

## Evaluation of ginger genotypes for commercial cultivation in Mizoram and future prospects

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ARTICLE INFO	ABSTRACT
Received : 23 November 2022 Revised : 19 March 2023 Accepted : 01 April 2023  Available online: 25 June 2023  <b>Key Words:</b> Economics High yielders Performance Quality Ginger	<p>A study was carried out for three years (2019, 2020 &amp; 2021) in the experimental field at ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram to check the performances of seven ginger genotypes viz., Gurubathani, Bold Nadia, Bhaise, John's ginger, PGS 121, PGS 95 and PGS 102 against Local ginger cv Thingria and their economic feasibility for commercialization in Mizoram, India. Out of seven genotypes when compared with Local ginger cv Thingria, five genotypes have out yielded Local cultivar in the range of 21.25 to 45.45% with Bhaise having 45.45% higher rhizome yield than Local ginger. On the other hand, Bold Nadia possesses a combination of good quality traits. The highest B:C ratio was obtained in Bhaise (2.08) followed by PGS 102 (1.99), Gurubathani (1.95) and Bold Nadia (1.87). The highest cost of cultivation was contributed by labour cost which was 53.40% of total cost of cultivation. The four genotypes viz., Bold Nadia, Bhaise, PGS 102 and Gurubathani can be selected as potential genotypes possessing optimum combination of all traits. Based on economic analysis, these genotypes can be considered for commercial purposes under Mizoram condition. Different production systems such as intercropping, pro-tray technology, and bulb extraction method may increase the overall income of farmers. Farmers need to venture the possibilities of value addition in ginger on commercial basis. Government intervention is required for creating marketing infrastructures, initiating youth-centered schemes, occasional skill training and developing farmer-friendly policies to protect them from market risks and exploitation. Ginger has been an important horticultural crop and widely marketed spice crop of Mizoram, a potential enterprise contributing to state economy.</p>

### Introduction

Ginger was more frequently described as a medicinal plant than a spice crop in ancient India, but it has since evolved into one of the most valuable spices in India today. It is an important commercial spice across the country and also holds an important position in international trade. The production of ginger in India is 2224.8 thousand tonnes from an area of 204.8 thousand hectares with productivity of 10.86 t/ha (Anonymous, 2021a). India is one of the largest producers of

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ginger accounting for approximately 35-40% of world production. Ginger has been grown practically in all regions of India since time immemorial. Major ginger growing states like Karnataka, Madhya Pradesh, Assam, West Bengal, Maharashtra, Odisha, Gujarat, Sikkim, Manipur, Meghalaya and Mizoram together contributed 89.10% of total production of ginger in India (Anonymous, 2021a). The contribution from the Northeast region has amounted to 23.63% of total ginger production in India from 33.14% ginger growing area which offers great scope for increasing the production of quality ginger (Anonymous, 2021b). As a result, many researchers from different institutions have focused on tapping the potential of ginger cultivation in the Northeast region. The farmers have attributed quality ginger production in the region possibly to the favourable climatic condition that prevails throughout the year. Mizoram stood 11<sup>th</sup> position in the overall production of ginger in India with 60.13 thousand tonnes from an area of 8.55 thousand hectares with productivity of 7.03 t/ha (Anonymous, 2021a) which is still low as compared to the national average (10.86 t/ha). Ginger is a major spice of Mizoram and is an important cash crop which plays a vital role in the economic stability of the farmers. It is a moderate shade loving crop, intercropping with shade giving crops like climbing vegetables, plantation crops, fruit orchards, *etc.*, can provide both optimum condition and additional income to farmers. Most of the ginger produced in Mizoram are consumed and sold in fresh form and a small quantity of the produce is converted into different processed products. Mizo gingers are prized for their excellent quality. The majority of the ginger commercially cultivated in Mizoram are local genotypes, low in yield and cultivated without proper agronomic practices. As farmers are not aware of high-yielding varieties, the potentials and economic aspect of these varieties are not well understood. As a result, local genotypes of unknown characteristics are grown in masses and the hard work of farmers is not rewarded sufficiently. As the quality of a variety has direct impact on the production and productivity of ginger (Utpala *et al.*, 2006), careful selection of suitable varieties with good quality will have a direct impact on ginger production (Soni *et al.*, 2022a) and

marketability. Ginger is predominantly eaten in fresh form or used as a spice in cooking different dishes in Mizoram, although it has certain uses as food products, spice blends, and beverage industries. It possesses numerous medical benefits; thus, it also has a substantial impact on the pharmaceutical industry. Medicinal uses include the treatment of nausea, nervous diseases, migraines, rheumatic disorders, muscular pain, digestive ailments *etc.* It is reported to possess antiseptic, antioxidant, anti-inflammatory, and carminative properties (Afzal *et al.*, 2001). Various bioactive components in ginger have been identified by numerous researchers based on their properties and potential health benefits. Among these, the phenolic compounds are found to have high antioxidant capacity and are associated with many biological activities (WHO, 1999) which prevents the cells from oxidative damage induced by free radicals. Many researchers have identified antioxidant activities of ginger (Smith *et al.*, 2004; Willetts *et al.*, 2003). Most ginger varieties with large rhizomes are not suitable for dry ginger due to their high moisture content which results in poor quality, difficulty in drying with often low-quality oleoresin. Also, there exists significant variation in the pungency of ginger based on regions and varieties. Evaluation of ginger genotypes based on their biochemical properties and careful selection of ginger for commercial purpose with regards to their end use is also very important. Hence, it is important to evaluate and tap the potentials of high yielding varieties under specific region as little information is available with regards to commercial aspect and economic feasibility in Mizoram, India.

## Material and Methods

### Planting materials

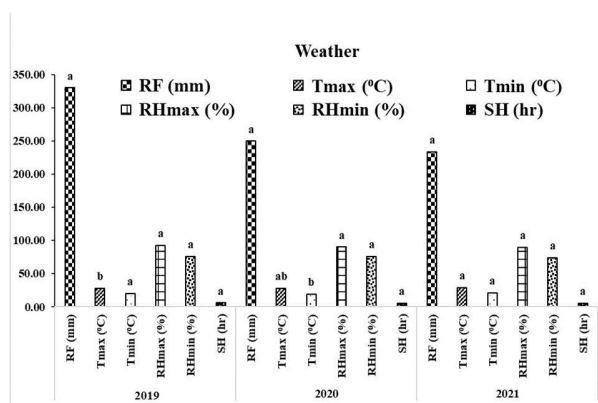
The eight ginger genotypes which includes local ginger *cv* Thingria as check were evaluated for three years (2019, 2020 & 2021) in the experimental field at ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram (92°40'52'E longitude and 24°12'77'N latitude with a MSL 650-700 m) to evaluate their performances and economic feasibility for commercialization in Mizoram. These genotypes were collected from different sources and are given in Table 1.

**Table 1: Sources of different genotypes used in the experiment**

SN	Genotypes	Sources of collection
1	Gurubathani	Pundibari, West Bengal
2	Bold Nadia	Nagaland
3	Bhaise	Sikkim
4	John's ginger	Kerala
5	PGS 121	Pottangi, Odisha
6	PGS 95	Pottangi, Odisha
7	PGS 102	Pottangi, Odisha
8	Local ginger cv Thingria	Mizoram

**Experimental design**

The ginger genotypes were grown as a sole crop on a raised bed of size 3 × 1 × 0.15 m, at 30 × 25 cm spacing and 40 plants per plot were accommodated with three replications in randomized block design. The temperature ranges from 19.82 to 28.19°C in the experimental field. The change in weather data was given in Figure 1. The soil was clayey loam with soil pH (5.0-5.5) and 1.2-1.4% organic carbon content.



**Figure 1: Weather condition for three years during the experiment from April to December. The different parameters having same letter indicated non-significant at 5% level of significance by Tukey's test**

**General procedures**

The seed rhizomes (35-50 g) having 2-4 active buds per rhizome were used as planting material. Carbendazim 12% + mancozeb 63% WP @ 2 g/L was used for seed rhizome treatment in which rhizomes are dipped for 30 minutes and shade-dried for 24 hours before sowing. Sowing of rhizomes is done in second week of May. Small pits were dug to which carbofuran 3G and farm yard manure were

applied at the rate of 5 and 100 g per pit, respectively. The recommended dose of fertilizer (80N:100P:80K kg/ha) was applied in three splits where half doses of N (40 kg), full dose of P (100 kg) and K (80 kg) per hectare were incorporated at land preparation and the remaining 40 kg of nitrogen was applied at 40 and 60 days after planting at 20 kg each application. For nitrogen source, urea was used, single super phosphate for phosphorus source and muriate of potash as source of potassium.

**Data recording and analysis**

Observations were taken at 180 DAS for plant height, leaf area index (LAI), number of leaves/hill, and number of tillers/plant while fresh weight of clump, number of rhizomes/plant and dry recovery were recorded at 210 DAS (maturity). Five representative plants were selected from each plot for recording the observations. The yield of rhizome was recorded in quintals per hectare. Quality parameters such as total chlorophyll and total carotenoid were recorded at 180 DAS; total phenol content (mg GAE/100g), 6-gingerol (%) and oleoresin (%) were recorded at maturity. For LAI, the fresh leaves were detached from five plants from each plot and placed in leaf area meter (LICORLI-3100C area meter) to record leaf area (cm<sup>2</sup>) and LAI was calculated by formula as (Yoshida, 1976):

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Spacing (cm}^2\text{)}}$$

For the estimation of leaf pigments, 50 g of freshly harvested leaf tissue was placed in a test tube, 5 ml of Dimethyl Sulphoxide (DMSO) was poured directly to the sample at room temperature and kept overnight till tissue becomes colourless. The sample extracts were subjected to UV/VIS Spectrophotometer at wavelength of 420, 663 and 645 nm while DMSO solution was used as blank. The different pigments were calculated from the formula given below (Hiscox and Israelstam, 1979):

$$\text{Chlorophyll a (mg/g F.W)} = (12.7 A_{663} - 2.69 A_{645}) \times \text{Dilution factor}$$

$$\text{Chlorophyll b (mg/g F.W)} = (22.9 A_{645} - 4.68 A_{663}) \times \text{Dilution factor}$$

**Total Chlorophyll (mg/g F.W) = (20.2 A<sub>645</sub> + 8.02 A<sub>663</sub>) × Dilution factor**

**Total carotenoids (mg/g F.W) = [1000 A<sub>470</sub> – (3.27 Chl 'a' + 104 Chl 'b')] × Dilution factor**

$$\text{Dilution factor} = \frac{V}{W \times 1000}$$

Where, *V* stands for volume of extract (ml), *W* stands for fresh weight of sample (g), F.W stand for fresh weight.

The oleoresin was extracted from ginger powder where ginger rhizomes were cleaned by thoroughly washing with water, oven-dried at 60°C for 48 hours and grounded into fine powder and screened through a sieve of 30 US Mesh to obtain a particle size of 0.6 mm. The oleoresin was extracted through Soxhlet apparatus using solvent ethanol. 10 mg of ginger powder was packed in a filter paper and put inside the extraction chamber. 150 ml of ethanol (80%) was used as extraction solvent which was poured from the inlet using a funnel. The extractor was refluxed at 78°C for 7 hours until the solvent in extraction chamber was transparent. The extract was evaporated at room temperature which was then filtered. The residue in filter paper was air-dried and weighed. The oleoresin (%) was calculated as (AOAC, 1975):

$$\text{Oleoresin (\%)} = \frac{W_2 - W_1}{\text{Weight of sample (g)}} \times 100$$

Where,

*W*<sub>1</sub> = Weight of empty beaker (g)

*W*<sub>2</sub> = Weight of beaker with air dried oleoresin (g)

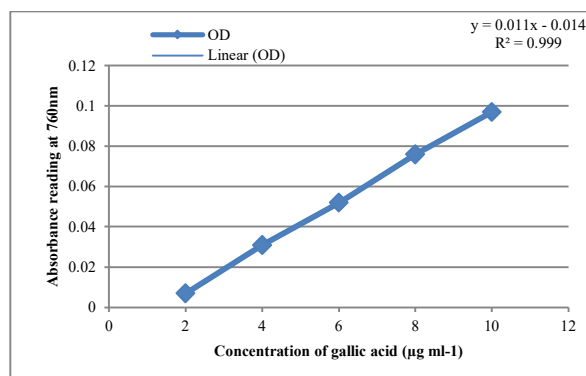
The total phenol content was determined by Folin-Ciocalteu colorimetric method (Singleton *et al.*, 1999) with a little modification. For preparing standard gallic solution, gallic acid (10 mg) was dissolved in 10 ml of methanol to get concentration 1000 µg/ml. Various concentrations of gallic acid solutions (2, 4, 6, 8, 10 µg/ml) were prepared from the standard solution. A 5 ml solution of 10% Folin–Ciocalteu reagent (FCR) was added to 1 ml each concentration and blank solution (1 ml of methanol). After 8 minutes, 7% Na<sub>2</sub>CO<sub>3</sub> (4 ml) was added to make a final volume of 10 ml. The solution was shaken well and kept in 40°C water bath for 30 minutes to remove precipitation in

solution. The absorbance reading was measured at 760 nm against blank solution. The means absorbance values of different concentrations of gallic acid were used to plot the calibration curve (Figure 2). The samples were prepared the same way as standard where 10 mg of ginger extract obtained from Soxhlet extraction was dissolved in 10 ml of methanol. 0.5 ml of sample solution was diluted to 10 ml methanol. 1 ml sample solution was taken and 5 ml of 10% FCR was added. Similarly, 4 ml of 7% Na<sub>2</sub>CO<sub>3</sub> was added after 8 minutes to make a final volume of 10 ml. The solution was shaken well and kept in 40°C water bath for 30 minutes and absorbance reading was measured at 760 nm using UV/VIS Spectrophotometer. All the observations were carried out in triplicates. The total phenol content in mg GAE/g was calculated by the formula (Oluyemi *et al.*, 2007),

$$C = c \frac{V}{m}$$

where *C* = total phenolic content mg GAE/g dry extract, *c* = concentration of gallic acid obtained from calibration curve in mg/ml, *V* = volume of extract in ml, and *m* = mass of extract in g.

All the quality analyses were carried out in three replications.



**Figure 2: Standard graph for total phenol content**

The pungency of ginger, 6-gingerol was determined from ginger extract obtained from solvent extraction using Soxhlet apparatus. 10 mg of ginger extract obtained from Soxhlet extraction was dissolved in methanol (100 ml) to get concentration 100 µg/ml. 5 ml was taken and volume was raised to 25 ml with methanol and the reading was taken

at 282 nm wavelength using UV/VIS Spectrophotometer against methanol as blank. Percentage gingerol present in ginger extract was calculated from reference UV Spectra of Standard Gingerol (Shukla *et al.*, 2012). The mean data were statistically analysed using IBM SPSS Software, Version 26.

#### Economic analysis of ginger

In the Mizoram market, ginger is majorly sold in the form of fresh ginger for local consumption.

**Cost of production:** It was calculated by the summation of all the expenditures of variable cost items. These variable costs include cost of rhizomes, labour (land preparation, manure application, planting, intercultural operations, harvesting and other post-harvest activities), farm yard manure (FYM), fertilizer, herbicide, irrigation, insect-pest management, and disease management.

**Benefit-cost analysis:** The benefit-cost analysis was calculated using the total variable cost and gross returns from ginger production. The benefit-cost analysis was carried out by using the formula:

$$B:C \text{ Ratio} = \frac{\text{Gross return}}{\text{Total cost of production}}$$

Where,

Gross return (in Rs) = Total quantity of ginger marketed (q) × price (per quintal) of ginger in Mizoram.

Total cost of production = Total variable cost *i.e.*, the total expenditure of all variables involved in production.

#### Results and Discussion

High yielding varieties are gaining importance to fill production gap as a result of growing population. The choice of low yielding landraces for mass cultivation has been attributed to the cause of unsatisfactory economic condition of ginger growers, despite ginger being an important cash crop of Mizoram (Soni *et al.*, 2022b). Even high yielding varieties may not reach their full potential across different locations. So, it has become important to evaluate the high yielding ginger genotypes under Mizoram condition to understand their performance capacity. The performance of eight ginger genotypes for growth, yield and quality parameters were observed and mean values for twelve important parameters were presented in Table 2. Plant height is an important determinant for rhizome yield in ginger. It is found to have significant positive correlated response to rhizome

yield by Singh (2001) and Anargha *et al.* (2020). From our study, there is no significant variation in plant height among the genotypes at 80 DAS. The plant height exhibited an average value of 52 cm, ranging between 48.23 cm (PGS 95) to 57.30 cm (Gorubathani). Similar values in the range of 46.74 cm to 67.45 cm was reported by Abua *et al.* (2021). A more or less similar trend in plant height was also reported previously by Shadap *et al.*, (2013) and Islam *et al.* (2008). While slightly higher values in plant height was reported by Babu *et al.* (2019) under shade net condition. This may be the result of the genetic makeup of the genotypes, genotypic potential and availability of nutrients in the soil, which were influenced by low light intensity and high relative humidity condition under shade net situation (Amin *et al.*, 2010). Gorubathani exhibited 10.14% increase in plant height over Local ginger. LAI is an important parameter associated with yield of ginger. It helps in understanding photosynthesis, light interception, nutrient and water utilization, growth of crop and potential of yield (Smart, 1974; Williams, 1987). There was a significant difference among genotypes for LAI. Bold Nadia has significantly highest LAI (4.51) and 38.76% increment over Local ginger which was followed by PGS 121 (3.85) and Bhaise (3.74) while the lowest LAI (2.21) was recorded in PGS 95. More or less similar findings were also reported by Supriya *et al.* (2020), Babu *et al.* (2019) and Mahender *et al.* (2015) in different genotypes. Shadap *et al.* (2013) has reported higher LAI (12.64) in ginger planted in the month of June recorded which was closely followed by May planting (12.45) and the lowest LAI was recorded in March planted crops (3.50). The variation in LAI among the genotypes may be due to genotypic differences in terms of number of tillers and number of leaves per plant, interaction between genotypes and conducive environmental conditions. The number of leaves is an important determinant when selecting genotype for rhizome yield. The genotypes that have higher number of leaves per plant and produced more tillers gave the best rhizome yields (Chukwudi *et al.*, 2020). The genotype, Bold Nadia exhibited significant variation in number of leaves/hill (64.11) and 22.99% increment over Local ginger followed by PGS 102 (62.46) and PGS 121 (61.71). While lowest was recorded in PGS 95 for number of

leaves/hill (44.96). A more or less similar results were reported by different researchers (Chukwudi *et al.*, 2020; Lepcha *et al.*, 2019). A high number of leaves/plant was recorded in the range of 166.56 to 245.16 (Babu *et al.*, 2019) which may be due to relatively low temperatures combined with low light intensity that contributed to development of more chlorophyll in ginger plants grown in shade leading to higher number of leaves (Vastrad *et al.*, 2006). The variation in number of leaves/hill among the genotypes may be due to differences in genetic constitution and genotypic potential of genotypes and interaction of genotypes with conducive environmental conditions. Bold Nadia exhibited highest significant number of tillers/plant (6.33) which has 5.56% increase over Local ginger followed by Bhaise (6.08). While lowest was recorded in PGS 95 for number of tillers/plant (4.08). The number of tillers is also an important yield contributing character in ginger, it influences the yield and mother rhizome as reported in ginger (Singh *et al.*, 2009) and turmeric (Balakrishnamurty *et al.*, 2009; Singh, 2013). A more or less similar number of tillers/plant were also reported by Ridwansyah *et al.* (2020), Anargha *et al.* (2020) and Abua *et al.* (2021). The variation in number of tillers/plant may be due to genetic constitution of genotypes and interaction between genotypes and conducive environmental conditions.

Fresh weight of clump is an important trait as it has significant positive correlated response with the yield of rhizome. The fresh weight of clump has a mean value of 0.145 kg ranging from 0.097 to 0.178 kg. Bold Nadia has exhibited significantly highest fresh weight of clump (0.178 kg) followed by Gorubathani (0.168 kg) and PGS 102 (0.167 kg), which are having more weight to the range of 28.69, 21.83 and 21.14%, respectively over Local ginger. The fresh weight of rhizome/hill can reach upto 0.362 kg under partial shade condition in different genotypes (Bhuiyan *et al.*, 2012). The fresh weight of clump also has significant interaction with spacing and fertilizer treatment (Martini and Paramita, 2021). The variation among genotypes for traits may be the result of genetic constitution of genotypes, influence of environment on genotypes expression, insect pest and disease infections. Nowadays, the growing popularity of ginger as well as market demand is related to

quality. Ginger has a wide range of uses in pharmaceutical and food industries due to its aroma, pungent taste and bioactive compounds. Many scientific researches have now focused not only on yield improvement of ginger but more on quality. Quality traits such as dry recovery, total chlorophyll content, total carotenoid content, total phenol content, 6-gingerol and oleoresin (Table 2) has mean values of 200.54 g/kg, 0.83 mg/g F.W, 0.16 mg/g F.W, 602.43 mg GAE/100 g, 1.85% and 4.84%, respectively. The dry recovery (g/kg) was significantly highest in Bold Nadia (242.86 g/kg) followed by PGS 102 (236.26 g/kg). Bold Nadia exhibited 26.36% more dry recovery than Local ginger. Dry recovery is an important parameter to identify genotypes with high biomass after drying. The genotypes suitable for processing into dry ginger should possess high dry recovery percentage. The total chlorophyll and total carotenoid contents varied from 0.66 mg/g F.W (John's ginger) to 1.07 mg/g F.W (Bold Naida, PGS 95) and 0.13 mg/g F.W (John's ginger) to 0.19 mg/g F.W (PGS 95), respectively. Bold Nadia and PGS 95 have 50.70% more total chlorophyll over Local ginger whereas Bold Nadia has 31.69% total carotenoid over Local ginger. Bold Nadia exhibited highest total phenol content (743.73 mg GAE/100g) which is 21.41% more than Local ginger and is at par with John's ginger while lowest was recorded in Gorubathani (430.12 mg GAE/100g) with an average of 602.43 mg GAE/100g among the genotypes. A more or less similar range of total phenol content in ginger extract was reported by Ezez and Tefera (2021). They have concluded higher phenolic content in ginger extract using methanol as solvent and least phenolic content using acetone extract. Hence, the choice of solvent extract used for determining the total phenolic content in ginger play an important role. The 6-gingerol content was 1.85% among the eight genotypes and ranging from 1.24 to 2.08%. Gorubathani exhibited significantly highest 6-gingerol content followed by PGS 102 (2.03%) and Bhaise (2.01%) while oleoresin content was significantly highest in Bold Nadia (9.06%) and minimum in Gorubathani (2.60%). The mean content of 6-gingerol obtained from the studied genotypes were found to be on par with results by

**Table 2: Mean values for growth, rhizome yield and quality traits of genotypes of ginger**

Genotypes	PH	LAI	NOL	NOT	FWC	DR	TC	TCA	TPC	6-GIN	OLR	YLD
Gurubathani	57.30 <sup>a</sup>	3.19 <sup>bc</sup>	58.85 <sup>ab</sup>	5.29 <sup>ab</sup>	0.17 <sup>ab</sup>	195.63 <sup>ab</sup>	0.75 <sup>cd</sup>	0.15 <sup>abc</sup>	430.12 <sup>d</sup>	2.08 <sup>a</sup>	2.60 <sup>e</sup>	95.68 <sup>a</sup>
Bold Nadia	50.24 <sup>a</sup>	4.51 <sup>a</sup>	64.11 <sup>a</sup>	6.33 <sup>a</sup>	0.18 <sup>a</sup>	242.86 <sup>a</sup>	1.07 <sup>a</sup>	0.18 <sup>ab</sup>	743.73 <sup>a</sup>	1.87 <sup>cd</sup>	9.06 <sup>a</sup>	91.64 <sup>ab</sup>
Bhaise	48.77 <sup>a</sup>	3.74 <sup>ab</sup>	57.51 <sup>ab</sup>	6.08 <sup>a</sup>	0.14 <sup>bc</sup>	165.01 <sup>b</sup>	0.71 <sup>de</sup>	0.15 <sup>abc</sup>	649.76 <sup>b</sup>	2.01 <sup>ab</sup>	6.81 <sup>b</sup>	101.99 <sup>a</sup>
John's ginger	54.03 <sup>a</sup>	2.27 <sup>c</sup>	44.97 <sup>b</sup>	4.42 <sup>b</sup>	0.12 <sup>cd</sup>	174.46 <sup>c</sup>	0.66 <sup>c</sup>	0.13 <sup>c</sup>	729.70 <sup>a</sup>	1.75 <sup>d</sup>	4.99 <sup>c</sup>	67.42 <sup>c</sup>
PGS 121	55.61 <sup>a</sup>	3.85 <sup>ab</sup>	61.71 <sup>ab</sup>	5.92 <sup>a</sup>	0.15 <sup>bc</sup>	196.87 <sup>ab</sup>	0.89 <sup>b</sup>	0.14 <sup>bc</sup>	598.00 <sup>c</sup>	1.91 <sup>bc</sup>	3.27 <sup>f</sup>	85.02 <sup>abc</sup>
PGS 95	48.23 <sup>a</sup>	2.21 <sup>c</sup>	44.96 <sup>b</sup>	4.08 <sup>b</sup>	0.10 <sup>d</sup>	201.04 <sup>ab</sup>	1.07 <sup>a</sup>	0.19 <sup>a</sup>	448.49 <sup>d</sup>	1.94 <sup>bc</sup>	3.46 <sup>f</sup>	67.00 <sup>c</sup>
PGS 102	49.78 <sup>a</sup>	3.30 <sup>abc</sup>	62.46 <sup>ab</sup>	4.67 <sup>b</sup>	0.17 <sup>ab</sup>	236.26 <sup>bc</sup>	0.81 <sup>bc</sup>	0.14 <sup>bc</sup>	607.06 <sup>bc</sup>	2.03 <sup>ab</sup>	4.03 <sup>e</sup>	97.46 <sup>a</sup>
Local ginger cv Thingria	52.03 <sup>a</sup>	3.25 <sup>abc</sup>	52.13 <sup>ab</sup>	6.00 <sup>a</sup>	0.14 <sup>c</sup>	192.20 <sup>ab</sup>	0.71 <sup>de</sup>	0.14 <sup>abc</sup>	612.57 <sup>bc</sup>	1.24 <sup>c</sup>	4.51 <sup>d</sup>	70.12 <sup>bc</sup>
Mean	52.00	3.29	55.84	5.35	0.145	200.54	0.83	0.16	602.43	1.85	4.84	84.54
Range	48.23-57.30	2.21-4.51	44.96-64.11	4.08-6.33	0.097-0.178	165.01-242.86	0.66-1.07	0.13-0.19	430.12-743.73	1.24-2.08	2.60-9.06	67.42-101.99

\*Means with the same letter in each column are not significantly different at  $p \leq 0.05$ , Tukey's post hoc test.

PH: Plant height @ 180 DAS (cm); LAI: Leaf area index @ 180 DAS; NOL: Number of leaves/hill@ 180 DAS; NOT: Number of tillers/plant @ 180 DAS; FWC: Fresh weight of clump at maturity (kg); DR: Dry recovery (g/kg); TC: Total chlorophyll content (mg/g F.W); TCA: Total carotenoid content (mg/g F.W); TPC: Total phenol content (mg GAE/100g); 6-GIN: 6-gingerol content (%); OLR: Oleoresin content (%); YLD: Yield of rhizome (q/ha)

Zhang *et al.* 1994. Crop duration is very important to get higher yield of oleoresin. Increased accumulation of oleoresin was reported with increased crop duration in ginger (Aggarwal *et al.*, 2002; Shadap *et al.*, 2013). Gorubathani exhibited 66.89% more 6-gingerol than Local ginger while Bold Nadia exhibited 101.11% more oleoresin than Local ginger. This variability may be the result of differences in genetic constitution among the genotypes from different regions, environmental effects such as climate, soil properties, and may also be the result of analytical methods and extraction processes. The yield of rhizomes varies from 67.00 q/ha (PGS 95) to 101.99 q/ha (Bhaise) which is 4.45% lower and 45.45% higher than Local ginger (70.12 q/ha). Yield variation may be due to genotypes, associated with congenial environment and soil properties. Also, incidence of rhizome rot has been a major concern in heavy rainfall region like Mizoram. Yield variation may also be the result of diseases especially rhizome rot caused by *Pythium aphanidermatum* that attacked during crop growth (Soni *et al.*, 2022a). Based on average values of different morphological, yield and quality traits, the four genotypes of ginger *viz.*, Bold Nadia, Bhaise, PGS 102 and Gorubathani can be selected as suitable genotypes for cultivation under Mizoram condition. For farmers to start commercial farming in order to support their livelihood, making a livable profit is crucial. Profitability can be significantly influenced both by internal factors like cultivation area, variety of crop,

crop quality, quantity and external factors like cost of cultivation, price, market condition and public support price policy. The feasibility of these genotypes for commercial cultivation under Mizoram condition is important to understand. The economics of ginger cultivation under Mizoram condition was estimated for an area of one hectare and based on prevailing costs of crop and labour hiring in the region. In this study, the cost of cultivation of ginger per hectare area was estimated to be Rs. 1,77,207 (Table 3). This cost of cultivation includes rhizome cost, labour cost, FYM cost, fertilizer cost, herbicide cost, irrigation cost, insect and pest management cost and disease management cost. Among these variables, highest cost was incurred for labour (Rs. 94,620), which was found to be 53.40% of total cost of cultivation. In regions like Mizoram, machine power is rarely used due to the undulating topography which do not allow use of machinery for different field operations. So, the main resort is man power to handle all field operations, which is one of the major reasons to why human force contributed to major cost of cultivation. Also, the use of machines increases work efficiency resulting in greater output. Other cost variables include rhizome cost (25.39%), FYM cost (11.29%), fertilizer cost (3.77%), disease management cost (2.45%), insect and pest management cost (2.26%), irrigation cost (0.65%) and herbicide cost (0.81%). Seed cost had contributed upto 25% (Ewuziem and Onyenobi, 2012), 30.38% (GOK, 2011), 46% (USAID, 2011)

and 65.10% (Poudel *et al.*, 2017) in several studies by researchers while percentage of cost share observed on human labour and organic manure was 15.3% and 10.5% respectively (Poudel *et al.*, 2017).

**Table 3: Economics of ginger cultivation**

Cost of production		
Variable costs	Amount	% Share in total cost of production
Rhizome cost	45,000	25.39
Labour cost	94,620	53.40
FYM cost	20,000	11.29
Fertilizer cost	6,681	3.77
Herbicide cost	1,431	0.81
Irrigation cost	1,130	0.64
Insect pest management cost	4,000	2.26
Disease management cost	4,345	2.45
<b>Total cost of production/ha</b>	<b>1,77,207</b>	<b>100</b>
Genotypes	Gross return (in Rs.)	B:C Ratio
Gurubathani (Pundibari)	3,46,445	1.95
Bold Nadia (Nagaland)	3,31,841	1.87
Bhaise (Sikkim)	3,69,306	2.08
John's ginger (IISR)	2,44,128	1.38
PGS 121 (Pottangi)	3,07,870	1.74
PGS 95 (Pottangi)	2,42,607	1.37
PGS 102 (Pottangi)	3,52,891	1.99
Local ginger cv Thingria (Mizoram)	2,53,905	1.43

As seed cost also contributed a major share of the cost of cultivation, pro-tray technology has been proved to be useful. The yield of ginger from pro-tray technology was on par with conventional planting system with a benefit cost ratio of 2.98 over 1.08 in conventional system of planting (Shil *et al.*, 2018). Based on wholesale price of ginger in Mizoram (*i.e.*, Rs. 3621/q; Economic Survey Mizoram, 2020), the gross return from ginger production is Rs. 3,69,306 (Bhaise), Rs. 3,52,891 (PGS 102), Rs. 3,46,445 (Gorubathani) and Rs. 3,31,841 (Bold Nadia) which gives 45.45, 38.99, 36.45 and 30.70% increment, respectively over Local ginger (Rs. 2,53,905). The benefit-cost ratio was highest for Bhaise (2.08) followed by PGS (1.99), Gorubathani (1.95) and Bold Nadia (1.87), which indicated that the cultivation of these

genotypes will be profitable under Mizoram condition. Similar findings of profitability in ginger production were also reported (Poudel *et al.*, 2017; Acharya *et al.*, 2019). The lowest benefit cost ratio was obtained in PGS 95 (1.37). The higher profitability of a genotype is the result of variation in rhizome productivity with highest in Bhaise (101.99 q/ha) and lowest in PGS 95 (67.00 q/ha). This clearly showed the importance of choosing high yielding suitable genotypes of ginger for cultivation along with optimization of farm resources to get maximum revenue from ginger cultivation in Mizoram. Correlation analysis is important to understand the relationship between dependent and independent variables as selection of one trait can have correlated response in many other traits (Table 4). The correlation between yield of rhizome and all other traits (plant height, LAI, number of leaves/hill, number of tillers/plant, fresh weight of clump, dry recovery, total chlorophyll, total carotenoid, total phenol content, 6-gingerol content, oleoresin content) have shown that the yield of rhizome has highest positive significant correlation with fresh weight of clump (0.707\*\*) followed by 6-gingerol content (0.522\*\*). An increase in the fresh weight of clump and 6-gingerol content will increase the yield of rhizome. Fresh weight of clump also exhibited positive significant correlation with dry recovery. LAI has significant positive correlation with number of leaves/hill, number of tillers/plant, fresh weight of clump and oleoresin content. Number of leaves/hill and number of tillers/plant also has significant positive correlation with fresh weight of clump. Dry recovery with total chlorophyll content of leaf, total chlorophyll content of leaf with total carotenoid content of leaf and total phenol content with oleoresin content exhibited positive significant correlation. Hence, the two traits *viz.*, fresh weight of clump and 6-gingerol content are considered as an important selection indicator for yield improvement of rhizome in ginger. Ginger based intercropping system offers higher yield and income as a result of synergistic effects between the crops. The finding shows that ginger intercropping with papaya, taro, sweet corn, maize and other leguminous crops increase crop equivalent yield upto 30% over sole ginger yield. One finding has reported the benefit-cost ratio to be as high as 2.28



**Table 4: Correlation of yield and quality attributes with yield of rhizome**

Characters	PH	LAI	NOL	NOT	FWC	DR	TCHL	TCA	TPC	GIN	OLR	YLD
PH	1	0.174	0.274	0.014	0.166	-0.190	-0.267	-0.255	-0.140	-0.001	-0.362	-0.211
LAI		1	0.913**	0.552**	0.619**	0.292	0.189	0.273	0.305	0.099	0.456*	0.343
NOL			1	0.262	0.574**	0.307	0.117	0.284	0.096	0.254	0.171	0.292
NOTI				1	0.491*	0.114	-0.018	-0.052	0.353	-0.210	0.479*	0.392
FWC					1	0.432*	-0.013	-0.046	0.219	0.257	0.304	0.707**
DR						1	0.563**	0.179	0.064	0.158	0.179	0.173
TCHL							1	0.641**	-0.149	0.265	0.223	-0.065
TCA								1	-0.205	0.161	0.225	-0.080
TPC									1	-0.273	0.759**	0.026
GIN										1	-0.073	0.522**
OLR											1	0.229
YLD												1

\*\* , Significant at the 0.01 level; \* , Significant at the 0.05 level

in banana + ginger mixture (Regeena and Kandaswamy, 1987), 3.22 in cowpea + ginger mixture (Baruah and Deka, 2019) and 2.04 in mango + ginger mixture (Rajesh *et al.*, 2019). One of the major constraints the farmers are facing is marketing of ginger during glut season. Excess rhizomes during glut season can be utilized as seed rhizomes for off-season harvest while leaving the finger rhizomes as planting material for uniform harvest during the main season. This practice called bulb (mother rhizome) extraction, is a traditional practice by the farmers in Mizoram. In this practice, the seed rate can be increased by 1 tonne against the normal seed rate (1.2 - 1.5 t/ha) and planted in the month of March-April. After two months of sowing (May-June) at 3-4 crop leaf stage, the mother rhizomes (about 1 tonne) can be extracted while the sprouted finger rhizomes can be put back in soil to grow. Extraction of rhizome done at later stages *i.e.*, 90 and 120 DAS resulted in 20.85 and 32.89%, respectively of mother rhizome losses due to rotting of rhizomes. So, the best time for operation of this method is two months (60 DAS) to get optimum and healthy bulbs. Vermicompost or well decomposed farm yard manure can be applied after 15 days of bulb extraction. During the off-season, farmers can earn around Rs. 40,000 per hectare (Rs. 40/kg ginger rhizome) without significantly affecting main crop yield. Market constraints is another factor that diminished the interest of ginger cultivation. Government intervention has taken place in the past several times to regulate marketing of ginger, but to no

avail till today. Introduced marketing guidelines were used to a more or less fresh plan. Since that time, the role served by the government in the marketing of ginger has diminished to that of a promoter rather than a legislator. With ginger cultivating in most parts of Mizoram, public intervention has become important more than ever to protect the farmers from exploitation and market risks. Market constraints is intertwined with no storage facilities or infrastructures. In order to profit from momentary price swings, farmers are unable to seize opportunities for efficient marketing and price speculation. Farmers dispose their fresh goods at any prices and through any marketing channels since they lack storage facilities to wait for excellent selling opportunities. Farmers need to make use of the technologies that are readily available as many research institutions have developed low-cost storage technologies using locally available materials. In such cases, state departments, ICAR institutions, KVKs, NGOs, SHGs and other private agencies are always available for contact and enquiry. Farmers need to upgrade from traditional practices to problems driven solutions and new technologies to make the best use of these institutions. Farmers can also explore the possibilities of processing ginger into processed products such as dry ginger, ginger candy, ginger paste, ginger powder, ginger wine, *etc.* and high-end products like oleoresin, ginger oil, *etc.* which offers great scope that have not yet been fully tapped in this region. Processed products open new opportunities for commercialization of

ginger and farmers need to be encouraged to take up this venture. Mizoram contributes only 2.7% of total ginger production in India which is still very low. The climate and land suitability for ginger cultivation is in no doubt excellent in Mizoram, and quality of produce possesses unique characteristics. Ginger have been considered an important cash crop due to its extensive cultivation across the state and marketing within and outside the state. It is crucial to identify, evaluate and analyse the weaknesses and threats associated with ginger cultivation to strengthen and grab the opportunities for production so that farmers could be aware of ginger enterprise and necessary developments can be taken on time.

Therefore, the strength, weaknesses, opportunities, and threats (SWOT) tool was used in this context. The strengths for ginger production in Mizoram include ginger as an important source of income and employment to farmers. It requires less care and rainfed crops also give bumper harvest. It is the major spice in Mizoram and 3<sup>rd</sup> in production among all horticultural crops. Mizoram also offers suitable climate and as a result, quality of produce has been improved. There is vast potential area available under horticultural crops. Moreover, the cooperatives and farmer's group are involved in the production of ginger. Ginger being less perishable than other crops is an important takeaway to the strengths of ginger production. Major factor contributing to its weakness is that farmers, mostly resource poor, practise subsistence farming and traditional production system such as Jhum cultivation over scientific cultivation methods. There is no credit system for production, so farmers do not afford high capital investment required to purchase the rhizome seeds. Lack of proper marketing channels and infrastructures also leads to disruption in production. Storage facilities and infrastructures for processing are also insufficient in the state. Post-harvest handling is rarely done, and poor packaging of ginger and its products are common. Lastly but crucially, there is little co-operation from the government. There are various opportunities of ginger production in the state such as adoption of high yielding varieties that boost the production and yield per unit area of ginger, increasing demand of Mizo ginger for their quality and wide options for value addition as a new

venture. Organic cultivation of ginger in Mizoram offers a great scope for sustainable farming and presently, government initiatives support the growth of horticulture including ginger. Rhizome rot, a devastating disease is prevalent in the state and poses a great threat to producers. The incidence of diseases and pests discourage farmers to cultivate ginger on a large scale. High price fluctuation, improper marketing channels, uncertain external trade and slow growth of development in infrastructures leave ginger production in Mizoram in a vulnerable state.

### **Conclusion**

Careful selection of high-yielding genotypes with superior quality for cultivation is of paramount importance for increased production. The four genotypes *viz.*, Bold Nadia, Bhaise, PGS 102 and Gorubathani possess optimum combinations of yield and quality traits, and based on economic analysis, these genotypes can be considered for commercial purposes under Mizoram condition. Farmers should be aware of the variety of ginger they grow especially on commercial basis to improve productivity of ginger. The potential of high yielding varieties possessing good quality traits and disease resistance are needed to be realised for the benefit of the farmers. High labour cost for commercial production of ginger can be minimized by choosing right farm tools and mechanization. Ginger based intercropping system can be followed to achieve higher net return. Ginger processing to develop novel products will open new market opportunities for many farmers in Mizoram. Hence, ginger cultivation for commercial purpose is still a viable option for income generation in Mizoram and mass cultivation of high yielding genotypes will boost productivity in the state of Mizoram. Government training and extension programmes on ginger cultivation should be improved. Government intervention is really important for this crop for price regulation and marketing channels. This will attract more farmers to cultivate this important crop without fear of risk factors involved in cultivation. The development of policies and initiatives should focus on encouraging youth to pursue ginger farming is necessary. It is occasionally necessary to provide skill training for farmers, agribusiness owners, extensionists, and

others to keep up with evolving technologies. Considering the quality, suitability, economics, strengths, and opportunities for ginger cultivation in Mizoram, more farmers need to take up ginger cultivation as a viable income source.

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### Conflict of interest

The authors declare that they have no conflict of interest.

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