**Effect of fertigation and retained black pepper tendrils to produce new shoots for cuttings**

**Devi Rusmin1, Rudi Suryadi1, Ireng Darwati1, Joko Pitono1, Octivia Trisilawati1, Melati1, Setiawan1, Ekwasita Rini Pribadi2, Hasim Munawar3, Taupik Rahman4, Bagem Sembiring5, and Dwi Setyorini1\***

1 Research Center for Horticultural and Estate Crops, National Research and Innovation Agency, Bogor 16111, West Java, Indonesia.

2 Research Centre for macro-economic and finance, National Research and Innovation Agency, Jakarta, Indonesia

3 Rearch Center for Nano Technology and Material, National Research and Innovation Agency, Bogor 16111, West Java, Indonesia.

4 Research Center for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, Serpong, Tangerang Selatan 15314, Banten

5 Research Center for Agroindustry, Research Organization for Agriculture and Food, National Research and Innovation Agency

\*Corresponding author (rinibptpjatim@gmail.com).

**ABSTRACT**

Black pepper (*Piper nigrum* Linn.) is generally propagated vegetatively by cuttings to obtain homogeneous morphogenic seedlings. The aim of this study was to determine the best poles, nutrient doses for fertilizing, and the number of tendrils remaining after pruning to produce new climbing shoots for cuttings. The research was conducted in two stages: (1) The effect of buffer polishing and nutrient doses on the production of climbing tendrils, and (2) Testing the quality of climbing shoots for cuttings. The plot uses a four-replicate design-based field trial. The main plot consists of living (*Gliricidia* sp.) and artificial (carpeted pipes) columns. Subplots consisted of 12 combinations of nutrient doses, methods of fertilization, and a number of tendrils used. The length of the tendrils, the number of leaves, the diameter of the tendrils, the chlorophyll content, the number of tendrils, and the number of tendril branches are parameters to measure the plant's response to fertigation treatment. The second stage was carried out by examining the quality of the tendrils obtained from the first stage including germination and viability. The results showed that the addition of 50% of the recommended nutrients through fertigation sufficiently increased black pepper growth, black pepper cuttings production, and leaf chlorophyll. Seed quality (germination percentage, shoot height) in the second stage was better than control seeds (without fertilization). The results of the study concluded that artificial support poles were better than live pole supports resulting in higher production and quality of black pepper seeds.

**Key words:** Support pole; fertigation, black pepper; quality; seed production

**INTRODUCTION**

Black pepper (*Piper nigrum*) is considered the “King of Spices” in international market trade as it is widely used as a spice, medicine, and perfume (Srivastava and Singh, 2017; Lee et al., 2020). One of the most active components of black pepper is *Piperine* (Tiwari et al., 2008). The pharmacological effects of *Piperine* are diverse, including hypotensive and anticoagulant effects (Tiwari et al., 2008), antitumor, antioxidant, anti-inflammatory, insecticidal, and larvicidal effects (Manoharan et al., 2009). *Piperine* exhibits various pharmacological activities such as hypotensive and anticoagulant, antioxidant, antitumor, antipyretic, analgesic, anti-inflammatory, antidiarrheal, antispasmodic, hepatoprotective, antibacterial, antifungal, antithyroid, antiapoptotic, anti-spermatogenic, insecticidal and larvicidal activity (Matsuda et al., 2008).

Black pepper plants need reliable support, commonly referred to as support, to grow properly and produce a good yield. Black pepper is typically grown on coconut and areca trees over 5 m tall (Sivaraman et al., 1999). In contrast, Indonesia uses more tree-based or living stems for black pepper growth and development. In addition, without proper fertilization and soil fertility management, black pepper yields cannot be increased, and it is not easy to sustain the production of tendril material for vegetative propagation. Most black pepper plants are grown in soils with low fertility and nutrient storage capacity (Paduit et al., 2018).

Inefficient fertilization in soils lost due to the low cation exchange capacity of the soil is traditionally overcome by the application of fertilizers, so the nutrient recovery rate is less than 60% (Baligar et al., 2001; Gajaraj et al., 2013).. Thus, various stake applications and strategic fertilization treatments become attractive parameters to produce black pepper tendrils optimally. Based on the above issues, this study aims to determine the type of pole and the right dose of fertilization for tendril production and black pepper quality.

**MATERIALS AND METHODS**

To achieve the objectives of this study, we conducted a two-stage experiment to determine the effect of stake control and fertilization, including the effect of support clump and nutrient composition, on the yields of black pepper climbing plants. The quality of the climbing tendrils produced for the cut was then checked.

**Work package 1: Effect of support poles and nutrient doses on the production of climbing tendril**

**Preparation for planting black pepper and poles**

Black pepper plants (Natar-1 variety, 4 months after germination) were planted at the beginning of the rainy season. Black pepper tendrils were tied to poles as described in the experimental design section and shaded by reed leaves; Therefore, the plants are not exposed to direct sunlight. Planting of live poles and installation of artificial poles were carried out at a distance of 1.5 x 1.5 m before planting black pepper. Planting in double rows with a distance of 3 m. Drainage channels are made between the pillars with a depth of 30 cm and a width of 20 cm, while the ditch all around has a depth of 30 cm and a width of 40 cm. The planting hole is made with a size of 60 cm x 60 cm x 60 cm. Each plant receives 10 kg of manure.

**Experimental design**

The experimental design uses split plots which include the main plot and subplots. For climbing shoots, the main plot in this study was prepared for seedlings containing live plant seeds (*Gliricidia* sp.) and artificial seedlings (PVC pipes covered with polyvinyl carpet, 10 cm in diameter, 2 m in length) as shown in Figure 1 while the side chart shows the feeding doses of the twelve combinations as shown in Table 1.

**Preparation of nutrient combination**

The nutrient combination includes fertilization techniques (conventional and fertilizing), nutrient doses, and a number of tendrils. Urea fertilizer (45% N), SP-36 fertilizer (36% P2O5), and KCl fertilizer (60% K2O) are used as nutrient sources and formulated according to recommended nutrient doses including 200g Urea, 96g SP-36, 40g KCl per plant per year. Experimental controls (C1, C2, and C3) were prepared at 100% of the recommended nutrient dose with different numbers of tendrils as shown in Table 1. Controls used conventional treatment, administering granular fertilizer at the recommended dose into the prepared channels around plants and then covering them with soil. They are applied four times during the rainy season. For the fertigation experiment, each nutrient source was initially diluted in water to a concentration of 100,000 g.L-1. The fertilizer is then automatically mixed by adding water to the tank until the NPK nutrient mix reaches a concentration of ± 4,500 g.L-1 (from 50% to 100% of the recommended dose). The recommended fertilization dose is 50%, 75%, and 100%. Fertilizer treatment with liquid fertilizer at intervals of 2 weeks. The fertigation network consists of tubes arranged along the rows of plants. The slope of the property was previously measured. A pipe with plastic tubing for each black pepper plant passed around the root zone. By installing shut-off valves on pipes and plastic hoses, the nutrient solution is evenly distributed.

**Plant response observation**

The experimental parameters were (1) Plant growth: tendrils length, leaves number, tendrils diameter, climbing tendril number, and branched tendrils number (measured every month), (2) Black pepper stem production (measured every six months), and (3) Physiological parameters consisting of chlorophyll content (measured using chlorophyll meter/ SPAD). Data collected were subjected to one-way analysis of variance (ANOVA) using SAS, and the difference between treatments mean were tested using DMRT with a probability of 5%.

**Work package 2: The Quality test of climbing shoot for cutting**.

**Pruning black pepper plants and taking tendril shoots for cutting**

The first pruning was done when the plants are six months old, the cut is made 50 cm above the ground and is repeated twice every six months. Two, four, and six new tendrils were retained because the treatment suggested producing plant material as cuttings.

**Planting cutting from the main tendril shoot**

In nurseries, single-internode tendrils are grown as cuttings. Fifty cuttings per treatment were planted in polybags with soil mixed with manure at a 1:1 ratio. The overall treatment can be seen in Table 1.

**Observation of cutting from the main tendril shoot**

Variables of cutting quality were the percentage of germination, number of internodes, number of leaves/tendrils, and height of shoots until the cuttings were ready for distribution five months after planting. The data collected were subjected to a one-way analysis of variance (ANOVA) using SAS, and mean differences between treatments were tested using DMRT with a probability of 5%.

**RESULTS**

**Effect of support poles and nutrient doses on growth production of climbing tendrils**

The growth of black pepper supplemented with nutrients using a two-rod irrigation system was observed at 12 weeks of age (tendril length, number of leaves, tendril diameter, and chlorophyll content). Statistical analysis showed that there was no interaction between the main plot and subplots in terms of tendril length, number of leaves, tendril diameter, and chlorophyll content of black pepper aged 12 months. However, the type of post-treatment significantly affected the length of the tendrils, the number of leaves, the diameter of the tendrils, and the chlorophyll content. Artificial support poles produced longer tendrils, more leaves, larger tendril diameter, and higher chlorophyll content compared to live support poles with dimensions of 115.12 cm, 16.31, 6.54 cm, and 47.38% (Table 2).

**Leaf chlorophyll content**

In addition, the combination of nutrient doses and the number of tendrils maintained had a significant effect on the growth of the tendrils, the number of leaves, the diameter of the tendrils, and the chlorophyll content. Increasing the dose of nutrients through the fertigation system did not increase the growth rate of black pepper. Combining a 50% nutrient dose with fertilization techniques, both preserved tendrils 2, 4, and 6 are enough to increase the length of the tendrils (93.82 - 97.89 cm), the number of leaves (13.46 - 13.85) and increase the diameter of the tendrils (5.96-5.99 cm) compared to control, without fertigation system (70.57-83.32 cm), (10.16-11.00) and (4.99 - 5.14 cm) (Table 2 ).

Statistical analysis showed that there was no interaction between the main plot, type of support pole, secondary plot, nutrient dosage, and the number of tendrils on the chlorophyll content of black pepper plants 12 months after planting (Table 2). Treatment of the type of support pole has a significant impact on the chlorophyll content. Treatment of artificial support poles produced more chlorophyll in plants compared to live poles with a difference of 5.69%.

Increasing the dose of nutrients in the fertilization technique and the number of tendrils did not increase the chlorophyll content of black pepper leaves. The combination of fertilization doses and fertilization techniques on 2, 4, or 6 tendrils that are maintained can increase chlorophyll levels compared to controls or without fertilization (Table 2). Keeping more tendrils will not affect chlorophyll levels. This indicates that the addition of up to 6 tendrils at 50%, 75%, and 100% nutrient fertilization does not cause competition for nutrients and light between tendrils.

**Number of climbing tendrils**

Statistical analysis showed that there was an interaction between the main plot (type of support pole) and subplot (combination of nutrient doses and the number of tendrils maintained) on the production of seed cuttings. The production of seed cuttings was observed with the parameters of the number of climbing tendrils and branch tendrils. Overall, the seed cuttings produced on artificial poles were higher than those on live support (Table 4). The number of climbing tendrils increased with the addition of nutrient doses in the fertigation fertilization technique and the initial number of tendrils was maintained. The combination of 100% nutrient dose with the remaining 6 tendrils resulted in the highest number of climbing tendrils, namely 67.35. These findings suggest that raising more tendrils (up to 6) can increase the number of climbing tendrils. For life support poles, a nutrient dose of 75% by maintaining 4 tendrils resulted in the highest number of climbing tendrils for seed cutting and was significantly different from the control with 2 and 6 tendrils and a nutrient dose of 100% + 4 tendrils maintained. The combination of 50% nutrient dose and two tendrils produced 22.25 cuttings with a production of 44.66% higher than the control with two tendrils.

**Number of branching tendrils to cut**

Statistical analysis showed an interaction between the type of support poles and the combination of nutrient doses and the number of tendrils maintained for the production of tendril cuttings. Overall, the number of tendrils with artificial supports was higher than with live supports (Table 4). Artificial support poles, 50% nutrient dose with fertilization technique, and 6 tendrils produced the highest number of branches, and not significantly different with 50% + nutrient dose and 2 tendrils retaining, 75% + 6 retaining tendrils, and 100% + retaining dose 4 nutrients tendrils. Treatment with a nutrient dose of 50% + maintenance of 2 tendrils increased 133.54% the number of branching tendrils of the control, maintenance of 2 tendrils. On living support poles, the highest number of tendril branches was produced by 75% nutrient doses + 4 tendrils and was not significantly different from those treated with 100% nutrient doses and 6 tendrils.

**Quality test of climbing shoots for cutting.**

Climbing tendrils are taken from mother plants that are treated according to applicable regulations and used as plant material for seed production by cuttings. The quality of plant materials and seeds was tested by growing them in nurseries for 3 months (Table 6.). Parameters observed to determine seed quality were the percentage of germination, number of internodes, number of leaves, and shoot length.

Statistical analysis of seed quality showed no interaction between the main plot, support poles, subplots, nutrient doses, number of black pepper tendrils, and seed quality three months after sowing. Black pepper quality parameters using live and artificial poles were not significantly different except for shoot length. The climbing tendrils of the 100% nutrient fertilization technique with a dose of 6 tendrils produced the highest percentage of crown height and crowns, while the highest number of nodes and leaves was in the 100% + 2 tendrils treatment (Table 6).

**DISCUSSION**

**Effect of support poles and nutrient doses on growth production of climbing tendrils.**

Increase in tendril length, number of leaves, the diameter of tendrils, and chlorophyll content on artificial support poles by 66.02%; 79.62%; 40.95%, or 0.69% for life support. The use of live support stems inhibits the formation and growth of black pepper plant leaves (Issukindarsyah et al., 2021). Leaves more tendrils after initial pruning, will not affect black pepper growth. This means that the retained up to 6 tendrils with a nutrient dose of 50% and 75% will not stop plant growth because competition for water and nutrients between tendrils is not significant. This is an opportunity to increase cuttings production. In addition, not many fertilization methods have been carried out on black pepper plants. The application of fertilization methods ensures better growth and yields compared to traditional fertilization by adding fertilizer to the soil. Some plants that use fertigation are horticultural crops and fruit trees (Table 3). This is supported by another berry crop study showing increased berry yield by the fertigation fertilization method, due to better plant response to nutrient availability due to the weekly application of fertilizer solutions (Shigvan et al., 2023).

**Leaf chlorophyll content**

The higher chlorophyll content in the artificial black pepper supports is due to the lack of nutritional competition between the black pepper and the live stems. The higher chlorophyll content in artificial black pepper support stems is caused by a lack of competition for nutrients between black pepper and live stems, whereas black pepper uses live supports to compete for nutrient uptake (Issukindarsyah et al., 2021).

The combination of nutrient doses and the number of tendrils that are maintained has a significant effect on the chlorophyll content of black pepper leaves. Application of a fertilizer solution by fertigation increased chlorophyll content, dissolved sugar, quantum photochemical results, and photosynthetic efficiency index compared to control plants, this also happened to mint plants (Mentha piperita L.) (Maluin et al., 2021). This is due to N deficiency in this treatment, which causes reduced vegetative growth and accumulation of dry biomass from aerial parts of the watermelon (Da Silva Pereira et al., 2020). Phyto technical parameters and results of the synthesis of important N compounds such as protein, chlorophyll and DNA (Ishida and Makino, 2018).

Chlorophyll is a green pigment that absorbs light particles to produce energy for plant growth. The formation of chlorophyll is influenced by many factors, one of which is the intensity of light received by the leaves. The decrease in leaf chlorophyll content is probably caused by shading which reduces the intensity of light received by the leaves. The chlorophyll content of black pepper leaves grown on life support began to decrease when the black pepper plants were six months old. Shade from the canopy supports reduces the intensity of light received from the ridges of the pepper leaves and reduces the rate of photosynthesis, which in the long term inhibits the growth and production of black pepper. These results indicate that planting black pepper using live support poles causes competition for nutrient absorption between black pepper and support poles resulting in a decrease in chlorophyll content. According to the decline in black pepper production with live support poles, one of the reasons is the competition for light and oxygen between black pepper and support poles. Further studies have shown that all available surfaces for tendrils can attach to support trees. sunlight between trees is an important factor influencing black pepper yield, followed by life support (Dinesh et al., 2005)

The provision of nutrients using the fertigation technique on black pepper has proven to be very efficient and effective in plant growth. Gradually sending dissolved nutrients directly to the roots can make them easier to absorb. Kafkafi and Tarchitzky (2011) state that a water fertigation system, providing water directly to the roots, will minimize water loss due to evaporation. In drip irrigation, the plant root system becomes shallow and dense, and the volume of fine roots increases significantly due to increased aeration and nutrients in the root zone. Fertilization with fertigation technique is more effective for plants because plants absorb nutrients through the roots in the form of ions in solution. In general, injecting nutrients into irrigation water (fertigation) gives a better plant response compared to tape or broadcasting. Fertigation provides fertilization flexibility that allows the specific nutritional needs of plants to be met at various growth stages (Haynes, 1985).

Providing nutrients with fertigation techniques can increase the chlorophyll content in the leaves because the nutrients can be directly absorbed by the root system. Chlorophyll is an important photosynthetic catalyst present in the thylakoid membrane as a green pigment in photosynthetic plant tissues, which is loosely bound to proteins but easily extracted into lipid solvents such as acetone and ether (Gandul-Rojas et al., 2004). Increasing the pigment content in the leaves can increase the growth and production of black pepper plants as previously described. Previously Senthilkumar et al. (2014) reported that the combination of applying recommended nutrient doses of 50% and 75% and 300 g consortium biofertilizer using fertigation techniques significantly increased the chlorophyll content of banana leaves compared to 100% nutrient dose through the soil. Providing nutrients through fertigation supports plant growth and seed production and improves the physiological quality of seeds (growth percentage and sprout growth). The fertigation technique is useful for seed production because the provision of nutrients through fertigation can increase the production of black pepper seeds both in quantity and quality. This also applies to commodities such as coffee and shallots (Dingre et al., 2016; Coelho et al., 2018).

**Number of climbing tendrils**

These findings indicate that black pepper with living support poles maintains tendrils more efficiently. Raising more tendrils will not increase the number of climbing tendrils due to competition for nutrients, light, and oxygen between the tendrils and support poles, which can inhibit black pepper growth. The apparent superiority of the dead stanchion over the living is due to the competition between the main crop and the stanchion plant for factors such as light, water, and nutrients. The results may indicate a competition effect for nutrients. As evidenced by much higher yields when dead stanchions are used even when nutrients are at the highest levels, market competition due to two other factors is evident. Similar trends were observed in the case of various components of growth and yield (Kumar and Cheeran, 1981). This implies the importance of selecting the right support trees to maximize black pepper yields, as well as the possibility of using exotic tree species such as *A. auriculiformis* to trail these tendrils. However, tree management techniques such as pruning and felling are necessary to maintain the shape of the supporting tree and avoid excessive shading of the tendrils; otherwise, species such as *A. auriculiformis* (which has a densely spread crown) can cause over-shading and have a significant impact on main crop production (Kumar et al., 2021).

**Number of branching tendrils to cut**

In general, artificial supports had better performance (tendril length, number of leaves, and seed production from cuttings). Artificial climbing reduces competition for nutrients, water, light, and oxygen between the main culm and climbing tendrils. Black pepper tendrils can also be provided with other dead supports such as concrete, granite, wood (e. g. teak) columns, and specially designed PVC columns. Such as dead wood pillars which are already popular in countries such as Malaysia, Viet Nam, Brazil, and Indonesia (Kumar et al., 2021)

In the trellis using *Gliricidia,* the black pepper root system, and the stanchion were located in the same zone, which could lead to competition that might inhibit plant growth. Canopy support posts can also block light for black pepper. This hypothesis could explain the reason for the lower chlorophyll content in living scaffolds. The calcium content in the black pepper tissue indicates that there is no competition between the black pepper and the stanchion. The ability of the main plant to absorb nutrients is low when planted with living support (living support poles), because the length and surface area of black pepper roots are smaller so that plant growth is lower (Issukindarsyah et al., 2021). Yield gain due to non-living support properties which are not competitive is a clear advantage (Kumar et al., 2021).

**Quality test of climbing shoots for cutting.**

Overall, the seed quality obtained at 100% nutrient dose with 2, 4, and 6 tendrils was better than the control. The fertilization of cucumber plants and the number of different tendrils have a significant effect on various stages of growth (Singh et al., 2022). Starch is synthesized in leaves during photosynthesis during the day and will be degraded at night for more growth to maintain metabolism, if the starch supply is low then plant growth will be slower. Starch is stored for a long time in non-photosynthetic tissues, such as seeds and stems, and is remobilized during germination, sprouting, or regrowth to provide energy during the absence of photosynthesis (Pfister and Zeeman, 2016). In general, the starch content of artificial piles was higher than that of live piles, 20.34% and 18.73% respectively (Figure 1.). Increasing the dosage of nutrients tends to increase the starch content, especially in artificial poles. The highest starch content was obtained at the application of 100% fertigation dose and preservation of 6 tendrils. It corresponds to the proportion of germination and high shoots. Whereas in live poles, the highest starch content was obtained at a fertigation dose of 50% + 6 tendrils.

**CONCLUSION**

Artificial poles with the application of fertigation fertilization provide better tendril growth on the mother plant as a source of plant material compared to living support poles with conventional fertilization. The addition of 50% of the recommended nutrient dose through fertigation was more effective in increasing the growth of black pepper tendrils for planting materials, production of black pepper cuttings, chlorophyll content, and seed quality compared to control (non-fertigation). Fertilizing black pepper with fertigation techniques can increase cutting production without affecting plant growth. Increasing the number of shoots maintained by up to six shoots can facilitate the production of cuttings with quality seeds (growth rate).

**Acknowledgments**

We would like to thank the Indonesian Spices and Medicinal Crops Research Institute (ISMCRI), the Indonesian Agency for Agricultural Research and Development, and the Indonesian Ministry of Agriculture, for supporting this study by providing the facilities. Thank is also conveyed to other parties who have contributed to this study.

**Author contribution**

Conceptualization, D.R., I.D., R.S., J.P., O.T. Methodology, D.R., I.D., R.S., E.P, J,P., M., S., B.S. Software, B.S., M., S., H.M., T.R, D.S. Data curation, E.P., R.S., B.S, O.T., M., T.R. D.S., Writing-original draft, D.R. I.D., R.S., D.S., Writing-review & editing, E.P., B.S., J.P., O.T, M., H.M., D.S., Visualization, T.R. J.P., O.T., E.P., M., S., D.S., Supervision, I.D., D.R., R.S. O.T. B.S, E.P., Project administration, I.D., D.R, R.S., J.P., D.S. Funding acquisition D.R, I.D. All co-authors reviewed the final version and approved the manuscript before submission.

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**Tables and Figures**

**Table 1**. Treatment Combination in the sub plot

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sub plot | | | | | |
| Fertilizer methode |  | Nutrient doses/ plant | | | Tendril kept after pruning (pc) |
| Conventional (C) | Urea (g) | | SP-36 (g) | KCl (g) |  |
| C1 | 200 | | 96 | 40 | 2 |
| C2 | 4 |
| C3 | 6 |
| Fertigation (F) | Urea (g) | | SP-36 (g) | Kcl (g) |  |
| F1 | 100 | | 48 | 20 | 2 |
| F2 | 4 |
| F3 | 6 |
| F4 | 150 | | 72 | 30 | 2 |
| F5 | 4 |
| F6 | 6 |
| F7 | 200 | | 96 | 40 | 2 |
| F8 | 4 |
| F9 | 6 |

**Table 2.** Impact of single factor types support pole and combination of nutrient doses with a number of tendrils retained to tendrils length, leaves number/tendrils, tendrils diameter and chlorophyll content at 12 months after planting.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Tendrils’  lengths (cm) | Numbers of Leaves/ tendrils | Tendril diameters (cm) | chlorophyll content (unit) |
| **Main plot: Types of pole**  Live plant pole  Artificial pole  **Subplot: Treatment Combination**  Conventional, recommended doses (Control), 2 tendrils  Conventional, recommended doses (Control), 4 tendrils  Conventional, recommended doses (Control), 6 tendrils  Fertigation, 50% recommended doses, 2 tendrils  Fertigation, 50% recommended doses, 4 tendrils  Fertigation, 50% recommended doses, 6 tendrils  Fertigation, 75% recommended doses, 2 tendrils  Fertigation, 75% recommended doses, 4 tendrils  Fertigation, 75% recommended doses, 6 tendrils  Fertigation, 100% recommended doses, 2 tendrils  Fertigation, 100% recommended doses, 4 tendrils  Fertigation, 100% recommended doses, 6 tendrils  **Significance:**  Main plot : Types of pole  Subplot: Treatment Combination  Interaction: Type of pole x Treatment combination | 69.34 a  115.12 b  70.57 c  80.45 d  83.32 cd  97.89 ab  93.82 ab  96.78 ab  99.65 ab  96.29 ab  102.28 a  96.91 ab  97.12 ab  91.66 bc  \*\*  \*\*  ns | 9.08 a  16.31 b  10,16 c  11.00 c  10.86 c  13.86 a  13.64 a  13.46 a  14.21 a  12.94 ab  13,62 a  13.63 a  13.52 a  11.45 bc  \*\*  \*\*  ns | 4.64 a  6.54 b  5.14 bc  5.11 bc  4.99 c  5.96 a  5.99 a  5.99 a  5.60 abc  5.73 ab  5.53 abc  5.87 a  5.70 ab  5,51 abc  \*\*  \*\*  ns | 44.83 a  47.38 b  42,17 c  41.82 c  41.80 c  46.43 b  45.14 b  47.45 ab  47.81 ab  46.88 ab  47.40 ab  50.68 a  47.57 ab  48.10 ab  \*\*  \*\*  ns |

Note: Interaction (Type of pole x Treatment combination) is not significant (ns), main plot and subplot are significant at P ≤ 0.05 (\*\*). Different letters for the same parameter indicate significant differences according to the DMRT test at 95%.

**Table 3.** Fertigation on horticulture, black pepper, and fruit growth and production.

|  |  |  |  |
| --- | --- | --- | --- |
| No | Kinds of plant | Result | References |
|  | Tomato | Fertigation using the Nutrient Film Technique (NFT) can increase fruit production with the right Electric Conductivity (EC) and media | (Xu, et al., 1995) |
|  | Black pepper | Fertigation using a pitcher gives almost the same results as applying fertilizer directly to the soil. b | (Hermantor, et al., 2003) |
|  | Rosa | Fertigation @ 500 ml at intervals of 2 days is the most effective in increasing vegetative and reproductive growth. | (Qasim, et al,. 2008) |
|  | Papaya | Yield components such as number of fruit/plants, weight, length, volume and Total Soluble Solids (TSS) of fruit in fertigation treatment were better than by applying fertilizer through the soil, | (Sadarunnisa et al., 2010) |
|  | Tomato | Drip fertigation with 100% of NPK more effectively supports tomato fruit production than furrow irrigation. | (Badr et al., 2010) |
|  | Blueberry | Fertigating N fertilization at high doses encouraged growth more effectively than applying N as granules. The application of high N as granules can cause the plant to die due to an increase in ammonium ions and Electric Conductivity in the soil. | (Bryla and Machado, 2011) |
|  | Strawberry | Fertigation gave better growth and bigger quantity (fruit length, fruit width, and fruit weight) and quality (TSS value, total sugar, anthocyanin and ascorbic acid) than conventional fertilization. | (Kachwaya and Chandel, 2015) |

**Table 4.** Interaction between types of support pole and treatment combination (nutrient doses and a number of tendrils retained) to main climbing and branched tendrils number**.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Main Plot (Type of Pole) | | | |
| Live pole | Artificial Pole | Live pole | Artificial Pole | |
| The number of climbing tendrils | | The number of branched tendrils | | |
| **Sub plot (Treatment combination)**  Conventional, recommended doses (Control), 2 tendrils  Conventional, recommended doses (Control), 4 tendrils  Conventional, recommended doses (Control), 6 tendrils  Fertigation, 50% recommended doses, 2 tendrils  Fertigation, 50% recommended doses, 4 tendrils  Fertigation, 50% recommended doses, 6 tendrils  Fertigation, 75% recommended doses, 2 tendrils  Fertigation, 75% recommended doses, 4 tendrils  Fertigation, 75% recommended doses, 6 tendrils  Fertigation, 100% recommended doses, 2 tendrils  Fertigation, 100% recommended doses, 4 tendrils  Fertigation, 100% recommended doses, 6 tendrils  **Significance:**  Main plot : Type of pole  Sub plot :Treatment combination  Interaction : Type of pole x Treatment combination | 15.45 d  25.86 ab  17.61 cd  22.35 abc  26.01 ab  25.20 ab  26.06 ab  28.05 a  23.94 ab  23,17 abc  20.04 bcd  22,35 abc  ns  ns  \*\* | 21.20 d  32.05 cd  42.36 c  32.40 cd  45.75 cb  58.69 ab  36.44 c  59.08 ab  65.41 a  35.91 c  60.38 a  67.35 a  ns  ns  \*\* | 3.92 abc  2.71 abc  2.43 abc  2.88 abc  3.90 abc  4.10 ab  3.73 abc  4.18 a  2.79 abc  2.00 c  2.96 abc  2.16 bc  ns  ns  \*\* | 3.19 cd  2.39 d  5.74 bcd  7.45 a  7.06 abc  11.10 a  2.91 cd  6.16 bcd  8.54 ab  5.18 bcd  7.25 abc  5.45 bcd    ns  ns  \*\* | |

Note: Interaction is significant at P ≤ 0.05 (\*\*), the main plot and subplot are not significant (ns). Different letters for the same column indicate significant differences according to the DMR test at 95%.

**Table 5.** Impact of single factor support pole types and combination of nutrient doses with the number of tendrils retained to germination percentage, internode number, leaves number, shoot height at 3 months after planting of cutting.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Gemination percentage (%) | Internodes number | Leaves number | Shoot height  (cm) |
| **Main plot: Types of pole**  Live plant pole  Artificial pole  **Subplot: Treatment combination**  Conventional, recommended doses (Control), 2 tendrils  Conventional, recommended doses (Control), 4 tendrils  Conventional, recommended doses (Control), 6 tendrils  Fertigation, 50% recommended doses, 2 tendrils  Fertigation, 50% recommended doses, 4 tendrils  Fertigation, 50% recommended doses, 6 tendrils  Fertigation, 75% recommended doses, 2 tendrils  Fertigation, 75% recommended doses, 4 tendrils  Fertigation, 75% recommended doses, 6 tendrils  Fertigation, 100% recommended doses, 2 tendrils  Fertigation, 100% recommended doses, 4 tendrils  Fertigation, 100% recommended doses, 6 tendrils  **Significance:**  Main Plot :Type of pole  Sub Plot :Treatment Combination  Interaction : Type of pole x Treatment combination | 96.70 a  97.50 a  93.50 d  96.75 abcd  96.00 bcd  98.00 abc  96.50 abcd  98.50 abc  95.50 cd  95.75 cd  99.25 ab  98.00 abc  98.50 abc  99.50 a  ns  \*\*  ns | 2.08 a  2.11 a  2.21 ab  2.05 b  1. 98 b  2.01 b  1.91 b  1.99 b  2.09 ab  2.18 ab  2.19 ab  2.40 a  2.03 b  2.11 ab  ns  \*\*  ns | 1.28 a  1.29 a  1.39 ab  1.22 bc  1.04 c  1.24 abc  1.20 bc  1.29 abc  1.35 ab  1.33 ab  1.29 abc  1.53 a  1.16 bc  1.36 ab  ns  \*\*  ns | 8.94 b  10.46 a  8.81 cd  7.87 de  7.38 e  9.20 bc  10.32 ab  9.89 abc  9.89 abc  10.66 a  10.45 ab  10.79 a  10.12 ab  10.99 a  \*\*  \*\*  ns |

Note: Subplot is significant at P ≤ 0.05 (\*\*), interaction and main plot are not significant (ns). Different letters for the same parameter indicate significant differences according to the DMRT test at 95%.

A picture containing tree, outdoor, conifer, plant

Description automatically generatedA picture containing tree, outdoor, plant, garden

Description automatically generated

poles wrapped with polyvinyl carpet

pole height 1.5 m

Figure 1. Black pepper plant: *Gliricidia* plant as a living pole (Left) and artificial pole (Right)

**Figure 2.** Starch content of main climbing from two types of support poles and treatment combination of nutrient doses and number of tendrils kept