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Effect of organic and NPK fertilizer rates on the growth and yield of sand ginger (*Kaempferia galanga* L.)

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ABSTRACT

Sand ginger (*Kaempferia galanga* L.) is a valuable medicinal and spice plant, traditionally used for various therapeutic purposes. However, overexploitation has led to a decline in its natural reserves, highlighting the need for sustainable cultivation. This study examines the combined effects of chemical (NPK) and microbial organic fertilizers on its growth and yield, providing insights for sustainable production and conservation in Vietnam. The field experiment was conducted from March 2023 to June 2024 at a local farmer's farm at Ayun commune, Mang Yang district, Gia Lai province, Vietnam. The study used a split-plot design with microbial organic fertilizer (Song Gianh) at four levels (0–3 t/ha) and NPK fertilizer at five levels (0–150 kg N, 0–150 kg P, O... , 0–110 kg K, O/ha). The results showed that the microbial organic fertilizer and NPK had a positive effect on the growth and yield of sand ginger. Fertilization at 3 t/ha of the organic microbial fertilizer with inorganic fertilizer levels of P2 (120 kg N, 120 kg P_2O_5 and 90 kg K_2O/ha) was the optimal dose for the highest growth and yield of sand ginger. Soil decomposed with the combined fertilizers increased organic matter and improved soil physical, chemical and biological properties. Therefore, the combined fertilizers can be used for sand ginger production.

Key words: Combined fertilization, *Kaempferia galanga*, microbial organic fertilizer, sand ginger, soil fertility

INTRODUCTION

Sand ginger (*Kaempferia galanga* L.) is a potential medicinal plant in many countries around the world (Shetu *et al.*, 2018; Kumar, 2020). Sand ginger has been used in folk medicine for a long time with many effects such as treating flatulence, expectorant, diuretic, antipyretic, hypertension, diabetes, respiratory diseases such as asthma and cough, rheumatic diseases such as sprains, fractures, dizziness, hives, intestinal ulcers (Shetu *et al.*, 2018; Chukwudi *et al.*, 2020; Kumar, 2020; Anami, 2024). In Vietnam, sand ginger is a native plant found in natural forests, nature reserves, and national parks and is grown by local people in many different ecological zones, especially under the canopy of trees (Nguyen *et al.*, 2019c; Nguyen *et al.*, 2023; Tran *et al.*, 2024). Sand ginger has long been used as a spice and folk medicine by local people. Over the years, the wild plants have been exploited by local people for use or sale on the market, which has led to a serious decline in the natural reserve of the species (Nguyen *et al.*, 2023). Researching cultivation processes suitable for local natural conditions to develop the production of this plant as a commodity, serving the conservation and development of indigenous genetic resources, and adding another plant to the list of crops serving the restructuring of the agricultural sector of some localities in Vietnam is an urgent issue today.

Many factors such as variety, fertilizer, season, planting density, shade affect the growth, yield and quality of sand ginger (Nguyen *et al.*, 2019a; Nguyen *et al.*, 2019b; Santosh and Sagar, 2022; Saitama *et al.*, 2023; Widaryato *et al.*, 2023) of which soil nutrient is the main one (Nguyet *at al.*, 2019b; Widaryato *et al.*, 2023). Fertilization plays a major role among cultural

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practices for improving soil fertility and increasing crop production. A combination of mineral and organic fertilizers provides the short-term and long-term nutritional needs for crop plants (Gao *et al.*, 2003; Luo *et al.*, 2024). The excessive use of chemical fertilizers containing high nutrient contents is the fastest way of boosting crop production due to its rapid availability and release for plant uptake (Mahmud *et al.*, 2021). Organic fertilizers, usually of animal or plant origin, can improve soil fertility by activating soil microbial biomass. Although nutrients are slowly released, organic fertilizers promote root initiation, root growth and development, provide good soil structure and enhance soil water retention; biologically, it promotes the growth of beneficial soil organisms (Gao *et al.*, 2023; Khan *et al.*, 2024). The objective of this study was to determine the combined effect of chemical fertilizers (NPK) and microbial organic fertilizers on the growth, yield of sand ginger. The results of the study provide a comprehensive understanding of the use of fertilizers for sand ginger production in Vietnam.

MATERIALS AND METHODS

The field experiments were conducted from March 2023 to June 2024 at a local farmer's farm at Ayun commune, Mang Yang district, Gia Lai province, Vietnam (N14°11′13.944″; E108°17′44.666″). The soil at the farm can be characterized as Ferralsols. The soil properties of the experimental sites are shown in Table 5. The weather parameters of the experiment period were daily recorded with an ATMOS-41 complex weather station (max temp: 37.2°C; min temp: 11.6°C; average temp: 23.0°C; rainfall: 1976.8 mm; humidity: 82.0%).

A split-plot design with three blocks (replications) was employed. The whole-plot factor was a microbial organic fertilizer named Song Gianh with four application levels, such as S0 (0 t/ha), S1(1 t/ha), S2(2 t/ha) and S3 (3 t/ha). Song Gianh is a commercially available organic fertilizer produced by Song Gianh Corp., Quang Binh, Vietnam; its properties are given in Table 1 (Hoang *et al.*, 2023). The split-plot factor was NPK fertilizers with 5 application levels such as P0 (0 NPK), P1 (150 kg N, 150 kg P_2O_5, 110 kg K_2O/ha), P2 (120 kg N, 120 kg P_2O_5, 90 kg K_2O/ha), P3 (90 kg N, 90 kg P_2O_5, 70 kg K_2O/ha) and P4 (60 kg N, 60 kg P_2O_5, 50 kg K_2O/ha). The area of each plot was 6.0 m^2 (1.2 m × 5.0 m). Sand ginger rhizomes collected from Kon Ka King National Park, Gia Lai, Vietnam, was individually planted in rows of 20 cm × 40 cm spacing. The whole amount of microbial organic fertilizer and phosphorus was applied as a basal. The remaining fertilizers were applied twice for the top dressing. The first top dressing application was at 120 days after planting with 50% K_2O and 50% N, and the second was at 180 days after planting with 50% K_2O and 50% N. As a control, no fertilizer was applied.

Table 1. Properties of the microbial organic fertilizer

Property	Value
pH (H_2O)	6.5
Total organic carbon	122 mg/g
Humic acid	0.318%
Total nitrogen	4.11 mg/g
Available nitrogen	10.1 mg (100/g)
Ammonium	14.7 mg/kg
Total phosphorus (as P_2O_5)	3.27 mg/g
Available phosphorus (as P_2O_5)	0.92 mg/g
Available potassium (as K_2O)	1504 mg/kg
Total potassium (as K_2O)	2.2 8 mg/g

Ten plants in each plot were randomly selected to record agronomic traits. Growth time was recorded for each stage (*e.g.*, days to germination, true leaf emergence, tillering, flowering and harvesting). The canopy diameter was measured at the widest part of the bush at 60, 90, 120, 150 and 180 days after planting. At harvest, these ten plants were harvested, and the number of rhizomes and fresh rhizome weight/plant, fresh rhizome weight/clump and fresh rhizome yield were counted and measured.

Soil samples were taken from a depth of 0-30 cm before arranging the experimental plots and after harvesting. All soil samples were transported to the Soil Science Laboratory, University of Agriculture and Forestry, Hue University for analysis.

Data were analyzed using SAS9.1 (SAS Institute Inc., Cary, NC, USA). Two-way ANOVA was used to compare the differences in agronomic traits and yield among treatments. In all cases, $P < 0.05$ was considered to be significant.

RESULTS AND DISCUSSION

The growth duration of a crop plant is greatly influenced by the varieties. However, fertilizers also have an important influence on the growth time of each growth stage of a plant (Muqtadir *et al.,* 2019; Nguyen and Tran, 2020; Nguyen and Tran, 2022). This indicator helps farmers to arrange proper crop calendars for their crops to avoid unsuitable conditions and to meet the market's requirements. Table 2 shows that the germination time had no statistically significant difference among treatments. The germination time of the sand ginger was about 22 - 24 days after planting. Thus, when the sand ginger is planted in a suitable environment, it will break the dormancy, stimulate germination without being affected much by fertilizers. Similarly, time required for true leaf emergence was non-significantly different among treatments, ranging from 39 and 46 days after planting. Although the impact of fertilizers on the time for true leaf emergence of the sand ginger plant did not have a clear difference among treatments, however, the plants grown in the base fertilized with phosphate and the microbial organic fertilizer tended to have a faster time for true leaf emergence than plants in treatments that were not fertilized. Especially in the treatments that were fertilized with high amounts of the organic microbial fertilizer, leaf growth was faster than in the treatments that were fertilized with low amounts of the organic microbial fertilizer or not fertilized. This shows that fertilizing the sand ginger plant with organic fertilizer will increase the ability to grow leaves faster.

There was a statistically significant difference in tillering time among treatments, ranging from 82 to 102 days after planting. Plants fertilized with high doses, especially with the organic microbial fertilizer, had shorter tillering time than plants in treatments with little or no fertilizer. Tillering time was shorter in treatments with high amounts of organic microbial fertilizers but no inorganic fertilizers (*e.g.*, 82, 83, 86 and 90 days in S3P1, S3P2, S3P3, and S3P3, respectively). On the contrary, plants have longer tillering time when fertilized with inorganic fertilizers but not organic fertilizers (e.g. 95, 96, 96 and 100 days in S0P1, S0P2, S0P3 and S0P4, respectively). Tillering time is one of the important yield components. When plants have an early tillering time, it will help increase the number of tubers, the accumulation time will be longer, creating conditions for increased yield and quality of agricultural products. Therefore, determining the appropriate

Table 2. Effects of fertilization on growth time (days after planting) of *Kaempferia galanga*

Treatment	Germination	True leaf emergence	Tillering	Flowering	Harvesting
S0P0	22.7	46.7	102.3	119.3	286.7
S0P1	23.7	41.0	94.7	119.7	286.3
S0P2	23.7	43.0	96.0	123.7	290.7
S0P3	22.7	44.7	96.7	123.7	290.3
S0P4	24.3	45.0	100.3	121.3	287.7
S1P0	24.3	43.7	95.0	124.3	291.7
S1P1	24.3	41.7	92.0	131.3	301.0
S1P2	22.7	41.0	92.3	131.7	300.0
S1P3	22.3	41.0	93.3	128.7	303.3
S1P4	22.3	42.0	93.7	127.0	305.0
S2P0	22.7	42.3	94.0	131.3	308.7
S2P1	23.0	40.7	90.3	130.0	312.3
S2P2	24.3	40.3	89.7	131.7	310.3
S2P3	24.0	40.3	92.3	128.3	309.0
S2P4	24.7	41.0	93.0	128.7	310.7
S3P0	23.7	42.0	92.3	125.3	309.0
S3P1	23.7	39.0	82.0	126.7	311.7
S3P2	22.0	39.0	83.3	129.7	310.0
S3P3	23.0	40.7	85.7	130.3	309.3
S3P4	23.3	40.3	90.0	132.0	305.3
CV%	9.6	11.2	7.4	12.0	13.7
F_S	0.21^{ns}	2.24^{ns}	7.91*	538.99*	3.07*
F_P	0.2^{ns}	0.95^{ns}	2.07^{ns}	63.47*	0.07^{ns}
F_{SP}	0.39^{ns}	0.54^{ns}	1.53^{ns}	0.21^{ns}	0.16^{ns}

Values in a column followed by same letters are not significantly different by two-way ANOVA at P<0.5; *: Significant difference (P<0.05); ns: Not Significant difference.

amount of fertilizer for plants to help plants tiller well is very important to help plants produce high yields.

Table 2 shows that there was no statistically significant difference in the combined effect of the microbial organic and NPK fertilizers on the time from planting to flowering and the time from planting to harvesting of the sand ginger plant (*P*> 0.05), ranging from 121 to 132 days and 286 to 311 days, respectively. However, low levels of the microbial organic or NPK fertilizers or no fertilizers tend to shorten the time from planting to flowering and the time from planting to harvesting compared to plants that are provided with adequate nutrients. Shortening the growth period of the plant will also affect the accumulation time of the tubers, affecting the yield and quality of the sand ginger plant tubers. Our results were in agreement with the results of some authors who reported that fertilizer significantly affected on growth time of crop plants. Muqtadir *et al.* (2019) reported that combined inorganic fertilizers with high levels of organic manure resulted in decrease in days to harvest of okra. Our previous study indicated that the total growth time of the streaky maize was shorter in humic acid organic fertilizer treatments (Nguyen and Tran, 2020); and organic fertilizer caused the growth time of okra to be shorter (Nguyen and Tran, 2022). However, the days to first harvest of okra plants were not significantly different when organic and inorganic fertilizers were applied (Mateo *et al.*, 2010). Therefore, how to properly apply inorganic and organic fertilizers in the right amounts so that the sand ginger plants can grow best is an important issue.

Leaves are the photosynthetic organs that create organic matter for plants. Plants will create biomass and yield high yields when their leaves grow well. Canopy diameter is a very important indicator of plant growth. Table 3 shows that the canopy diameter of sand ginger plants in the treatments over the monitoring periods all had statistically significant differences. The canopy diameters reached higher values when fertilizer application rates were increased. In particular, treatments using high amounts of organic fertilizer have wider canopy diameters. The treatments that applied less fertilizer, especially in the treatment that did not apply fertilizer (S0P0), had the lowest canopy diameter, and the plants grew poorly. This may explain that the sand ginger is a tuber plant,

Table 3. Effects of fertilization on canopy diameter of *Kaempferia galanga* at different days after planting (DAP)

Treatment	60	90	120	150	180
S0P0	8.1 d	10.0 e	14.1 f	16.2 d	18.8 e
S0P1	8.2 cd	11.5 abcde	17.3 cdef	18.2 bcd	19.8 de
S0P2	8.2 cd	11.3 abcde	15.2 ef	17.2 bcd	21.6 bcde
S0P3	8.4 bcd	10.6 cde	15.9 def	16.7 cd	21.0 bcde
S0P4	8.4 bcd	10.5 de	15.3 ef	16.5 cd	20.8 cde
S1P0	8.6 bcd	11.0 bcde	16.0 def	17.0 cd	21.4 bcde
S1P1	8.3 cd	12.4 abcd	21.9 abc	22.6 abc	28.4 abcd
S1P2	8.4 bcd	12.3 abcd	21.3 abcd	22.4 abcd	26.4 abcde
S1P3	8.7 bcd	11.8 abcde	19.7 abcde	22.1 abcd	24.8 abcde
S1P4	8.7 bcd	11.7 abcde	19.5 abcdef	21.1 abcd	24.4 abcde
S2P0	8.5 bcd	11.3 abcde	17.0 cdef	17.5 bcd	22.4 bcde
S2P1	9.2 bcd	12.7 abc	23.5 ab	24.6 a	29.6 ab
S2P2	9.5 abcd	12.7 abc	22.9 ab	23.5 ab	29.5 ab
S2P3	9.6 abcd	12.4 abcd	22.8 ab	23.4 ab	28.4 abcd
S2P4	9.8 abcd	11.8 abcde	21.2 abcd	21.5 abcd	25.8 abcde
S3P0	8.3 cd	11.6 abcde	19.1 bcdef	19.8 abcd	24.4 abcde
S3P1	9.2 bcd	13.3 a	24.7 a	25.9 a	31.6 a
S3P2	9.9 abc	13.2 a	24.5 ab	25.8 a	31.4 a
S3P3	10.1 ab	12.8 ab	24.3 ab	25.3 a	31.0 a
S3P4	11.1 a	12.6 abcd	22.8 ab	23.5 ab	29.4 abc
CV%	9.6	9.2	14.1	15.4	17.2
F_S	8.74*	8.77*	23.03*	16.19*	17.41*
F_P	2.86*	3.92*	7.28*	6.18*	4.89*
F_{SP}	2.65*	2.12*	4.68*	3.27*	2.72*

Values in a column followed by same letters are not significantly different by two-way ANOVA at P<0.5; *: Significantly different at P<0.05.

Table 4. Effects of fertilization on yield components and yield of *Kaempferia galanga*

Treatment	Number of rhizomes/plant	Rhizome fresh weight (g/plant)	Rhizome fresh weight (g/clump)	Yield (fresh) (t/ha)
S0P0	5.6 g	12.1 d	68.4 f	8.6 g
S0P1	7.5 fg	13.4 abcd	100.1 f	11.8 g
S0P2	6.2 g	12.7 bcd	78.9 f	9.7 g
S0P3	5.8 g	12.3 d	74.4 f	8.9 g
S0P4	5.7 g	12.3 d	70.1 f	8.8 g
S1P0	6.0 g	12.4 cd	74.6 f	9.3 g
S1P1	12.5 cde	16.5 ab	199.6 cde	22.6 bcd
S1P2	11.7 de	16.1 abcd	188.4 de	21.9 bcde
S1P3	10.5 ef	15.6 abcd	161.8 e	18.7 de
S1P4	10.4 ef	15.3 abcd	157.9 e	17.1 ef
S2P0	6.4 g	12.8 bcd	79.2 f	9.8 g
S2P1	15.1 abc	16.7 ab	253.1 ab	26.6 ab
S2P2	14.5 bcd	16.7 ab	240.6 abc	25.1 bc
S2P3	12.7 cde	16.5 ab	208.7 cd	23.2 bcd
S2P4	11.6 de	15.7 abcd	179.0 de	20.3 cde
S3P0	8.1 fg	13.4 abcd	107.1 f	12.9 fg
S3P1	17.9 a	17.5 a	281.2 a	31.6 a
S3P2	17.6 ab	17.3 a	275.5 a	31.5 a
S3P3	16.9 ab	16.9 a	264.7 a	30.1 a
S3P4	13.1 cde	16.4 abc	216.8 bcd	23.5 bcd
CV%	16.7	14.0	14.2	15.28
F_S	54.54*	11.32*	112.21*	84.76*
F_P	23.59*	5.89*	53.33*	38.82*
F_{SP}	16.41*	2.71*	33.01*	24.69*

Values in a column followed by same letters are not significantly different by two-way ANOVA at P<0.5; *: Significantly different (P<0.05).

when the soil is fertilized with a high amount of organic fertilizer, it will be loose, helping the roots to grow strongly, and the absorption of nutrients when fertilized will become better. It helps the plant grow healthier leaves than plants that are fertilized with little or no organic fertilizer. Nguyen *et al.* (2019b) reported that when fertilized with microbial organic fertilizer or biological organic fertilizer at 3 tons/ha, the growth of the foliage of sand ginger plants was better than that of the plants fertilized with low fertilizer levels or no fertilizer. Regarding NPK fertilization for sand ginger plants, the foliage growth was best when fertilized with NPK at 150 - 180 kg N/ha. 150 - 180 kg P_2O_5/ha. 110 - 130 kg K_2O/ha. The results of Nguyen *et al.* (2019b) are consistent with our research results when fertilized with microbial organic fertilizer at 3 t/ha, the sand ginger plants grew better than when fertilized with little or no microbial organic fertilizer and plants supplemented with NPK fertilizer will also help the foliage growth to be better. This is the premise for nutrient accumulation for high yield and quality.

Yield is a key agronomic trait that is targeted to improve crop productivity. Therefore, yield is the main trait used to evaluate the performance of crop plants to fertilizers. Fertilizer for higher yields shows greater adaptability to local farmers (Tran and Tran, 2024). Table 4 shows that the yield components (*e.g.*, number of rhizomes/plants, rhizome fresh weight/plant and fresh rhizome weight/ clump) and yield of the sand ginger plants were significantly affected by the combined fertilizers (*P*<0.05). The treatments fertilized with high amounts of fertilizer, especially the organic microbial fertilizer, gave a higher number of rhizomes per plant, fresh rhizome weight/plant, and fresh rhizome weight per clump than the plants grown in treatments with little or no fertilizer. The sand ginger plant is a tuber plant, being fertilized with the organic microbial fertilizer helped the soil become loose, helped the root system grow well, leading to more branching and tuber production than plants fertilized with little or no organic microbial fertilizer. At the same time, the number of rhizomes and the rhizome weight were also proportional to the growth of the canopy. Treatments with good canopy growth also gave a high number and heavy weight of rhizomes. The fresh yield ranged between 8.6 and 31.6 tons/ha. Increasing the amount of organic microbial fertilizer resulted

Table 5. Soil properties of the experimental treatments before planting and after harvesting

Treatment	pH	OM (%)	Total N (%)	Total P (%)	Total K (%)	Available N (mg/100 g)	Available P (mg/100 g)	Available K (mg/100g)
Before planting	6.53	4.8	0.19	0.125	0.214	5.2	*11.2*	16.1
After planting								
S0P0	6.51	4.5	0.19	0.121	0.211	5.4	11.1	15.8
S0P1	6.05	4.3	0.20	0.123	0.210	5.6	11.3	16.9
S0P2	6.11	4.5	0.18	0.120	0.212	5.2	11.2	16.6
S0P3	6.14	4.6	0.18	0.125	0.214	5.6	11.5	16.2
S0P4	6.25	4.5	0.19	0.124	0.213	5.1	11.6	15.9
S1P0	6.54	5.4	0.21	0.122	0.212	5.5	11.2	15.2
S1P1	6.26	5.3	0.20	0.124	0.215	5.6	11.6	16.5
S1P2	6.29	5.3	0.24	0.126	0.219	5.3	11.4	16.3
S1P3	6.32	5.4	0.25	0.126	0.221	5.2	11.5	16.2
S1P4	6.31	5.2	0.22	0.133	0.220	5.2	11.2	16.6
S2P0	6.53	6.2	0.23	0.133	0.222	5.4	11.5	16.2
S2P1	6.28	6.3	0.25	0.129	0.215	5.7	11.3	16.0
S2P2	6.30	6.3	0.24	0.128	0.221	5.7	11.4	16.6
S2P3	6.37	6.1	0.26	0.124	0.219	5.3	11.6	16.3
S2P4	6.41	6.3	0.27	0.126	0.218	5.4	11.4	16.3
S3P0	6.55	6.7	0.25	0.133	0.220	5.2	11.3	16.3
S3P1	6.44	7.8	0.29	0.133	0.224	5.7	11.8	16.5
S3P2	6.49	7.3	0.28	0.130	0.223	5.8	11.5	16.5
S3P3	6.50	7.4	0.26	0.127	0.229	5.3	11.6	16.6
S3P4	6.50	7.1	0.27	0.127	0.226	5.7	11.5	16.2

OM: Organic matter; N: Nitrogen; P: Phosphorus; K: Potassium.

in higher yield. The highest yield reached 30.1 - 31.6 t/ha in the treatments of fertilizing with 3 t/ha of the organic microbial fertilizer with inorganic fertilizer levels of P1, P2 and P3, while there was a difference among the levels of P1, P2 and P3. These observations were consistent with the findings of a number researchers (*e.g.*, Nguyen *et al.*, 2019b; Saitama *et al.*, 2023; Widaryanto *et al.*, 2023) who revealed that inorganic and organic fertilizers, especially higher organic fertilizer application had a positive effect on the yield of sand ginger.

As the soil was low in N, P, K and organic carbon contents (Table 5). the positive combined effect of the microbial organic and NPK on sand ginger plants could be due to the contribution made by organic and NPK, especially the microbial organic fertilizer, to fertility status of the soil (Table 5). Increasing macro and micro nutrient and improving the physio-chemical properties of the soil (Table 5) by decomposing the combined fertilizers into the soil could resulted in high growth and yield of sand ginger plants.

CONCUSION

It is concluded that the microbial organic fertilizer named Song Giang and NPK had a positive effect on the growth and yield of sand ginger. Fertilization at 3 t/ha of the organic microbial fertilizer with inorganic fertilizer levels of P2 (120 kg N, 120 kg P_2O_5 and 90 kg K_2O/ha) were the optimal doses for the highest growth and yield of sand ginger. Soil decomposed with the combined fertilizers increased organic matter and improved soil physical, chemical and biological properties. Therefore, the combined fertilizers can be used for sand ginger production. However, it is necessary to study the effect of fertilizers on the quality of sand ginger to develop an appropriate cultivation process for growers.

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