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The Effects of Seed Rhizome Size on the Growth, Yield and Economic Return of Ginger (*Zingiber officinale* Rosc.)

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Abstract: An experiment was conducted to study the influence of seed rhizome size on the growth, yield and economic return of ginger to determine an optimum seed rhizome size. The experiment was conducted for three years (1995-1997) at Tepi Agricultural Research Sub-center using a locally grown ginger cultivar. It consisted of four different weight and sizes of seed rhizomes which were grouped as small (R-4 g), medium (R-8 g), large (R-16 g) and very large (R-32 g). The treatments were arranged in Randomized Complete Block Design (RCBD) with four replications. An increase in seed rhizome size significantly increased the major growth and yield component parameters of ginger. Seed rhizome size also significantly affected dry rhizome yield in all the 3 years that the largest seed rhizome size (R-32 g) had significantly higher rhizome yield than the other treatments in 1995 and 1996 and the small and medium size treatments in 1997. The R-32 g treatment increased rhizome yield by 124, 152 and 55% over the R-4 g treatment in 1995, 1996 (low rainfall year) and 1997 (high rainfall year), respectively suggesting the importance of using larger seed rhizomes under relatively lower than higher rainfall conditions. The R-32 g treatment gave a Marginal Rate of Return (MRR) of 235% with the highest residual indicating that using 32 g (>9.1 cm long) seed rhizomes is economically profitable for ginger production in South Western Ethiopia.

Key words: Ginger, seed rhizome size, growth, rhizome yield, marginal rate of return

INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is a spice used either in the form of fresh rhizome, preserved, or dried ground ginger. It is principally used as an ingredient in various spice blends in the food processing and beverage industries in many countries. Ginger is cultivated in the different parts of Ethiopia covering an area of 381 ha with an annual production of 1869.0 t (FAO, 2007).

Ginger is a herbaceous perennial usually grown as annual. Its seeds are virtually unknown and propagation is normally carried out using a small portion of rhizomes known as seed rhizomes or seed sets (Dupriez and De Leener, 1992; Borget, 1993; Ravindran *et al*., 2004). The seed rhizome is the economic yield as well as the planting material of ginger and other rhizomatous crops and affects both the economic return of the grower and the establishment, growth and yield of the crops. The use of large seed rhizomes means the loss of the commercial product whereas the use of small seed rhizome means reduced growth and yield. Therefore, selecting the right size of planting material (length, weight and number of growing buds per seed) is a very critical factor in the cultivation of rhizomatous spices such as ginger and turmeric.

Several studies have been conducted to determine the optimum seed rhizome of different rhizomatous crops. The use of large seed rhizomes is generally found to increase the final yield of rhizomatous spices such as ginger (Whiley, 1990; Borget, 1993). For example, a review of previous works in India by Nybe and Raj (2004) indicate that large sized seed rhizomes of ginger give significantly higher yields than planting of small pieces. An increase in the yield of ginger with an increase in seed rhizome size was also reported in Ghana (Blay *et al*., 1998) and Australia (Whiley, 1990). Hossain *et al*. (2005) found high yield of turmeric from using 30-40 g seed rhizomes compared to 10 and 20 g seed rhizomes. A yield advantage of more than 90% was also reported for turmeric in Ethiopia from using larger (6-8 cm) seed rhizomes than smaller (2-4 cm) ones (Woldu, 1993).

Although it is now clear that an increase in seed rhizome size increases yield in ginger, there is little information on the economic return of large seed

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rhizomes. Moreover, there is no recommendation on the optimum seed rhizome size of ginger for its production in Ethiopia although it has become one of the most important cash crops of the country. Therefore, the objective of this study was to determine the optimum seed rhizome size of ginger with respect to its growth, yield and economic return.

MATERIALS AND METHODS

The experiment was conducted in South Western Ethiopia at Tepi Agricultural Research Sub-center experiment field in 1995, 1996 and 1997. The site is located at a latitude of 7°30' N, a longitude of 35°0' E and an altitude of 1200 m above sea level. The experimental site receives a long-term mean annual rainfall of 1688 mm and has a mean maximum and minimum temperature of 29.5 and 15.3°C, respectively (Edossa, 1998). The experimental soil is classified as Dystric Nitisol and it is dominated by a loam texture.

A locally grown high yielding ginger cultivar was used for the study. The experiment consisted of four different weight and sizes of seed rhizomes which were grouped as small (R-4 g), medium (R-8 g), large (R-16 g) and very large (R-32 g) (Table 1). The treatments were arranged in Randomized Complete Block Design (RCBD) with four replications.

The land was ploughed three times and seed rhizomes were planted manually. Each plot had 10 rows (4.5 m long) of plants and the inter- and intra-row spacings were 30 and 15 cm, respectively while the distance between blocks and plots were 100 and 50 cm, respectively. The seed rhizomes were planted on April 26 and March 29 and harvested on March 11 and February 7 in 1995 and in 1996 and 1997 cropping seasons, respectively. No fertilizer was applied to the field and the plots were kept free of weeds by hand weeding.

Growth, yield and yield component data were collected at appropriate times throughout the experimental periods. Plant height, number of leaves per tiller, length and width of fully opened leaves, diameter of stem and number of tillers per plant were measured from 5 randomly selected plants per plot at 150 Days After Planting (DAP). Number of fingers per rhizome, length, width and weight of rhizome and total rhizome yield were determined at harvest from the net plot area (10.8 m^2). Dry rhizome yield was taken as 0.20 times fresh rhizome yield.

The data were analyzed using SAS software (SAS, 2001) and mean separation was made using the Least Significant Difference (LSD) test. The economic feasibility of the seed rhizome treatments was assessed using partial budget, marginal rate of return and residual analyses following the procedures of CIMMYT (1988). The three years mean yield data was used for the economic feasibility analysis. Because of expected variations between yield at the experimental plot and the farmers' fields due to differences in crop management and plot size (CIMMYT, 1988), rhizome yield was adjusted down by 20%. Local market sell price of fresh seed rhizomes of Ethiopian Birr (ETB) 0.5 kg^{-1} and three years (1995-1997) average local sell price of ETB 7.00 kg^{-1} of dried ginger were used. Although harvesting and transporting are usually done by the farmers themselves, these activities are costed at ETB 0.10 and 0.09 kg^{-1}, respectively in order to take into account the opportunity cost of the farmers' labor.

Table 1: Weight, length, diameter and number of buds of ginger seed rhizomes used for the study

Treatments	Mean fresh weight of seed rhizome (g)	Length of seed rhizome (cm)	Mean diameter of seed rhizome (cm)	Mean No. of buds per seed rhizome
Small	4.0	<3.0	2.3	4.1
Medium	8.0	3.1-6.0	3.4	7.1
Large	16.0	6.2-9.0	4.1	13.1
Very large	32.0	>9.0	4.8	18.3

RESULTS

Climatic conditions during the experimental periods: The rainfall and temperature of the experimental periods in 1995, 1996 and 1997 is shown in Fig. 1. The mean monthly maximum and minimum temperatures showed similar monthly variation across the experimental years. However, the amount of annual total rainfall and its monthly distribution were different among the experimental years (Fig. 1). The total rainfall received was 1739.9, 1526.1 and 1892.7 mm in the years 1995, 1996 and 1997, respectively indicating that 1996 was the driest year while 1997 was the wettest year.

Effects of seed rhizome size on the growth of ginger: Seed rhizome size significantly affected most of the growth parameters measured. Plant height and number of tillers per plant were significantly affected by differences in seed rhizome size in all the three years. Plant height significantly increased with an increase in seed rhizome size. However, there was no significant difference in plant height between the R-8 g and R-16 g treatments. The number of tillers per plant also increased significantly with an increase in seed rhizome size. Compared to the other treatments, the R-32 g treatment gave the highest number of tiller per plant in all the three experimental years. Except the R-16 g in 1996, the R-4 g, R-8 g and R-16 g seed rhizome sizes gave similar number of tillers per plant in 1995, 1996 and 1997 (Table 2).

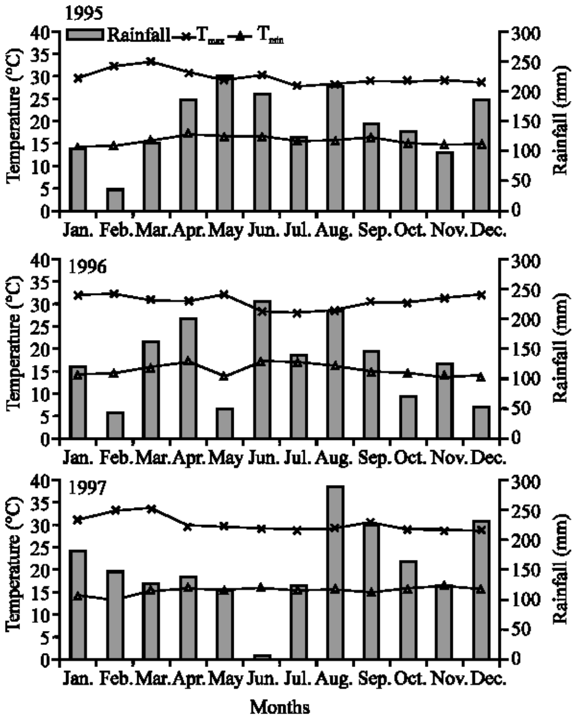

Fig. 1: Total monthly rainfall and mean monthly maximum (T_{max}) and minimum (T_{min}) temperatures during the experimental periods in 1995, 1996 and 1997 at Tepi, Ethiopia

Table 2: Effects of seed rhizome size on the growth of ginger grown at Tepi during 1995-1997

Treatments	PLH[a] (cm)	NTPP	NLPT	SD (cm)	LFL (cm)	WFL (cm)
1995[µ]						
R-4 g	69.5c	11.8b	21.0	0.70ab	23.8	2.4a
R-8 g	86.6ab	11.3b	19.8	0.61b	20.1	2.1b
R-16 g	82.4b	12.8b	18.3	0.73a	23.1	23.1a
R-32 g	91.0a	15.8a	18.3	0.71a	22.1	22.1ab
Statistical significance	***	*	ns	*	ns	ns
CV (%)	5.7	14.1	11.7	10.40	6.2	7.8
1996						
R-4 g	67.9b	10.7c	19.8b	0.66	23.6	2.3
R-8 g	81.4a	11.3c	19.5b	0.62	22.4	2.3
R-16 g	83.2a	15.5b	19.8b	0.63	21.6	2.2
R-32 g	89.3a	21.0a	22.7a	0.73	21.5	2.2
Statistical significance	**	***	*	ns	ns	ns
CV (%)	6.8	8.0	6.4	11.80	7.2	5.3
1997						
R-4 g	75.1c	11.5b	21.0b	0.70b	19.0	1.6
R-8 g	88.9b	16.8b	21.5b	0.78b	18.3	1.8
R-16 g	88.5b	14.8b	27.0a	0.90a	17.7	2.1
R-32 g	102.2a	23.3a	27.5a	0.90a	17.5	1.9
Statistical significance	***	**	**	*	ns	ns
CV (%)	4.9	22.0	8.7	9.0	8.5	14.1

*, **, ***Treatment effects significant at p≤0.05, p≤0.01 and p≤0.001, respectively; ns: non-significant treatment effect (p>0.05), [µ]Means followed by the same letter(s) in a column within a year are not significantly different at 5% p-level, [a]PLH: Plant Height; NLPT: No. of Leaves Per Tiller; LFL: Length of Fully opened Leaves per plant; WFL: Width of Fully opened Leaves per plant, NTPP: No. of Tillers per Plant; SD: Stem Diameter per plant

Table 3: Effects of seed rhizome size on the yield components of ginger grown at Tepi during 1995-1997

Seed rhizome size	NFPR[a]	WtR (g)	LR (cm)	WdR (cm)
1995[µ]				
R-4 g	4.8b	39.5b	8.2b	3.0b
R-8 g	4.8b	64.0b	9.9ab	4.8a
R-16 g	6.3ab	62.5b	10.4a	4.6a
R-32 g	8.3a	98.5a	10.9a	4.7a
Statistical significance	*	**	*	*
CV (%)	21.8	26.2	12.5	13.5
1996				
R-4 g	5.5	33.5b	6.2c	3.1b
R-8 g	7.3	48.0b	8.0b	3.6ab
R-16 g	6.5	55.5ab	8.7b	3.6ab
R-32 g	7.8	76.5a	10.6a	4.1a
Statistical significance	ns	*	**	ns
CV (%)	16.4	31.6	12.6	12.8
1997				
R-4 g	5.3	44.7c	9.5	5.4
R-8 g	6.0	60.4b	10.8	5.3
R-16 g	5.5	62.0b	9.6	5.5
R-32 g	6.5	78.8a	10.6	6.0
Statistical significance	ns	***	ns	ns
CV (%)	18.2	10.7	8.7	6.6

*, **, ***Treatment effects significant at p≤0.05, p≤0.01 and p≤0.001, respectively; ns: non-significant treatment effect (p>0.05), [µ]Means followed by the same letter(s) in a column within a year are not significantly different at 5% p-level, [a]NFPR: No. of Fingers Per Rhizome, WtR: Weight of fresh Rhizome, LR: Length of Rhizome, WdR: Width of Rhizome, DRY: Dry Rhizome Yield

Number of leaves per tiller and stem diameter were significantly affected by rhizome seed size in two of the three experimental years. Significantly higher number of leaves per tiller was recorded from the R-32 g in 1996 and from the R-32 g and R-16 g in 1997. The number of leaves per tiller was not significantly affected by seed rhizome size in 1995. The R-4 g and R-8 g had significantly lower stem diameter than the R-16 g and R-32 g treatments in 1995 and 1997, but seed rhizome size had no significant effect on stem diameter in 1996. Seed rhizome did not also affect length and width of fully open leaves at 150 DAPS in all the years (Table 2).

Effects of seed rhizome size on yield components of ginger: Number of fingers per rhizome was significantly affected by seed rhizome size in 1995 but not in 1996 and 1997. The largest seed rhizome size gave significantly higher number of fingers per rhizome compared to the other seed rhizome treatments in 1995. Fresh rhizome weight per rhizome was significantly affected by seed rhizome size in all the three years. The largest seed rhizome treatment produced significantly heavier fresh rhizomes per rhizome in all the three years compared to the rest of the seed rhizome treatments. Relative to the R-4 g, the R-32 g treatment increased fresh rhizome weight per rhizome by 149, 128 and 76% in 1995, 1996 and 1997, respectively (Table 3). However, there was no significant difference in fresh rhizome weight per rhizome among the R-4, R-8 and R-16 g treatments in 1995 and 1996 although

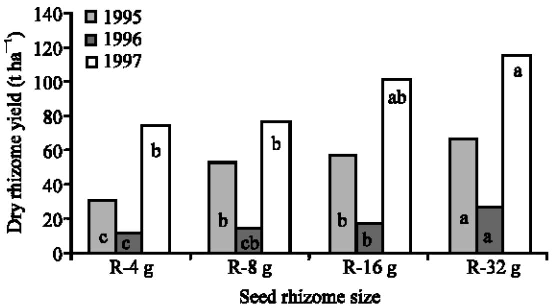

Fig. 2: Effect of seed rhizome size on the rhizome yield of ginger at Tepi, Ethiopia during 1995-1997. (Bar graphs indicated by the same letter(s) within a year are not significantly different at 5% p-level)

the R-4 g treatment gave significantly lower fresh rhizome weight than the other two treatments in 1997.

The length of fresh rhizomes was significantly affected by seed rhizome size in two (1995 and 1996) of the three years and it increased with an increase in seed rhizome size. However, there was no significant difference between the R-8 and R-16 g treatments in 1996 and among the R-8, R-16 and R-32 g treatments in 1995.

Width of fresh rhizomes was significantly affected only in 1995 and that the R-4 g treatment produced significantly lower width of rhizome compared to the other treatments which had similar values (Table 3).

Effects of seed rhizome size on the yield of ginger: Seed rhizome size significantly affected dry rhizome yield in all the experimental years. Dry rhizome yield showed differences among the experimental years in which ginger yield was high in 1997, medium in 1995 and low in 1996. Dry rhizome yield increased with an in increase in seed rhizome size. The R-32 g gave significantly higher rhizome yield than the rest of the seed rhizome treatments in 1995 and 1996 and the R-4 and R-8 g treatments in 1997. There was no significant difference between the R-8 and R-16 g treatments in 1995 and 1996 and among the R-4, R-8 and R-16 g treatments in 1997. Relative to the R-4 g treatment, the R-32 g increased rhizome yield by 124, 152 and 55% in 1995, 1996 and 1997, respectively (Fig. 2).

Economic analysis: The economic analysis of the effect of seed rhizome size on ginger production is presented in Table 4, 5 and 6. It is evident from these tables that an increase in seed rhizome size increased the economic return of ginger production. The highest MRR (904%) was derived from using a seed rhizome size of R-8 g followed by R-16 and R-32 g treatments in that order (Table 5). However, the residual analysis in Table 6 indicated that the use of R-32 g (highest residual) was the most profitable option compared to the other seed rhizome treatments. Therefore, if a farmer would invest ETB 100 on purchasing very large seed rhizomes (R-32 g), he might get a benefit of ETB 235 (MRR = 235%).

Table 4: Partial budget for ginger production in Tepi using four different seed rhizome sizes

	Seed rhizome size			
Parameters	R-4 g	R-8 g	R-16 g	R-32 g
Dry rhizome yield (kg ha^{-1})	3807.50	4902.70	5764.50	6934.70
Adjusted dry rhizome yield (kg ha^{-1})	3046.00	3922.00	4612.00	5548.00
Gross benefit (ETB ha^{-1})	21322.00	27455.12	32281.20	38834.32
Fresh seed rhizome (kg ha^{-1})	888.90	1777.80	3555.60	7111.20
Cost of planting material (ETB ha^{-1})	444.45	888.90	1777.80	3555.60
Cost of labor for harvest (ETB ha^{-1})	304.60	392.21	461.16	554.77
Cost of transport to the nearest market (ETB ha^{-1})	274.14	352.99	415.04	499.29
Total costs that vary (ETB ha^{-1})	1023.00	1634.00	2654.00	4610.00
Net benefit (ETB ha^{-1})	20299.00	25821.00	29627.00	34225.00

Table 5: Marginal rate of return for ginger production in Tepi using four different seed rhizome sizes

Seed rhizome size	TCTV[a]	MC	NB	MB	MRR
	(ETB ha^{-1})				(%)
R-4 g	1023	-	20299	-	-
R-8 g	1634	611	25821	5522	904
R-16 g	2654	1020	29627	3806	373
R-32 g	4610	1956	34225	4597	235

[a]TCTV: Total Costs That Vary, MC: Marginal Cost, NB: Net Benefit, MB: Marginal Benefit, MRR: Marginal Rate of Return

Table 6: Residual analysis for ginger production in Tepi using four different seed rhizome sizes

Seed rhizome size	TCTV	NB	Return required	Residual
	(ETB ha^{-1})			
R-4 g	1023	20299	738	19561
R-8 g	1634	25821	1053	24768
R-16 g	2654	29627	2222	27406
R-32 g	4610	34225	4243	29981

DISCUSSION

Seed rhizome size significantly affected most of the plant growth parameters of ginger (plant height, number of leaves per tiller, number of tillers per plant and stem diameter) at least in two of the three experimental years. These growth parameters increased with an increase in seed rhizome size which could be due to larger buds and large amount of food reserves in the larger seed rhizomes which enhanced plant growth as observed in ginger (Blay *et al*., 1988) and turmeric (Hossain *et al*., 2005). The lack of significance difference among the seed rhizome size treatments in the length and width of fully opened leaves at 150 DAP indicate similar leaf growth attained at that particular moment. However, this might not necessarily indicate lack of significant difference among the treatments before the measurement period because of the dynamic nature of growth. For example, Hossain *et al.*

(2005) found significant differences among seed rhizomes sizes of turmeric in plant height before 180 DAP but similar plant height at 180 DAP in one of its greenhouse experiments.

Seed rhizome size also significantly affected fresh rhizome weight and length of rhizome in at least two of the three experimental years and number of fingers per rhizome and width of rhizome in one of the three years. Rhizome yield per hectare also significantly increased with an increase in seed rhizome size in all the three years. This is in agreement with previous findings in ginger (Whiley, 1990; Blay *et al*., 1998) and turmeric (Hossain *et al*., 2005) that rhizome yield significantly increased with an increase in seed rhizome size in the respective crops. Rhizome yield was positively significantly correlated with plant height (r = 0.65*, n = 12), number of leaves per tiller (0.66*), stem diameter (0.83**), length of rhizome (0.65*) and width of rhizome (0.94***). Therefore, the highest rhizome yield in the largest seed rhizome size used in the current study is due to taller plants that have higher number of leaves per tiller, larger stem diameter and longer and thicker rhizomes.

In the current study, an increase in rhizome yield due to the largest seed size relative to the smallest seed rhizome size was greater in the lowest rainfall year (1996) compared to the other high rainfall years. This suggests that the use of large seed rhizomes is more essential in maintaining high rhizome yield of ginger under unfavorable environmental conditions than favorable ones.

Since the rhizome is both the planting material and the economic yield of ginger, it is necessary to consider the size of the planting material that is economically feasible to the grower. Partial budget, marginal rate of return and residual analyses of the three years data indicated that the use of R-32 g seed rhizome size was economically feasible to the farmers in the experimental area. Farmers could get a benefit of 2.35 times the cost they invest on very large seed rhizomes of ginger. The importance of using MRR in identifying optimum treatment levels has been also exemplified in ginger fertilization experiments (Halder *et al*., 2007).

CONCLUSION

An increase in seed rhizome size of ginger significantly improved most of the growth and yield components of ginger. It also significantly increased rhizome yield and provided an attractive marginal rate of return. Therefore, the use of seed rhizomes as large as 32 g improves the growth and yield of ginger and it is economically profitable to the grower in the study area.

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