STUDY ON SOME AGRITECHMQUES TO IMPROVE YIELD AND QUALITY OF WHITE TUMERIC (*Curcuma zedoaria* Rosc.) IN THANH TRI DISTRICT, HANOI CITY

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ABSTRACT

This study examined the effects of several agro-techniques on yield and quality of *Curcuma zedoaria* Rosc. A split-plot design incorporating four levels of K_2O fertilizer (60, 90, 120 and 150 kg/ha) and three levels of plant spacing (25 x 35, 45 x 35, 65 x 35 cm) were implemented. The results revealed that optimal rhizome yield of white turmeric was achieved when cultivated with a planting spacing of 25 x 35 cm and applying 90 and 120 kg/ha of K_2O fertilizer, yielding within the range of 24.7 - 25.5 tons/ha; essential oil yield from 106.15 - 108.45 l/ha. Moreover, a randomized complete block design was conducted to examine the effect of four different harvest times on the yield and quality of white turmeric. Harvesting when 50% of leaves withered to completely withered resulted in the highest yields, ranging from 25.53 - 26.20 tons/ha, with essential oil yield from 109.19 - 119.56 l/ha, respectively, thus achieving the highest economic efficiency.

Keywords: *White turmeric, Curcuma zedoaria* Rosc., *plant spacing, potassium, yield, essential oil.*

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1. INTRODUCTION

Curcuma zedoaria, commonly known as "zedoary" and "white turmeric," is a valuable plant native to northeast India and Indonesia, extensively cultivated in various regions such as India, Southeast Asia, Thailand, Indonesia, Japan, and China [1, 2]. The rhizome resembles ginger externally and turmeric internally. Its powder has a unique aroma but a bitter taste, and it can be used as a substitute for ginger for culinary purposes. White turmeric has been utilized to alleviate various health issues, including hematologic abnormalities, vascular problems, injuries, digestive concerns, skin conditions and infections. Multiple parts of *C. zedoaria* are studied to demonstrate pharmacological properties, notably anticancer and anti-inflammatory effects, antiallergy, antibacterial, and antifungal activities [3 - 8]. The essential oil derived from its rhizomes contains predominantly sesquiterpenoids and monoterpenoids, with significant components including *epicurzerene*, *curzerene*, *curdione*, *curzerenone* and *debromofiliforminol* [1, 2, 9, 10]. Its diverse chemical composition and pharmacological properties have elevated its status in traditional medicine and modern pharmaceutical research, highlighting its global significance [1].

Eighteen genetic resources of white turmeric were collected from 5 different ecological regions in Vietnam and their morphological characteristics, yield and quality of these 18 genetic resources were preliminarily described [11]. However, information regarding plant spacing, fertilizer regimes, and harvest timing for white turmeric in Vietnam remained limited. Therefore, this study aims to assess the cultivation practices that influence the yield and quality of white turmeric for its optimized production.

2. MATERIALS AND METHODS

2.1. Materials

The rhizome of the NgT-01 cultivar was selected from white turmeric (*Curcuma zedoaria*

Rosc.) germplasm resources conserved by the National Research Center for Medicinal Plant Germplasm and Breeding - National Institute of Medicinal Materials. The planted rhizome, prepared from the mother plant, was cut into pieces 5 cm long and at least 1.5 cm in diameter.

The experiments were conducted at the National Research Center for Medicinal Plant Germplasm and Breeding, Ha Noi, Vietnam.

2.2. Experiment design

Experiment 1. Investigate the effects of potassium fertilizer and plant spacing on the yield and quality of white turmeric.

A split-plot experiment with three replications was designed to determine the effect of potassium fertilizer levels on the yield and quality of white turmeric planted at different plant spacings.

The main factor, potassium fertilizer (K_2O fertilizer), with four levels (K1 to K4), was completely randomly assigned to the main plots, and the sub-factor, plant spacing (M1 to M3 levels), was assigned to smaller plots. Details of K_2O levels and plant spacings were described as follows:

K_2O levels: K1: 60 kg K_2O K2: 90 kg K_2O	Plant spacings: M1: 25 x 35 cm M2: 45 x 35 cm
K3: 120 kg K_2O	M3: 65 x 35 cm
K4: 150 kg K_2O	

The area for each plot was 10 m^2/treatment/replication. Each treatment was applied with the same amount of 4 tones of micro-biofertilizer, 90 kg N and 65 kg P_2O_5/ha and 500kg of agricultural limes per hectare. The total amount of micro-biofertilizer, P_2O_5 and agricultural limes was applied as a basal application, while N and K were split three times. At the seedling stage (30 - 40 days after planting), 1/3 of the total amount of N was applied. During the branching and initial rhizome boosting stage (90 - 100 days after planting), the remaining 2/3 of N and 1/2 of K were applied. Finally, the remaining K was used at the rhizome development stage (170 - 180 days after planting).

The experiment was conducted from March 2023 to January 2024.

Experiment 2. Examine the influence of harvest time on the yield and quality of white turmeric.

The experiment was conducted in a randomized complete block design with replications [12] for two consecutive years. The treatment plot size was 20 m^2. The treatments included four levels of harvesting time as follows:

+ TH1: In the first year and when the leaves start withering

+ TH2: In the first year, when 50% of the leaves withered

+ TH3: In the first year, when 100% of the leaves withered (completely withered)

+ TH4: In the second consecutive year, 100% leaves withered

All plants were grown from March 15 with a spacing of 25 x 35 cm. The fertilizer regimes of 4 tones of micro-biofertilizers + 90 kg N + 65 kg P_2O_5 + 120 K_2O were applied in this experiment.

In both experiments, all necessary agronomical and field management practices were implemented in reference to the Guidelines for cultivation and care techniques for Yellow turmeric [13]. Pests and disease investigation were implemented according to National technical regulations on Surveillance methods of plant pests [14].

2.3. Data collection and analysis

A five-diagonal point sampling was employed. Ten plants per treatment were collected at the active vegetative stage (seven months after planting). Growth parameters such as plant height, number of leaves/cluster, number of tillers/cluster, leaf length, leaf width and leaf area index (LAI) were recorded. Yield and yield components, including rhizome length (cm), rhizome diameter (cm), individual yield (fresh yield/cluster) (g), rhizome yield (tons/ha) and fresh/dry biomass ratio, were collected at harvest (nine months after planting-for experiment 1 and at the specific harvesting time in experiment 2).

Essential oils were quantified using the steam distillation method according to Vietnam Pharmacopeia V [15].

Essential oil yield was measured at the harvesting time, including total essential oil content (%) of dry rhizome and essential oil yield (l/ha) = dry yield x essential oil content.

Data were processed using Microsoft Excel and Irristat version 5.0 software.

3. RESULTS AND DISCUSSIONS

3.1. Effects of potassium fertilizer and plant spacings on yield, quality and economic efficiency of white turmeric

3.1.1. Effects of potassium fertilizer and plant spacings on growth of white turmeric

The effect of potassium fertilizer regimes and plant spacings on the growth parameters of turmeric are shown in table 1.

Different potassium exhibited significant effects on leaf number, tiller number, leaf length, and LAI. Potassium level K4 showed the highest plant height (147.5 cm), higher number of leaves (25.3), higher number of tillers (5.8), most extended leaf length (54.4 cm), and leaf width (13.9 cm) and highest LAI (6.3). The effect of K3 was statistically comparable to K4 for plant height (145.8 cm), tiller number (5.6), leaf width (13.3 cm) and LAI (6.1). Lowest plant height (142.0), minimum number of leaves (19.7), number of tillers (4.5), leaf length (46.2 cm), leaf width (13.6 cm) and lowest LAI (5.3) was obtained in K1 level.

Plant spacing was found to have a significant effect only on the number of tillers and LAI, while no significant difference was obtained in plant height, number of leaves, lead length and leaf width. M2 resulted in having tallest plants (145.9 cm), leaf number (23.3), tiller number (5.6), leaf length (51.2 cm) and leaf width (13.3 cm) but lower LAI (4.9). M1 showed a comparable lowest value in these growth parameters but possessed the highest LAI of 9.0. The interaction between potassium levels and plant spacing was found only in leaf width.

Table 1. Effects of potassium fertilizer and planting spacing on the growth of white turmeric

Potassium levels	Plant spacing	Plant height (cm)	Leaf number (leaves/cluster)	Tillers number (Tillers/cluster)	Leaf length (cm)	Leaf width (cm)	LAI
K1	M1	142.5	19.0	4.1	44.0	12.0	8.3
	M2	143.4	20.0	4.7	47.5	14.2	4.3
	M3	140.0	20.0	4.7	47.1	14.7	3.4
K2	M1	143.0	20.0	4.7	48.6	12.2	8.9
	M2	145.0	22.0	5.7	49.8	12.7	4.8
	M3	144.8	22.0	5.7	49.6	12.8	3.6
K3	M1	144.3	23.0	4.7	51.0	13.2	9.2
	M2	147.0	25.0	5.7	53.4	12.9	5.2
	M3	146.0	24.0	6.3	43.3	13.7	3.9
K4	M1	147.0	24.0	4.7	53.4	14.0	9.5

	M2	148.0	26.0	6.3	54.2	13.4	5.4
	M3	147.6	26.0	6.3	55.7	14.4	4.2
Average $_{K1}$		142.0b	19.7d	4.5c	46.2b	13.6a	5.3c
Average $_{K2}$		144.3ab	21.3c	5.4b	49.3ab	12.6a	5.7b
Average $_{K3}$		145.8ab	24.0b	5.6ab	49.2b	13.3a	6.1a
Average $_{K4}$		147.5a	25.3a	5.8a	54.4a	13.9a	6.3a
	Average $_{M1}$	144.2a	21.5b	4.6b	49.2a	12.8a	9.0a
	Average $_{M2}$	145.9a	23.3a	5.6a	51.2a	13.3a	4.9b
	Average $_{M3}$	144.6a	23.0a	5.8a	49.0a	13.9a	3.7c
	$F_{(K)}$	0.3^{ns}	42.6***	24.4***	3.8*	2.5^{ns}	26.6***
	$F_{(M)}$	2.1^{ns}	6.9^{ns}	10.4*	0.28^{ns}	0.3^{ns}	151.9**
	$F_{(KxM)}$	0.2^{ns}	0.3^{ns}	0.9^{ns}	1.0*	1.1^{ns}	0.5^{ns}
	$CV_{\%}$	3.4	5.2	8.0	10.6	8.5	4.3

*K1: 60 kg K_2O, K2: 90 kg K_2O, K3: 120 kg K_2O, K4: 150 kg K_2O; M1: 25 x 35 cm, M2: 45 x 35 cm, M3: 65 x 35 cm. Means with the same letter in each column are not significantly different at $p < 0.05$ by LSD test. *, **,***: significant at $p < 0.05$, $p < 0.01$, $p < 0.001$; ns: non-significant*

3.1.2. Effects of potassium fertilizer and plant spacings on yield and yield components of white turmeric

The application of potassium had different effects on the yield and yield components of white turmeric plants (Table 2). Potassium levels had a significant effect on rhizome length and individual yield, while plant spacings statistically influenced actual yield.

Specifically, at higher levels of potassium (K2, K3 and K4), the rhizome lengths obtained were 6.3 mm, 6.6 mm, and 6.8 mm, respectively. In contrast, applying K1 (60 kg/ha) yielded remarkably shortest rhizome length of 5.9 mm. The rhizome diameters were not significantly affected by the potassium levels. Individual yield, measured as the weight of individual turmeric clusters, ranged from 314.0 - 340.0 g/cluster. Applying different amounts of potassium also significantly affected individual yields. Higher individual yield (338.3 g/cluster) was found at K4 level and considerably higher than K1 level (314.7 g/cluster) and K2 level (322.3 g/cluster). However, there were no statistical differences in the actual yield of white turmeric among K levels. The average actual yield ranged from 16.1 tons/ha (K1) to 17.4 tons/ha (K4).

Plant spacing tends to slightly increase rhizome length, diameter, and individual yield compared to narrower spacings; however, it was not significantly different. However, regardless of applying different fertilizer regimes, different plant spacings resulted in statistical differences in the actual rhizome yield. The actual yield was significantly different due to the smaller spacing, resulting in more plants per unit area; in detail, M1 spacing (25 x 35 cm) yielded an average of 24.8

tons/ha. M2 spacing (45 x 35 cm) achieved an average of 15.3 tons/ha and the lowest yield (10.3 tons/ha) when planted at M3 spacing (65 x 35 cm).

In this study, the actual yield was significantly affected by the spacing, which disagreed with the work of Joy *et al.* (2002) [16], who reported a non-significant effect in their different spacing settings.

Table 2. Effects of potassium fertilizer and plant spacings on yield and yield components of white turmeric

Potassium levels	Plant spacing	Rhizome length (cm)	Rhizome diameter (cm)	Individual yield (g/cluster)	Fresh-dry ratio	Actual yield (tons/ha)
K1	M1	5.7	1.58	315	3.52	24.0
	M2	5.9	1.60	314	3.58	14.3
	M3	6.0	1.62	315	3.58	10.1
K2	M1	6.2	1.68	320	3.56	24.7
	M2	6.5	1.73	322	3.59	15.0
	M3	6.2	1.72	325	3.57	10.2
K3	M1	6.5	1.70	330	3.55	25.0
	M2	6.8	1.73	335	3.63	15.7
	M3	6.4	1.74	330	3.54	10.4
K4	M1	6.7	1.74	335	3.50	25.5
	M2	7.0	1.75	340	3.61	16.0
	M3	6.6	1.78	340	3.60	10.61
Average $_{K1}$		5.87c	1.60a	314.7b		16.1a
Average $_{K2}$		6.30b	1.71a	322.3b		16.6a
Average $_{K3}$		6.57a	1.72a	331.7ab		17.0a
Average $_{K4}$		6.77a	1.76a	338.3a		17.4a
	Average $_{M1}$	6.28a	1.68a	325.0a		24.80a
	Average $_{M2}$	6.55a	1.70a	327.7a		15.25b
	Average $_{M3}$	6.30a	1.72a	327.5a		10.34c
	$F_{(K)}$	12.3***	0.8^{ns}	6.0**		0.6^{ns}

	$F_{(M)}$	0.33^{ns}	1.7^{ns}	0.2^{ns}		1577.4***
	$F_{(KxM)}$	0.4^{ns}	0.01^{ns}	0.1^{ns}		0.1^{ns}
$CV_{\%}$			13.6	3.9	-	12.2

*Note: K1: 60 kg K_2O, K2: 90 kg K_2O, K3: 120 kg K_2O, K4: 150 kg K_2O; M1: 25 x 35 cm, M2: 45 x 35 cm, M3: 65 x 35 cm. Means with the same letter in each column are not significantly different at $p<0.05$ by LSD test. *, **,***: significant at $p<0.05$, $p<0.01$, $p<0.001$; ns: non-significant.*

3.1.3. Effects of potassium fertilizer and plant spacings on quality of white turmeric

The quality of white turmeric medicinal herbs is managed according to Vietnam Pharmacopoeia V, and the total essential oil content is required to be not less than 1.0%. In this study, the attained oil content ranged from 1.38% (K1M1) to the highest of 1.59% (K4M3), which meets the Vietnam Pharmacopeia V requirements.

Analysis data presented in table 3 showed a decrease in total essential oil content across all plant spacings in K1 treatment with an average of 1.42. Higher levels of potassium applications (K2, K3, and K4) increased the total essential oil content, with average values ranging from 1.55% (K2) to 1.59% (K4).

The essential oil yield of all treatments fluctuated from 40.1 l/ha (K1M3) to 112.2 l/ha (K4M1). In terms of plant spacing, rhizome harvested within all M3 spacing exhibited the lowest essential oil yield (averaging 44.53 l/ha) compared to both M2 spacing (65.04 l/ha) and M1 spacing (105.22 l/ha) (Table 3).

The study determined that total essential oil content was comparably higher than that of Joy *et al.* (2002) [16]. This discrepancy suggests that factors beyond planting spacing, such as soil composition, climate conditions, cultivation techniques, or plant genetics, may have contributed to the differences in yield.

Table 3. Effects of planting spacing and potassium fertilizer on the essential oil content of white turmeric

Potassium levels	Plant spacing	Total essential oil content (%)	Essential oil yield (l/ha)
K1	M1	1.38	94.09
	M2	1.45	57.92
	M3	1.42	40.10
K2	M1	1.53	106.15
	M2	1.56	65.18
	M3	1.56	44.57
K3	M1	1.54	108.45
	M2	1.56	67.47
	M3	1.58	46.60

K4	M1	1.54	112.2
	M2	1.57	69.58
	M3	1.59	46.86
Average $_{K1}$		1.42	64.04
Average $_{K2}$		1.55	71.97
Average $_{K3}$		1.56	74.17
Average $_{K4}$		1.57	76.21
	Average $_{M1}$	1.51	74.27
	Average $_{M2}$	1.55	78.66
	Average $_{M3}$	1.56	83.68

Note: K1: 60 kg K_2O, K2: 90 kg K_2O, K3: 120 kg K_2O, K4: 150 kg K_2O; M1: 25 x 35 cm, M2: 45 x 35 cm, M3: 65 x 35 cm.

3.1.4. Effects of potassium fertilizer and plant spacings on the economic efficiency of white turmeric

The economic efficiency of growing turmeric is directly impacted by factors such as planting spacing and the amount of applied fertilizer. Plant spacing will determine the amount of rhizome used for planting, which is the most crucial input cost for turmeric cultivation [17] while fertilizers play a critical role in enhancing yield and quality.

In this study, total costs for white turmeric cultivation are related to the cost of rhizome, labor, fertilizers and plant protection chemicals. The total revenue was calculated by multiplying the total rhizome production per ha (kg/ha) and the market price per kilogram of rhizome.

Table 4. Effect of potassium fertilizer and plant spacing on economic efficiency of white turmeric

Unit: Million VND/ha

Potassium levels	Plant spacing	Total costs	Total revenue	Profit
K1	M1	284.16	360.00	75.84
K2		285.17	370.50	85.33
K3		286.17	375.00	88.83
K4		287.17	382.50	95.33
Average		*285.67*	*372.00*	*86.33*
K1	M2	268.94	215.31	-53.63
K2		269.94	217.73	-52.21
K3		270.94	223.33	-47.61

K4		271.94	226.67	-45.27
Average		*270.44*	*220.76*	*-49.68*
K1	M3	263.07	151.62	-111.45
K2		264.08	153.00	-111.08
K3		265.08	156.66	-108.42
K4		266.08	159.16	-106.92
Average		*264.58*	*155.11*	*-109.47*

Note: K1: 60 kg K_2O, K2: 90 kg K_2O, K3: 120 kg K_2O, K4: 150 kg K_2O; M1: 25 x 35 cm, M2: 45 x 35 cm, M3: 65 x 35 cm.

In this experiment, the economic efficiency of potassium fertilizer and plant spacing in white turmeric cultivation was presented in table 4. The profitability of each treatment was affected by varying levels of potassium fertilizer and plant spacing, while other factors (labor costs, cultivation costs, selling price and input rhizome) remained constant. Data showed that the narrow spacing (M1) in white turmeric cultivation gained the highest revenue on average of VND 372.00 million/ha, accompanied by the highest costs of VND 285.67 million/ha, resulting in the highest profit of VND 86.33 million/ha. Notably, employing M2 and M3 spacing of 65 x 35 cm causes a deficit, with losses ranging from VND -111.46 to -45.28 million per hectare. Consequently, optimizing economic efficiency involves utilizing a fertilizer within the 90 - 150 kg/ha range (K3 and K4) and adopting a 25 x 35 cm plant spacing.

3.2. Effect of harvest time on yield and quality of white turmeric

3.2.1. Effect of harvest time on the yield and yield components of white turmeric

Turmeric is a perennial plant characterized by withering leaves in the winter and regrowing in the following spring. A longer growth duration results in higher dry mass accumulation and higher yield [18].

Table 5. Effect of harvest time on yield and yield components of white turmeric

Harvest time	Rhizome length (cm)	Rhizome diameter (cm)	Rhizome weight/cluster (g)	Actual yield (tons/ha)
TH1	6.00	1.59	313.00	20.37
TH2	6.50	1.70	326.00	25.53
TH3	6.80	1.75	334.00	26.20
TH4	7.40	2.03	400.50	31.33
$LSD_{0,05}$	*0.92*	*0.25*	*44.97*	*2.31*
$CV_{\%}$	*6.9*	*7.2*	*6.6*	*4.5*

TH1: 1st-year harvest when the leaves start withering; TH2: 1st-year harvest when 50% of the leaves withered; TH3: 1st-year harvest when 100% of the leaves withered (completely withered); TH4: 2nd consecutive year when 100% leaves withered.

Timing in harvesting increased rhizome length, rhizome diameter, and cluster rhizome weight (Table 5). Harvesting in the second consecutive year when the leaves were 100% dead (TH4) exhibited a significantly longer rhizome (7.4 cm), greater rhizome diameter (2.03 cm), and higher rhizome weight (390 g/cluster) than TH1, TH2 and TH3. Harvesting when the leaves initiated withering showed the lowest value in rhizome length (6.0 cm), rhizome diameter (1.59 cm) and cluster rhizome weight (313 g/cluster). A similar trend was observed in all treatments' actual yield (ton/ha), with TH4 yielding the highest at 31.33 tons/ha while TH1 showed the lowest value at 20.37 tons/ha.

3.2.2. Effect of harvest time on the quality of white turmeric

The accumulation of biologically active ingredients in turmeric depends on various factors, such as variety, climate, cultivation practices and harvesting time [19]. It was reported that appropriate harvesting time could increase yield and quality, storage capacity, and reduce disease risk [20].

The essential content of rhizomes harvested at different harvesting times and plant growth duration varied (Table 6). The total oil content and essential oil yield increased proportionally with the delay in harvesting time. The lowest oil content, 1.35%, was recorded at TH1 when the onset of yellow leaves occurred. The highest content, 1.69%, was recorded when leaves completely withered in the second year of consecutive growth.

The lowest essential oil yield was recorded when harvesting was made at TH1, 75.34 l/ha, while the highest was 151.28 l/ha at TH4.

Table 6. Effect of harvest time on the quality of white turmeric

Harvest time	Total essential oil content (%)	Essential oil yield (l/ha)
TH1	1.35	75.34
TH2	1.53	109.19
TH3	1.62	119.56
TH4	1.69	151.28

TH1: 1st-year harvest when the leaves start withering; TH2: 1st-year harvest when 50% of the leaves withered; TH3: 1st-year harvest when 100% of the leaves withered (completely withered); TH4: 2nd consecutive year when 100% leaves withered.

3.2.3. Effects of harvest time on the economic efficiency of white turmeric cultivation

Table 7. Effect of harvest time on economic efficiency of white turmeric

	Unit: million VND/ha		
Harvest time	Total costs	Total revenue	Profit
TH1	286.17	305.55	19.38
TH2	286.89	382.95	96.06
TH3	287.61	393.00	105.39
TH4	457.06	469.95	12.89

TH1: 1st-year harvest when the leaves start withering; TH2: 1st-year harvest when 50% of the leaves withered; TH3: 1st-year harvest when 100% of the leaves withered (completely withered); TH4: 2nd consecutive year when 100% leaves withered.

Determining the harvest time for maximizing yield, highest essential oil content, and economic efficiency is imperative for white turmeric production. Prolong duration from planting to harvesting raises the cultivation costs. The findings revealed that harvesting at the onset of leaves withering (TH1) yields a profit of 19.38

million VND, while TH2 and TH3 returned 96.06 million and 105.39 million, respectively. Although harvesting in the second year returned the highest revenue, costs for maintaining the cultivation were also encountered, leading to a profit of only 12.89 million. Notably, harvesting at TH2 and TH3 produced the highest profit, as presented in table 7.

4. CONCLUSION

In conclusion, our findings highlighted the significant influence of potassium fertilizer application amount and different plant spacings on the yield and essential oil content of white turmeric plants. Specifically, employing a plant spacing of 25 x 35 cm, combined with an optimal application of 90 - 120 kg K_2O fertilizer, resulted in a promising yield of 24 - 25 tons/ha. Moreover, under these optimal cultivation practices, the highest oil yield was attained from 108.45 to 112.2 l/ha.

The study further revealed that harvesting when the leaves showed either 50% or complete withering achieved the highest rhizome yield (26.2 - 31.3 ton/ha) and essential oil yield (119.56 - 151.28 l/ha) compared to other harvesting times.

For optimal economic efficiency, white turmeric is cultivated under a K_2O dose of 90 - 150 kg/ha in a 25 x 35 cm spacing and harvested when the 50 - 100% leaf senescence 50% to 100% returns the highest profit.

REFERENCES

1. Purkayastha J., Nath S. C., Klinkby N. (2006). Essential oil of the rhizome of *Curcuma zedoaria* (Christm.) Rosc. native to Northeast India. *J Essent Oil Res,* 18: 154 - 155.

2. Zhou L., Zhang K., Li J., Cui X., Wang A., Huang S., Zheng S., Lu Y., Chen W. (2013). Inhibition of vascular endothelial growth factor-mediated angiogenesis involved in reproductive toxicity induced by sesquiterpenoids of *Curcuma zedoaria* in rats. *Reprod Toxicol,* 37: 62 - 69.

3. Ansari M. H., Ahmad S. (1991). Screening of some medicinal plants for antiamoebic action. *Fitoterapia,* 62: 171 - 175.

4. Lobo R., Prabhu K. S., Shirwaikar A., Shirwaikar A. (2008). *Curcuma zedoaria* Rosc. (white turmeric): A review of its chemical, pharmacological and ethnomedicinal properties. *J Pharm Pharmacol,* 61: 13 - 21.

5. Makabe H., Maru N., Kuwabara A., Kamo T., Hirota M. (2006). Anti-inflammatory sesquiterpenes from *Curcuma zedoaria*. *Nat Prod Res,* 20: 680 - 685.

6. Matsuda H., Tewtrakul S., Morikawa T., Nakamura A., Yoshikawa M. (2004). Anti-allergic principles from Thai zedoary: Structural requirements of curcuminoids for inhibition of degranulation and effect on the release of TNF-α and IL-4 in RBL-2H3 cells. *Bioorganic Med Chem,* 12: 5891 – 5898.

7. Pitasawat B., Champakaew D., Choochote W., Jitpakdi A., Chaithong U., Kanjanapothi D., Rattanachanpichai E, Tippawangkosol P, Riyong D., Tuetun B., Chaiyasit D. (2007). Aromatic plant-derived essential oil: An alternative larvicide for mosquito control. *Fitoterapia,* 78: 205 – 210.

8. Seo W.G., Hwang J. C., Kang S. K., Jin U. H., Suh S. J., Moon S. K., Kim C. H. (2005). Suppressive effect of Zedoariae rhizoma on pulmonary metastasis of B16 melanoma cells. *J Ethnopharmacol,* 101: 249 - 257.

9. Lai E. Y. C., Chyau C. C., Mau J. L., Chen C. C., Lai Y. J., Shih C. F., Lin L. L. (2004). Antimicrobial activity and cytotoxicity of the essential oil of *Curcuma zedoaria*. *Am J Chin Med,* 32: 281 - 290.

10. Mau J. L., Lai E. Y. C., Wang N. P., Chen C. C., Chang C. H., Chyau C. C. (2003). Composition and antioxidant activity of the essential oil from *Curcuma zedoaria*. *Food Chem,* 82: 583 - 591.

11. Tran T. T., Nguyen V. K., Tran B. D. (2021). Initial assessment of morphological markers, genetic diversity and correlations of some genetic resources of white turmeric (*Curcuma zedoaria* Rosc.). *Vietnam J Agric Rural Dev,* 417: 134 - 140.

12. Pham T. D. (2008). Experimental design and result analysis using the statistical software IRRISTAT. Hanoi University of Agriculture Publishing House

13. Nguyen B. H., Nguyen D. T. (2005). Yellow turmeric. In: Tech. Cultiv. Using, Process. Med. Plants. Agricultural Publishing House, pp 162 - 170.

14. Vietnam National Standard TCVN 13268-5: 2022 Plant protection - Pest surveillance method - Part 5: Medicinal plants.

15. Ministry of Health (2017). White turmeric. In: Vietnam Pharmacopoeia V. Medical Publishing House, pp. 1261-1262

16. Joy P.P., Thomas J., Mathew S., Skaria B.P. (2002). Agrotechniques for the cultivation of *Curcuma zedoaria* (berg.) Rosc. *Anc Sci Life,* 21: 260 - 267.

17. Begum M., Miah M..M., Rashid M., Islam M., Hossain M. (2019). Economic analysis of turmeric cultivation: evidence from Khagrachari district. *Bangladesh J Agric Res,* 44: 43 - 58.

18. Chempakam B., Leela N. K., John S. P. (2014). Effect of harvested dates on yield and quality in turmeric. In: Ramana K..V., Eapen S..J., Babu N..K., Krishnamurthy S.K, Kumar A. (eds) Spices Aromat. Plants - Challenges Oppor. New Century, pp. 293 - 296.

19. Hazra P., Roy A., Bandopadhyay A. (2000). Effect of harvest dates on quality and yield in turmeric (*Curcuma longa* L.). *Crop Res Hisar,* 19: 235 - 240.

20. Hossain M. A. (2010). Effects of harvest time on shoot biomass and yield of turmeric (*Curcuma longa* L.) in Okinawa. *Plant Prod Sci* , 13: 97 - 103.