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EFFECT OF SEED RHIZOME SIZE AND PLANT SPACING ON GROWTH, YIELD AND QUALITY OF GINGER (*ZINGIBER OFFICINALE* ROSC.) UNDER COCONUT CROPPING SYSTEM

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Abstract

A field experiment was conducted to study the effect of seed rhizome size and plant spacing on growth, yield and quality of ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut cropping system during *Kharif*-2014 at Horticultural College and Research Institute Farm, Anantharajupet, Y.S.R. Dist., Andhra Pradesh, India. The study comprised of three seed rhizome sizes *viz.*, 20 g, 30 g and 40 g with five plant spacings *viz.*, 25 cm × 15 cm, 25 cm × 25 cm, 30 cm × 20 cm, 30 cm × 30 cm and 40 cm × 20 cm. The experiment was laid out in a factorial randomized block design with three replications. The rhizome size of 40 g (S_3) took least number of days to first sprouting of rhizome (12.73) followed by 30 g (S_2). Similarly plant height at harvest (67.87 cm), number of tillers per plant (11.51) and leaf area index (3.59), yield per hectare (27.41 t), essential oil content (1.83%) and starch content (30.27%) were recorded maximum with 40 g seed rhizome size. Regarding plant spacing highest plant height (65.07 cm), leaf area index (5.25) and yield per hectare (26.40 t) was recorded from closest plant spacing of 25 cm × 15 cm (D_1). The most satisfactory rhizome yield (38.06 t/ha) was found from the treatment combination of 40 g seed rhizome size with 25 cm × 15 cm plant spacing (S_3D_1).

Key words : Ginger, seed rhizome size, spacing, yield.

Introduction

Ginger or Adrak (*Zingiber officinale* Rosc.) belonging to the family Zingeberaceae is one of the major herbaceous tropical underground stem spice originated in South-East Asia. The distinct flavour, aroma and pungency of ginger is due to oleoresins and volatile oils. Ginger rhizome contains 2-3% proteins, 0.9% fats, 2.4% fibre, 12.3% carbohydrates and is good source of vitamins, minerals and trace elements.

Ginger requires warm and humid climate and thrives well from sea level to an altitude of 1500 m above MSL. A well distributed rainfall of 150 to 300 mm during growing season and harvesting are required for the crop. Lateritic loamy soils are preferred for higher yields.

Development of suitable production technology to boost the crop yield is essential as the yield potential of the variety alone is not sufficient for increasing the yield (Yadav *et al.*, 2013). Seed rhizome size, plant spacing are the important aspects of production system of ginger. It is well documented that rhizome sizes and plant spacing have significant influences on the growth and yield of ginger (Monnaf *et al.*, 2010). Inadequate as well as high plant population leads to low productivity with poor quality.

Growing ginger in coconut orchard proves profitable without hampering the performance of the main crop and the natural resources *i.e.*, soil, water, air space and solar radiation can be better utilized by raising the ginger as intercrop. Considering these facts, the investigation was undertaken to optimize the seed rhizome size and plant spacing for obtaining higher yield in ginger.

Materials and Methods

The experiment was conducted at Horticultural College and Research Institute, Anantharajupet which is located in Rayalaseema region of the Andhra Pradesh and situated at an altitude of 215 m above MSL and located at 13.98^0 North latitude and 79.40^0 East longitudes. The present experiment was conducted under coconut cropping system. The experiment was laid out in a randomized block design with factorial concept with three seed rhizome sizes of ginger *viz*., 20 g, 30 g and 40 g and five plant spacings *viz*., 25 cm × 15 cm, 25 cm × 25 cm, 30 cm × 20 cm, 30 cm × 30 cm and 40 cm × 20 cm. Fifteen treatment combinations were replicated thrice.

Growth, yield and yield component data were collected at appropriate times throughout the experimental periods from five randomly selected plants per plot. The data obtained during investigation was statistically analyzed as per the procedure and design given by Panse and Sukhatme (1985). The statistical significance was tested by applying 'F' test at 0.05 level of probability and critical differences were calculated for those parameters which turned significant ($P < 0.05$) to compare the effects of different treatments.

Results and Discussion

Vegetative growth parameters

i) Days to first sprouting

The data revealed significant effect of different seed rhizome size on days to first sprouting. The rhizome size of 40 g (S_3) took least number of days to first sprouting of rhizome (12.73) followed by 30 g (S_2) and 20 g (S_1) rhizome sizes (13.47 and 13.93, respectively). Similar results were reported by Yothasiri *et al*. (1997) in turmeric who also found significant results for days to first sprouting as affected by different seed rhizome size.

The effect of plant spacing on days to first sprouting was non-significant. However, spacing of 30 cm × 30 cm (D_4) took lowest number of days to first sprouting (12.78) while, the highest number of days to first sprouting was recorded by 25 cm × 25 cm (D_2). These results are in conformity with the findings of Kiran *et al*. (2013) in turmeric.

The interaction effect of seed rhizome size and plant spacing differed significantly. Significantly lowest number of days to first sprouting (11.33) was recorded from a combination of 40 g rhizome size with 30 cm × 30 cm (S_3D_4) spacing.

ii) Leaf area index

Seed rhizome size had significant influence on leaf area index of ginger under coconut cropping system. The treatment of 40 g rhizome size (S_3) recorded significantly highest leaf area index (3.59), while lowest harvest index (3.18) was observed in the 20 g rhizome size (S_1). These results are in accordance with the findings of Blay *et al.* (1998).

Plant spacings showed significant variation regarding leaf area index. The spacing treatment of 25 cm × 15 cm (D_1) produced highest leaf area index (5.25) and lowest (2.45) recorded from spacing of 30 cm × 30 cm. At closer spacing, more plants per unit area can be achieved compared to medium and wider spacings as a result more leaf area per unit area of land. These findings are in accordance and in conformity with the findings of Kandiannan and Chandaragiri (2006) in turmeric crop.

The interaction between seed rhizome size and spacing showed significant effect leaf area index of ginger. Significantly highest leaf area index (5.88) was observed from a combination of 40 g rhizome size with 25 cm × 15 cm (S_3D_1).

iii) Plant height (cm)

Seed rhizome size showed significant influence on plant height throughout the crop growth stages in ginger (table 2). Among different seed rhizome sizes, 40 g rhizome size (S_3) recorded significantly highest plant height at 30 DAP, 120 DAP and at harvest (16.68 cm, 43.25 cm and 67.87 cm, respectively) followed by 30 g rhizome size (S_2) (15.36 cm, 41.99 cm and 63.76 cm respectively). While, 20 g seed rhizome size (S_1) recorded

Table 1 : Days to first sprouting and leaf area index of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

T	Days to first sprouting						Leaf area index					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	15.33	15.00	13.67	12.67	13.00	13.93	5.00	3.13	3.09	2.12	2.56	3.18
S_2	12.67	13.33	13.33	14.33	13.67	13.47	4.88	3.51	3.36	2.60	2.79	3.43
S_3	13.00	13.33	11.67	11.33	14.33	12.73	5.88	3.35	3.18	2.65	2.89	3.59
Mean	13.67	13.89	12.89	12.78	13.67		5.25	3.33	3.21	2.45	2.75	

	Days to first sprouting S.Em±	Days to first sprouting CD at 5%	Leaf area index S.Em±	Leaf area index CD at 5%
S	0.26	0.76	0.06	0.17
D	0.34	NS	0.07	0.21
S × D	0.59	1.71	0.13	0.37

S = Rhizome size, D = Spacing, S_1 = 20 g, S_2 = 30 g, S_3 = 40 g, D_1 = 25 cm × 15 cm, D_2 = 25 cm × 25 cm, D_3 = 30 cm × 20 cm, D_4 = 30 cm × 30cm, D_5 = 40 cm × 20 cm, T = treatments, S × D = Interaction, NS = Non-significant.

Table 2 : Plant height (cm) of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

T	30 DAP						120 DAP						210 DAP (At harvest)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	15.00	15.13	14.83	14.87	14.70	14.91	38.40	33.33	35.73	38.13	38.00	36.72	61.53	60.40	62.33	55.27	61.47	60.20
S_2	16.69	16.03	14.33	16.27	13.50	15.36	43.60	43.60	41.13	43.93	37.67	41.99	66.33	64.20	62.00	63.73	62.53	63.76
S_3	17.33	17.10	16.13	16.03	16.80	16.68	45.40	43.07	43.00	44.27	40.53	43.25	67.33	69.67	66.40	68.13	67.80	67.87
Mean	16.34	16.09	15.10	15.72	15.00		42.47	40.00	39.96	42.11	38.73		65.07	64.76	63.58	62.38	63.93	

	30 DAP S.Em ±	30 DAP CD at 5%	120 DAP S.Em ±	120 DAP CD at 5%	210 DAP S.Em ±	210 DAP CD at 5%
S	0.27	0.78	0.66	1.92	0.40	1.17
D	0.35	1.01	0.86	2.48	0.52	1.51
S × D	0.61	NS	1.48	NS	0.90	2.62

Table 3 : Number of tillers per plant in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

T	30 DAP						120 DAP						210 DAP (At harvest)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	1.73	1.40	1.73	1.73	1.87	1.69	6.87	6.67	7.87	9.73	8.07	7.84	8.93	7.53	8.47	9.53	9.13	8.72
S_2	2.33	2.27	2.60	2.60	3.13	2.59	11.00	9.93	8.40	10.27	10.33	9.99	10.20	9.53	10.67	12.33	9.80	10.51
S_3	3.20	2.67	2.73	3.60	2.67	2.97	11.40	10.40	8.13	12.80	10.00	10.55	12.47	10.53	10.87	13.07	10.60	11.51
Mean	2.42	2.11	2.36	2.64	2.56		9.76	9.00	8.13	10.93	9.47		10.53	9.20	10.00	11.64	9.84	

	30 DAP S.Em ±	30 DAP CD at 5%	120 DAP S.Em ±	120 DAP CD at 5%	210 DAP S.Em ±	210 DAP CD at 5%
S	0.11	0.32	0.23	0.67	0.13	0.36
D	0.14	NS	0.30	0.86	0.16	0.47
S × D	0.25	NS	0.52	1.50	0.28	0.82

S = Rhizome size; D = Spacing; S_1 = 20 g; S_2 = 30 g; S_3 = 40 g; D_1=25 cm × 15 cm; D_2 = 25 cm × 25 cm; D_3 = 30 cm × 20 cm; D_4 = 30 cm × 30cm; D_5=40 cm × 20 cm; T = treatments; S × D = Interaction; NS = Non-significant.

the lowest plant height at 30 DAP, 120 DAP and at harvest (14.91 cm 36.72 cm and 60.20 cm, respectively). The reason for highest plant height recorded from 40 g rhizome size could be explained in terms of availability of sufficient food reserves which probably encouraged vigorous plant growth. This is in agreement with the findings of Kumar (2005) in ginger.

Closer spacing of 25 cm × 15 cm (D_1) recorded maximum plant height at 30 DAP, 120 DAP and at harvest (16.34 cm, 42.47 cm and 65.07 cm, respectively). Plant height decreased with increased plant spacing. Under closer spacing, plant might have adjusted its canopy in the vertical space by increasing inter nodal length as there was limited horizontal space. These results are in accordance with the findings of Yadav *et al*. (2013) in ginger.

Interaction effect of rhizome size and plant spacing on plant height was found to be non-significant at 30 DAP and 120 DAP. However at harvest, it was found to be significant. Among the treatments, the combination of 40 g rhizome size and 25 cm x 25 cm plant spacing recorded the highest plant height (69.67 cm) at harvest.

iv) Number of tillers per plant

Rhizome size and plant spacing had significant influence on number of tillers per plant (table 3). Seed rhizome size of 40 g has recorded significantly highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (2.97, 10.55 and 11.51, respectively). Variation in number of tillers per plant due to rhizome size might be due to the fact that the plants produced from the largest seed rhizome size might be emerging earlier and showed vigorous and rapid growth using the initial reserve food materials than the smallest rhizome size in ginger. These results are in conformity with the findings of Sengupta and Dasgupta (2011) in ginger.

Plant spacing of 30 cm × 30 cm (D_4) has recorded highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (2.64 at 10.93 and 11.64, respectively). The plant density had marked influence on the capacity of plants to utilize environmental factors in building up the plant tissues through regulation of absorption capacity of plants due to better utilization of resources and lesser plant to plant competition. These results are in line with the earlier findings of Yadav *et al*. (2013) in ginger crop.

The interaction effect of seed rhizome size and plant spacing showed significant influence on number of tillers per plant except at 30 DAP. However, a combination of 40 g rhizome size with 30 cm × 30 cm spacing (S_3D_4) produced the highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (3.60, 12.80 and 13.07, respectively).

Yield and yield attributes

i) Rhizome length (cm) and breadth (cm)

Different seed rhizome sizes showed significant variation for rhizomes characters (table 4). Among the rhizome sizes, 40 g seed rhizome size (S_3) followed by 30 g rhizome size (S_2) recorded the longest (15.82 cm and 14.55 cm) and broadest rhizome (15.89 cm and 14.79 cm). Highest length and width of fresh rhizome might be due to increase in seed rhizome size used for planting. These findings are in accordance and in conformity with the findings of Hailemichael and Tesfaye (2008).

Plant spacings showed non-significant variation with regard to rhizome characters. Among the spacing treatments, 30 cm × 30 cm plant spacing (D_4) produced longest rhizome (14.90 cm) and broadest rhizome (14.67 cm). The reason for longest and broadest rhizome with wider spacing might be due to better availability of plant nutrients, moisture and light in wider spaced plants. Similar results were reported by Modupeola *et al*. (2013) and Yadav *et al*. (2013).

The interaction effect of rhizome size and plant spacing on rhizome characters was found to be significant. Among the interactions, a combination of 40 g rhizome size with 25 cm × 25 cm spacing (S_3D_2) recorded maximum rhizome length (17.20 cm) and combination of 40 g rhizome size with 30 cm × 30 cm spacing (S_3D_4) recorded maximum rhizome breadth (17.07 cm).

ii) Rhizome yield per plant (g) and hectare (t)

Seed rhizome size and different plant spacings showed significant effect on rhizome yield of ginger (table 5). Rhizome size of 40 g (S_3) produced significantly highest rhizome yield per plant (204.01 g) and rhizome yield per hectare (27.41 t).

Results regarding variation in yield due to seed rhizome size might be due to the fact that the plants produced from the largest rhizome size emerged earlier and showed vigorous and rapid growth using the initial reserve food materials and producing maximum yield and yield attributes than the smaller rhizome size in ginger. These results are in conformity with the findings of Blay *et al*. (1998), Monnaf *et al*. (2010), Sengupta and Dasgupta (2011).

Among the plant spacings, 30 cm × 30 cm spacing (D_4) produced highest rhizome yield per plant (203.02 g). The higher rhizome weight in wider spacing might be due to better availability of nutrients, moisture and space for the enlargement of rhizomes. These results are in line with the earlier findings of Yadav *et al*. (2013).

Table 4 : Rhizome characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

T	Rhizome length						Rhizome breadth					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	13.20	12.87	12.60	13.00	13.80	13.09	11.73	11.47	13.13	11.53	13.13	12.20
S_2	13.53	14.53	14.80	14.87	15.00	14.55	13.93	15.07	14.60	15.40	14.93	14.79
S_3	15.20	17.20	15.07	16.82	14.80	15.82	15.93	15.93	15.47	17.07	15.07	15.89
Mean	13.98	14.87	14.16	14.90	14.53		13.87	14.16	14.40	14.67	14.38	
	S.Em±		CD at 5%				S.Em±			CD at 5%		
S	0.22		0.63				0.17			0.49		
D	0.28		NS				0.22			NS		
S × D	0.49		1.41				0.38			1.10		

Table 5 : Effect of seed rhizome size and plant spacing on ginger yield under coconut cropping system.

T	Yield per plant (g)						Yield per hectare (t)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	169.07	165.87	160.47	184.93	147.20	165.51	19.00	18.06	18.42	18.36	21.81	19.13
S_2	173.47	196.80	199.53	208.73	189.20	193.55	22.14	28.58	19.69	19.17	18.22	21.56
S_3	201.13	206.80	195.13	215.40	201.60	204.01	38.06	32.39	23.89	22.22	20.47	27.41
Mean	181.22	189.82	185.04	203.02	179.33		26.40	26.34	20.67	19.92	20.17	
	S. Em ±		CD at 5%				S. Em ±			CD at 5%		
S	1.79		5.19				1.34			3.87		
D	2.31		6.70				1.72			5.00		
S × D	4.01		11.61				2.99			8.65		

S = Rhizome size, D = Spacing, S_1 = 20 g, S_2 = 30 g, S_3 = 40 g, D_1 = 25 cm × 15 cm, D_2 = 25 cm × 25 cm, D_3 = 30 cm × 20 cm, D_4 = 30 cm × 30cm, D_5 = 40 cm × 20 cm, T = treatments, S × D = Interaction, NS = Non-significant.

Table 6 : Quality characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

T	Essential oil content (%)						Starch content (%)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	1.78	1.78	1.76	1.74	1.73	1.76	30.30	30.25	30.20	30.31	30.31	30.27
S_2	1.80	1.77	1.82	1.82	1.83	1.81	30.31	30.31	30.29	30.33	30.33	30.31
S_3	1.83	1.80	1.83	1.85	1.82	1.83	30.30	30.32	30.48	30.36	30.33	30.36
Mean	1.80	1.78	1.80	1.81	1.79		30.31	30.29	30.32	30.33	30.32	
	S.Em ±		CD at 5%				S.Em ±			CD at 5%		
S	0.01		0.02				0.01			0.03		
D	0.01		NS				0.01			NS		
S × D	0.01		0.04				0.02			0.07		

S = Rhizome size, D = Spacing, S_1 = 20 g, S_2 = 30 g, S_3 = 40 g, D_1 = 25 cm × 15 cm, D_2 = 25 cm × 25 cm, D_3 = 30 cm × 20 cm, D_4 = 30 cm × 30cm, D_5 = 40 cm × 20 cm, T = treatments, S × D = Interaction, NS = Non-significant.

However, green ginger yield per hectare was significantly highest with a closer spacing of 25 cm × 15 cm (26.40 t), while the lowest green ginger yield per hectare (19.92 t) was recorded from 30 cm × 30 cm spacing. The significant increase in yield per hectare under closer spacing might be solely ascribed on the function of higher plant density per unit area of land together with efficient availability and utilization of nutrients by the growing plants. Similar results were reported by of Yadav *et al*. (2013).

The interaction effect of seed rhizome size and spacing showed significant effect on ginger yield. Significantly highest green ginger yield per plant (215.40 g) was observed from a combination of 40 g rhizome size with 30 cm × 30 cm spacing (S_3D_4). The yield of green ginger per hectare varied significantly with seed rhizome size and plant spacings. The highest green ginger yield per hectare (38.06 t) was recorded by a combination of 40 g rhizome size with 25 cm × 15 cm spacing (S_3D_1).

Quality attributes

i) Essential oil and starch content (%)

Rhizome size showed significant effect on essential oil content and starch content of ginger under coconut cropping system (table 6). Among the treatments, 40 g rhizome size (S_3) recorded significantly higher essential oil content (1.83%) and starch content (30.27%) followed by 30 g rhizome. It was observed that essential oil content increased with the increase in seed rhizome size in ginger.

The essential oil content and starch content differed non-significantly among the spacing treatments. However, highest essential oil content (1.81%) and starch content were observed in 30 cm × 30 cm spacing.

Interaction effect of rhizome size and plant spacing was seen significant on essential oil content and starch content. Highest essential oil content (1.85%) was observed from a combination of 40 g rhizome size with 30 cm × 30 cm spacing (S_3D_4) and highest starch content (30.48%) was observed from a combination of 40 g rhizome size with 30 cm × 20 cm spacing (S_3D_3).

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