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総　説

沖縄におけるウコン（*Curcuma longa* L.）の収量及び品質に影響する要因

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Factors influencing yield and quality of turmeric (*Curcuma longa* L.) in Okinawa, Japan

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Keywords： ウコン，クルクミン含量，栽培技術，肥培管理，収穫時期，無機成分，土壌の種類，収量および品質

Keywords： *Curcuma* sp., curcumin content, cultivation technology, fertilizer management, harvest time, mineral content, soil types, yield and quality.

要　約

ウコン類（*Curcuma* sp.）は，熱帯及び亜熱帯地域で広く栽培されるショウガ科の多年草で，根茎は四千年以上前から天然の香辛料・染料・医薬・化粧品として利用されてきた．日本にはおよそ六百年前，シャム(現在のタイ)から琉球へ伝わったとされる．秋ウコン（*C. longa* L.）はウコン類の80％を占め，世界中で約50種存在し，広く利用されてきた．沖縄は日本の中でも薬草類を利用した食品が有名であり，沖縄県における薬草関連の収益全体の30％以上はウコンが占めている．最近，ウコンに含まれる機能性成分の一つであるクルクミンには，血液の浄化，癌や腫瘍形成の予防，肝臓や腎臓機能改善などの様々な効果が認められてきている．このように，ウコンの利用法や機能性成分に関する情報が多いにもかかわらず，ウコン栽培に関する情報はほとんどない．本稿では，沖縄におけるウコンの収量及び品質に影響を与える栽培環境要因について，筆者が得たこれまでの研究成果を紹介したい．

ウコンの栽培に適する土壌は，島尻マージとジャーガルであり，またこれらの土壌肥沃(ひよく)度を向上させるには牛糞堆肥とマメ科緑肥(りょくひ)を用いると良いことがわかった．ネットによる遮光（20～30％の減光）は，収量とクルクミン含量を増加させるだけでなく，台風被害から植物体を護ることができる．ネットを用いた栽培結果から，ウコンは樹木やバナナ，オレンジなどの果樹の下での栽培が可能であると考えられる．台風の被害を最小限にするためには，ネットによる遮光に加え，植え付けを３～４月に行い，75～100cm幅の畝(うね)に，２列の千鳥植えで，８～12cmの深さに30cm株間で種イモとなる主根茎やより大きな側根茎の植え付けを行うとよい．施肥(せひ)については，植

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え付け後60日目から45日間隔で3回行い，窒素（150-210 kg/ha）とカリ（125-150 kg/ha）の複合施肥により収量とクルクミン含量を有意に高めることができる．収穫期については，11月，12月，1月に収穫をした場合，根茎生重量にはほとんど差はなく，乾物重量は1月収穫で最も高くなることから，この時期が収穫に適している．クルクミン含量が最も高くなるのは地上部の生長が停止する11～12月であり，地上部が完全に枯死する翌年1月以降は徐々に減少する．また，根茎内の無機成分では，カリウム，カルシウム，マグネシウムが，生育後期（11～1月）より生育中期（9～10月）で高くなる．ウコン類の栽培種や品種のクルクミン含量は，0.06～9.3%と幅広い変異が認められており，沖縄の在来秋ウコンを調査したところ，クルクミン含量は0.06～0.41%であった．一方，琉球大学で育成されたウコン品種‘琉大ゴールド’は在来種に比べ，1.29～2.99%の高いクルクミン含量を有しており，品種レベルにおいても幅広い変異が認められた．

以上のように，ウコンの収量及び品質は，栽培方法，遮光率，土壌の種類，植え付け時期と方法，肥培管理，および収穫時期など様々な環境要因によって変化する．そのため，ウコンを栽培する際は，環境要因について考慮した栽培を行い，またウコンを工業原料として利用する際は，どのような栽培環境条件で栽培されたものか留意する必要がある．

今後は，クルクミン合成系の解明，ウコン品種の開発，および高収量・高品質のウコンを確保するための沖縄県における栽培技術の開発に関する研究を行う必要がある．

Abstract:

Turmeric is a tropical and subtropical rhizomatous plant, which has been using for more than 4000 years as a natural dye, spice, cosmetic and medicine. It was entered in Japan around 600 years ago from Siam (Thailand) via Ryukyu Kingdom. Okinawa is popular for herbs and herbal foods in Japan, and earning more than 30 billions yen a year from herb business; turmeric accounts for more than 30% of total herbs. Curcumin of turmeric purifies blood, prevents cancer and tumor formation, improves liver and kidney functions, and could be used against biliary and hepatic disorders, and diabetic. *Curcuma longa* covers more than 80% of turmeric species used in the world. This review has evaluated the factors influencing yield and quality of turmeric (*C. longa*) in Okinawa. There are many cultivars of *C. longa* in the world, which have variable levels of curcumin (0.06-9.3%). Aki Ukon, the only cultivar of *C. longa* in Okinawa, contains only 0.06-0.41% curcumin. Ryudai gold, a new cultivar released by the University of the Ryukyus, provides higher yield and high curcumin content of 1.29-2.99%. Higher yield and quality of turmeric are obtained when grown in Shimajiri mahji (dark red soil, pH 5.5-6.5) and Jagaru (gray soil, pH 6.5-7.3) than in Kunigami mahji (red soil, pH 4.0-5.0). Cow manure and legume compost are better for improving soil productivity, and increasing yield and quality of turmeric. Shading (20-30%) by net could increase yield and curcumin content, and protect turmeric-plants from typhoon damage. Turmeric could be cultivated under trees and in orchards like banana and orange. Turmeric planting in March and April obtains higher yield than that planting earlier or later. Seed rhizomes of 30-40 g each planting in a 30-cm-triangular pattern at the depth of 8-12 cm on two-row ridges spaced 75-100 cm increase yield and quality significantly, and reduce typhoon damage remarkably. Three combined applications of N (150-210 kg/ha) and K (125-150 kg/ha) are significant for increasing both yield and curcumin content. Turmeric obtains highest curcumin content when shoot-growth reaches to plateau in November and December, and slightly lower when shoots wither completely in January. Potassium (K), Ca and Mg are the major minerals of turmeric, which are higher at middle growth stage (September-October) than at matured stage (November-January). Fresh-yield of turmeric

harvesting in November, December and January is almost the same, but dry-yield is the highest in January. This review indicates that yield and quality of turmeric differ significantly with cultivars, sunlight levels, soil types, planting time and methods, fertilizer management and harvest time, which should be considered for cultivation and industry raw-material collection. Further studies are needed on curcumin synthesis mechanism, variety development and mechanical cultivation technology to ensure yield and quality of turmeric in Okinawa.

Introduction

Turmeric (*Curcuma* sp.) has been using as a natural dye, spice, cosmetic and medicine for more than 4000 years. It was domesticated in Southern or South-East Asia (probably India), and is now being widely cultivated in many countries in the world due to valuable medicinal properties. Several studies reported that curcumin of turmeric has anti-inflammatory, anticancer, anti-oxidant and antibacterial properties[4, 15, 16, 17]. Curcumin purifies blood, prevents tumor formation, improves liver and kidney functions, and could be used against biliary and hepatic disorders, and diabetic[4]. Several studies found significant variations of turmeric efficacy on a specific disease[4, 15, 16, 17]. It is amused that there are many species and varieties of turmeric, and yield and quality of a species/variety differ with locations, soil types, temperature levels, sunlight levels, day lengths, planting time and procedures, fertilizer and water management, harvest time and storing systems[1, 5, 8, 9].

Turmeric was entered in Japan around 600 years ago via Ryukyu Kingdom from Siam (Thailand). Okinawa is popular for herbs and herbal foods in Japan, and earning more than 30 billions yen a year from herb business; turmeric (*Curcuma* sp.) accounts for more than 30% of total herbs. More than 5 million tourists visit Okinawa every year to enjoy herbal foods and supplements, which significantly contribute to local economy. Demand of turmeric is increasing over time in Japan, but its production and quality are not stable because information on species, varieties and cultivation technology is not available. This review has evaluated the factors influencing yield and quality of turmeric which is helpful for the growers as well as industry raw-material collection.

Species and cultivars

There are more than 50 turmeric species in the world including wild ones, and *Curcuma aromatica* SALISB, *C. longa* L. and *C. Zedoaria* L. Rosc are the major cultivating species (Fig. 1). These three species grow well in Okinawa. *C. longa* is widely used among all species as a natural medicine because of its curcumin[4, 9, 10]. Many cultivars/lines of *C. longa* are available in the world, which have variable color, chemical compositions and yield. Hossain et al.[5] divided the cultivars/lines of *C. longa* into three groups (i) red/reddish turmeric, (ii) orange turmeric and (iii) yellow turmeric (Fig. 2), which have different levels of curcumin (0.06 to 2.58%). Some cultivars of *C. longa* in Bangladesh and India contain up to 9.3% curcumin. Aki Ukon, the only cultivar of *C. longa* in Okinawa, contains very little curcumin (0.06-0.41%). The University of the Ryukyus has recently released a new cultivar, Ryudai gold, which provides higher yield and high curcumin content (1.29-2.99%) (Fig. 3).

Climate and soil

Turmeric requires a hot and moist climate and around 1,500 mm rainfall per annum. It grows well in sunny condition in all places ranging from sea level to an altitude of 1,500 m. It is very sensitive to low atmospheric

Fig. 1. Different turmeric species (left: *C. longa;* middle: *C. aromatica*; right: *C. zedoaria*)

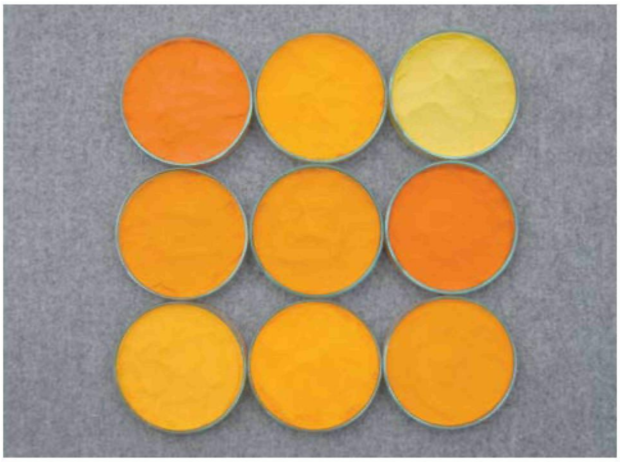

Fig. 2. Color variations of different lines of *C. longa*

temperature. The temperature range of 20-30 ℃ from March to December is favorable to better shoot growth and high yield of turmeric in Okinawa (Fig. 4). Turmeric is a partial shade-loving plant which could be cultivated under trees and in orchards like banana, orange, guava, etc. Optimum shading (20-30%) increases both yield and curcumin content of turmeric in Okinawa, but too much shading (> 50%) reduces them[11].

Turmeric grows in different soils with a pH range of 4.0-8.0, however yield and quality are better with the pH 5.5-7.0[9]. Turmeric grows best on loamy and alluvial soil with loose, friable and fertile condition. It also grows in well-drained sandy and clay loams, light black

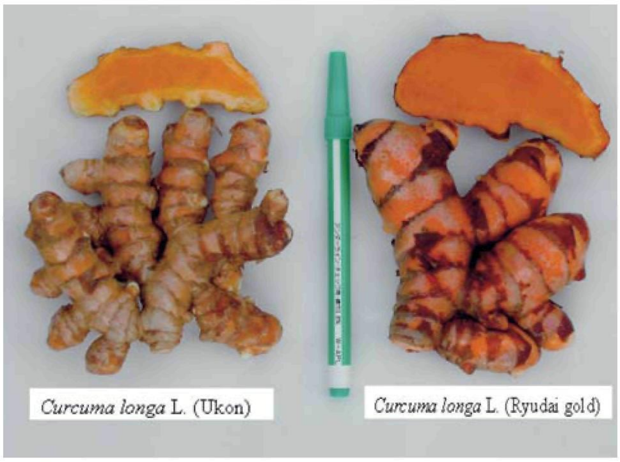

Fig. 3. Differences in color and size of rhizome between Ukon (left) and Ryudai gold (right)

Fig. 4. Turmeric growing in the field of Subtropical Field Science Center, Univ. Ryukyus, Okinawa

soil, ashy loam and red soil. Soils of Okinawa are not favorable to turmeric cultivation because the soils are compact and hard, as compared to soils in India and Bangladesh. However, dark-red soil (Shimajiri mahji, pH 5.5-6.5) and gray soil (Jagaru, pH 6.5-7.3) are better than red soil (Kunigami mahji, pH 4.0-5.0) for turmeric cultivation in Okinawa[9] (Table 1). Soils of Okinawa could be improved by applying legume-compost and cow manure for turmeric cultivation; compost from woody plants is not suitable for soil improvement[10].

Continuous cropping injury of turmeric

Continuous cultivation of a plant species in a field for several years causes disease incidences,

Table 1. Yield and quality parameters of turmeric cultivated on dark-red soil, gray soil and red soil in Okinawa, Japan

Soil type	Yield (g plant^{-1})	Protein (%)	Fat (%)	Curcumin (%)
Dark-red soil	39.5^{a}	5.21	3.63	0.20
Gray soil	27.5^{b}	3.40	3.64	0.10
Red soil	30.2^{b}	3.36	2.15	0.06

Modified from Hossain and Ishimine[9].
Note: Data were recorded on the dry weight basis. Means with the same superscript are not signipicantly diffierent at the 5% level, as determined by LSD test.

soil microorganism hazard, soil fertility degradation, and yield and quality reduction. Degree of continuous cropping injury may differ with the soil types and plant species. Yamawaki et al.[18] reported that continuous cropping injury of turmeric is appeared significantly from the third year in dark-red soil. This problem could be solved by crop rotation and applying farmyard manure such as cow manure and legume manure.

Planting time

Turmeric requires longer time to emerge when it is planted in February and March due to low temperature (below 25 ℃)[14], and the plants planted in February, March and April completes emergence at almost the same time in June. Turmeric planted in different months completes lifecycle in the same time in December and/or January due to low temperature (≦ 20 ℃). The highest yield is achieved when turmeric is panted in April, followed by March, February and May in Okinawa (Table 2).

Table 2. Effects of planting time (month) on shoot biomass and yield (dry rhizome) of turmeric.

Planting time	Shoot (g m^{-2})	Yield (g m^{-2})
February 15	515±44^{b}	693±65^{a}
March 15	527±37^{ab}	709±89^{a}
April 15	577±32^{a}	722±59^{a}
May 15	486±35^{b}	572±35^{b}
June 15	230±10^{c}	404±18^{c}

Modified from Ishimine et al.[14]. Data are means ± SD of replications. Means with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

Planting depth

Turmeric emerges earlier and evenly when planted at 8, 12 and 16 cm depth, which provides higher shoot biomass compare to those planted in shallower ones[13]. Turmeric plants are less affected by typhoon, rhizomes develop earlier and more, and yield (rhizome) increases significantly when it is planted at an 8, 12 or 16 cm depth (Table 3). Rhizome-stub of a turmeric plant develops 7-11 cm upward and downward from the seed. Yield of turmeric planted at 8, 12 and 16 cm depth is almost the same but harvesting is difficult for the 16 cm, which indicates that turmeric should be planted at a depth of 8 to12 cm for minimizing typhoon damage and obtaining higher yield in Okinawa.

Table 3. Effects of planting depth on shoot biomass and yield (dry rhizome) of turmeric.

Planting depth (cm)	Shoot biomass (g m^{-2})	Yield (g m^{-2})
4	479±22^{b}	362±16^{b}
8	645±92^{a}	465±41^{a}
12	655±48^{a}	466±53^{a}
16	653±63^{a}	449±42^{ab}

Modified from Ishimine et al.[13]. Data are means ± SD of replications. Means with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

Seed size

Turmeric propagates by mother and daughter rhizomes. Seed-rhizome size is one of the important factors to consider for better turmeric cultivation because it has primary, secondary and tertiary daughter (finger) rhizomes which are different in size. Rhizome size of turmeric varies from 3 to 100g (one rhizome) depending on species, cultivars and rhizome types. Healthier seedlings from the larger seeds develop bigger shoot base and a higher number of daughter rhizomes, and increase yield significantly[2, 7]. However, the seed-rhizome greater than 40 g each has no positive effect on turmeric yield. Mother rhizome also provides healthy seedlings and higher yield[2, 7]. Hossain et al.[7] reported that mother rhizome and daughter rhizome of 30-40 g each provide higher yield of turmeric.

Ridge distance, row number, plant distance and planting pattern

Turmeric shoots become thinner and intercultural practices are troublesome when ridge spacing is 50 cm or less. Ridge spacing of 75-100 cm is optimum for proper growth and development of turmeric in Okinawa (Table 4). Shoot biomass and yield of turmeric decrease with the ridge spacing of 125 cm or greater[8]. Minimum typhoon damage occurs and yield increases significantly when turmeric grows with two-row on a ridge spaced 75-100 cm, comparing to the plants with one-row.

Table 4. Effects of ridge distance and row number on shoot biomass and yield (dry rhizome) of turmeric.

Ridge distance (cm)	Row number	Shoot (g m^{-2})	Yield (g m^{-2})
50	1	256 ± 43^{b}	532 ± 33^{c}
75	1	211 ± 14^{c}	448 ± 71^{d}
75	2	337 ± 27^{a}	724 ± 41^{a}
100	1	131 ± 6^{de}	299 ± 12^{e}
100	2	265 ± 29^{b}	619 ± 27^{b}
125	1	128 ± 14^{de}	295 ± 22^{e}
125	2	208 ± 6^{c}	478 ± 43^{cd}
150	1	110 ± 9^{e}	151 ± 20^{f}
150	2	170 ± 6^{cd}	354 ± 24^{e}

Modified from Hossain et al.[8]. Data are means ± SD of replications. Means with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

The plants with a 20- or 30-cm spacing obtain a significantly higher shoot biomass than the plants with the larger spacing[8]. In Okinawa, rhizome-stub could develop horizontally up to 27 cm, which needs at least 30 cm spacing. Significantly highest yield is obtained with the 30-cm spacing followed by the 20-cm (Table 5). The plants could be planted closer in the places where warm period is shorter like Miyazaki, Kumamoto, etc.

Table 5. Effects of planting distance on shoot biomass and yield (dry rhizome) of turmeric.

Planting distance (cm)	Shoot (g m^{-2})		Yield (g m^{-2})	
	2002	2002	2002	2002
20	613 ± 59^{a}	669 ± 48^{a}	822 ± 69^{a}	765 ± 52^{b}
30	581 ± 51^{a}	653 ± 43^{a}	963 ± 58^{a}	842 ± 40^{a}
40	493 ± 51^{b}	516 ± 39^{b}	700 ± 57^{b}	658 ± 43^{c}
50	363 ± 28^{c}	383 ± 17^{c}	554 ± 33^{c}	513 ± 19^{d}
60	307 ± 34^{c}	324 ± 17^{c}	467 ± 18^{c}	430 ± 18^{e}

Modified from Hossain et al.[8]. Data are means ± SD of replications. Means with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

Shoots become thicker and leaves expand properly for the turmeric grown in a triangular pattern, which result in a higher shoot biomass and suppresse weed growth than the plants grow in a quadrate pattern[8]. Well expanded leaves receive higher sunlight which

Table 6. Effects of planting pattern on shoot biomass and yield (dry rhizome) of turmeric.

Planting pattern	Shoot (g m^{-2})		Yield (g m^{-2})	
	1999	2000	1999	2000
T1 (30×30)	471 ± 33^{a}	536 ± 42^{a}	624 ± 28^{a}	601 ± 34^{a}
Q1 (30×30)	417 ± 27^{ab}	512 ± 45^{a}	576 ± 26^{a}	523 ± 13^{b}
T2 (40×40)	434 ± 33^{ab}	481 ± 37^{a}	507 ± 31^{b}	480 ± 27^{b}
Q2 (40×40)	374 ± 13^{b}	469 ± 27^{a}	484 ± 34^{b}	417 ± 18^{c}

Modified from Hossain et al.[8]. T1, 30-cm triangular; T2, 40-cm triangular; Q1, 30-cm quadrate; Q2, 40-cm quadrate. Data are means ± SD of replications. Means with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

contributes to higher photosynthesis and results in a higher yield. Turmeric in a 30-cm triangular pattern effectively uses all the soil space for developing rhizomes, which results in a higher yield in Okinawa (Table 6).

Fertilizer management

Cow-manure (30 ton/ha), goat-manure (30 ton/ha) and legume-compost (30 ton/ha) are very effective for improving soil productivity, and increasing growth and yield of turmeric[10] (Table 7). Chemical fertilizer is not necessary

Table 7. Effects of different kinds of farmyard manure on shoot biomass and yield (dry rhizome) of turmeric.

Farmyard manure	Shoot biomass (g plant^{-1})	Yield (g plant^{-1})
Control	68.2 ± 6.1^{c}	98.6 ± 10.1^{d}
Chicken manure	89.6 ± 11.2^{b}	133.0 ± 15.1^{c}
Goat manure	110.8 ± 5.9^{a}	156.0 ± 9.6^{b}
Cow manure	112.6 ± 9.1^{a}	175.4 ± 7.8^{a}

Modified from Hossain and Ishimine[10]. Data are means ± SD of replications. Data with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

to apply at planting time because most of fertilizers are used by weeds due to late emergence of turmeric. Nitrogen (N) is very effective for vegetative growth and K is for rhizome growth of turmeric. Nitrogen fertilizer at 125-150 kg/ha is required to apply at 2- to 3-leaf stage (around 60 days after planting) for proper growth of shoots, thereafter two combined applications of N (125-150 kg/ha), P (50-75 kg/ha) and K (125-150 kg/ha) are required at a 45-day interval for increasing both shoots and rhizome-yield. Akamine et al.[1] reported that combined application of N (210 kg/ha), P (150 kg/ha) and K (150 kg/ha) results in a greater yield but could not improve curcumin content (Table 8). The highest curcumin content is obtained from turmeric grown with K, but K alone could not increase yield. The combined application of N and K improves both yield and curcumin content significantly (Table 8). P has very little impact on turmeric.

Table 8. Effects of N, P and K applied alone or in combination on yield (dry rhizome) and curcumin content of turmeric.

Fertilizer treatments	Yield (g plant^{-1})	Curcumin content (%)
Control	17.5 ± 1.9^{e}	0.15 ± 0.01^{de}
N	55.1 ± 2.1^{d}	0.14 ± 0.01^{e}
P	20.2 ± 2.4^{e}	0.17 ± 0.01^{c}
K	18.2 ± 2.3^{e}	0.21 ± 0.00^{a}
N plus P	61.4 ± 3.2^{c}	0.18 ± 0.00^{b}
N plus K	148.4 ± 6.1^{b}	0.19 ± 0.00^{b}
P plus K	8.6 ± 0.8^{f}	0.12 ± 0.00^{f}
N plus P plus K	165.9 ± 8.4^{a}	0.16 ± 0.00^{cd}

Modified from Akamine et al.[1]. Data are means ± SD of replications. Data with the same superscripts within each column are not significantly different at the 5% level, as determined by LSD test.

Mulching

Mulching with straw, grasses and legume plants reduces weed competition, prevents water evaporation and increases growth and yield of turmeric[2]. Some farmers use black polyethylene for mulching in turmeric, which inhibits rain-water penetration, causes soil microorganism hazard and increases labor cost for fertilizer and water application.

Water management

Irrigation is required just after turmeric planting for proper germination. Addition irrigation is necessary after each weeding and fertilizer application. Turmeric could not survive in wet condition for several weeks. Water should not be applied when turmeric shoots turn to yellowing naturally in December-January (maturing stage).

Insects, nematodes, fungus and weeds

Diseases are not the severe problem in turmeric cultivation in Okinawa. However, shoot borer (*Conogethes punctiferalis*), rhizome scale (*Aspidiella hourtii*), leaf roller (*Udaspes folus*), root knot nematodes (*Meloidogyne* spp.) and burrowing nematodes (*Radopholus similes*) are found in turmeric. Rhizome rot caused by *Pythium* sp., leaf spot due to *Colletotrichum capsici* and leaf blotch by *Taphrina maculans* are the major fungal diseases of turmeric. Shoot borer, leaf roller and mite could be controlled with malathion, carbaryl and methyl parathion, respectively. Soil pesticide and fungicide could be applied before turmeric planting for preventing pest and diseases.

Turmeric in Okinawa is infested with several weeds such as *Solanum nigrum* L., *Chenopodium album* L., *Eleusine indica* (L.) Gaertn, *Bidens pilosa* L., *Rottboellia cochinchinensis* (Lour.) W. Clayton, *Paspalum distichum* L., *Mimosa pudica* L., *Amaranthus viridis* L., *Digitaria ciliaris* L., *Amaranthus spinosus* L., *Panicum repens* L., *Digitaria violascens* Link[6, 7, 8, 12, 14]. The combined weed species reduce turmeric yield greater than 40%[12, 14]. Weeds need to remove during 70 to 160 day after planting for higher yield of turmeric[12].

Yield and quality of turmeric at different harvest times

Farmers in Bangladesh, India, Myanmar and Nepal harvest turmeric-rhizome (yield) almost throughout the year for their daily needs, whereas it is harvested at a time when cultivated for commercial purpose. Turmeric is usually planted in March-April and rhizome develops from July to December in Okinawa. Shoots turn to yellowing from November and dry in January. Fresh yield of turmeric in November, December and January is almost the same, but dry yield is higher in January when shoots wither completely (Hossain, data unpublished).

Turmeric-rhizome contains highest curcumin when shoot-growth reaches to plateau in November and December, and slightly lower when shoots wither completely in January. Potassium (K), Ca and Mg are the major minerals of turmeric, which are higher at middle growth stage (September-October) than at matured stage (November-January). Potassium comprises around 80% of total minerals (29-52 mg g^{-1} powder), whereas Ca, Mg and P (1.0-3.0, 1.8-3.7, 2.5-6.5 mg g^{-1}) together comprise around 15%.

Problems in turmeric cultivation in Okinawa

The following problems could be considered in turmeric cultivation in Okinawa. (i) Aki Ukon is the only cultivar of *C. longa* in Okinawa, which contains very poor curcumin (0.06-0.41%). (ii) Soils in Okinawa are unfertile and compact for turmeric cultivation, which requires more labor for harvest. (iii) Labor is expensive, but turmeric is relatively very cheap. (iv) Typhoon occurs several times in a year, which causes severe damage to turmeric-yield. (v) Turmeric production in Okinawa is decreasing because more than 95% of consumed turmeric is imported from many countries due to low price and high curcumin content.

Precautions for local agriculture and industries

It is every one's responsibility to ensure healthy food security and sound environment in a region. Every agricultural product is locally typical. Local industries and consumers must use local materials for saving local agriculture and maintaining reputation of local products. We have to keep it in mind that a farmer struggles every day with various problems in agriculture. A farmer will never continue his farming for a long time if he does not get proper price of his product. It is not wise to compare a local product-price to a foreign product-price. I feel, originality of

Okinawa-herb is disappearing due to using foreign materials, and turmeric business is shifting from Okinawa to other places.

Conclusion and future research

There are many cultivars of *C. longa* in the world, which have variable curcumin contents (0.06-9.3%), colors and rhizome sizes. Aki Ukon, the only cultivar of *C. longa* in Okinawa, contains only 0.06-0.41% curcumin; and a new cultivar, Ryudai gold, contains high curcumin (1.29-2.99%). Turmeric grows better in dark red soil and gray soil than in red soil in Okinawa. Cow manure, goat manure and legume compost improve soil productivity and turmeric yield. Turmeric is a partial shade-loving plant, which is possible to cultivate under trees. Larger rhizome (30-40 g each) could be planted in a 30-cm-triangular pattern at the depth of 8-12 cm on two-row ridges spaced 75-100 cm during March to April for minimizing typhoon damage and obtaining higher yield. Three combined applications of N and K are necessary for higher yield and curcumin content. Turmeric-rhizome contains highest curcumin when shoot-growth reaches to plateau in November and December, and slightly lower when shoots wither in January. Potassium (K), Ca and Mg are the major minerals of turmeric, which are higher at middle growth stage (September-October) and lower at matured stage (November-January). Fresh yield in November, December and January is almost the same, but dry yield is greater in January. This review indicates that yield and quality of turmeric differ significantly with cultivars, sunlight levels, soil types, planting time and methods, fertilizer management and harvest time, which should be considered for cultivation and industry raw-material collection.

Further studies are needed on curcumin synthesis mechanism, variety development and mechanical cultivation technology to ensure yield and quality of turmeric in Okinawa.

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References

1) Akamine H., Hossain M. A., Ishimine Y., Yogi K., Hokama K., Iraha Y. and Aniya Y. Effects of application of N, P and K alone or in combination on growth, yield and curcumin content of turmeric (*Curcuma longa* L.). Plant Prod. Sci., 10(1), 151-154 (2007).
2) Alam M. K., Islam Z., Rouf M. A., Alam M. S. and Mondal H. P. Response of turmeric to planting material and mulching in hilly region of Bangladesh. Pak. J. Biol. Sci., 6, 7-9 (2003).
3) Aoi K. Characteristics and cultivation of medicinal plant turmeric. Agric. Hortic., 67, 507-511 (1992).
4) Hermann P. T. A. and Martin A. W. Pharmacology of Curcuma longa. Planta Med., 57, 1-7 (1991).
5) Hossain M. A., Ishimine Y., Inafuku N., Motomura K. and Nakamur I. Comparison of morphological characteristics, yield and quality in different lines of *Curcuma longa* L. Jpn. J. Crop Sci., 73 (extra issue 2), 194-195 (2004).
6) Hossain M. A. Agronomic practices for weed control in turmeric (*Curcuma longa* L.). Weed Biol. Manag., 5(4), 166-175 (2005).
7) Hossain M. A., Ishimine Y., Akamine H. and Motomura K. Effects of seed rhizome size on growth and yield of turmeric

(*Curcuma longa* L.). Plant Prod. Sci., 8, 87-95 (2005).
8) Hossain M. A., Ishimine Y., Motomura K. and Akamine H. Effects of planting pattern and space on growth and yield of turmeric (*Curcuma longa* L.). Plant Prod. Sci., 8, 96-106 (2005).
9) Hossain M. A. and Ishimine Y. Growth, yield and quality of turmeric (*Curcuma longa* L.) cultivated in dark-red soil, gray soil and red soil in Okinawa, Japan. Plant Prod. Sci., 8, 482-486 (2005)
10) Hossain M. A. and Ishimine Y. Effects of farmyard manure on growth and yield of turmeric (*Curcuma longa* L.) cultivated in dark-red soil, red soil and gray soil in Okinawa, Japan. Plant Prod. Sci., 10(1), 146-150 (2007).
11) Hossain M. A., Ishimine Y., Akamine H., Teruya R., Aniya Y. and Yamawaki K. Effects of sunlight levels on yield and curcumin content of turmeric (*Curcuma longa* L.). Jpn. J. Crop Sci., 76 (supplement 2), 104-105 (2007).
12) Hossain M. A., Yamawaki K., Akamine H. and Ishimine Y. Weed infestation in turmeric (Curcuma longa) in Okinawa, Japan. Weed Technol., 22 (1), 56-62 (2008).
13) Ishimine Y., Hossain M. A., Ishimine Y. and Murayama S. Optimal planting depth for turmeric (*Curcuma longa* L.) cultivation in dark red soil in Okinawa Island, Southern Japan. Plant Prod. Sci., 6, 83-89 (2003).
14) Ishimine Y., Hossain M. A., Motomura K., Akamine H. and Hirayama T. Effects of planting date on emergence, growth and yield of turmeric (*Curcuma longa* L.) in Okinawa Prefecture, Southern Japan. Jpn. J. Trop. Agric., 48, 10-16 (2004).
15) Nakamura Y., Ohto Y., Murakami A., Osawa T. and Ohigashi H. Inhibitory effects of curcumin and tetrahydrocurcuminoids on tumor promoter-induced reactive oxygen species generation in leukocytes in vitro and in vivo. Jpn. J. Cancer Res., 89, 361-370 (1998).
16) Osawa T., Sugiyama Y., Inayoshi M. and Kawakishi S. Antioxidative activity of tetrahydrocurcuminoids. Biosci. Biotech. Biochem., 59, 1609-1612 (1995).
17) Sugiyama Y., Kawakishi S. and Osawa T. Involvement of the β-diketone moiety in the antioxidative mechanism of tetrahydrocurcumin. Biochem. Pharmacol., 52, 519-525 (1996).
18) Yamawaki K., Hossain M. A., Morita H. and Ishimine Y. Studies on continuous cropping injury of turmeric (*Curcuma longa* L.) in dark-red soil. Jpn. J. Crop Sci., 77 (extra issue 1), 118-119 (2008).