Yield and Quality Assessment of Ginger (*Zingiber officinale* Rosc.) Genotypes

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Ginger (*Zingiber officinale* Rosc.) is an important spice crop used either in the form of fresh rhizome or dried ground ginger. It is principally used as an ingredient in various spice blends in food processing and beverage industries. In north eastern region of India, ginger is an important cash crop, which support the livelihood and improve the economic level of tribal community. In the present study, 33 genotypes including some local genotypes of ginger was undertaken to identify the desirable type and proper stage of harvesting for commercial production. The changes in yield, dry matter, fiber, starch, protein and essential oil were determined at four stages of maturity *i.e.* five, six, seven and eight months after sowing these ginger genotypes. The increase in yield was non significant after seven months of sowing. With the advent of maturity, study revealed that dry matter, fibre, and starch content of rhizome increases while protein and oil content decreases. The genotypes Jugijan, Suprabha and Varada can be harvested at early stages (6 months after sowing) while Nadia and Mahima may be harvested at full maturity for high yield and better quality *i.e.* low fiber and high volatile oil recovery. It is concluded that ginger crop could be harvested after seven months of sowing due to increase in yield and quality parameter which was non significant after seven months.

Key Words: Genotypes, Quality, Yield, *Zingiber officinale*

Introduction

Ginger (*Zingiber officinale* Rosc.) is an important spice crop used either in the form of fresh rhizome or dried ground ginger. It is principally used as an ingredient in various spice blends in the food processing and beverage industries. Ginger is commercially available in various forms such as green ginger, dry ginger, ginger powder, ginger oil, ginger oleoresin and preserved ginger (Kizhakkayil and Sasikumar, 2009). The refreshing aroma and the pungent taste makes ginger an essential ingredient of most world cuisine and of the food processing industry. In western countries, ginger is used in gingerbread, biscuits, cakes, puddings, soups, pickles, beer and wine (Sanwal *et al*., 2010). In Saudi Arabia, it is predominantly used for flavouring coffee (Pruthi, 1993). Although ginger is grown in Jamaica, Sierra Leone, Nigeria, South China, Japan, Taiwan and Australia, the Indian ginger is considered as one of the best in the world (Philip, 1989). Among all spices, ginger is the main cash crop supporting the livelihood and improving the economic level of many ginger growers of north eastern region (Yadav *et al.*, 2004). The North Eastern Hill (NEH) region of India is accounting 49% of India's ginger area and 72% of production (Rahman *et al.*, 2009).

The varieties presently grown are not much suitable for dry ginger production and there is no nearby market for green ginger in bulk quantities. Thus to make the crop remunerative, it has been essential to convert at least a part of the harvest in low volume high cost produce, like dry ginger. A good quality ginger is one which contains less fiber and high protein and fat. Though, the amount of fiber, protein, fat etc. varies from variety to variety but the stage of harvesting also affect the quality characters in ginger (Ratnambal *et al.*, 1987; Vernin and Parkanyi, 2005). Therefore, the present investigation was undertaken to identify the desirable types and proper stage of harvesting for commercial production of ginger for different end uses *i.e.* dehydrated ginger, oil, oleoresin, etc.

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Materials and Methods

Field experiments were conducted for two consecutive seasons during 2006-2008 (April-December) at the ICAR Research Complex for the NEH Region, Umiam, Meghalaya, India. The experimental site was located at 26° N latitude and 92° E longitude, with an elevation of 950 m above mean sea level. The soil was a sandy loam in texture, acidic (pH 5.4), having an organic carbon content of 1.9 %, with 286.97, 11.24 and 206.76 kg/ha of available N, P and K, respectively.

The experimental design was a randomized block with 33 genotypes having three replications. A rhizome size weighing 40-50g having at least two active buds were planted at a spacing of 30 × 25 cm on raised beds with a plot size of 5.1 × 3.0 m^2 during first week of April in each growing season. The rhizomes were harvested 5, 6, 7, and 8 months after sowing, where periodical development of rhizomes, dry matter, fiber, starch, protein and volatile oil were determined. The fresh samples were peeled off, dried in a hot air oven at 60°C until a constant mass was reached and then ground for chemical analysis. The dry matter content of rhizome was determined according to the procedure in the AOAC (1965). Crude fiber was determined with a Fibertec 2021 Fiber Cap™ system (Foss Tecator AB, Hoganas, Sweden) as per AOAC (1965). Volatile oil content on dry weight basis were determined as per AOAC (1997), while the crude protein was estimated by multiplying the nitrogen content of rhizome by a factor of 6.25 (based on the assumption that nitrogen constitutes 16% of a protein). The starch was estimated with anthrone reagent method (Malik and Singh, 1980). Data were subjected to ANOVA (Gomez and Gomez, 1984), and if year is found non significant, the data were pooled and appropriate means were separated with Least Significant Difference analysis.

Results and Discussion

Rhizome Yield

From the pooled analysis of 2 years data on rhizome yield, it was found that rhizome yield of any genotype was not stabilized in all the four stages of harvesting (Table 1). The genotype, Mahima had highest yield at 150 days of harvesting followed by 294 Vars, Jugijan and Moran; while Jugijan, Suprbha and Varada did well both at 150 and 180 days of harvesting. At full maturity stage (240 days) the highest yield was recorded in Nadia followed by Varada and Mahima though the difference was non significant. The variety Jugijan and Suprabha prformed better than other genotypes at early stage of harvesting *i.e.* 150-180 days while harvesting at full maturity, Nadia, Varada and Mahima were better option than other genotypes for yield. The average value of 33 genotypes for different traits at different stages of harvesting presented in Table 3. It shows that the most significant increase in rhizome yield was between 150 to 180 days. A relative percentage increase of 60.15, 34.14 and 19.67 in the yield took place between 5-6, 6-7 and 7-8 months, respectively, after sowing.

Dry Matter

At the first sampling, dry matter was higher in Jugijan than the other genotypes, while the genotypes Karakal and Var 35 had higher dry matter content at remaining stages of harvesting (Table 1) *i.e.* 180, 210, 240 days. It is observed that dry matter content increased with maturity (Table 3). However, the dry matter build up in the green rhizome was found higher between 5-6 months than by 6-7 and 7-8 months.

Fiber Content

On an average, the crude fiber content at 150 days was 2.9% and increased to 6.41% at full maturity (Table 3). Though the increase in fiber content was noticed up to the last stage of harvesting, the maximum rise in the fiber content observed between 150 to 180 days of harvesting (Fig 1). The genotypes namely, China, Tura Local, Mahima, Kachai Ginger and Nadia had low amount of fiber content than the other genotypes. Fully matured ginger had crude fiber about 2.25 times higher than first harvesting. Jogi *et al.* (1972) also reported the similar kind of trend for crude fiber.

Starch Content

With the advent of maturity, the starch content followed increasing trend (Table 2, Fig 1). In the most genotypes there were little increase in starch content between 150-180 days, but there was considerable increase between 180-210 days and 210-240 days and it was almost double at full maturity than first harvesting. The genotypes 14 Vars, Karakal and Suprabha had high amount of starch content.

Protein Content

A non significant change in protein content was recorded between 5-6 months. In contrast the yield, dry matter, fiber and starch content, the protein content decreased

Table 1. Yield, dry matter and fibre content of ginger germplasm at different harvesting stages

Genotypes	Yield (q/ha)				Dry matter (%)				Crude fiber (%)			
	150 days	180 days	210 days	240 days	150 days	180 days	210 days	240 days	150 days	180 days	210 days	240 days
45 Vars	62.16	112.80	173.26	202.26	11.17	15.93	20.42	23.86	3.20	3.69	4.91	6.71
64 Vars	75.29	125.43	180.16	191.35	12.05	15.48	18.97	21.35	3.09	4.21	5.93	6.57
40 Vars	70.74	112.32	167.76	182.26	11.99	16.15	19.64	22.45	3.16	4.44	5.78	6.59
Khonsa	81.78	126.24	150.89	190.97	11.86	15.78	18.29	23.86	2.90	4.02	4.98	6.15
Jugijan	91.75	148.45	193.16	210.29	14.13	17.12	20.15	23.12	2.94	4.82	5.32	6.74
Suprabha	86.66	143.26	192.20	215.47	10.67	13.42	17.82	21.93	2.79	3.63	4.78	5.77
142 Vars	62.65	117.59	167.26	193.26	12.48	18.76	21.14	23.67	2.89	3.83	5.12	5.89
Karakal	79.26	116.65	167.30	198.70	11.12	17.88	22.82	25.43	3.04	4.58	5.42	6.50
Manipuri o 1	48.66	101.34	164.47	171.26	10.35	15.15	18.32	21.18	2.57	4.26	5.87	6.77
China	68.65	109.25	152.60	168.25	11.95	13.66	18.74	21.15	1.98	3.02	4.60	5.16
Burdwan	74.26	119.33	163.28	183.70	10.66	14.15	17.78	19.57	3.34	5.27	6.88	8.03
Ernad	81.25	122.76	158.95	196.36	10.95	16.34	18.50	22.78	2.95	3.87	5.88	6.59
294 Vars	92.26	136.60	180.60	217.61	10.73	14.55	18.18	23.98	3.18	4.10	5.28	6.75
35 Vars	80.64	130.63	163.29	188.74	10.13	17.82	21.40	25.62	3.45	5.01	6.07	7.21
Basar	78.65	136.30	187.29	209.40	11.41	16.74	21.36	22.54	3.19	4.36	5.78	7.02
Rejatha	77.78	110.82	182.44	213.95	12.64	16.09	17.48	20.89	2.67	3.43	4.74	5.88
Deomali	60.65	112.74	175.51	190.39	10.76	13.98	18.12	22.81	3.32	4.26	5.64	6.54
116 Vars	76.34	116.75	154.09	199.91	10.60	14.36	17.26	21.65	3.46	5.19	6.28	7.66
179 Vars	84.65	127.61	171.33	201.75	11.29	15.62	18.66	22.80	2.76	3.90	4.98	6.56
Mahima	93.24	131.78	191.88	223.43	12.54	14.43	18.97	20.70	2.45	3.54	4.32	5.66
Pune	63.70	116.84	166.96	183.26	10.92	13.37	17.64	19.76	2.87	4.06	4.99	6.24
Varada	83.23	137.64	189.26	224.60	11.84	14.65	18.40	21.38	2.99	3.26	4.87	5.93
Tura Local	65.26	137.04	160.27	178.26	12.15	15.45	18.24	21.90	2.25	3.80	4.13	5.50
Thingpui	69.06	109.84	154.66	193.41	12.51	17.91	20.25	22.47	2.01	3.13	4.65	5.74
Moran	91.50	122.72	165.75	198.15	11.36	15.40	20.48	24.02	2.12	3.79	4.70	6.25
27 Vars	83.66	127.95	175.39	202.61	11.42	15.78	18.47	21.93	3.15	4.47	5.87	6.88
Khasi Local	54.66	98.65	122.65	147.65	9.88	13.12	18.05	20.12	3.25	4.75	5.59	7.02
204 Vars	79.15	128.62	175.42	199.95	9.26	13.49	17.40	20.24	3.30	4.96	5.82	6.16
Thinglaidon	73.85	131.33	168.28	184.25	11.18	16.25	19.04	22.38	2.66	3.46	5.00	5.86
14 Vars	62.94	99.26	162.44	178.20	11.02	15.26	18.74	22.49	2.75	4.26	5.43	6.64
Kachai Ginger	80.80	124.46	173.26	200.98	12.50	16.24	19.52	24.87	3.10	4.22	5.09	5.72
Nagaland ocal	76.88	110.42	163.26	191.80	9.98	14.14	16.89	19.80	2.95	4.19	5.02	6.93
Nadia	102.64	123.88	176.20	232.80	10.48	15.55	19.14	22.25	3.00	3.94	5.16	5.88
CD at 5%	1.62	2.95	2.91	4.55	0.24	0.34	0.33	0.43	0.02	0.99	0.51	0.28
CV%	15.70	10.12	8.46	8.94	8.77	9.34	7.24	7.12	13.51	13.92	11.30	9.77

Table 2. Percentage starch, protein and essential oil in ginger germplasm at different harvesting stage

Genotypes	Starch (%)				Protein (%)				Essential oil (%)			
	150 days	180 days	210 days	240 days	150 days	180 days	210 days	240 days	150 days	180 days	210 days	240 days
45 Vars	20.66	22.15	33.45	44.54	14.90	14.72	9.54	7.24	2.30	2.10	2.00	1.50
64 Vars	22.44	24.36	31.32	40.37	12.50	12.74	8.60	7.12	2.85	2.30	1.90	1.80
40 Vars	18.60	20.50	30.69	39.45	12.24	13.42	9.12	8.10	2.50	2.30	1.80	1.45
Khonsa	23.75	23.90	34.16	44.24	15.00	13.63	8.41	6.23	3.10	2.70	2.55	1.80
Jugijan	25.05	25.98	32.16	42.34	13.18	13.74	7.72	7.26	2.85	2.40	1.75	1.35
Suprabha	27.48	29.30	36.42	47.12	14.25	13.78	8.14	6.12	3.00	2.35	1.90	1.80
142 Vars	20.12	24.35	31.26	40.78	12.42	12.56	6.24	5.77	3.05	2.65	2.15	1.90
Karakal	19.25	23.35	37.60	48.20	12.00	12.85	9.75	8.90	3.00	2.20	1.80	1.35
Manipuri o 1	21.26	25.16	32.42	41.70	13.62	12.56	8.25	5.75	2.75	2.60	2.10	1.45
China	20.30	24.63	35.08	43.68	14.25	13.50	7.45	7.25	2.85	2.20	1.90	1.85
Burdwan	25.28	26.15	33.14	42.74	12.60	12.80	8.00	6.10	2.60	2.45	1.85	1.60
Ernad	26.20	31.10	33.77	45.16	13.00	11.80	7.50	7.60	3.15	2.90	2.15	1.70
294 Vars	19.45	21.18	32.47	44.60	15.20	14.36	9.58	6.40	2.55	2.40	2.10	1.60
35 Vars	26.30	27.62	33.70	46.80	12.24	11.45	7.94	5.54	3.55	2.80	2.20	1.70
Basar	23.64	24.95	31.42	43.19	13.20	13.46	6.45	7.02	3.10	2.95	2.15	1.30
Rejatha	22.25	24.76	30.41	42.42	15.32	13.46	8.64	6.20	3.90	3.30	2.85	2.15
Deomali	21.70	24.50	33.52	43.44	13.33	13.20	7.46	6.20	3.55	3.05	2.40	1.90
116 Vars	26.15	238.32	34.42	40.18	14.55	12.76	7.42	5.12	2.80	2.10	1.70	1.60
179 Vars	25.50	26.13	37.12	46.09	12.50	13.26	8.66	6.44	3.05	2.90	1.85	1.65
Mahima	19.98	21.26	29.18	41.12	16.20	14.80	9.22	7.24	3.00	2.60	1.95	1.70
Pune	22.40	26.29	33.83	41.47	15.25	14.20	10.12	7.15	3.55	2.45	1.80	1.45
Varada	22.18	25.30	31.93	38.88	14.60	13.40	8.60	8.75	3.40	2.75	1.90	1.75
Tura Local	23.60	28.19	34.76	44.55	16.24	14.56	9.15	7.20	2.90	2.75	2.10	1.55
Thingpui	24.33	26.12	32.60	43.80	14.00	12.80	7.56	5.45	3.20	2.80	2.40	1.80
Moran	24.96	25.45	33.60	43.12	14.60	12.50	8.50	8.45	2.95	2.80	2.10	1.75
27 Vars	22.41	23.30	31.57	39.80	13.60	14.30	9.65	7.20	3.55	2.40	1.70	1.25
Khasi Local	26.66	29.40	37.35	47.81	14.20	12.80	7.40	5.50	2.75	1.90	1.45	1.10
204 Vars	21.33	24.70	30.42	41.74	12.45	12.80	9.10	7.65	3.10	2.45	1.80	1.25
Thinglaidon	22.45	25.05	33.30	44.67	16.20	14.50	9.50	8.80	2.70	2.70	2.05	1.45
14 Vars	27.20	29.45	38.07	48.52	13.10	14.25	8.50	7.90	3.20	3.05	2.20	1.60
Kachai inger	25.32	26.45	32.40	41.64	12.70	13.45	8.65	8.40	3.45	2.60	1.90	1.70
Nagaland cal	24.12	29.44	35.38	43.03	15.60	14.20	9.40	8.65	3.70	2.50	2.30	1.85
Nadia	20.05	24.66	35.10	44.76	13.25	13.50	8.85	8.20	2.40	2.15	1.50	1.45
CD at 5%	0.53	0.47	0.43	0.47	0.42	0.28	0.20	0.24	0.16	0.16	0.16	0.12
CV%	10.98	116.33	6.64	5.89	9.20	6.13	11.16	15.59	12.67	12.52	14.40	14.27

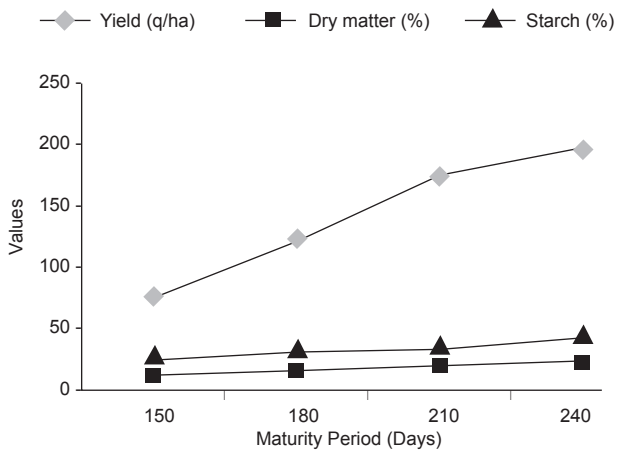

Fig. 1. Changes in yield, dry matter and starch with crop maturity

with maturity (Table 3). Between 6-7 months a significant decrease in almost all the varieties was recorded and it was continue upto full maturity but at lesser extent (Table 3). A relative percentage of decrease, 3.6, 58 and 20% in the protein content took place between 5-6, 6-7 and 7-8 months after sowing. At the first sampling, the protein content was higher in Tura local and Mahima, while at full maturity it was found higher in Karakal, Thinglaidon and Varada (Table 2).

Essential Oil

With the advent of maturity, the essential oil also decreased and it was recorded highest (3.04%) at 150 days. At full maturity it was almost half of the first sampling (Fig 2). Accumulation of starch and *in vitro* loss of volatiles decrease the essential oil content during ontogenesis of rhizomes (AOAC, 1965). The presence of essential oil in the outer skin established by histochemical

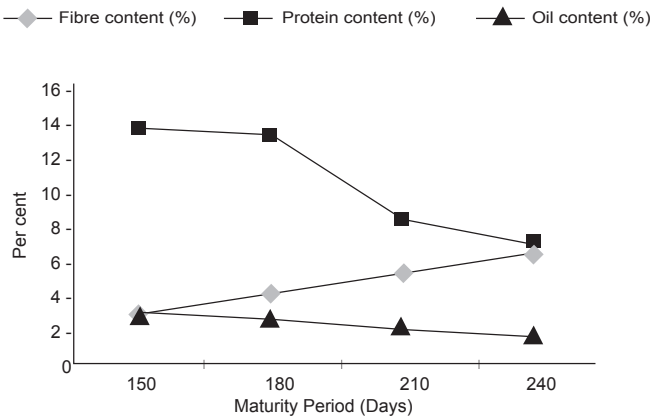

Fig. 2. Changes in quality characters with crop maturity

Table 3. Effect of different stages of harvesting on rhizome yield and quality

Maturity period (days)	Yield (q/ha)	Dry matter (%)	Crude fibre (%)	Starch (%)	Protein (%)	Volatile oil (%)
150	76.20	11.33	2.90	23.10	13.89	3.04
180	122.04	15.46	4.11	31.92	13.40	2.56
210	173.71	18.98	5.30	33.46	8.46	2.01
240	195.92	22.27	6.41	43.39	7.06	1.61
Mean	141.97	17.01	4.68	32.97	10.70	2.31
CD at 5%	24.90	2.01	0.44	1.94	0.42	0.16
CV%	37.80	27.62	32.34	25.22	32.25	27.15

examination of ginger peel confirms decreasing levels of essential oil during rhizome development (Mangalakumari *et al*., 1984). The genotype Rejatha had highest amount of volatile oil at all stages of harvesting followed by Nagaland Local and Deomali.

Correlation between yield and quality characters with maturity

With the advent of maturity, yield, dry matter, fiber, and starch content increased, and the correlation between them was also statistically significant (Table 4). The level of protein content and volatile oil decreased significantly as maturity progressed. Yield was negatively correlated with protein and volatile oil content. These results were in close agreement with the findings of Ratnambal *et al*. (1987). Dry matter recovery was also negatively correlated with protein and volatile oil during rhizome development. A positive correlation of starch and fiber with dry matter further confirmed accumulation of these constituents during maturation. Protein and volatile oil showed negative correlation with all the characters under study; however, these two characters were positively and significantly correlated with each other. The starch build up during maturation evidently reduces essential oil levels.

The results indicated that the genotypes Jugijan, Suprabha and Varada could be harvested at early stages (5-6 months) because at this stage they had higher dry matter and low fibre content besides higher yield. The genotypes Nadia and Mahima are suitable for harvesting at full maturity. The genotype Rejatha had higher amount of oil content at all stages of maturity. From the study it may be concluded that the ginger crop could be harvested after seven months of sowing because after that the increase in yield was non-significant and other quality parameters like fiber, oil, etc. were also in acceptable limit.

Table 4. Correlation matrix for ginger yield and quality parameters with crop maturity

Parameters	Maturity	Yield (q/ha)	Dry matter (%)	Fibre (%)	Starch (%)	Protein (%)	Volatile oil (%)
Maturity	1.000	0.989**	0.824**	0.790**	0.881**	-0.842**	-0.880**
Yield (q/ha)		1.000	0.925**	0.984**	0.910**	-0.902**	-0.910**
Dry matter (%)			1.000	0.812**	0.875**	-0.742**	-0.720**
Fibre (%)				1.000	0.973**	-0.652*	-0.990**
Starch (%)					1.000	-0.896**	-0.651*
Protein (%)						1.000	0.764**
Volatile oil (%)							1.000

** Significant at 1% and * 5%

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