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Comparison of conventional and transplant production systems on yield and quality of ginger (*Zingiber officinale*)

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ABSTRACT

Ginger (*Zingiber officinale* Roscoe), is an important horticultural crop and its rhizomes possess myriad health benefits. Three year field experiment (2012-13 to 2014-15) comprising four different planting systems (two transplant and two direct plant) were compared for yield and quality at ICAR-Indian Institute of Spices Research, Kozhikode, Kerala, India. The experiment was conducted to study the performance of transplant production system of ginger for commercial cultivation with comparable yield and quality to conventional planting. The different planting systems influenced the subsequent growth and yield in the field but not significantly. Among yield contributing characters, leaf length showed significant differences among the planting systems. The maximum pooled mean (20.39 t/ha) was recorded by direct planting (20-25 g) followed by two sprout transplant (20.17 t/ha) and single sprout transplant (19.86 t/ha) system. The mean yield of transplant and conventional planting of rhizomes showed no significant difference. The quality parameters in the rhizomes of conventional and transplant systems with respect to the oleoresin, crude fibre and essential oil were comparable. The essential oil of four different planting systems was analyzed by GC-MS. In all the four treatments, the major constituent was zingiberene (24.17% - 26.61%) although the composition was by and large similar. The results of this study demonstrated the suitability of single sprout transplant system by considering the reduction in seed rhizome quantity and eventually reduced cost on seed rhizomes, without significant reduction in yield and quality.

Key words: Ginger, Oil, Oleoresin, Rhizome, Transplant system, Yield

Ginger (*Zingiber officinale* Roscoe) is an herbaceous perennial, the rhizomes of which are used as a spice and is now commercially cultivated in nearly every tropical and subtropical country. It is believed to have originated in Southeast Asia, but was under cultivation from ancient times in India and China. India is a leading producer in the world (FAOSTAT 2016) during 2014-15, produced 0.76 million tonnes from an area of 0.14 million ha. Ginger is extensively cultivated in most of the Indian states, viz. Karnataka, Asom, West Bengal, Madhya Pradesh, Meghalaya, Mizoram, Arunachal Pradesh, Nagaland and Manipur (DASD 2016). Being aromatic and pungent, ginger adds a special flavour to a number of food products and has been a common ingredient in Asian cuisines since centuries. Ginger is comprised of key components including amino acids, shoagoals, gingerols, fibre, essential oils and minerals, and is therefore used commonly as an ingredient in a variety of products for its flavouring and medicinal value (Camacho and Brescia 2009). Suresh *et al*. (2012) reported zingiberene, -sesquiphellandrene and ar-curcumene were the major constituents in most of the ginger rhizome oils.

Ginger is propagated vegetatively by portions of rhizomes known as seed rhizomes (20-25 g). The seed rate varies from 1500 to 2500 kg/ha seed rhizome in India, 5252 to 7250 kg/ha in Southeast Asia, 4000-6000 kg/ha in Jamaica and 8000-10000 kg/ha in Australia, depending on seed size and spacing (Parthasarathy *et al*. 2012) and accounts for about 40-50% of total cost of production (Nybe and Mini Raj 2005). Usually, bigger seed rhizomes (20-80 g) are planted to promote earlier seed sprout, more vigorous growth and higher yield (Sengupta *et al*. 1986, Whiley 1990, Wang *et al*. 2003, Xizhen *et al*. 2005). The pathogens that are rhizome borne in nature, play an important role in the transmission of the pathogen across growing regions through rhizomes (Dohroo 2005). This leads to increased demand for healthy seed rhizomes for large scale planting, which are available in limited quantities. Consequently, the scarcity in good quality seed rhizomes has become a major bottleneck in ginger production among the growing countries. Hence, a rapid method of multiplication with comparable yield and quality is needed especially for newly developed high yielding varieties, which are usually available only in limited quantities. Earlier, detached sprouts from seed rhizomes were tried as planting material and proved successful (Nair 1977, Mahesh and Korla 1998,

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Nath and Korla 2001). However, no systematic research was done to use ginger sprouts as seedling for transplanting for large scale commercial planting.

Hence the present study was undertaken with the objective to compare transplant and direct plant systems on yield and quality of ginger.

MATERIALS AND METHODS

Field experiment was conducted at the Chelavoor Campus of ICAR-Indian Institute of Spices Research (ICAR-IISR), Kozhikode, Kerala, India. The geographical coordinates of the experimental location is 11°17′N, 75°50′E and 60 m MSL. The study reported here was initiated in June 2012 and was repeated for a period of three years from 2012-13 to 2014-15. The area falls under warm humid climate with bimodal distribution of rainfall in which 75% of rainfall is received during the southwest monsoon. The experiment was conducted under rainfed condition (the mean annual rainfall and number rainy days received during 2012, 2013, 2014 were 2220.2 mm, 3033.3 mm, 2888.3 mm in 111, 126 and 120 days, respectively). The soil of experimental plot was Ustic humitropept with clay loam texture, pH 4.4, organic carbon content 2.3%, phosphorus 12 kg/ha, potassium 338 kg/ha, calcium 719 kg/ha, magnesium 162 kg/ha and zinc 0.6 mg/kg. Soil organic C was estimated by the Walkley–Black method (Nelson and Sommers 1982) and Bray P using the dilute acid–fluoride extractant (Kuo 1996). Exchangeable –K, -Ca and -Mg in the NH_4OAc extract (Helmke and Sparks 1996) and available Zn in the DTPA extract (Lindsay and Norvell 1978) were estimated using an atomic absorption spectrophotometer.

The experimental materials consisted of four treatments of different planting systems, laid out in a randomised block design (RBD) with five replications. In treatment 1 (T_1), ginger rhizomes were cut into ~3-5g with a single sprout in each piece, raised in pro-trays and transplanted. Regarding T_2, slightly bigger rhizome bits of ~8-10g with two sprouts, raised in pro-trays were transplanted. The rhizomes of ~8-10g size with two sprouts were directly used for planting in T_3 and 20-25g of rhizomes was used for direct planting in T_4. In the first two treatments, seedlings were raised using 50 cell pro-trays, using partially decomposed coir pith and vermicompost (3:1) enriched with *Trichoderma* as a nursery medium (Prasath *et al*. 2014) and 35 day old seedlings were transplanted on to raised beds of size 3 × 1 × 0.30 m (l × b × h). During planting, shallow pits of 5-10 cm depth were made at a spacing of 25 × 25 cm in the beds and the seed rhizomes or transplants was placed 3.5-5.0 cm deep in these pits. The pits with rhizome were then covered with soil and transplants were planted. All the treatments were field planted in mid-June and harvested during mid-January of every year. An improved ginger variety 'IISR Rejatha' known for its high yield was used in the study. Green leaf mulch (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) was applied @ 15 t/ha immediately after planting, to all the beds, irrespective of the treatments. The mulching is practiced to prevent soil erosion and exposure of ginger rhizomes by heavy rainfall. This was repeated twice during 45 and 90 DAP after weeding, fertilizers application and earthing up @ 7.5 t/ha. Recommended package of practices of ICAR-IISR were followed (Jayashree *et al*. 2015).

The biometric observations were recorded at the end of grand growth phase i.e. 150 days after planting. The plot (3 × 1 m) yield was recorded at harvest and projected to tonnes/ha. The significance among treatments was determined using one-way ANOVA followed by post hoc comparison of means using the least significance difference (LSD) test.

Growth analysis measurements, viz. number of tillers, fresh weight of tillers, fresh weight of rhizomes and roots/plant were made at planting, 60, 120 and 180 days after planting of the growing season on five randomly selected plants per treatment.

The essential oil and oleoresin of dried ginger were estimated by ASTA (2010) and fibre content by AOAC (2007). The volatile oil constituents of different treatments were determined by GC-MS. The essential oil samples were analyzed using a gas chromatograph (Shimadzu GC 2010) equipped with mass spectrometer and capillary column (RTX-Wax, 30m × 0.25mm id × 0.25μm). Helium was used as the carrier gas at a flow rate of 1 ml/min. The column temperature was programmed as follows: at 60^0C for 5 min and then increased to 110^0C @ 5^0C/min, 110^0C - 200^0C @ 3^0C/min, 200^0C- 220^0C @ 5^0C/min, at 220^0C for 5 min. The injection port temperature was maintained at 250^0C, the detector temperature was 250^0C. The split ratio was 1:40. Ionization energy: 70 eV; Mass range: 40-650 am. 0.1μl of essential oil was injected. The percent composition of the components was determined by area normalization. The constituents of the oil were identified by comparison of mass spectra with that of NIST library and relative retention indices using n-alkanes as standard (Adams 2007).

RESULTS AND DISCUSSION

Influence on growth and yield

The plant height among the treatments varied between 64.34 - 69.22 cm and maximum was recorded in single sprout transplant system (Table 1). Maximum number of tiller per plant (23.81) was recorded by the planting of 20-25 g rhizomes (T_4), which was similar to the other treatments. The data on mean leaf length showed maximum leaf length (23.00 cm) in direct planting of 20-25 g rhizomes and minimum (20.20 cm) in single sprout transplant system, suggesting a positive effect of the amount of rhizome food reserve on leaf length. The leaf width was not influenced by planting systems and maximum (2.98 cm) was recorded in T_1. The maximum number of leaves/plant and leaves/main pseudostem (373.62, 21.40) were recorded by planting of 20-25 g rhizomes and minimum (359.11, 19.33) in single sprout transplant system. Maximum plant height, number of tillers, leaf length and width was recorded by planting of 20-25 g rhizomes. This variation in plant growth parameters is due to easy establishment of plants and its early growth.

Table 1　Effect of ginger planting systems on growth characters (pooled data for three years)

	Plant height (cm)	No of tillers	Leaf length (cm)	Leaf width (cm)	No. of leaves in the main tiller	Total number of leaves
T_1	69.22	22.07	20.20	2.98	19.33	359.11
T_2	65.50	22.50	20.82	1.87	20.28	373.46
T_3	68.14	23.62	22.75	2.02	20.45	364.50
T_4	64.34	23.81	23.00	2.11	21.40	373.62
Mean	66.80	23.00	21.69	2.25	20.37	367.67
LSD (P≤0.05)	NS	NS	2.74	NS	NS	NS
CV (%)	8.05	16.20	9.24	10.05	8.95	21.38

T_1, Single bud transplant; T_2, 2-3 buds transplant; T_3, direct planting of 2-3 buds; T_4, direct planting of 20-24g.

Similar findings in different potato planting systems were earlier reported by Wiersema and Cabello (1986) and Batra *et al*. (1992). Though it was non-significant, the number of tillers per plant increased with increase in rhizome weight and is attributed to increase in number of buds.

The rhizome yield was recorded over three consecutive years and pooled mean yield varied from 16.11 t/ha (T_3) to 20.39 t/ha (T_4). The analysis of variance showed no significant differences for yield among the treatments in all the three years (Table 2). The maximum (20.39 tonnes/ha) pooled mean was recorded by direct planting (T_4) followed by two transplant systems, T_2 (20.17 tonnes/ha) and T_1 (19.86 tonnes/ha). Smith and Hamil (1996) reported reduced rhizome yield in micropropagated first generation ginger plantlets as compared to that of normal seed rhizomes. In Ethiopia, Girma and Kindie (2008) reported that the rhizome size of 32 g recorded maximum yield (55-124%) compared to 4 g seed rhizomes. Whereas, in the present study transplant system of 5 g single sprouts produced rhizome yield that was on par with 25 g direct plant system, apparently due to the cumulative effect of better growth in nursery and in field. Moreover, the composted coir pith, vermicompost and *Trichoderma* mixture used for raising transplants is an ideal potting medium which helps in establishment and better growth in initial stages (Prasath *et al*. 2014). This early establishment and bulking of rhizomes of transplanted ginger might be the reason for higher yield. Bhagyalakshmi and Singh (1988) reported that vegetative bud regenerated plants were at par with the conventionally propagated ones except that they need longer (additional 2 months) crop duration for the same effect. Studies conducted at Tamil

Table 2　Mean of fresh rhizome yield of ginger plants established by transplant and direct plant systems

	Yield (fresh rhizomes) (kg 3m^2)				Projected yield (tonnes/ha)
	2013/14	2014/15	2015-16	Mean	
T_1	6.12	8.31	9.40	7.94	19.86
T_2	5.44	8.54	10.22	8.07	20.17
T_3	5.51	6.62	7.20	6.44	16.11
T_4	6.02	8.60	9.86	8.16	20.39
Mean	6.02	8.60	9.86	6.02	19.13
LSD (P≤0.05)	NS	0.95	0.84		
CV (%)	20.14	21.11	18.23		

T_1: Single bud transplant; T_2: 2-3 buds transplant; T_3: Direct planting of 2-3 buds; T_4: Direct planting of 20-25 g

Table 3　Essential oil composition of dried ginger rhizomes established by transplant and direct plant systems

AI	Compound	Composition (%)			
		T_1	T_2	T_3	T_4
0894	2-Heptanol	0.12	0.23	0.21	0.17
0932	α-Pinene	0.85	1.76	1.84	1.18
0946	Camphene	3.02	3.36	5.78	4.05
0.969	Sabinene	0.04	0.07	0.07	0.06
0969	β-Pinene	0.20	0.35	0.33	0.30
0988	β-Myrcene	1.08	1.72	1.73	1.48
1002	β-Phellandrene	2.49	3.62	3.57	3.24
1002	α-Phellandrene	0.28	0.22	0.22	0.21
1026	1,8-Cineole	3.61	4.94	5.22	4.68
1054	γ-Terpinene	0.25	0.31	0.30	0.29
1095	β-Linalool	2.21	2.82	2.67	2.81
1141	Camphor	0.14	0.18	0.17	0.18
1165	Borneol	1.71	1.90	1.95	1.91
1174	4-Terpineol	0.24	0.26	0.29	0.28
1186	α-Terpineol	1.06	1.20	1.15	1.24
1195	Myrtenal	0.12	0.16	0.17	0.15
1223	Citronellol	0.29	0.38	0.45	0.36
1264	Geranial	0.98	0.84	0.77	0.92
1389	β-Elemene	0.73	0.67	0.62	0.69
1440	β-Farnesene	1.05	1.01	1.06	1.02
1458	Allo–aromadendrene	0.37	0.34	0.31	0.39
1462	Dehydro-aromadendrene	0.44	0.41	0.41	0.43
1479	α-Curcumene	7.23	6.69	6.29	6.91
1493	Zingiberene	26.61	24.43	24.17	24.17
1505	α-Farnesene	5.57	4.19	4.74	4.51
1505	β-Bisabolene	3.60	3.92	3.75	3.81
1521	β-Sesquiphellandrene	13.43	12.09	11.77	12.27
1548	Elemol	1.16	1.06	0.94	1.16
1561	Nerolidol	2.57	2.38	2.25	2.56
1602	Ledol	0.86	0.79	0.75	0.84
	Zingiberenol	1.70	1.29	1.21	1.35
1630	γ-Eudesmol	0.16	0.16	0.16	0.16
1649	β-Eudesmol	1.88	1.76	1.84	1.90
1674	β-Bisabolol	1.31	1.76	1.70	1.34
1698	Farnesol(2Z, 6Z)	1.24	1.11	1.08	1.25

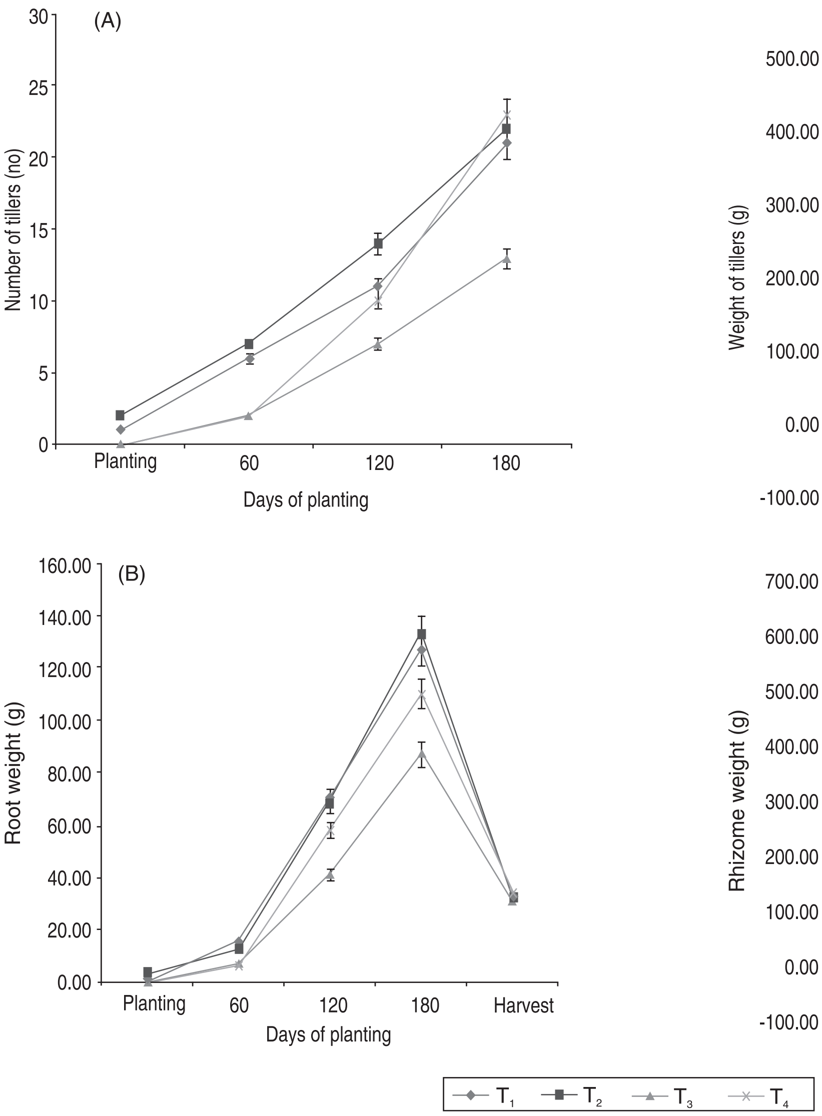

Fig 1 Number of tillers/plant (A), tiller weight (C), rhizome weight (D) and root weight (B) at different growth stages of ginger under different planting systems. Vertical bars represent the standard errors of the means. (T_1: Single bud transplant; T_2: 2-3 buds transplant; T_3: Direct planting of 2-3 buds; T_4: Direct planting of 20-25 g)

Nadu Agricultural University, Coimbatore, Tamil Nadu, India on turmeric using single sprout transplants also showed early establishment, more leaf numbers at early stages, early rhizome development, up to 25% increase in rhizome yield and higher economic returns as compared to direct planting of 25 g seed rhizomes (Shylaja *et al*. 2016).

Growth analysis

The results in Fig 1 A&C demonstrate that total number of tillers and fresh weight of tiller increased with increasing duration of the crop in all four treatments. However, the increase of both the parameters in T_4 was higher after 60 days of planting. Maximum number of tillers and fresh weight of tillers were recorded in T_4 and minimum in T_3. The rhizome weight increased with increasing duration of the crop in all the planting systems, but slight decrease was recorded after 180 days till harvest (Fig 1D). The maximum rhizome weight was recorded in T_4 and minimum in T_3. Whereas, fresh root weight at different growth stages were maximum in T_1 followed by T_2 (Fig 1B). In all the four treatments, the plants partitioned the greatest share of their production into tillers, and least into rhizomes in the initial stages of growth. With increased duration, the plants also allocated a greater share of their dry matter production into rhizomes and roots. Compared to direct planting, the root system in the transplant system at all three developmental stages was high and this aided in easy establishment, better growth and comparable yield and quality of transplants.

Influence on quality

The yield of essential oil from the four different planting systems was 1.20%. Maximum (3.56%) oleoresin was recorded in single sprout transplanting (T1) and minimum (3.15%) in planting of 5-10 g rhizomes. Maximum crude fiber (5.60%) was recorded by planting of 5-10 g rhizomes. Earlier, Govindarajan, (1982) reported 1.0-2.7% oil and 3.9-

Table 4 Cost economics of ginger under different planting systems

	Transplanting		Direct planting	
Seed size (g) of different planting systems	5	10	10	25
No. of plants (ha)	80000	80000	80000	80000
Seed rhizome requirement/ha (kg)	400	800	800	2000
Cost of seed rhizomes/ ha (₹)			40000	100000
Cost of seedling/ha (₹)	40000	64000		
Yield (t/ha)	19.86	20.17	16.11	20.39

9.3% acetone extract in ginger. The quality parameters in the rhizomes of conventional and transplant planting systems with respect to the oleoresin, crude fibre and essential oil were comparable. The chemical composition of ginger oils were shown in Table 3. Thirty six compounds representing more than 80% of the oil is identified by GC-MS analysis. The oil comprised of mainly, zingiberene (24.17-26.61 %), β-sesquiphellandrene (11.77-13.43%), 1,8-cineole (3.61-5.22%), nerolidol (2.25-2.57%), bisabolene (3.60-3.92%), α-curcumene (6.29-7.23%) and α-farnesene (4.19-5.57%), besides several minor constituents. The comparison of levels of 36 compounds in the rhizomes of four planting systems indicated less variation with respect to the essential oil composition among the treatments. The oil composition of four treatments revealed zingiberene (24.17% - 26.61%) was the major constituent, although the composition was by and large similar. As in this study, Nampoothiri *et al*. (2012) also reported zingiberene (32.2%) and β-sequiphellandrene (10.9%) as major compounds in essential oil.

Among the four planting systems compared, single sprout transplant was advantageous by considering the saving in cost of seed rhizomes over conventional planting of 20-25g rhizomes. The advantage of this transplant method is reduction in seed rhizome quantity and eventually reduced cost on seed rhizomes (Table 4). In potato, Singh (2012) also reported reduced cost of cultivation, increased net returns and benefit: cost ratio by planting smaller seed tubers i.e. 10-20 g tubers compared to 50-60 g.

Summarizing the results obtained in the present study, we may conclude that ginger can be successfully grown using single sprout transplant system with comparable yield and quality of conventional rhizome planting under open-field conditions. The planting systems of ginger varied in their influence on growth and development of rhizomes in the field. The yield and quality of rhizomes were on par in the transplant and direct planting systems. However, the transplant system benefitted significantly from reduced seed rhizome quantity. This would eventually reduce the cost incurred on seeds.

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