand, lemon plant cannot withstand in water-logged condition (Abu, 2001). Despite the fact that lemon and lime hold considerable promise as a nutritional strategy, the extent of scientific studies of cultural management practices of those fruits to augment yield is still in its infancy. Considering the above facts, the present study was undertaken to observe the effect of divergence management practices on the growth and yield of lemon and lime.

Materials and methods

Study location

The present experiment was conducted at the Germplasm Centre of Bangladesh Agricultural University, Mymensingh during the period from August 2010 to January 2011.

Experimental materials

The experiment was done on four years old citrus plants (BAU-Kagzi lebu, Semi seedless lebu and Elachi lebu). The plants were more of less established by layers and planted in 2007 and all the plants were uniform in size. The plants were under the partial shade of aonla, horitoki and bohera trees.

Experimental design and treatments

The Two-factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each block contains 24 plants. Per replication, there was a single plant. Thus the total number of plants were (3×8×3×1) = 72. In each block, combination of different treatments and varieties were assigned randomly. Planting was in hexagonal system giving spacing of 4m×4m.

The experiment was designed to study the effect of different types of management practices (Pruning, manuring and irrigation application) on the fruiting of lime and lemon. The experiment consisted of two factors, which were as follows: Factor A: Types of citrus fruits, viz. V_1 = BAU Lebu-1 (Kagzi), V_2 = BAU Lebu-2 (Elachi scented) and V_3 = BAU Lebu-3 (Semi seedless) and Factor B: Treatment, viz. T_1 = pruning, T_2 = manuring, T_3 = irrigation, T_4 = pruning + manuring, T_5 = manuring + irrigation, T_6 = irrigation + pruning, T_7 = pruning + manuring + irrigation and T_8 = control (no pruning + no manuring + no irrigation).

Management practices

Pruning was done on 12 August 2010. Diseased, dead, unproductive branches, cross branches, shoots, water sprouts and leaves were pruned with the help of secateurs as per treatment. All plants were pruned in same height and almost same number of branches was kept. The application of manures and fertilizers was done immediately after pruning and before blossoming. All the manures and fertilizers were mixed together and applied around the plant base with sufficient care. All the treatments were fertilized with 30kg-350g-300g-300g-1kg per plots cow dung-urea-TSP-MP-paragon super respectively. When fertilization of all plants was completed, then irrigation was applied by supplying pipe and subsequent irrigation was done as and when required. Intercultural operation was done as when necessary.

Data collection and analysis

Data were recorded on plant height (cm), canopy volume (m^3), number of leaves per plant, time of flowering, time of fruit setting, time of harvesting, no. of total fruits per plant, number of harvested fruits per plant, number of damage fruits per plant, weight of individual fruit (g), length and breadth of fruit (cm), weight of pulp (g), weight of peel (g), percent (%) edible portion, total soluble solids (TSS%), Yield per plant (kg), yield per hectare (t/ha) from each plant. In case of fruit, five (5) fruits were selected at

random from each plant labeled and data were recorded after harvesting of the fruits. The recorded data were analyzed following Gomez and Gomez (1984) and means were compared at the 5% level of probability.

Results and discussion

Effect of treatments, variety and variety x treatment (combined) on plant height (m)

Three types of citrus showed highly significant variation in plant height due the effect of different treatments.

During the period of plant growth the highest plant height (3.19 m) was noted from the treatment of pruning + manuring + irrigation at 150 DAT (days after treatment) and control gave the lowest plant height (2.02 m) at 150 DAT (Table 1).

Table 1. Effect of treatment on plant height (cm), number of leaves per plant, canopy volume (m^3), time of flowering, time of fruit setting and time of harvesting of lime and lemon.

Treatment	Plant height (cm)			No. of leaves/plant			Canopy volume (m^3)			Time of flowering		Time of fruit setting		Time of harvesting	
	30 DAT	90 DAT	150 DAT	30 DAT	90 DAT	150 DAT	30 DAT	90 DAT	150 DAT	From	To	From	To	From	To
T_1	2.06	2.17	2.28	200.77	286.77	340.01	6.21	7.74	9.27	19Nov	29Dec	28Nov	30Jan	25Jan	20Mar
T_2	2.04	2.24	2.32	279.98	344.19	428.06	6.64	8.74	10.70	15Nov	17Dec	24Nov	30Dec	28Jan	21Mar
T_3	2.02	2.19	2.54	264.06	364.50	482.08	6.05	7.45	9.02	16Nov	27Dec	22Nov	28Dec	26Jan	17Mar
T_4	2.09	2.24	2.51	281.55	383.64	372.52	5.91	7.66	9.41	10Nov	17Dec	17Nov	28Dec	27Jan	21Mar
T_5	2.09	2.47	2.71	223.74	365.12	389.00	7.42	9.95	11.90	16Nov	15Dec	24Nov	22Jan	1Feb	22Mar
T_6	2.12	2.47	2.84	220.59	315.55	377.13	7.41	10.28	13.15	28Nov	10Dec	5 Dec	25Jan	9Feb	28Mar
T_7	2.27	2.63	3.19	451.12	449.63	524.06	10.40	13.37	16.58	15Nov	20 Dec	24 Nov	20 Jan	31Jan	20Mar
T_8	1.84	1.93	2.02	82.18	236.04	319.16	5.62	7.43	9.18	18Nov	7 Dec	25Nov	28Dec	2Jan	27Mar
LSD (0.05)	0.095	0.079	0.120	12.884	18.002	15.228	0.419	0.443	0.423	-	-	-	-	-	-

DAT = Days after treatment, T_1 = Pruning, T_2 = Manuring, T_3 = Irrigation, T_4 = Pruning + Manuring, T_5 = Manuring + Irrigation, T_6 = Irrigation + Pruning, T_7 = Pruning + Manuring + Irrigation, T_8 = Control, LSD = Least Significant Difference.

The increased plant height was possibly due to the readily available nutrients which might have encouraged more vegetative growth and development. Singh *et al.* (2003) reported that application of nitrogen had a significant effect on vegetative growth in term of plant height. A marked variation in plant height was observed due to influence of different types of citrus. This variation in plant height was highly significant. During the period of plant growth, the highest plant height (2.64 m) was found in the BAU Lebu-3 (Semi seedless) at 150 DAT and the lowest plant height (2.47 m) was found in BAU Lebu-2 (Elachi lebu) at 150 DAT (Table 2). The variation might be due to the fact of genetic makeup of BAU Lebu-3 which encouraged more vegetative growth through rapid cell elongation leading to the highest length. The combined effect of types of citrus plants and treatments on plant height was found to be statistically significant. The highest plant height (3.35 m) was found in the citrus plant and treatment combination of BAU Lebu-3 with pruning + manuring + irrigation and the lowest plant height (1.79 m) was found in the citrus plant and treatment combination of BAU Lebu-2 with control (Table 3). In respect of plant height, BAU Lebu-3 showed the better performance than BAU Lebu-1 and BAU Lebu-2 with combined treatments.

Effect of treatments, variety and variety x treatment (combined) on number of leaves/plant

The effect of treatment on number of leaves/plant was found to be statistically significant. The highest number of leaves/plant (524.06) was found in the treatment of pruning + manuring + irrigation at 150 DAT and the lowest number of leaves/plant (319.16) was found in control (Table 1). The highest number of leaves in case of pruning + manuring + irrigation treatments might be due to the improved

management practices. Bhujbal (2002) reported that the maximum number of leaves and flushes were obtained from topping and light pruning. Types of citrus plants exhibited significant effect on number of leaves/plant. The highest number of leaves/plant (554.95) was found in the BAU Lebu-3 at 150 DAP and the lowest number of leaves/plant (236.37) was found in BAU Lebu-2 (Table 2).

Table 2. Effect of variety on plant height (cm), number of leaves per plant, canopy volume (m^3), time of flowering, time of fruit setting and time of harvesting of lime and lemon.

Treatment	Plant height (cm)			No. of leaves/plant			Canopy volume(m^3)			Time of flowering		Time of fruit setting		Time of harvesting	
	30 DAT	90 DAT	150 DAT	30 DAT	90 DAT	150 DAT	30 DAT	90 DAT	150 DAT	From	To	From	To	From	To
V_1	2.05	2.30	2.55	264.91	383.62	420.68	7.42	9.52	11.73	10 Nov	15Dec	17Nov	27Dec	2Jan	22Feb
V_2	1.90	2.13	2.47	142.58	174.88	236.37	4.60	6.19	7.86	15Nov	27Dec	24Nov	25Jan	29Jan	19Mar
V_3	2.25	2.45	2.64	344.01	471.04	554.95	8.85	11.51	13.87	14Nov	29Dec	22Nov	30Jan	12Jan	28Mar
LSD (0.05)	0.058	0.049	0.074	7.913	11.057	9.353	0.258	0.272	0.260	-	-	-	-	-	-

DAT = Days after treatment, V_1 = BAU Lebu-1(Kagzi), V_2 = BAU Lebu-2 (Elachi scented) = V_3 = BAU Lebu-3 (Semi seedless), LSD = Least Significant Difference.

The lower number of leaves might be due to the genetic characteristics of the citrus plant of that type. The combined effect of three citrus plant and treatments on number of leaves/plant was found statistically significant. The maximum number of leaves/plant (712.46) was found by treatment combination of V_3T_7 (BAU Lebu-3 and pruning + manuring + irrigation) and minimum number of leaves/plant (165.69) was recorded by the treatment combination of V_2T_8 (BAU Lebu-3 with control) (Table 3).

Table 3. Combined effect of variety x treatment on plant height (cm), number of leaves per plant, canopy volume (m^3), time of flowering, time of fruit setting and time of harvesting of lime and lemon.

Treatment	Plant height (cm)			No. of leaves/plant			Canopy volume(m3)			Time of flowering		Time of fruit setting		Time of harvesting	
	30 DAT	90 DAT	150 DAT	30 DAT	90 DAT	150 DAT	30 DAT	90 DAT	150 DAT	From	To	From	To	From	To
V_1T_1	2.05	2.13	2.25	195.19	277.42	385.54	5.73	7.65	9.57	26Nov	8Dec	4Dec	5Jan	25Jan	16Feb
V_1T_2	1.93	2.35	2.45	245.94	355.63	462.89	7.90	9.06	10.80	15Nov	25Nov	24Nov	25Dec	28Jan	18Feb
V_1T_3	2.01	2.20	2.40	307.94	392.55	459.96	5.24	6.96	8.68	16Nov	25Nov	28Nov	21Dec	2Feb	17Feb
V_1T_4	2.03	2.23	2.61	346.67	451.33	574.62	6.04	7.82	9.60	10Nov	20Nov	17Nov	25Dec	27Jan	18Feb
V_1T_5	2.15	2.41	2.69	247.09	335.52	412.65	8.88	11.49	13.73	16Nov	25Nov	28Nov	27Dec	1Feb	19Feb
V_1T_6	2.11	2.42	2.76	277.17	382.54	440.41	7.96	11.43	14.90	28Nov	15Dec	5Dec	22Dec	9Feb	18Feb
V_1T_7	2.25	2.66	3.13	316.34	426.31	524.48	10.60	12.80	15.61	16Nov	27Nov	24Nov	26Dec	31Jan	22Feb
V_1T_8	1.88	2.01	2.11	182.95	247.67	307.93	7.00	9.02	10.97	20Nov	26Nov	30Nov	25Dec	2Jan	20Feb
V_2T_1	2.03	2.09	2.14	131.32	218.63	263.64	4.98	6.28	7.59	19Nov	17Dec	28Nov	20Dec	14Feb	27Feb
V_2T_2	1.90	1.99	2.44	117.64	179.63	217.83	3.15	4.50	5.86	17Nov	27Nov	25Nov	30Dec	1Feb	22Feb
V_2T_3	1.69	1.93	2.16	108.41	208.34	286.16	3.63	4.68	6.25	21Nov	27Dec	30Nov	28Dec	2Feb	20Feb
V_2T_4	1.91	2.03	2.43	95.28	186.12	261.48	3.89	5.98	8.06	30Nov	17Dec	10Dec	27Dec	12Feb	20Mar
V_2T_5	1.88	2.38	2.67	85.97	180.48	245.75	4.13	5.79	7.46	17Nov	26Nov	24Nov	22Jan	2Feb	20Feb
V_2T_6	2.08	2.39	3.05	76.20	152.20	215.20	4.35	5.90	7.46	14Dec	24Nov	30Dec	25Jan	29Jan	19Feb
V_2T_7	2.13	2.51	3.09	99.09	185.32	235.24	9.99	12.28	14.67	15Nov	20Dec	30Dec	20Jan	11Feb	19Mar
V_2T_8	1.64	1.72	1.79	64.77	118.34	165.69	2.74	4.14	5.54	18Nov	27Nov	25Nov	28Dec	3Feb	20Feb
V_3T_1	2.12	2.30	2.47	205.81	264.27	311.32	7.94	9.30	10.65	23Dec	29Dec	30Dec	30Jan	30Jan	20Mar
V_3T_2	2.31	2.38	2.09	214.38	307.32	364.46	8.88	12.66	15.44	2Dec	17Dec	13Dec	25Dec	11Feb	21Mar
V_3T_3	2.37	2.44	3.06	245.84	292.62	350.12	9.29	10.72	12.15	14Nov	24Nov	22Nov	10Dec	26Jan	17Mar
V_3T_4	2.33	2.46	2.51	251.72	2843.48	343.47	7.81	9.20	10.59	24Nov	5Dec	29Nov	28Dec	30Jan	21Mar
V_3T_5	2.25	2.64	2.77	338.16	479.36	508.61	9.26	12.57	14.53	5Dec	15Dec	14Dec	25Dec	11Feb	22Mar
V_3T_6	2.19	2.62	2.71	308.42	411.92	475.79	9.93	13.51	17.10	30Nov	10Dec	6Dec	10Dec	12Jan	28Mar
V_3T_7	2.45	2.74	3.35	337.93	437.26	512.46	10.62	15.05	19.48	26Nov	6Dec	2Dec	15Dec	3Feb	20Mar
V_3T_8	2.01	2.06	2.17	98.83	342.11	546.42	7.13	9.14	11.03	27Nov	7Dec	5Dec	26Dec	11Feb	27Mar
LSD (0.05)	0.164	0.138	0.208	22.359	31.240	26.427	0.728	0.769	0.734	-	-	-	-	-	-

DAT = Days after treatment, V_1 = BAU Lebu-1(Kagzi), V_2 = BAU Lebu-2 (Elachi scented), V_3 = BAU Lebu-3 (Semi seedless), T_1 = Pruning, T_2 = Manuring, T_3 = Irrigation, T_4 = Pruning + Manuring, T_5 = Manuring + Irrigation, T_6 = Irrigation + Pruning, T_7 = Pruning + Manuring + Irrigation, T_8 = Control, LSD = Least Significant Difference

Effect of treatments, variety and variety x treatment (combined) on canopy volume (m^3)

A marked variation in canopy volume was found due to the influence of different treatments. This variation in canopy volume was highly significant. The highest canopy volume (16.58m^3) was observed in the plants grown with T_7 (pruning + manuring + irrigation) and T_8 (control) gave the lowest canopy volume (9.02m^3) at 150 DAT (Days after pruning) (Table 1). Significant variation was observed in case of canopy volume (m^3) due to types of citrus plant. The maximum canopy volume (13.87 m^3) was found in the BAU Lebu-3 (Semi seedless) at 150 DAT and minimum canopy volume (7.86 m^3) was found in the BAU Lebu-2 at 150 DAT (Table 2). Wheaton and Parsons (2008) observed that greater irrigation significantly increased tree growth and canopy volume of citrus plant. The combined effect of three types of citrus plants and different treatments had significant influenced on canopy volume from the data collected at 30 DAT, 90 DAT and 150 DAT. The maximum canopy volume (19.48 m^3) was recorded in the types of citrus plants and treatment combination of BAU Lebu-3 with pruning + manuring + irrigation at 150 DAT and minimum canopy volume (5.54 m^3) was found from the types of citrus plants and treatment combination of BAU Lebu-2 with control (Table 3). T_7 (pruning + manuring + irrigation) possibly supply more available nutrients that encouraged more growth of BAU Lebu-3 producing the highest canopy volume.

Table 4. Effect of treatments on growth and yield and fruit characters of lime and lemon.

Treatments	Total fruit	Harvested fruit	Number of damaged fruits/plant	Individual fruit wt per plant	Fruit size in length (cm)	Fruit size in breadth (cm)	Pulp weight (g)	Peel weight (g)	TSS (%)	Percent edible portion	Yield/plant (kg)	Yield (t/ha)
T_1	16.39	15.08	1.33	130.53	7.91	5.44	77.36	53.17	13.44	62.63	1.69	2.43
T_2	16.82	15.71	1.11	134.55	7.41	5.33	83.22	51.33	14.04	62.11	1.51	2.17
T_3	20.61	18.72	1.89	115.86	7.97	5.97	69.81	46.05	13.68	64.60	1.81	2.60
T_4	20.63	19.74	0.89	113.72	7.89	5.59	69.95	43.77	14.06	66.28	2.04	2.94
T_5	17.68	16.68	1.00	132.30	8.59	6.16	82.63	49.62	13.89	67.46	2.01	2.89
T_6	19.97	19.13	0.77	135.93	8.85	6.38	81.27	39.50	14.41	69.65	2.24	3.22
T_7	24.15	23.16	2.23	184.63	9.39	7.16	103.39	109.73	14.85	73.63	3.04	4.37
T_8	15.99	13.77	0.67	82.35	7.22	4.56	48.72	20.30	12.95	59.21	1.33	1.92
LSD at 5%	0.841	0.592	0.060	9.620	0.485	0.289	4.190	3.268	0.416	1.987	0.099	0.116

T_1 = Pruning, T_2 = Manuring, T_3 = Irrigation, T_4 = Pruning + Manuring, T_5 = Manuring + Irrigation, T_6 = Irrigation + Pruning, T_7 = Pruning + Manuring + Irrigation, T_8 = Control, LSD = Least Significant Difference.

Effect of treatments, variety and variety x treatment (combined) on time of flowering

Time of flowering varied significantly due to treatment. The earliest flowering (10 November) was found with the treatment of pruning + manuring and latest flowering (29 December) was found in the pruning treatment (Table 1). Jones and Smith (2004) found that adequate amount of nitrogen was required for better flowering. In case of pruning, the reserve food materials i.e. the amount of carbohydrate was high and the nitrogen content was in optimum amount and C: N ratio was in balanced condition resulting the early flowering but in case of no pruning, the C: N ratio remained in imbalanced condition due to the less amount of carbohydrate, resulting the maximum time required for time of flowering. Reddy and Satyanarayana (1970) reported that the earliest flowering was noticed in pruned plants. Time of flowering varied significantly due to types of citrus plant. The earliest flowering (10 November) occurred in the BAU Lebu-1 and the latest flowering (29 December) was found in the BAU Lebu-3 (Table 2). This difference might be due to types of citrus species. The combined effect of types of citrus plant and treatments on the time of flowering was found to statistically significant. The earliest flowering (10 November) was occurred in the BAU Lebu-1 and

treatments combination with pruning + manuring and the latest flowering was found in the types of citrus plant and treatment combination of BAU Lebu-3 with pruning 29 December (Table 3). This was caused due to the presence of balanced C: N ratio and available plant nutrient.

Effect of treatments, variety and variety x treatment (combined) on time of fruit setting

Time of fruit setting varied significantly due to treatment. The earliest fruit setting (17 November) was found in the pruning + manuring treatment and latest fruit setting (30 January) was found in the pruning treatment (Table 1). Jones and Smith (2004) found that adequate amount of nitrogen was required for better fruit setting. Time of fruit setting varied significantly due to types of citrus plants. The earliest fruit setting (17 November) was occurred in the variety of BAU Lebu-1 and the latest fruit setting (30 January) was found in the variety of BAU Lebu-3. This was caused due to the genetic makeup of three types of citrus (Table 2). Fan *et al.* (2002) stated that single application of fertilizer produced more fruiting branches without old leaves. The combined effect of types of citrus plants and treatments on time of fruit setting was found to be statistically significant. The earliest fruit setting (17 November) was occurred in the variety of BAU Lebu-1 and treatments combination with pruning + manuring and the latest fruit setting was found in the types of citrus plant and treatment combination of BAU Lebu-3 with pruning on 30 January (Table 3). The similar results were found by Reddy and Satyamarayana (1970).

Table 5. Effect of variety on growth and yield and fruit characters of lime and lemon.

Treatments	Total fruit	Harvested fruit	Number of damaged fruits/plant	Individual fruit wt per plant	Fruit size in length (cm)	Fruit size in breadth (cm)	Pulp weight (g)	Peel weight (g)	TSS (%)	Percent edible portion	Yield/plant (kg)	Yield (t/ha)
V_1	20.71	19.63	1.58	87.18	4.85	4.67	49.38	20.43	13.37	78.59	1.93	2.78
V_2	16.92	15.81	0.87	120.93	8.82	6.16	82.84	54.36	13.93	53.98	1.58	2.28
V_3	19.46	17.80	1.25	178.09	10.79	6.64	98.91	80.26	14.44	64.52	2.36	3.39
LSD at 5%	0.516	0.364	0.037	5.909	0.298	0.177	2.573	2.007	0.256	1.220	0.061	0.071

V_1 = BAU Lebu-1(Kagzi), V_2 = BAU Lebu-2 (Elachi scented) = V_3 = BAU Lebu-3 (Semi seedless), LSD = Least Significant Difference.

Effect of treatments, variety and variety x treatment (combined) on time of harvesting

Time of harvesting varied significantly due to treatment. The earliest harvesting (2 January) was found in the control and latest harvesting (28 March) was found in the irrigation + pruning (Table 1).Time of harvesting varied significantly due to types of citrus plant. The earliest harvesting (2 January) was occurred in the BAU Lebu-1 and the latest harvesting (28 March) was found in the BAU Lebu-3 (Table 2).The combined effect of types of citrus plants and treatments on time of harvesting was found to be statistically significant. The earliest harvesting (12 January) was occurred in the BAU Lebu-1 with control treatment and the latest harvesting was found in the types of citrus plant and treatment combination of BAU Lebu-3 with irrigation + pruning 28 March (Table 3).

Effect of treatments, variety and variety x treatment (combined) on total fruits/plant

Number of total fruits/plant varied significantly due to the influence of treatments. The highest number of total fruits (24.15) was recorded in the treatment of pruning + manuring + irrigation and the lowest number of total fruits (15.99) was found in control (Table 4). Effect of types of citrus plant on the number of total fruits/plant was found to be statistically significant. The highest number of total fruits (20.71) was found in the BAU Lebu-1 (Kagzi) and the lowest number of total fruits (16.92) was found in the BAU Lebu-2 (Table 5). The highest number of fruits/plant produced by the treatments of

BAU Lebu-1 was probably due to the production of more number of flowers. Qin *et al.* (2006) reported that application of potassium fertilizer increase the fruit weight and yield/plant from 74.00 to 113.3 g and 23.83 kg respectively. The combined effect of types of citrus plants and treatments on total fruits/plant was found to be statistically significant in all respects. The maximum number of total fruits (24.81) was observed in the types of citrus plant and treatment combination of BAU Lebu-3 (Semi seedless) with pruning + manuring + irrigation and the minimum number of total fruits (14.01) was found in the types of citrus plant and treatment combination of BAU Lebu-2 with control (Table 6).

Table 6. Combined effect of variety x treatment on growth and yield and fruit characters of lime and lemon.

Treatments	Total fruit	Harvested fruit	Number of damaged fruits/plant	Individual fruit wt. per plant	Fruit size in length (cm)	Fruit size in breadth (cm)	Pulp weight (g)	Peel weight (g)	TSS (%)	Percent edible portion	Yield/plant (kg)	Yield (t/ha)
V_1T_1	18.50	17.17	1.33	65.67	4.69	4.64	42.94	22.73	12.45	72.73	1.79	2.57
V_1T_2	17.86	17.19	2.00	63.46	4.89	4.72	54.60	13.82	12.86	75.33	1.51	2.17
V_1T_3	22.33	20.33	2.67	50.61	4.82	4.67	43.93	15.68	13.54	78.57	1.88	2.71
V_1T_4	23.44	22.11	0.67	65.55	4.63	4.44	51.03	14.52	13.84	80.00	1.91	2.75
V_1T_5	18.34	17.67	1.00	68.61	5.11	4.87	54.09	14.37	13.64	82.00	2.04	2.93
V_1T_6	22.13	21.13	1.00	60.43	5.08	4.72	53.22	15.78	14.13	82.67	2.13	3.06
V_1T_7	26.49	23.46	3.03	68.42	5.22	5.12	55.05	12.33	15.21	84.71	2.84	4.08
V_1T_8	16.66	15.33	1.00	55.73	4.42	4.20	40.18	10.22	14.45	72.73	1.39	2.00
V_2T_1	15.00	12.87	1.34	125.61	8.42	5.25	78.74	46.87	13.48	55.17	1.39	2.00
V_2T_2	14.36	13.69	0.67	149.63	7.81	5.61	94.75	54.88	14.53	52.76	1.14	1.64
V_2T_3	18.12	17.12	1.00	112.34	8.64	6.42	69.89	42.45	13.56	50.38	1.31	1.89
V_2T_4	18.05	17.38	0.67	125.34	8.62	6.13	78.56	46.78	13.74	53.26	1.58	2.27
V_2T_5	17.02	15.69	1.33	150.67	9.43	6.74	95.45	55.22	13.86	53.72	1.88	2.70
V_2T_6	17.66	17.13	0.33	142.62	9.84	6.87	90.08	50.20	14.27	55.41	2.06	2.96
V_2T_7	21.17	20.17	1.33	170.83	10.11	7.78	104.56	122.96	14.89	62.50	2.42	3.48
V_2T_8	14.01	12.47	0.33	90.43	7.72	4.50	50.69	15.55	13.14	48.67	0.93	1.33
V_3T_1	16.67	15.42	1.33	200.32	10.63	6.45	110.41	89.91	14.39	60.00	1.89	2.72
V_3T_2	18.25	16.25	0.67	185.62	9.55	5.67	100.32	85.30	14.74	58.26	1.89	2.72
V_3T_3	21.40	18.73	2.00	175.64	10.46	6.84	95.61	80.03	13.95	64.85	2.24	3.22
V_3T_4	20.42	19.75	1.33	150.28	10.43	6.21	80.27	70.01	14.62	65.60	2.65	3.81
V_3T_5	17.68	16.68	0.67	177.63	11.23	6.87	98.36	79.27	14.17	66.67	2.12	3.05
V_3T_6	20.13	19.13	1.00	160.86	11.64	7.55	100.52	52.54	14.83	70.87	2.54	3.65
V_3T_7	24.81	23.17	2.33	273.52	12.84	8.60	150.56	139.91	13.61	73.68	3.87	5.56
V_3T_8	16.33	13.33	0.67	100.89	9.54	4.98	55.29	35.14	12.11	56.25	1.69	2.43
LSD at 5%	1.459	1.028	0.104	16.694	0.842	0.501	7.271	5.671	0.722	3.448	0.172	0.201

Effect of treatments, variety and variety x treatment (combined) on number of harvested fruits/plant

Different treatments had significant effect on the number of harvested fruits per plant. The treatment of pruning + manuring + irrigation produced the highest number of fruits (Table 4). Number of harvested fruits per plant varied significantly due to be influence of types of citrus plant. The highest number of harvested fruits (19.63) was found in the BAU Lebu-1(Kagzi), whereas the lowest (15.81) was from that of BAU Lebu-2 (Table 5).The combined effect of types of citrus plant and treatments on harvested fruits/plant was found to be statistically significant in all respects. The maximum number of harvested fruits/plant (23.46) was observed in the types of citrus plant and treatment combination of BAU Lebu-1 with pruning + manuring + irrigation and the minimum number of total fruits (12.47) was found in the types of citrus plant and treatment combination of BAU Lebu-2 with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on number of damage fruits/plant

Number of damage fruits/plant was influenced

significantly by the treatments. The maximum number of damage fruits/plant (2.23) was recorded in the treatment of pruning + manuring + irrigation and minimum number of damage fruits/plant (0.67) was observed in the treatment with control (Table 4). Significant variation was observed in case of number of damage fruits per plant due different types of citrus plant. The maximum number of damage fruits/plant (1.58) was obtained from BAU Lebu-1 (Kagzi), whereas the lowest (0.87) was found in the BAU Lebu-2 (Table 5). The combined and interaction effects of three types of citrus plant and eight treatments had significant influence on number of damage fruits per plant. The maximum number of damage fruits (3.03) was found in the types of citrus plant and treatment combination of BAU Lebu-1 (Kagzi) with pruning + manuring + irrigation and the minimum number of damage fruits (0.33) was found in the BAU Lebu-2 (Elachi) with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on individual fruit weight (g)

Individual fruit weight was varied significantly due to the influence of treatment. The maximum individual fruit weight (184.63g) was recorded in the treatment of pruning + manuring + irrigation and minimum individual fruit weight (82.35g) was obtained from that of control (Table 4). Individual fruit weight varied significantly due to influence of fruit types. The highest individual fruit weight (178.09g) was found in the BAU Lebu-3 (Semi seedless), whereas the lowest (87.18g) was from that of BAU Lebu-1 (Table 5). The combined effect of fruit types and treatment on individual fruit weight was found to be significant in all respects. The maximum individual fruit weight (273.52g) was observed in the fruit types and treatment combination of BAU Lebu-3 (Semi seedless) with pruning + manuring + irrigation and the minimum individual fruit weight (55.73g) was obtained from the fruit types and treatment combination of BAU Lebu-1(Kagzi) with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on length of fruit

Different treatments had significant effect on the length of fruit. The maximum length of fruit (9.39cm) was recorded in the treatment of pruning + manuring + irrigation and minimum individual fruit length (7.22cm) was obtained from that of control (Table 4). Length of fruit was varied significantly due to influence of variety types. The highest length of fruit (10.79cm) was obtained from BAU Lebu-3, whereas the lowest (4.85cm) was obtained from that of BAU Lebu-1. These might be due to the plant varietal character (Table 5). The combined effect of fruit types and treatment on length of fruit was found to be significant in all respects. The maximum length of fruit (12.84cm) was observed in the fruit types and treatment combination of BAU Lebu-3 (Semi seedless) with pruning + manuring + irrigation and the minimum length of fruit (4.42cm) were obtained from the fruit types and treatment combination of BAU Lebu-1(Kagzi) with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on breadth of fruit

Different treatments had significant effect on the breadth of fruit. The maximum breadth of fruit (7.14cm) was recorded in the treatment of pruning + manuring + irrigation and minimum breadth of fruit (4.56cm) was obtained in the treatment of control (Table 4). Breadth of fruit increased possibly due to readily available nutrient that might have encouraged more vegetative growth and development (Table 4).

Significant variation was observed in case of fruit breadth (cm) due to variety types. The maximum breadth of fruit (6.64cm) was obtained from BAU Lebu-3, whereas the lowest breadth of fruit (4.67cm) was obtained from that of BAU Lebu-1 (Table 5). The combined effect of fruit types and treatments on breadth of fruit was found to be significant in all respects. The maximum breadth of fruit (8.60cm) was observed in the variety and treatment combination of BAU Lebu-3 (Semi seedless) with pruning + manuring + irrigation and the minimum breadth of fruit (4.20cm) were obtained from the fruit types and treatment combination of BAU Lebu-1(Kagzi) with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on weight of pulp

Effect of treatments on the weight of pulp was found to be statistically significant. The maximum weight of pulp (103.39g) was recorded in the treatment of pruning + manuring + irrigation and minimum weight of pulp (48.72g) was found in the control (Table 4). Weight of pulp varied significantly due to the influence of variety types. The maximum weight of pulp (98.91g) was recorded in BAU Lebu-3 and minimum weight of pulp (49.38g) was found in the BAU Lebu-1(Table 5). The combined effect of fruit types and treatments was found to be significant in all respects. The maximum weight of pulp (150.56g) was found in the fruit types and treatment combination of BAU Lebu-3 with pruning + manuring + irrigation and the minimum weight of pulp (40.18g) were in BAU Lebu-1 with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on weight of peel

Effect of treatments on the weight of peel was found to be statistically significant. The maximum weight of peel (109.73g) was recorded in the treatment of pruning + manuring + irrigation and minimum weight of peel (20.30g) was found in the control treatment (Table 4).

Weight of peel varied significantly due to the influence of variety types. The maximum weight of peel (80.26g) was recorded in the BAU Lebu-3 (Semi seedless) and minimum weight of peel (20.43g) was found in the BAU Lebu-1(Table 5). The combined effect of fruit types and treatments was found to be significant in all respects.

The maximum weight of peel (150.56g) was found in the fruit types and treatment combination of BAU Lebu-3 with pruning + manuring + irrigation and the minimum weight of peel (40.18g) were obtained from the fruit types and treatment combination of BAU Lebu-1 with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on total soluble solids

Effect of treatment on the total soluble solids was found to be statistically significant. The maximum total soluble solids (14.85%) were recorded in the treatment of pruning + manuring + irrigation and minimum total soluble solids (12.95%) were found in the control treatment (Table 4). Total soluble solids varied significantly due to influence of variety types. The highest total soluble solids (14.44%) was found in BAU Lebu-3 (Semi seedless), whereas the lowest (13.37%) was found in the BAU Lebu-1 (Table 5). The combined effect of variety and treatments was found to be significant in all respects. The maximum TSS (15.21%) was found in the variety and treatment combination of BAU Lebu-3 with pruning + manuring + irrigation and the minimum TSS (12.11%) were obtained from the fruit types and treatment combination of BAU Lebu-1 with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on percent edible portion

Different treatments had significant effect on percent edible portion. The treatment of pruning + manuring + irrigation produced the highest edible portion (73.63%) per fruit, while the lowest (59.21%) was obtained from that of control (Table 4). Effect of variety types on percent edible portion was found to be significant in all respects. The highest percent edible portion (78.59%) was obtained from BAU Lebu-1 followed by BAU Lebu-2 (53.98%) and BAU Lebu-3(64.52%) and the minimum percent edible portion (53.98%) was found in BAU Lebu-2 (Table 5). The combined effect of fruit types and treatments was found to be significant in all respects. The maximum percent edible portion (84.71%) was found in the fruit types and treatment combination of BAU Lebu-1 with pruning + manuring + irrigation and the minimum percent edible portion (48.67%) was obtained from the fruit types and treatment combination of BAU Lebu-2 with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on yield per plant

Effect of treatment on the yield per plant was found to be statistically significant. The maximum yield per plant (3.04 kg) was recorded in the treatment of

pruning + manuring + irrigation and minimum yield per plant (1.33kg) was found in the treatment with control (Table 4). Yield per plant areas varied significantly due to the influence of types of citrus plant. The maximum yield per plant (2.36 kg) was obtained from BAU Lebu-3 (Semi seedless) and the minimum yield per plant (1.58 kg) was found in BAU Lebu-2 (Table 5). The combined effect of types of citrus plant and treatments was found to be significant in all respects. The maximum yield per plant (3.87 kg) was found in the types of citrus plant and treatment combination of BAU Lebu-3 with pruning + manuring + irrigation and the minimum yield per plant (0.93 kg) was obtained from the types of citrus plant and treatment combination of BAU Lebu-2 (Elachi) with control (Table 6).

Effect of treatments, variety and variety x treatment (combined) on yield per hectare

Effect of treatment on the yield per hectare was found to be statistically significant. The maximum yield per hectare (4.37 t/ha) was recorded in the treatment of pruning + manuring + irrigation and minimum yield per hectare (1.92 t/ha) was found in the treatment with control (Table 4).

Intrigliolo *et al.* (2003) studied the effect of degrees of pruning on yields and observed that the highest (531.5 kg/ha) yield was found by the light mechanical pruning and the lowest (265.7 kg/ha) was found by no pruning. Yield per hectare varied significantly due to the influence of types of citrus plant. The maximum yield per hectare (3.39t/ha) was obtained from BAU Lebu-3 (Semi seedless) and the minimum yield per plant (2.28t/ha) was found in BAU Lebu-2 (Table 5). The combined effect of types of citrus plant and treatments was found to be significant in all respects. The maximum yield per hectare (5.567 t/ha) was found in the types of citrus plant and treatment combination of BAU Lebu-3 (Semi seedless) with pruning + manuring + irrigation and the minimum yield per hectare (1.33 t/ha) was obtained from the treatment and variety combination of BAU Lebu-2 (Elachi) with control (Table 6). Bertonha *et al.* (2006) reported the effect of irrigation (7 rates) and nitrogen fertilizer (urea applied at 0-537.5 g/tree) application on citrus and found that yield was increased.

Conclusion

From the present study, it may concluded that the offseason fruit yield of lime and lemon could be incresed successfully through proper cultural managment practices and by cultivating the recommended vareities; BAU Lebu-1, BAU Lebu-2 and BAU Lebu-3.

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