Effects of Fertilizer and Irrigation on the Growth and Yield of Bush Pepper (*Piper nigrum* L.) Intercropped under Coconut

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Abstract

This research was conducted at the Intercropping and Betel Research Station of the Department of Export Agriculture, Sri Lanka, to assess the impact of different irrigation levels (6 L or 8 L per day) and amounts of inorganic fertilizer mixture (660 kg, 1320 kg, or 1980 kg per ha) consisting of Urea, MOP, and Eppawala Rock Phosphate, on the growth and yield of bush pepper planted under coconut. The study was a factorial experiment in a randomized complete block design with three replicates. Data on growth and yield were collected for five years. The findings didn't reveal significant differences in canopy diameter or branching. However, after 20 months, plants irrigated with 8 L per day exhibited a higher percentage of flowered plants, indicating that increased irrigation can accelerate flowering. Nevertheless, more spikes were observed under low fertilizer application, suggesting that low nutrient supply positively influences the anthesis of bush pepper. Although the increased irrigation and fertilizer application improved the spike filling rate, it showed a decrease in spike production. Nonetheless, no interaction between the two factors has been identified. Moreover, the decline in yield from the third to the fifth year was observed which can be attributed to the mutual shading of growing plants. However, these results do not support the feasibility of field cultivation of bush pepper, as the dry yield achieved in this experiment (maximum 660 kg/ha/year) falls short when compared to traditional climbing pepper.

Keywords: Bush pepper, Flowering, Fertilizer, Growth and yield, Irrigation

V. INTRODUCTION

Black pepper (*Piper nigrum* L.) is an important spice crop for Sri Lanka, with a significant contribution to the country's economy and the livelihoods of small-scale farmers. In 2022, the black pepper extent in Sri Lanka was 42,152 ha and production reached 24,029 MT. Pepper exports in 2022 were 11,416 T valuing Rs. Million 23,464 (Raby & Hettiarachchi, 2023). Black pepper is grown as a climbing vine, which requires stakes or support structures for vertical growth. However, propagating black pepper plants using plagiotropic branches (fruiting/side branches) results in bush-shaped plants, commonly known as "bush pepper" which is mostly suitable for pot cultivations. According to some studies, a bush pepper pot plant produces about 1.5 kg of green (fresh) pepper in 2-3 years, under average management conditions (TNAU, 2022; Priyadarshani et al., 2018). It is common in houses as an ornamental plant which delivers black pepper for family requirements (Kavindi, 2013).

The compact growth habit of bush pepper plants allows for higher plant densities and more efficient use of space. Additionally, bush pepper plants are easier to maintain than climbing pepper plants, as it needs no support or trellises, require less labour, and are quick to produce yield (Thankamani et al., 2002; Ngawit, Wangiyana, & Farida, 2022). However, Bhattacharya (2017) has reported that bush pepper plants of some varieties did not reach to bearing stage until 3 years.

According to these details, bush pepper can be considered as a potential intercrop for small-scale coconut farmers in Sri Lanka. Adopting bush pepper cultivation under coconut could increase land productivity, diversify income and improve resilience to changing climate. Research conducted by Priyadarshani et al., (2018) in Sri Lanka under coconut identified 1.8 m x 1.2 m as the suitable spacing for bush pepper which results in around 3000 plants per ha. Moreover, this study confirmed the potential of achieving nearly 750 kg/ha/year of dry pepper yield from the fifth year onwards but also notes the superiority of orthotropic plants (climbing pepper) in long-term results. Further, considering the possible differences in the root system and growth habits, bush pepper management should differ from climbing pepper. However, as most of the bush pepper studies are confined to pot experiments, the effect of agronomic practices like irrigation and fertilizing under field conditions remains unclear. Thankamani & Ashokan, (2011) showed 8 L drip irrigation during October – May is best for bush pepper under coconut in Kerala. Indian Institute of Spice Research has recommended the application of NPK at 10, 5, 20 g per bush at three months interval for field-grown bush pepper while recommending a lower dose for potted plants.

In Sri Lanka, the Department of Export Agriculture (DEA) recommends an annual application of 2380 kg/ha of a fertilizer mixture for climbing pepper vines. This mixture consists of Urea, Eppawala Rock phosphate (ERP), Muriate of Potash (MOP), and Kieserite in a 4:5:3:1 weight ratio. Additionally, DEA advise a seasonal application of 1400 kg/ha/year of the same mixture, applied twice a year (Anon, 2019). Yet, there is no specific fertilizer mixture recommended for bush pepper in Sri Lanka. Therefore, this research aimed to identify the effects of irrigation and inorganic fertilizer application on bush pepper plants grown under coconut in Sri Lanka.

VI. METHODOLOGY

This research was conducted at the Intercropping and Betel Research Station of the Department of Export Agriculture, Narammala, which is situated in the Low Country Intermediate Zone (IL1a) of Sri Lanka (7°24'19.0"N, 80°12'15.2"E). Annual average rainfall during the study period of 2016 to 2020 was 1904.8 mm. A coconut field over 20 years old was selected as the research site and divided into five blocks. The whole field was being managed according to the recommendations of the Coconut Research Institute, Sri Lanka, including the application of 3.3 kg of APM-W fertilizer mixture with 1 kg dolomite per palm once a year during September to October. Bush pepper plants were prepared from two-nodal cuttings of plagiotropic branches. After approximately four months, during the 2015-16 Maha season, these potted plants were planted into five blocks, with three plants per plot at 1.8 x 1.2 m spacing, following the previous research outcome (Priyadarshani et al., 2018). The experiment was conducted as a two-factor factorial experiment in a randomized complete block design with three replicates.

After establishment, the application of treatments was started. Treatments include two levels of irrigation and three levels of inorganic fertilizer. Two irrigation levels of 6 L and 8 L thrice a week were selected (Thankamani & Ashokan, 2011). The irrigation was halted during rainy days until the soil became visibly dry.

Since there was no specific recommendation for bush pepper in Sri Lanka, three levels of a fertilizer mixture used by some farmers in the Kurunegala district were selected. This fertilizer mixture, applied once in three months, consists of Urea, Eppawala Rock Phosphate (ERP), and MOP in a 2:5:4 ratio (w/w). The tested amounts were 660 kg/ha/year, 1320 kg/ha/year, and 1980 kg/ha/year, corresponding to 55 g, 110 g, and 165 g per plant every three months. These amounts were selected considering the DEA recommendations for pepper cultivation.

Table 02: Treatments of the experiment

Treatment	**Irrigation Amount**	**Fertilizer application (kg/ha/year)**	**Fertilizer (g/plant/3**
T1	6 L	660	55
T2	6 L	1320	110
T3	6 L	1980	165
T4	8 L	660	55
T5	8 L	1320	110
T6	8 L	1980	165

The Growth data like canopy diameter, number of plagiotropic branches, and number of spikes in a bush, were collected in monthly intervals throughout the study period. Further, the yield data including the fresh and dry weight of peppercorn, and fruit filling rate were recorded at irregular intervals depending on the availability of mature spikes.

The collected data were statistically analysed using the SAS OnDemand for Academics statistical application. Data were tested for normality, then the Kruskal-Wallis test was performed for nonnormal data, while analysis of variance was conducted for normally distributed data which includes, canopy diameter, percentage of flowered plants and spike filling rate. Mean separation was done using Duncan's Multiple

Range test. The analysis revealed no interaction effect between irrigation and fertilizer levels in this experiment. Thus, the results are discussed as single-factor effects.

VII. RESULTS & DISCUSSIONS

The statistical analysis of monthly records confirmed that none of the treatments had any significant effect on the canopy diameter of the plants during the study period, except 15 months after planting (MAP) between three different fertilizer levels, as shown in Table 02.

Table 03: Canopy diameter of bush pepper plants N=90

Dose of fertilizer	Canopy diameter (cm)		
	09 MAP	15 MAP	18 MAP
165 g	58.1 [a]	83.4 [ab]	92.2 [a]
110 g	56.0 [a]	77.5 [b]	86.5 [a]
55 g	64.5 [a]	90.1 [a]	92.5 [a]
CV %	35.78	24.70	26.44

Note: The means followed by the same letters are not significantly different at α = 0.05. MAP = months after planting.

This finding contradicts the majority of previous studies, which have highlighted the effect as well as the interaction between irrigation and fertilization in relation to plant growth and yield. Since, there were no significant differences in the most of canopy diameter data, indicating plants in this experiment have not suffered water or nutrient stress, the 55 g fertilizer and 6 L irrigation level is adequate for comparable growth of bush pepper plants. Therefore, further research is necessary with lower doses of fertilizer and irrigation to identify the optimum amounts for the growth of bush pepper plants.

No significant difference in the number of plagiotropic branches was identified. Also, the coefficient of variation of these data was over 50% which minimises the certainty of results. Therefore, it can be suggested that these irrigation or fertilizer application levels had no significant effect on the branching of bush peppers.

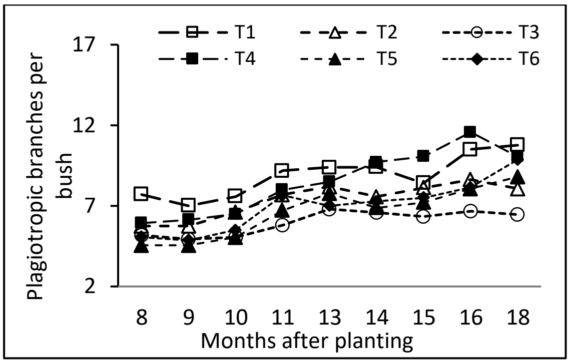

Figure 01: Plagiotropic branch formation of bush pepper under different irrigation and fertilizer levels. T1 to T6 denote daily irrigation and quarterly fertilizer application levels.

The results also showed that the percentage of plants with flowers was higher in 8 L irrigation compared to those irrigated with 6 L. The difference was statistically significant up to 20 months after planting. However, flowering under three fertilizer levels was not statistically significant (Table 03).

Table 04: Percentage of plants with flowers, 20 months after planting (MAP)

Dose of fertilizer	Plants with flowers (%)	Irrigation level	Plants with flowers (%)
165g	85.1 [a]	8 L	94.2 [a]
110g	80.0 [a]	6 L	77.9 [b]
55g	93.7 [a]		
CV %	22.52		

Note: Means followed by the same letters are not significantly different at α = 0.05

According to the results, higher irrigation levels can advance the flowering of plants even when the growth of plants remains unchanged. Unclear changes due to better water and nutrient availability might have caused this progress in 20 months. These results are consistent with previous research which has shown that irrigation can significantly influence the growth and development of pepper plants (Thankamani & Ashokan, 2011). The absence of significant differences between the three fertilizer levels is not consistent with previous studies that have reported a positive effect of fertilizer on flowering in pepper plants (Swarnapriya, 2020). Thus, while these results emphasise the importance of soil moisture for early flowering, further investigation is required to evaluate the effect of fertilizer on bush pepper flowering.

The data in Figure 02 represents the number of spikes in bush pepper plants, which measures the potential yield. It shows that the use of 55 g of fertilizer has resulted in a higher spike production in bush pepper plants. However, based on the data analysis, neither irrigation level nor fertilizer amount have significant effects on spike production.

Flowering can be enhanced either by high amounts of fertilizer which promote vegetative growth at the expense of spike production or insufficient fertilizer levels that trigger flowering as described by Wada & Takeno (2010). As no significant impact had been observed on plant growth, flowering of bush pepper might have been induced by fertilizer imbalance after the initial growth stage. This indicates the fertilizer level sufficient at the early growth stage may not be adequate at the latter stages, especially after anthesis. Hence, more studies should be conducted to determine the nutrient requirements at different stages of the bush pepper plant.

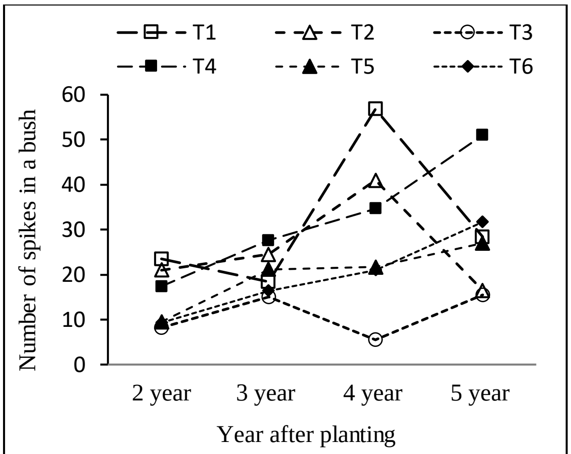

Figure 02: Number of spikes in a bush pepper plant.

The data on spike filling show the increase in the amount of fertilizer and water applied to the plants leads to a higher filling rate of bush pepper spikes (Table 04). This indicates that proper fertilizer application plays a crucial role in the growth and development of pepper fruits. Thus, emphasizing the importance of providing more water and fertilizer to the plants after flowering.

Table 04: Filling percentage of bush pepper spikes after 4 years of planting

Fertilizer level	Spike filling rate (%)	Irrigation	Spike filling rate (%)
165 g	78.3 [a]	8 L	76.6 [a]
110 g	73.2 [ab]	6 L	68.1 [b]
55 g	66.8 [b]		
CV	16.82		

Note; Means followed by the same letter are not significantly different. T1 to T6 denote daily irrigation and quarterly fertilizer application levels

Nevertheless, the spike length of bush pepper has been consistent through the treatments. Data shows that 84.1% of spikes had a length greater than 10 cm, while 19.5% had a length higher than 14 cm. Thus, nearly two-thirds of spikes had a length between 10 to 14 cm with an average of 11.9 cm.
According to the data in Table 05, which shows yield from the third year to the fifth year under different fertilizer and irrigation levels, bush pepper yield shows a reduction with time. Thus, it needs to be evaluated further in the field for a longer cultivation period. Also, the yield of bush pepper compared to traditional pepper is not adequate.

Table 05: The yield of bush pepper (dry yield kg per ha per year) under different irrigation and fertilizer levels

Treatment	3rd year	4th year	5th year
Fertilizer			
165 g	456.2 [a]	323.9 [a]	231.5 [a]
110 g	447.2 [a]	418.3 [a]	216.3 [a]
55 g	661.2 [a]	511.0 [a]	266.3 [a]
Irrigation			
8 L	520.7 [a]	319.3 [b]	247.3 [a]
6 L	547.0 [a]	555.1 [a]	227.7 [a]
CV	73.29	75.01	84.32

Note; Means followed by the same letter are not significantly different.

This kind of decline or fluctuation in yield is common in some bush pepper experiments (Priyadarshani, et al., 2018; Bhattacharya & Bandyopadhyay, 2017). Therefore, it can be a typical characteristic of black pepper plants of plagiotropic origin. But also, the effect of mutual shading of growing plants cannot be underestimated. Bush pepper plants naturally produce overlapping branches due to limited vertical growth. Its uncontrolled growth can reduce photosynthetic efficiency affecting the yield over time. Hence, pruning of bush pepper plants can be beneficial for a consistent yield for a long period. Therefore, further research on appropriate punning practices must be conducted.

In addition, the fertilizer formula used here (Urea: ERP: MOP; 2: 5: 4) is different from the recommended fertilizer mixture for black pepper in Sri Lanka (Urea: ERP: MOP: Kieserite; 4: 5: 3: 1). Therefore, plant growth and yield might have been affected by the imbalance of nutrients. Further, this demonstrates that applying fertilizer overdoses is pointless, thus emphasising the importance of providing a proper fertilizer recommendation for bush pepper in Sri Lanka. Since bush pepper has a comparatively small root system, its efficiency in nutrient uptake may not be similar to climbing pepper plants. Hence, bush pepper will be benefitted by providing readily available fertilizer mixtures. Therefore, replacing Eppawala rock phosphate (ERP) with more soluble triple super phosphate fertilizers should be considered in future bush pepper research (Srinivasan et al., 2008).

In conclusion, irrigation with 6 L or 8 L per bush thrice weekly or 660, 1320, and 1980 kg/ha/year of fertilizer mixture at three-month intervals shows no significant difference in the growth of bush pepper plants as measured by canopy diameter and number of plagiotropic branches. However, 8 L irrigation can bring plants into the flowering stage earlier than 6 L, though it can affect the production of spikes and final yield. Under these conditions, no interaction between fertilization and irrigation was observed. According to the results of this experiment, the use of 660 kg/ha/year of fertilizer has provided the plants with an adequate amount of nutrients for growth. Yet, the spike filling rate can be improved with higher irrigation and fertilizer application. Bush pepper in this experiment has produced around 660 kg/ha/year dry pepper yield at best, which is not satisfactory compared to about 5000 kg/ha/year yield of traditional climbing black peppers.

Finally, further research with irrigation and fertilizer levels less than 660 kg/ha/year, and changing with the growth phase of the bush pepper plants i.e., increased amount after the flowering, can be recommended.

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