Reproductive Behaviour of Lemon (\textit{Citrus limon} Burm.) Affected by Different Pruning Intensities and Integrated Nutrient Management Under Various Growing Seasons

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\textbf{Abstract} The main objective of this study was to know the reproductive behaviour of lemon (\textit{Citrus limon} Burm.) affected by different pruning intensities and integrated nutrient management under various growing season. The experiment was laid out in two factorial randomized block design with four levels of pruning, seven levels of nutrient, consisting recommended dose of fertilizers (RDF) and different combinations of organic manure (Vermicompost), inorganic fertilizer, biofertilizer (Azotobacter), Mycorrhiza (VAM) and their interaction to study their effect on plant reproductive behaviour during 2013–2015 on 9-year-old lemon plants in three growing seasons. The investigation revealed that the reproductive parameters, viz. number of flowers per plant, fruit set percentage and fruit yield, were found highest in lightly pruned plants fed with 75\% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza at Ambe, Mrig and Hasth bahr, respectively. Among the three seasons of cropping, Ambe bahr recorded the best result in respect to yield followed by Mrig and Hasth bahr.

\textbf{Keywords} Lemon · Nutrient management · Pruning · Yield

Citrus is the most economically important fruit crop in the world, is grown in developed and developing countries and certainly constitutes one of the main sources of vitamin C. There is also an increasing demand of “high-quality fresh citrus” driven by the World Health Organization recommendations [1]. Assam Lemon is one of the important varieties of lemon, extensively grown in the north-eastern parts of India. In northern parts of West Bengal, it is early bearing with three fruiting season, viz. April–May, August–September and November–December. The earlier vegetative flushes of the previous season growth generally are more productive [2]. It was observed that the main reason for declining the productivity of the plant is unbalanced overcrowded orchard which also resulted in high disease-pest infestation [3]. Therefore, pruning is essential to maximize sunlight penetration which not only influences the flowering and fruit set but also enhances fruit quality and colour development. As lemon plants bear three times in an year, proper manuring and fertilization has also to be resorted for obtaining highest yields and quality production [4]. However, the continuous use of chemical fertilizers has degraded the soil health in terms of fertility, productivity and has also caused soil pollution. In such a situation, combined application of organic, inorganic and biofertilizers needs to resort for avoiding the deleterious effect of chemical fertilizers and as well improves physical properties of soil. As information about the response of lemon against pruning and nutrient management is lacking for this area, the present investigation was conducted to know the reproductive behaviour of lemon (\textit{Citrus limon} Burm.) affected by different pruning intensities and

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integrated nutrient management under various growing seasons.

The present investigation was carried out during 2013–2015 on 7-year-old lemon cv. Assam lemon plants planted at 3 m × 3 m spacing at Instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India (26°19’86”N latitude and 89°23’53”E longitude). There were four levels of pruning, namely P₀–N₀ pruning (control), P₁–25 cm pruning from the terminal portion of the shoot, P₂–50 cm pruning from the terminal portion of the shoot, P₃–75 cm pruning from the terminal portion of the shoot and seven treatments of nutrient management, viz. N₁–100% Recommended Dose of Fertilizer (N@210 g/plant-P@140 g/plant-K@210 g/plant), N₂–Vermicompost (20 kg/plant) + Azotobacter (18 g/plant) + Vesicular Arbuscular Mycorrhiza (150 g/plant), N₃–Vermicompost, N₄–75% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza, N₅–75% RDF + Vermicompost, N₆–50% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza and N₇–50% RDF + Vermicompost, which were applied alone and in combination with different levels of the pruning. The experiment was laid out in two factorial asymmetrical randomized block design (RBD) and 28 treatment combinations (four levels of pruning and seven levels of nutrient) with three replications and six plants were kept in each treatment. All levels of pruning were done on 21 November 2013, after harvesting of Mrigbahar. Nitrogenous fertilizer was applied in two split doses. Firstly, half dose of nitrogen and full dose of phosphorus, potassium and vermicompost were applied in February 2014 and rest half of nitrogen was applied in April 2014. Azotobacter and Vesicular Arbuscular Mycorrhiza were applied in December 2013, after harvesting of Mrigbahar.

All the reproductive parameters, viz. number of flowers per plant, fruit set (%), fruit retention (%) and fruit yield, were recorded from six tagged plants for each treatment at three distinct seasons, viz. Ambe, Mrig and Hasth bahar, respectively. Analysis of variance (one way classified data) for each parameter was performed using ProcGlm of Statistical Analysis System (SAS) software (version 9.3). Mean separation for different treatments under different parameters were performed using Least Significant Different (LSD) test (P ≤ 0.05). Normality of residuals under the assumption of ANOVA was tested using Kolmogorov–Smirnov, Shapiro–Wilk, Cramer–Von Mises and Anderson–Darling procedure using Proc-Univariate procedure of (version 9.3) SAS [5].

Experimental results on number of flowers per plant showed significant variation in all the seasons under different pruning and nutrient levels (Table 1). The maximum number of flowers per plant (408.33, 378.33 and 259) was recorded in P₁ (25 cm pruning from the terminal portion of the shoot) at Ambe, Mrig and Hasth bahar followed by unpruned plants P₀ (388.33, 363.33 and 245) at Ambe, Mrig and Hasth bahar. The minimum number of flowers per plant was observed in P₃ (75 cm pruning from the terminal portion of the shoot) (288, 252 and 177.33) at Ambe, Mrig and Hasth bahar, respectively. The significantly highest number of flowers per plant was recorded (399, 371.67 and 250.33) in N₄ (75% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza), and the lowest number (386.33, 360 and 224.33) was observed in N₃ (Vermicompost) at Ambe, Mrig and Hasth bahar, respectively. The lowest number of flowers in severely pruned plants was due to loss of potential bearing wood of these plants [6]. The role of biofertilizer in fixation of atmospheric nitrogen and VAM involved in solubilization of phosphate are responsible for maintaining better soil environment which ultimately reflected in the flowering of the tree [7]. Similar findings also reported in bael [8]. The data pertaining to fruit set (%) have revealed that all the data were significantly different under different pruning and nutrient treatments. Maximum fruit set (%) was recorded (Table 1) in P₁ (25 cm pruning from the terminal portion of the shoot) at Ambe, Mrig and Hasth bahar (63.43%, 52.22% and 40.93%), and the minimum was observed in (P₀) unpruned plants (52.53%, 32.20% and 23.27%) at Ambe, Mrig and Hasth bahar, respectively. In the case of nutrients, the highest fruit set (%) was recorded (54.14%, 38.21% and 31.16%) in N₄ (75% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza) at Ambe, Mrig and Hasth bahar, respectively. These results are in close conformity with the findings in guava [9]. Increase in fruit set (%) might be due to the optimum supply of nutrients in integrated way which resulted in higher photosynthates production and thereby enhanced fruit set [7]. Observations on fruit retention (%) under different treatments and their combinations which are presented in Tables 1 and 2 were statistically significant in three cropping seasons. The significantly highest fruit retention (%) was recorded in P₁ (25 cm pruning from the terminal portion of the shoot) at Ambe, Mrig and Hasth bahar (84.56%, 67.89% and 36.79%), and the lowest retention (%) was observed in unpruned plants (50.49%, 39.32% and 21.05%) at Ambe, Mrig and Hasth bahar, respectively. The significantly highest fruit retention (%) was recorded (52.78%, 42.25% and 21.79%) in N₄ (75% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza) at Ambe, Mrig and Hasth bahar. It might be due to combination use of organic and inorganic fertilizers and better nutrient availability from them which was enhanced by biofertilizer and Vesicular Arbuscular Mycorrhiza resulted in better more retention of fruits at harvest. Fruit yield was
The data pertaining to fruit yield revealed that maximum number of harvested fruits was recorded (Tables 1, 2) in P1 (26.71 kg/plant, 16.86 kg/plant and 4.96 kg/plant) followed by P2 (18.11 kg/plant, 11.80 kg/plant and 3.45 kg/plant), and the lowest result was found in (P0) unpruned plants (1.52 kg/plant, 5.48 kg/plant and 1.38 kg/plant) at Ambe, Mrig and Hasth bahar, respectively. The significantly highest fruit yield was recorded (13.83 kg/plant, 7.67 kg/plant 2.14 kg/plant) in N4 (75% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza) at Ambe, Mrig and Hasth bahar. It might be because of more open tree canopy with wider leaf area resulted allowing more light penetration that led to assimilation of more photosynthetic materials which increased the number of laterals, leaf area, number of spurs, flower bud, fruit set and size, thus increasing total yield and also less competition for the growth of individual fruit as compared to unpruned trees [10]. Same results also reported in guava [11]. NPK in association with biofertilizer, VAM and Vermicompost at desired amount, enhanced leaf chlorophyll content resulting in accumulation of more photosynthates, ultimately resulted in higher yield [7, 12]. Similar result also found in lemon cv. Pant Lemon-1 [13].

In conclusion, the present results suggest that integrated application of inorganic fertilizers, organic and biological sources of nutrients in an efficient way that would not only reduce the sole dependence on inorganic fertilizers but also influence the flowering–fruiting in lemon. Besides, pruning has also significant effect in fruit yield. Among several levels pruning and nutrients application, light pruning (25 cm pruning from the terminal portion of the shoot) along with integrated use of fertilizers, viz. 75% RDF + Vermicompost + Azotobacter + Vesicular Arbuscular Mycorrhiza, proved as the best in terms of quality lemon production for this region.

| Treatments | Ambe bahar | Mrig bahar | Hasth bahar |
|------------|------------|------------|-------------|
|            | No. of flowers/plant | Fruit set (%) | Fruit retention (%) | No. of flowers/plant | Fruit set (%) | Fruit retention (%) | No. of flowers/plant | Fruit set (%) | Fruit retention (%) |
| P0         | 388.33d     | 52.53d     | 50.49 (45.29)d | 363.33d | 32.2d | 39.32d | 245d | 23.27 | 21.05 |
| P1         | 408.33c     | 63.43c     | 84.56 (66.89)c | 378.33c | 50.22c | 67.89c | 259c | 40.93 | 36.79 |
| P2         | 349.67b     | 60.63b     | 68.87 (56.11)b | 314.33b | 45.81b | 61.11b | 212b | 37.74 | 33.75 |
| P3         | 288a        | 58.33a     | 63.69 (52.95)a | 252a | 41.67a | 56.19a | 177.33a | 32.14 | 28.07 |
| SEm (±)    | 5.93        | 0.07       | 0.01            | 7.33 | 0.01 | 0.01 | 5.65 | 0.01 | 0.01 |
| LSD (P ≤ 0.05) | 16.82      | 0.20       | 0.03            | 20.78 | 0.02 | 0.02 | 16.02 | 0.02 | 0.02 |
| N1         | 388.33bc    | 52.53c     | 50.49 (45.29)e | 363.33cd | 32.2e | 39.32e | 245bc | 23.27 | 21.05 |
| N2         | 386.33bc    | 51.25d     | 48.48 (44.14)f | 362.33d | 32.02f | 33.62f | 245cd | 21.63 | 20.75 |
| N3         | 386.33c     | 51d        | 40.61 (39.58)g | 360d | 31.94g | 31.3g | 224.33d | 21.84 | 16.33 |
| N4         | 399a        | 54.14a     | 52.78 (46.61)a | 371.67a | 38.21a | 42.25a | 250.33a | 31.16 | 21.79 |
| N5         | 395.67ab    | 53.07b     | 52.38 (46.38)c | 365.33abc | 33.67c | 41.46c | 245.33abc | 30.57 | 21.33 |
| N6         | 397.67a     | 54.06a     | 52.09 (46.20)b | 371.33ab | 34.47b | 42.19b | 246.33ab | 30.85 | 21.05 |
| N7         | 391bc       | 52.94b     | 51.69 (45.97)d | 364bcd | 32.42d | 40.68d | 245bc | 28.16 | 20.29 |
| SEm (±)    | 7.85        | 0.09       | 0.01            | 9.69 | 0.01 | 0.01 | 7.47 | 0.01 | 0.01 |
| LSD (P ≤ 0.05) | 22.25      | 0.27       | 0.03            | 27.49 | 0.03 | 0.03 | 21.19 | 0.03 | 0.03 |

Means with the same letter are not significantly different
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