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Effects of Planting Pattern and Planting Distance on Growth and Yield of Turmeric (*Curcuma longa* L.)

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Abstract : The effects of planting pattern and planting distance on the growth and yield of turmeric (*Curcuma longa* L.) were examined in Okinawa Prefecture situated in southern Japan. The dry weights of shoot and rhizome (yield) of turmeric planted in a triangular pattern were heavier than those planted in a quadrate pattern. A 30-cm-triangular planting resulted in the heaviest shoot and rhizome yield among the planting patterns examined. Dry weight of shoot per unit land area (m^2) was significantly heavier when planted at a 20- and 30-cm spacing than when planted with a larger spacing, whereas the highest yield was obtained when planted at a 30-cm spacing followed by 20- and 40-cm spacing. When turmeric was planted at a 20-cm spacing, rhizome could not expand properly, which ultimately resulted in the smaller rhizome compared with that planted with a larger spacing. The highest turmeric yield coupled with the lowest weed biomass was obtained on the two-row ridge in a 75-100 cm width compared with a one- or two-row ridge in a larger or smaller width. This study indicates that for reducing weed interference and obtaining higher yield, turmeric should be planted in a 30-cm-triangular pattern on two-row ridge in a 75-100 cm width.

Key words : Planting density, Rhizome-stub expansion, Ridge width, Triangular planting, Turmeric yield, Weed interference.

Understanding the proper planting pattern and distance is very important to increase yield and to decrease interference with weeds (Baki et al., 1995; Knezevic et al., 2003; Murphy et al., 1996). A certain planting pattern for a specific root crop may provide an optimum space to maximize vegetative parts, which subsequently receives higher solar energy and results in maximum yield. Adjusting ridge and row spacing is one of the important agronomic practices for increasing yield of a row crop and reducing the competition with weeds (Murphy et al., 1996; Wicks et al., 2003).

Turmeric (*Curcuma longa* L.) is a very common spice in Bangladesh, India, Myanmar, Pakistan, Sri Lanka and Thailand. Curcuminoids, the active principles in turmeric-rhizomes, have anti-inflammatory, antimutagen, anticancer, antibacterial, anti-oxidant, antifungal, antiparasitic and detoxifying properties (Hermann and Martine, 1991; Ishimine et al., 2003; Nakamura et al., 1998; Osawa et al., 1995; Sugiyama et al, 1996). Curcumin and volatile oils of turmeric improve liver and kidney functions, and could be used against biliary disorders, diabetic and hepatic disorders (Hermann and Martin, 1991). Different supplements and drinks derived from turmeric have been widely used around the world for promoting health.

Many studies have been done to evaluate the medicinal value of turmeric, but very few studies have been conducted on turmeric cultivation (Hermann and Martin, 1991; Ishimine et al., 2003). Improvement of crop cultivation technology for local climatic and edaphic factors is important for successful production (Akamine et al., 1995; Aoi et al., 1988; Aoi, 1992; Ishimine et al., 2003). Turmeric is commercially cultivated in the south-western part of Japan, and Okinawa is the best place for its cultivation in Japan (Akamine et al., 1994; Aoi et al., 1988; Aoi, 1992; Ishimine et al., 2003). However, the production of turmeric per unit land area is very low because of the poor knowledge on proper cultivation technology of the farmers (Ishimine et al., 2003). Typhoons hit Okinawa several times a year, which cause severe damage to crops. It is also thought that an optimum planting distance could help turmeric plants survive from typhoon disaster. We previously determined the optimum planting depth and time under Okinawan environmental conditions (Ishimine et al., 2003, 2004). In this study, we investigated the effects of planting pattern and planting distance on growth and yield of turmeric.

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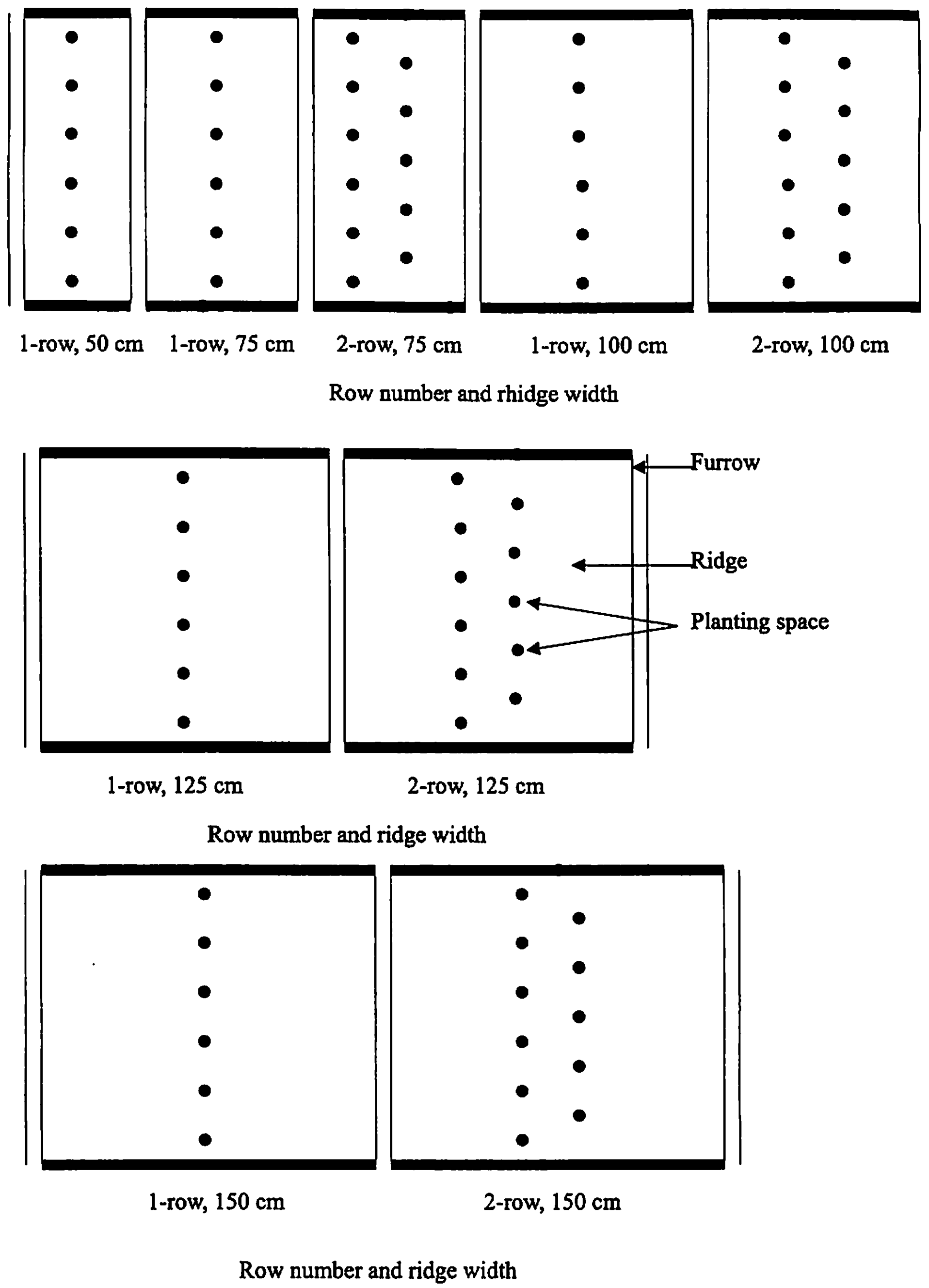

Fig. 1. Planting design of turmeric showing row number and ridge width. Ridge width is furrow-to-furrow distance. Ridge height is around 20 cm. Turmeric seed-rhizomes of 30 g each were planted at a 10 cm depth spaced 30-cm apart. Seed-rhizomes were planted in a triangular pattern in two rows.

Materials and Methods

1. Trial site

Five field experiments were conducted in 1999-2002 at the Subtropical Field Science Center of the University of the Ryukyus, Okinawa (24-28° N. Mean yearly ambient temperature, rainfall and percent humidity during 1999-2003 were 23.3±0.2 °C, 2198 ±436 mm and 72.2±2.1%, respectively. Data were collected from the Meteorology Branch Office, Naha), Japan.

2. Physical and chemical properties of soils

All experiments were conducted on the fields of dark red soil (Shimajiri Maji, Chromic Luvisols). The soil contained 0.8% organic matter, 0.89% C,

Table 1. Effect of planting pattern of turmeric on weed biomass at different weeding times.

	Weed biomass (g m^{-2})					
	Experiment-1999			Experiment-2000		
Planting pattern	50 DAP	90 DAP	130 DAP	50 DAP	90 DAP	130 DAP
T1 (30x30)	236±16a	136±7b	37±9b	230±12a	117±16b	29±8b
Q1 (30x30)	243±18a	145±8b	41±9ab	246±9a	129±14b	50±9a
T2 (40x40)	236±23a	146±4b	41±7ab	247±7a	141±12ab	52±12a
Q2 (40x40)	239±13a	165±8a	58±9a	238±24a	170±15a	66±7a

DAP: days after planting. Data are means±SD of three replications (three 6-m-long ridges). Means with the same letter within each column are not significantly different at 5% level, as determined by LSD test.

0.11% N, 134 mg P per 100 g soil, and pH was 6.08. Percent (w/w) clay, silt and sand were 66.3, 29.3 and 4.4, respectively, and bulk density (g cm^{-3}) was 0.85. Exchangeable K, Ca, Mg and Na were 0.17, 10.8, 1.35 and 0.31 meq (milligram equivalent) per 100 g soil, respectively.

3. Planting pattern

The experiment was conducted from April 30, 1999 to February 3, 2000, and it was repeated from May 10, 2000 to February 20, 2001. The field was plowed deeply (35 cm), and 6-m-long ridges 150 cm apart were prepared by making furrows. Four planting patterns tested were (1) 30-cm triangular (T1), (2) 30-cm quadrate (Q1), (3) 40-cm triangular (T2) and (4) 40-cm quadrate (Q2) patterns. Each treatment had three replications (three ridges).

Turmeric seed-rhizomes of 30 g each were planted manually at the 10 cm depth in two rows on the ridge according to the experimental design. Chemical fertilizer (N : P_2O_5 : K_2O = 2 : 1 : 2) was applied at 300 kg ha^{-1} 3 times at 60-day intervals from the 2- to 3-leaf stage. Overhead irrigation was provided immediately after turmeric planting and fertilizer application. The major weed species in the trial fields were *Amaranthus spinosus* L., *Amaranthus viridis* L., *Bidens pilosa* L., *Chenopodium album* L., *Cyperus rotundus* L, *Eleusine indica* (L.) Gaertn., *Mimosa pudica* L., *Oxalis corymbosa* DC., *Panicum repens* L., *Paspalum urvillei* Steud. and *Solanum nigrum* L. Hand hoeing was done at 50, 90 and 130 days after planting.

4. Planting distance

This experiment was conducted from March 29 to December 16, 2000. Field and 6-m-long ridges were prepared as described above. The seed rhizomes were planted at 20-cm, 30-cm, 40-cm, 50-cm and 60-cm spacing with 4 replications (4 ridges). The same experiment was repeated from April 15 to December 31, 2002. Turmeric seed-rhizomes of 30 g each were planted triangularly at a 10-cm depth on two-row ridges according to the experimental design. The same chemical fertilizer and irrigation as mentioned above were provided in this experiment. The major weed species in this experiment were *Amaranthus spinosus* L., *Amaranthus viridis* L., *Bidens pilosa* L., *Chenopodium album* L., *Cyperus rotundus* L., *Eleusine indica* (L.) Gaertn., *Mimosa pudica* L., *Oxalis corymbosa* DC., *Panicum repens* L., *Paspalum urvillei* Steud., *Setaria viridis* (L.) Beauv and *Solanum nigrum* L. Hand hoeing was done at 50, 90 and 135 days after planting .

5. Row number and ridge width

This experiment was conducted from April 11 to December 28, 2002. The field was well plowed, and 4-m-long ridges with different width were prepared. Treatments with 3 replications (each replication had 3 ridges) in this experiment were (1) one-row ridges in a 50-cm width, (2) one-row ridges in a 75-cm width, (3) two-row ridges in a 75-cm width, (4) one-row ridges in a 100-cm width, (5) two-row ridges in a 100-cm width, (6) one-row ridges in a 125-cm width, (7) two-row ridges in a 125-cm width, (8) one-row ridges in a 150-cm width and (9) two-row ridges in a 150-cm width (Fig. 1).

Turmeric seed-rhizomes of 30 g each were planted manually at a 10-cm depth spaced 30-cm apart. Rhizomes were planted in a 30-cm triangular pattern in two rows (Fig. 1). The same chemical fertilizer and overhead irrigation as mentioned above were provided. The major weed species found in this experiment were *Amaranthus spinosus* L., *Amaranthus viridis* L., *Bidens pilosa* L., *Chenopodium album* L., *Cyperus rotundus* L., *Eleusine indica* (L.) Gaertn., *Mimosa pudica* L., *Oxalis*

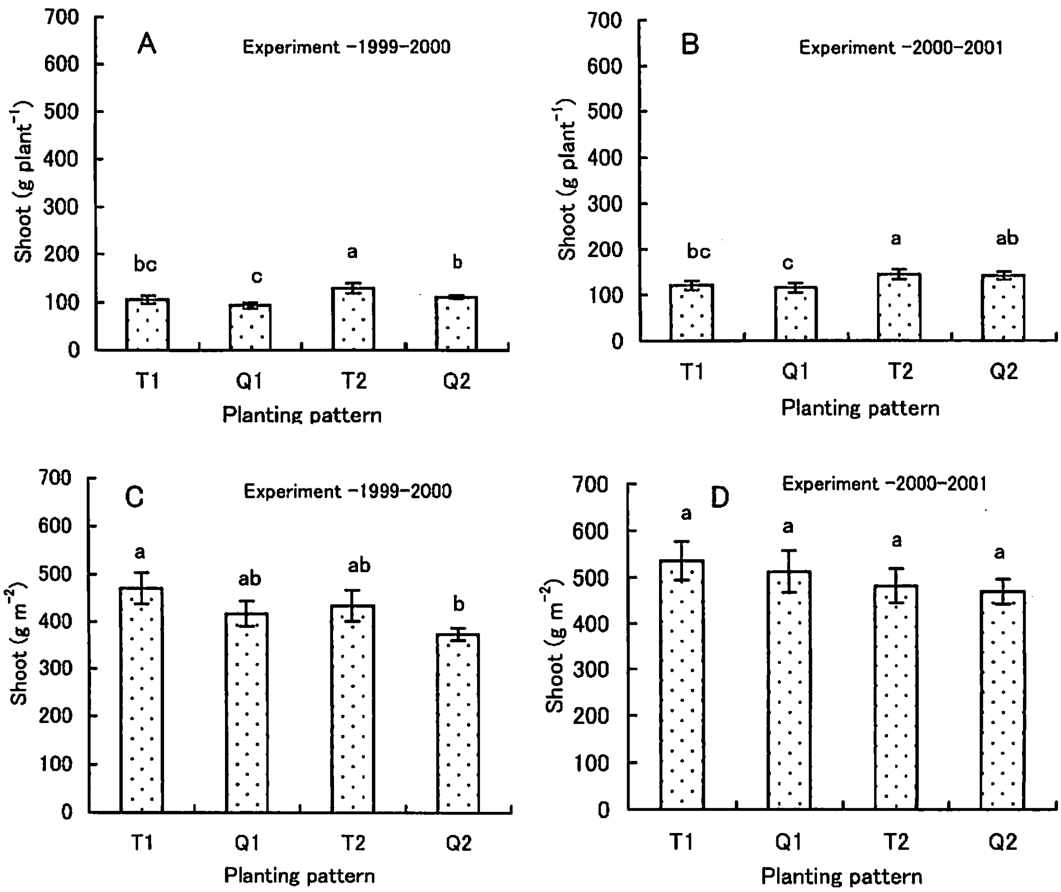

Fig. 2. Effect of planting pattern on shoot dry weight of turmeric per plant (A, B) and per unit land area (C, D). T1: 30-cm triangular; T2: 40-cm triangular; Q1: 30-cm quadrate; Q2: 40-cm quadrate. Data are means±SD of three replications. Data obtained from six plants for each replication and means were measured. Bars with the same letter are not significantly different at 5% level, as determined by LSD test.

corymbosa DC., *Panicum repens* L., *Paspalum urvillei* Steud., *Rottboellia exaltata* L f. and *Solanum nigrum* L. Hand hoeing was performed at 60, 120 and 160 days after planting.

6. Procedures of data collection and statistical analysis

Plant height and the number of tillers (shoots) were recorded when main shoot elongation terminated. Weed biomass was recorded at weeding time. Diameter of shoots (pseudostems) at soil surface, level of canopy structure and leaf overlapping, and rhizome overlapping were visually evaluated. Turmeric shoot damage caused by typhoons was visually evaluated on the basis of shoot broken and uprooting; and damage recovery level was visually evaluated on the basis of new leaf and tiller formation, and shoot survival. Turmeric was harvested when the aboveground shoot had completely withered; and horizontal and vertical lengths of rhizome-stub, and dry weight of shoots and rhizomes were measured. Plant parts were oven-dried at 80°C for 48 hr and weighed. Shoot and yield of turmeric per plant and per unit land area (m^2) were calculated. Means and standard deviations (SD) of the measured values were determined using analysis of variance (ANOVA). Fisher's Protected LSD test at the 5% level of significance was used to compare treatment means.

Results

1. Planting pattern

Weed biomass in the turmeric field during 50 days after planting did not vary with the planting pattern (Table 1). Thereafter, the degree of weed infestation was low in the field planted in a triangular pattern as compared with that planted in the quadrate pattern, and the lowest weed biomass was recorded in the field with a 30-cm-triangular planting pattern. Both the shoot biomass and yield (rhizome) per plant and per unit land area (m^2) were greater when turmeric was planted in a triangular pattern, compared with those when planted in a quadrate pattern (Fig. 2, 3). The highest shoot biomass and yield per plant were obtained when turmeric was planted in a 40-cm-

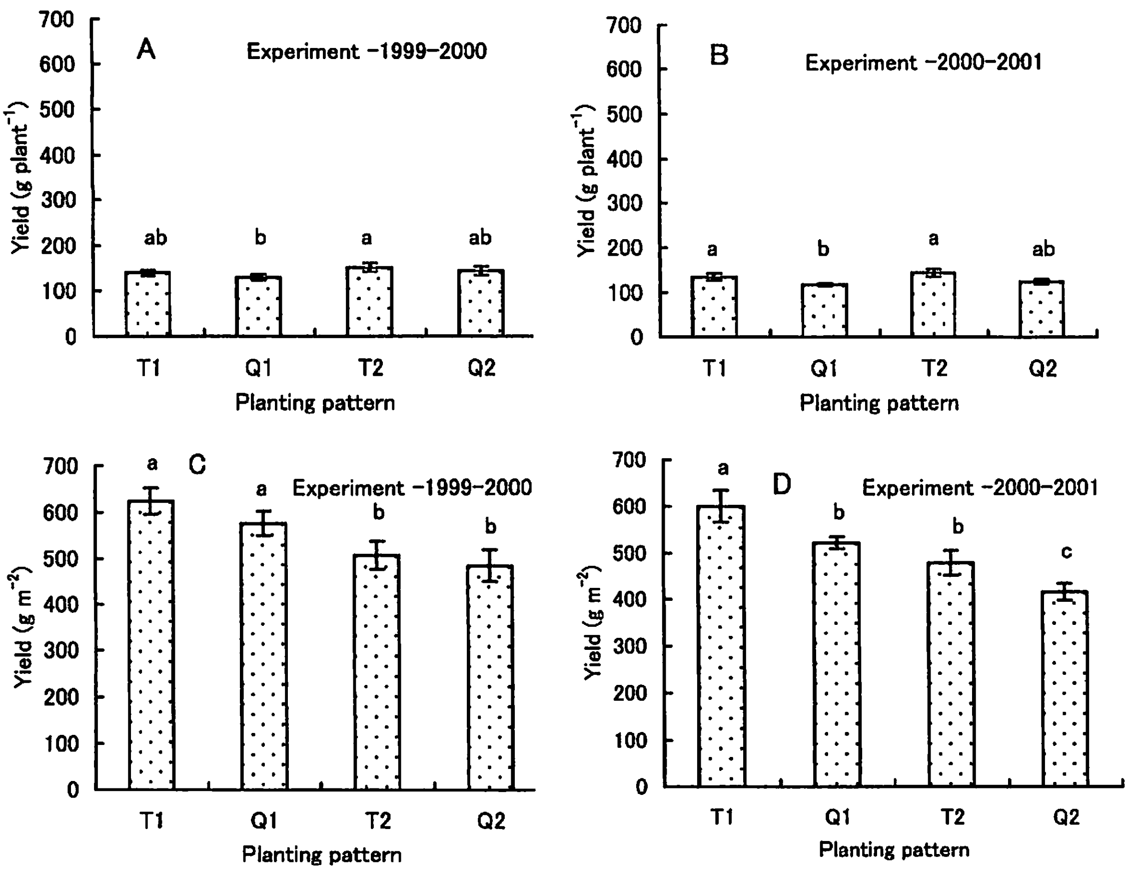

Fig. 3. Effect of planting pattern on yield (dry weight) of turmeric per plant (A, B) and per unit land area (C, D). T1: 30-cm triangular; T2: 40-cm triangular; Q1: 30-cm quadrate; Q2: 40-cm quadrate. Data are means ±SD of three replications. Data obtained from six plants for each replication and means were measured. Bars with the same letter are not significantly different at 5% level, as determined by LSD test.

triangular pattern, whereas the values per m^2 were the highest when planted in a 30-cm-triangular pattern among the treatments. However, the highest yield per m^2 was obtained when planted in a 30-cm-triangular pattern followed by 30-cm-quadrate pattern.

2. Planting distance

Plant height of turmeric was not affected by the planting distance, but the number of tillers was significantly reduced by planting at a 20-cm spacing, and the spacing of 30, 40, 50 and 60 cm resulted in a similar number of tillers (Table 2). Shoot dry weight per plant increased significantly when turmeric was planted at a 30-cm or larger spacing compared with a 20-cm spacing. No significant differences in shoot dry weight were observed among plants spaced 30, 40, 50 and 60 cm apart (Fig. 4), whereas a significantly heavier shoot dry weight per m^2 was obtained when planted at a 20-30 cm spacing than a larger spacing, and it was statistically similar at a 20- and 30-cm spacing. Shoot dry weight per m^2 decreased with the increasing planting distance to 40 cm or above. Weed biomass during 50 days after planting (DAP) was not affected by planting distance of turmeric, but that at 90 and 135 DAP was increased by increasing the planting distance (Table 3).

Rhizome-stub extended horizontally up to 27 cm when turmeric was planted at a 30-cm or larger spacing, which was significantly larger than that when planted at a 20-cm spacing (Fig. 5). Rhizome-stub length did not differ by planting at a 30, 40, 50 and 60 cm spacing. Vertical development of rhizome-stub was not influenced by turmeric planting distance.

The rhizome yield per plant was significantly and similarly higher when planted at a 30, 40, 50 and 60 cm spacing, than at a 20-cm spacing (Fig. 6), whereas the yield per m^2 was the highest when planted at a 30-cm spacing followed by 20-cm spacing, and the yield was significantly reduced by planting at a 40-cm or more spacing.

3. Row number and ridge width

Weed growth was not influenced by either ridge width or row number of turmeric plants until 60 DAP (Table 4). At 120 DAP, weed biomass was significantly lower when planted in two rows than in the one row,

Table 2. Effect of planting distance on shoot height and tiller formation of turmeric plant.

	Plant height (cm)		Number of tillers per plant	
Planting distance (cm)	Experiment-2000	Experiment-2002	Experiment-2000	Experiment-2002
20	175±4a	172±6a	4.4±0.3b	4.9±0.2b
30	182±6a	174±5a	5.0±0.2a	5.8±0.3a
40	180±7a	176±7a	5.5±0.4a	5.8±0.3a
50	181±6a	178±5a	5.5±0.2a	5.9±0.4a
60	185±4a	181±3a	5.4±0.3a	5.8±0.4a

DAP: days after planting. Data are means±SD of four replications (four 6-m-long ridges). Means with the same letter within each column are not significantly different at 5% level, as determined by LSD test.

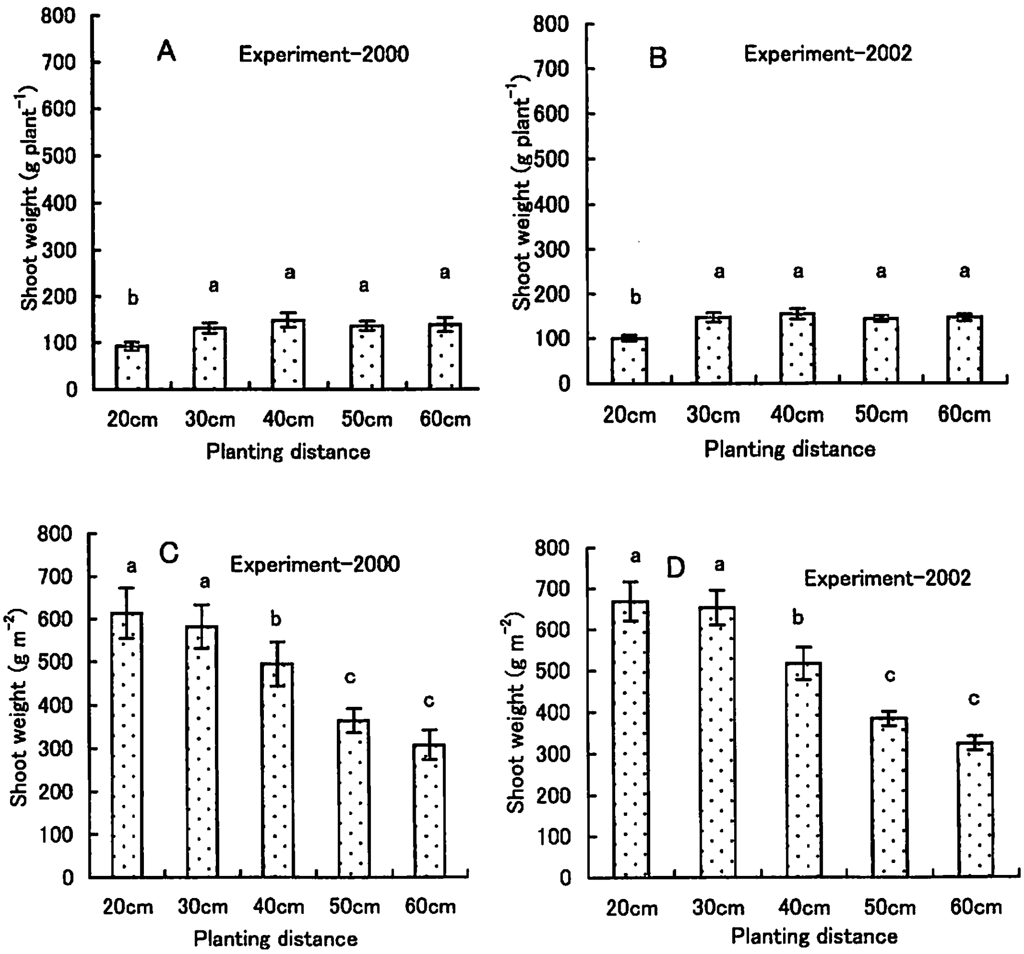

Fig. 4. Effect of planting distance on shoot dry weight of turmeric per plant (A, B) and per unit land area (C, D). Data are means±SD of four replications. Data obtained from six plants for each replication and means were measured. Bars with the same letter are not significantly different at 5% level, as determined by LSD test.

Table 3. Effect of planting distance of turmeric on weed biomass at different weeding times.

	Weed biomass (g m^{-2})					
	Experiment-2000			Experiment-2002		
Planting distance (cm)	50 DAP	90 DAP	135 DAP	50 DAP	90 DAP	135 DAP
20	250±28a	158±8c	50±10c	235±26a	154±11b	46±13c
30	253±16a	164±15bc	53±6c	249±25a	161±13b	64±6bc
40	257±29a	177±19abc	64±15bc	260±18a	183±23ab	74±16ab
50	252±15a	186±17ab	79±12ab	251±9a	194±23a	83±13ab
60	262±24a	196±16a	86±15a	257±13a	200±18a	90±11a

DAP: days after planting. Data are means±SD of four replications (four 6-m-long ridges). Means with the same letter within each column are not significantly different at 5% level, as determined by LSD test.

and weed biomass was not affected by the ridge width when turmeric was planted in one row on the ridges. Similar results were obtained when examined at 160 DAP.

Shoot biomass and yield of turmeric were significantly higher when planted in two rows than in one row, whereas they decreased with the increasing ridge width either when turmeric was planted in one row and two rows on the ridges (Table 5). Shoot biomass and yield of turmeric planted in one row on the ridges with a 50-75 cm width were similar to or significantly higher than that of turmeric planted in two rows on the ridges 125 cm or wider. Turmeric planted in two rows on the ridges with a 75-cm width had the largest shoot biomass and highest yield, followed by that on the ridges in 100-cm width.

Discussion

1. Planting pattern

Shoots of turmeric planted in a triangular pattern were thicker than that planted in quadrate patterns, and had a larger shoot biomass (Fig. 2). In turmeric planted in a quadrate pattern leaf overlapping was higher so that leaf senescence was earlier, than that planted in a triangular pattern. Similarly, Sarker et al. (2001) reported that mutual shading caused earlier and higher leaf senescence in rice plants. Rubio et al. (2003) reported that shading with neighboring plants is the principal factor of their competition, and shading is also an important factor because it greatly affects leaf deployment. Longevity of leaf might result from longer photosynthetic periods, which ultimately increased both vegetative and reproductive growth of turmeric planted in a triangular pattern. The center of quadrates in the field planted in a quadrate pattern was bare where weed grew more, than with the field planted in a triangular pattern. Earlier establishment of canopy structure in the triangular planting pattern resulted in a smaller weed biomass as compared with the field in the quadrate planting pattern (Table 1). Less competition with weeds ultimately resulted in a larger shoot biomass of turmeric, which is consistent with the results of Ishimine et al. (2003).

A larger shoot biomass and longer photosynthetic period in the plants in a triangular pattern were the causes of higher yield of turmeric than in the plants in a quadrate pattern (Fig. 3). Similarly, Hossain et al. (2000) and Ishimine et al. (2003) reported that turmeric yield increased with increasing shoot biomass. Turmeric planted in a triangular pattern effectively used all the space for expanding rhizome-stub for which resulting in a higher yield per plant than that planted in a quadrate pattern. In turmeric planted in a quadrate pattern rhizome stubs overlapped each other, and it was laborious to dig up rhizomes. The yield per m^2 was the highest in the 30-cm triangular planting pattern, because the number of plants per unit area was optimum and both the shoot and rhizome developed properly.

2. Planting distance

Plant height did not vary with the planting distance, but the number of shoots per plant was comparatively smaller in the plants spaced 20-cm apart (Table 2). It was thought that a spacing of 20 cm was insufficient for the growth of turmeric plants, and resulted in thinner shoot (visual observation) and lower number of shoots. Thinner shoot always develop smaller leaves, which receives lower solar energy for photosynthesis and results in lower yield. Shoot dry weight per plant was significantly lighter at a 20-cm spacing, and it was heaviest at a 30-cm spacing, and further increase

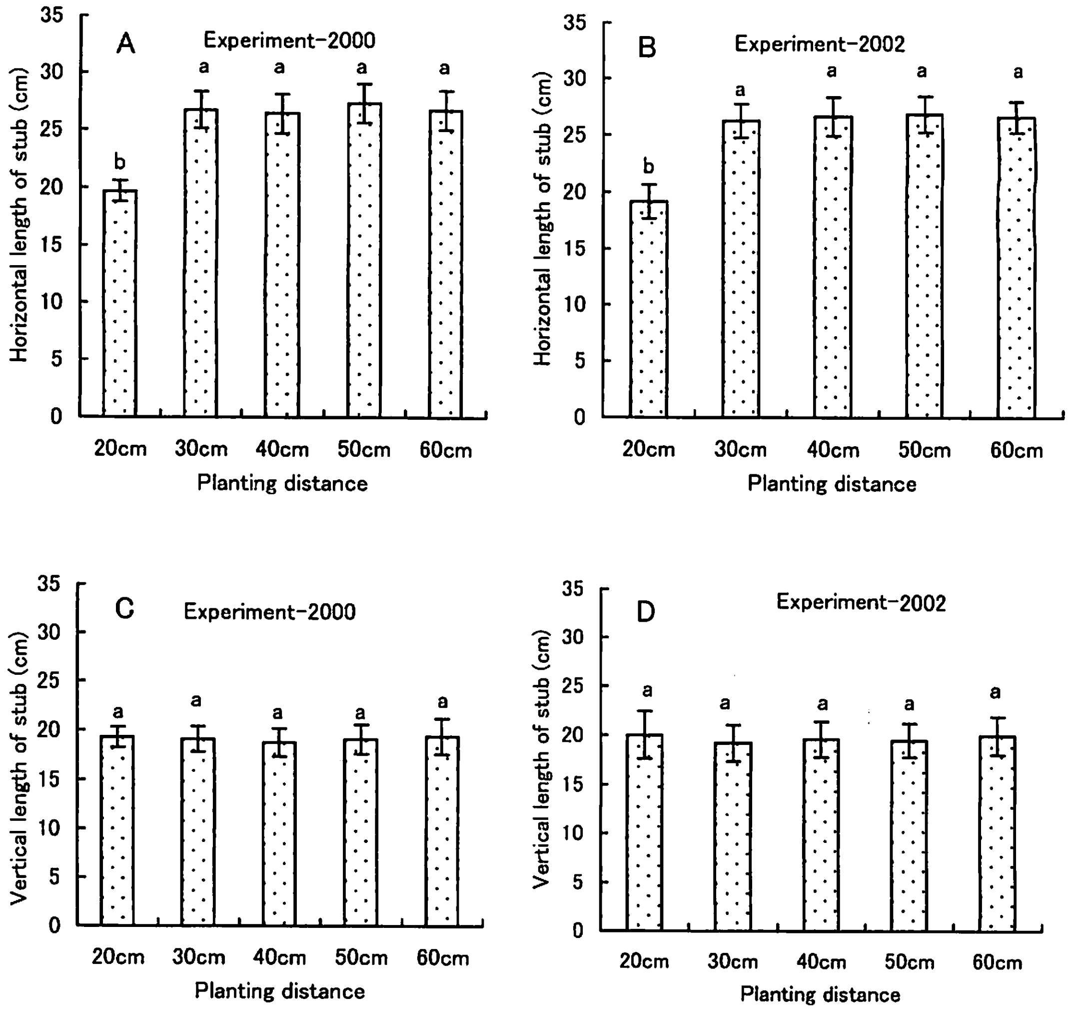

Fig. 5. Effect of planting distance on horizontal (A, B) and vertical (C, D) length of turmeric rhizome-stub per plant. Data are means±SD of four replications. Data obtained from six plants for each replication and means were measured. Bars with the same letter are not significantly different at 5% level, as determined by LSD test.

in spacing did not show any significant positive effect (Fig. 4). On the other hand, shoot dry weight per m^2 was significantly heavier at a 20- and 30-cm spacing compared with the larger spacing. These results indicate that planting at 30 cm spacing was appropriate for turmeric shoot growth. Similarly, Baki et al. (1995) reported that planting density has positive and negative effects on the growth and yield parameters of the rice plant. In this study leaf blades of turmeric plants at a 30-cm spacing grew up to 50 cm in length and 10 cm in width, and leaves expanded upward at an approximately 30° angle covering nearly 30-40 cm around the plant. Therefore, a 30-cm spacing is enough for maximizing the turmeric shoot biomass. Earlier establishment of canopy structure in the plants at a 20- and 30-cm spacing reduced weed biomass, which ultimately resulted in a larger shoot biomass of turmeric. Similarly, Ishimine et al. (2003) found a lower weed biomass in the field with the larger turmeric shoot biomass.

Spacing of more than 30 cm did not increase horizontal length of rhizome-stub (Fig. 5), and a rhizome-stub of 27 cm was about 1100g in fresh weight, which indicates that a 30-cm spacing resulted in the maximum rhizome-stub size. Vertical development of rhizome-stub was not affected by planting distance, because it was related to planting depths but not to spacing (Ishimine et al. 2003). Akamine et al. (1995) found a similar rhizome weight per plant in the same soil.

The highest yield per m^2 was obtained with a 30-cm spacing followed by a 20-cm spacing (Fig. 6), and the yield was significantly reduced by a 40-cm or more planting spacing, which further indicates that a more than 30-cm spacing was not necessary. Smaller rhizomes produced in the plants at a 20-cm spacing, and these rhizomes were laborious to harvest and had a lower market value. These results indicate that a

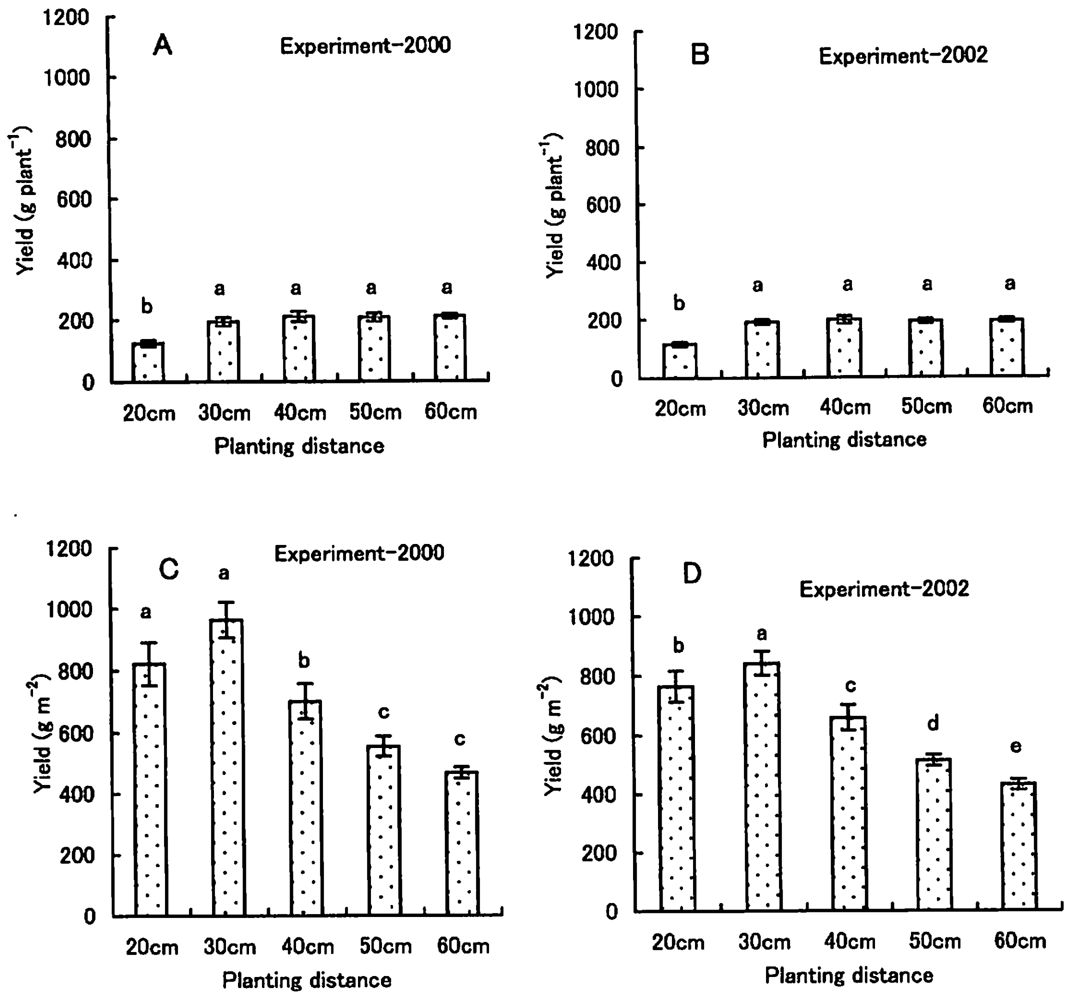

Fig. 6. Effect of planting distance on yield of turmeric per plant (A, B) and per unit land area (C, D). Data are means±SD of four replications. Data obtained from six plants for each replication and means were measured. Bars with the same letter are not significantly different at 5% level, as determined by LSD test.

30-cm spacing was appropriate for maximizing yield and for producing bigger rhizomes.

The temperature ranges between 20 and 30°C for a long time from March to November in Okinawa are favorable for maximizing vegetative and reproductive growth of turmeric. As a result, one plant produces around 1100 g of rhizomes (fresh weight) in Okinawa, which requires around a 30-cm planting spacing. In Tanegashima, Japan, one plant produces only 300-600 g of rhizomes due to the shorter period at an optimum temperature, and a smaller spacing is appropriate in such a district (Aoi et al., 1988; Aoi, 1992). These results indicate that spacing for turmeric plants should be adjusted considering the duration at the optimum temperature.

3. Row number and ridge width

Weed growth was not affected by ridge width and row-number of turmeric during the early growth stage of 60 DAP because canopy structure was not established during this period (Table 1). At 120 and 160 DAP, however, turmeric planted in two rows on the ridge developed a better canopy structure, which significantly reduced weed biomass. Similarly, other researchers reported that narrower rows and a higher planting density reduced weed biomass and increased crop yield (Murphy et al., 1996; Wicks et al., 2003).

Shoot biomass and yield decreased with increasing ridge width for both the one-row and two-row plantings (Table 2), because the number of plants per unit land area was reduced, weed infestation was increased, and shoot damage caused by typhoon became severe with increasing ridge width. The largest shoot biomass and highest yield were obtained when turmeric was planted in two rows on the ridges with a 75-cm width followed by 100-cm width among the treatments. This was because the number of turmeric plants per unit area (m^2) was higher, turmeric shoot growth was better

Table 4. Effect of row number and ridge width of turmeric on weed biomass at different weeding times.

		Weed biomass (g m^{-2})		
Row number	Ridge width (cm)	60 DAP	120 DAP	160 DAP
1	50	84±2a	41±6ab	34±2bcde
1	75	90±2a	50±5a	37±3abcd
2	75	93±6a	34±6b	23±5e
1	100	100±7a	51±5a	41±12abc
2	100	98±10a	35±7b	25±6de
1	125	88±10a	49±4a	46±7ab2
2	125	95±12a	36±4b	33±5cde
1	150	98±8a	50±1a	48±4a
2	150	101±10a	37±8b	34±6bcde

DAP: days after planting. Data are means±SD of three replications, and each replication consisted of three 6-m-long ridges. Means with the same letter within each column are not significantly different at 5% level, as determined by LSD test.

Table 5. Effect of row number and ridge width on shoot and yield of turmeric.

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

Data are means±SD of three replications, and each replication consisted of three 6-m-long ridges. Means with the same letter within each column are not significantly different at 5% level, as determined by LSD test.

and weed biomass was the lowest in the ridges with a 75-cm width followed by 100 cm width. In addition, turmeric shoots and roots in these fields were not markedly damaged by typhoon, and recovered faster, which resulted in larger shoot biomass and higher yield. Shoot biomass and yield of turmeric planted in one row ridges spaced 50-75 cm were similar to or significantly higher than that of turmeric planted on two-row ridges with 125-150 cm width because of severe shoot damage caused by typhoons in the latter.

Conclusions

When turmeric was planted in a triangular pattern, shoots became thicker, canopy-structure developed earlier, the plants increased shoot biomass and weed infestation was reduced than when planted in a quadrate pattern. In addition, the rhizome-stub developed properly, rhizome harvesting (dig up rhizome) was comparatively easier and yield increased markedly when planted in a triangular pattern. Turmeric planted in a 30-cm-triangulr pattern resulted in the largest shoot biomass, largest rhizome-stub and the highest yield. Turmeric planted at a 30-cm spacing produced the highest yield per m^2 and largest rhizomes. Turmeric planted at a 20-cm spacing produced smaller rhizomes than that planted at a 30-cm spacing though it had a similar yield of 30 cm space. When turmeric was planted on two-row ridges with a 75-100 cm width, shoots grew properly, canopy structure developed earlier, weed infested in the lowest level, shoots were damaged by typhoon at a minimum level, and the highest level of yield was obtained. These experiments indicate that for reducing weed interference, avoiding typhoon damage and obtaining maximum yield, turmeric should be planted in a 30-cm triangular pattern in two rows in a 75-100 cm width ridge in tropical and subtropical areas like Okinawa.

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