Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2022, Volume 35, Issue 1, Page 106-114

Performance of ginger genotypes on growth, yield and quality traits under Mizoram condition

Jeetendra Kumar Soni* • Vishambhar Dayal • Sunil Kumar Sunani • B. Lalramhlimi • Lungmuana • I. Shakuntala

ICAR RC NEH Region, Mizoram Centre, Kolasib-796081, India

ARTICLE INFO

Article history:
Received: 25 April, 2022
Revision: 19 May, 2022
Accepted: 01 June, 2022

Key words: Ginger, Genotype, Mizoram, Growth, Yield, Quality.

ABSTRACT

Mizoram has an excellent suitability for quality ginger production. Although productivity has shown an improving trend, the yield is still meagre as cultivation is dominated by local genotypes that are poor yielders. There is also a lack of systemic findings and recommendations to provide the detailed performance of high yielding genotypes with nearly similar in quality to local genotypes suitable for Mizoram. Therefore, a field experiment was carried out to evaluate the performance of ginger genotypes for three consecutive years (2019, 2020 & 2021). The experiment consists of seven genotypes (Gurubathani, Bold Nadia, Bhaise, John's ginger, PGS 121, PGS 95 and PGS 102) as treatments with RBD design having three replications. Fifteen observations were recorded to identify potential substitute for low yielding local genotypes to improve the overall production of ginger cultivation in Mizoram. Bhaise has recorded significantly highest rhizome yield (10.20 t/ha), number of tillers/plant at maturity (4.13); chlorophyll ‘b’ (0.47 mg/g) and total chlorophyll (1.77 mg/g) at 90 DAP. Moreover, the genotype Bold Nadia has recorded highest fresh weight of clump (177.59 g), dry recovery (24.29 %) and chlorophyll ‘a’ at 90 DAP (1.30 mg/g). Also, PGS 102 and Gurubathani have recorded at par yield of the above genotypes. Correlation analysis was performed to study the degree and direction of relationship between traits. The yield of rhizome has high positive significant correlation with fresh weight of clump (r = 0.817*). From the experiment it can be concluded that genotypes like Bold Nadia, Bhaise, PGS 102 and Gorubathani have performed best in terms of high fresh weight of clump, rhizome yield and other yield contributing traits. Whereas, for dry ginger purpose, Bold Nadia has performed best. Therefore, these genotypes are found suitable for large scale cultivation of ginger in Mizoram.

1. Introduction

Ginger (*Zingiber officinale* Rosc.) is one of India’s most important rhizomatous crops. It belongs to family Zingiberaceae and native to South East Asia. It is valued for its distinct aroma, flavour and pungency, which possess certain medicinal properties and uses. The world production of ginger is 4.97 million tonnes from an area of 0.47 million hectares (Anonymous, 2022). India is the leading producer, consumer and exporter of ginger in the world. The ginger production in India is about 37.97% of world’s ginger production. It has been a prime source of income for many farmers in India. The total area under ginger in India is 0.176 million hectares with a production of 1.887 million tonnes having productivity of 10.722 t/ha (Anonymous, 2021a). The state of Karnataka is leading in ginger production followed by Assam and West Bengal, while Mizoram stood 9th position in ginger production (Anonymous, 2021b). It has an excellent suitability for cultivation in Mizoram (Utpala et al., 2006), where cultivation is mostly done in jhum lands supporting the livelihood and income of many ginger growers of the state. The production of ginger in Mizoram is 60.13 thousand tonnes from an area of 8.55 thousand hectares with productivity of 7.03 t/ha (Anonymous, 2021b). Although productivity has shown an improving trend in Mizoram, it is still low as compared to the national average (10.69 t/ha). In some states like Gujarat, productivity can reach as high as 21.92 t/ha (Anonymous, 2021b). The quality of a variety has a direct impact on the production and productivity of ginger (Utpala et al., 2006). So, careful selection of suitable variety with good quality will have direct impact on ginger

*Corresponding author: jeetendra.soni@icar.gov.in

production. Ginger can be cultivated up to 2000 m above MSL with optimum elevation for its successful cultivation at 300–900 m MSL. Ginger performs well in a temperature range of 19-28°C with 70-90% humidity, and annual rainfall of 125-250 cm. Dry weather with average temperature ranges of 28-30°C for about a month before harvesting is ideal. The quality and overall yield of ginger is highly influenced by climate. Elevation and temperature have significantly influenced the yield and quality of different ginger varieties (Karthikeyan et al., 2018). The indigenous ginger cultivars of Mizoram such as Thinglaidum, Thingpuidum, Thingaria, Thingpui and Jugijan were reported to dominate the ginger cultivars of the state (Rahman et al., 2009; Soni et al., 2022). Among these cultivars, the farmers mostly prefer Thinglaidum, a medium-size rhizome as it contains less fibre showing a blackish ring and can yield upto 154 q/ha (Rymbai et al., 2018). However, these cultivars are usually low yielders than other improved varieties of different regions of India.

Some of the improved cultivars like Nadia, Bhaise, Gorubathani, Surabhi and Suprabha were evaluated in the regions. However, there is a lack of systemic findings and recommendations to provide the detailed performance of cultivars suitable for Mizoram. Moreover, local farmers are not aware of the yield potential and other quality traits of improved cultivars and are being afraid to take risks for mass cultivation of these cultivars, leading to less cultivation of these high yielding genotypes. Also, vegetatively propagated crop like ginger has a minimal chance of crop improvement. In that case, an alternate method is to collect, conserve and evaluate the different cultivars grown under diverse conditions suitable for specific agro-climatic conditions having higher productivity than existing cultivars with at par quality (Karthikeyan et al., 2018). Improvement of agronomic practices as well as the use of high yielding genotypes adapted to climatic conditions of Mizoram is essential for increasing the production and productivity of ginger. Trials were conducted at Agricultural Research Centres across India to evaluate the performances of different improved genotypes such as Gorubathani, Bhaise, Bold Nadia, John's ginger, PGS 121, PGS 95 and PGS 102 for adaptability, yield, and other important traits. These improved genotypes performed exceptionally well in different locations across India. During glut season, when ginger marketing in bulk quantities is a problem, a part of the produce can be converted to low volume high cost products such as dry ginger, ginger oil, ginger oleoresin, ginger powder, ginger candy and preserved ginger, etc. Dry ginger is used for preparing ginger powder, extracting ginger oil, oleoresin etc. 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. Recent improvements in ginger genotypes are focused on quality characters. The variety Bold Nadia is prevalent in the north-eastern region due to its low fibre content and tolerance to soft-rot (Verma et al., 2019), high dry matter content (22.6%) and higher yield up to 30 t/ha (Rymbai et al., 2018) which is about 32.16% more than local cultivar Thinglaidum.

High yielding improved genotypes possessing excellent quality could be the driving factor to achieving stable production, productivity and marketing of ginger. Evaluations of the improved genotypes were carried out under Mizoram conditions to identify potential substitutes with nearly similar in quality to low yielding local cultivars to improve the overall production of ginger cultivation in Mizoram.

2. Materials & Methods

Seven genotypes of ginger collected from different parts of India (Table 1) were tested and evaluated for three consecutive 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). The temperatures in the area range from 19.5 to 26.5℃. The soil is clayey loam in nature with slightly acidic pH (5.0-5.5) and has 1.2-1.4% organic carbon content. The ginger genotypes were grown as a sole crop on a raised bed of size 3 m × 1 m × 0.15 m (length x breadth x height), at a spacing of 30 cm × 25 cm, accommodating 40 plants/plot with three replications following randomized block design. The seed rhizomes weighing about 35-50 grams with 2 – 4 buds/rhizome were dipped in carbendazim 12% + mancozeb 63% WP @ 2 g/L for 30 mins and shade-dried for 24 hours. The planting of rhizomes is done in the 2nd fortnight of April and harvesting in 2nd fortnight of December. Small pits of 15 length × 15 width × 15 depth cm^3, were dug and FYM @ 500 g/pit, and carbofuran 3G @ 5 g/pit were incorporated. The recommended dose of fertilizer was applied at a rate of 80N:100P:80K kg/ha. Half doses of N (40 kg), full dose of P (100 kg) and K (80 kg) per hectare were incorporated at land preparation. Urea was used as N source, single super phosphate as P source and muriate of potash as source of K. The remaining 40 kg of N was applied in two splits at 60 and 120 days after planting.

Observations like plant height (cm), number of leaves/hill and number of tillers/plant were recorded at 90 DAP and maturity, respectively. Whereas, chlorophyll 'a' (mg/g), chlorophyll 'b' (mg/g), total chlorophyll (mg/g) and total carotenoid (mg/g) were recorded at 90 DAP; fresh weight of clump (g), number of rhizomes/plant, plant population/plot, dry recovery (%) and yield of rhizome (t/ha) were recorded after harvest. Five plants from each plot were selected for recording the observations. The dry ginger recovery was obtained by cleaning soil debris from rhizomes and sun-drying freshly harvested rhizomes until a constant weight was obtained and expressed in percent by the formula:

$$\text{Dry recovery (\%)} = \frac{\text{Weight of dried ginger (g)}}{\text{Weight of fresh ginger (g)}} \times 100$$

For chlorophyll content determination, freshly harvested leaf tissue (50 mg) was placed in a test tube containing 5 ml of dimethyl sulphoxide (DMSO) at room temperature overnight till tissue becomes colourless. The extracted samples were assessed by using UV/VIS Spectrophotometer at wavelength of 420, 663 and 645 nm while DMSO was used as blank. The different pigments were calculated from the formula given below (Hiscox and Israelstam, 1979) in mg/g FW:

Chlorophyll 'a' = (12.7 A_{663} – 2.69 A_{645}) x Dilution factor

Chlorophyll 'b' = (22.9 A_{645} – 4.68 A_{663}) x Dilution factor

Total chlorophyll = (20.2 A_{645} + 8.02 A_{663}) x Dilution factor

Total carotenoids = [1000 A_{470} – (3.27 Chl 'a'+ 104 Chl 'b')] x 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)

Table 1. Sources of different genotypes used in the experiment

Genotypes	**Sources**
Gurubathani	Pundibari, West Bengal
Bold Nadia	Nagaland
Bhaise	Sikkim
John's ginger	Kozhikode, Kerala
PGS 121	Pottangi, Odisha
PGS 95	Pottangi, Odisha
PGS 102	Pottangi, Odisha

Analysis of variance (ANOVA) was performed to determine the treatment and year effect using SPSS Version 20. The significance of the treatment was determined by the F-test and the difference between means of treatments and years was tested using Tukey at 5% probability level.

3. Results and discussion

The analysis of variance showed significant difference among genotypes and years for most of the traits under study. All the growth, yield and quality parameters exhibited coefficient of variation equal to, or below 20%, which confirmed the reliability of the experiment and indicating less genotype by environment interactions (Table 2). Among the years, coefficient of variation is at below 20% for all the traits under study which confirmed the reliability of the experiment.

The crop growth parameters are presented in Table 2. The genotype Gorubathani recorded significantly highest plant height at 90 DAP (45.77 cm) which was at par with Bold Nadia, PGS 95 and PGS 102 while the minimum was recorded in Bhaise (27.31 cm). Whereas, the highest plant height at maturity was recorded in PGS 121 (45.38 cm) and minimum in PGS 95 (40.89 cm). This could be due to interaction between genotypes and conducive climatic conditions. The growth and development of ginger are divided into two phases, *i.e* the rapid growth phase (active phase) where there is an increased growth rate of plant height followed by rhizome development phase where there is enlargement and expansion of rhizome. Some genotypes attain more height at 90 DAP indicating faster growth during active phase while other genotypes showed increased height at maturity which may be due to prolonged active growth phase. Similar plant heights were also reported by Shadap et al. (2013) and Abua et al. (2021). Number of leaves/hill showed significantly higher in PGS 102 (23.88) at 90 DAP statistically at par with PGS 121 while minimum was recorded in Bhaise (8.97). Whereas at maturity, the genotype PGS 121 (42.21) showed significantly higher number of leaves/hill at par with PGS 102 while lowest was recorded in John's ginger (26.84). These results corroborate the findings of Bhuiyan et al. (2012), Ridwansyah et al. (2020) and Abua et al. (2021) in different genotypes. There was a sharp increase in number of leaves from 90 DAP to maturity in all the genotypes under study. Tillers/plant at 90 DAP was significantly more in PGS 102 (2.53) similar to PGS 121 and Gorubathani while lowest was recorded in Bold Nadia (1.91). Whereas, the tillers/plant at maturity was significantly more in genotype Bhaise (4.13) at par with almost all the genotypes except John's ginger. These results corroborated the findings by Hossain et al. (2019) and Ridwansyah et al. (2020) in different genotypes. The variation in number of tillers/plant may be due to the overall positive interaction between the genotype of a plant, soil properties and congenial environmental conditions. The number of tillers/plant increased sharply from 90 DAP to maturity. The year effect on genotypes was found non-significant in almost all the crop growth traits except plant height at 90 DAP.

The chlorophyll 'a', 'b', total chlorophyll and total carotenoid content were determined from leaf tissues at 90 DAP (Table 3). The chlorophyll 'a' was recorded significantly highest in Bold Nadia (1.30 mg/g) which was at par with PGS 102 followed by PGS 95 while minimum was found in John's ginger (1.09 mg/g). The significant highest chlorophyll 'b' was recorded in Bhaise (0.47 mg/g) at par with PGS 102, Bold Nadia and Gorubathani whereas, least was obtained in PGS 121. The amount of total chlorophyll was found significantly maximum in Bhaise (1.77 mg/g) followed by Bold Nadia and least was observed under PGS

95 (1.36 mg/g). Similar results were also reported by Ghasemzadeh et al. (2010) in different genotype. Whereas, significantly highest total carotenoid was obtained under PGS 121 (0.38 mg/g) at par with Gorubathani and John's ginger and lowest in Bhaise (0.22 mg/g). Chlorophyll is the power-house of energy required for photosynthetic reactions, and determines the plant growth. It may be influenced by many factors including genetic constitution of a plant, soil, and climate. The year effect on genotypes was found non-significant in almost all the pigments under study at 90 DAP except for chlorophyll a.

Ginger yield attributing, yield and quality traits are depicted in Table 4. Fresh weight of clump is an important yield attributing trait. Ginger genotypes Bold Nadia (177.59 g), Gorubathani (168.12 g) and PGS 102 (167.18 g) showed significantly similar fresh weight of clump while minimum was observed in PGS 95 (96.90 g). The findings corroborate the results of Bhuiyan et al. (2012) and Martini et al. (2021) in different genotypes. The number of rhizomes/plant was significantly highest in John's ginger (4.75), which was statistically at par with Gorubathani and other genotypes except PGS 95 (2.29). Significant variation may occur due to varieties, soil properties and environmental conditions. Similar findings were also reported by Shadap et al. (2013) and Hossain et al. (2019) using different genotypes. Plant population/plot was significantly maximum under Bhaise (30.39) followed by PGS 121 and Gorubathani while minimum was recorded in John's ginger (14.67). The crop density is reported to increase the number of leaves and spread of rhizomes at the lower density while plant height and the number of tillers/plant were not significantly influenced by crop density (Dayankatti and Sulikeri, 2000). The significantly highest yield of rhizome was recorded in Bhaise (10.20 t/ha) which is at par with PGS 102, Gorubathani and Bold Nadia while minimum was recorded in PGS 95 (6.70 t/ha). Under Nagaland and Pottangi condition, Bold Nadia exhibited highest rhizome yield of 25.50 t/ha and 18.55 t/ha, respectively (AICRP, 2020). While under Kozhikode conditions, Bold Nadia yields about 26.28 t/ha and a slight yield reduction (12.72 t/ha) was obtained under Pundibari conditions. John's ginger and Bhaise could yield upto 22.28 t/ha and 20 t/ha, respectively under Kozhikode conditions. While under Pundibari conditions, Gorubathani (11.67 t/ha) and PGS-102 (10.95 t/ha) were found to exhibit higher yield of rhizomes (Aravind et al., 2020). Yield variation may be due to genotypic makeup, its growth and yield attributes, associated weather, soil and other management factors. 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. The quality of ginger is important as it is highly valued for medicinal purpose as well as processing into dry spice such as dry ginger. The maximum significant dry recovery (%) was recorded in Bold Nadia (24.29%) which was at par with PGS 102, PGS 95, PGS 101 and Gorubathani. While minimum dry recovery (%) was recorded in Bhaise (16.50%). These results corroborate the findings with Sanwal et al. (2012) in different genotypes. Most ginger varieties with big size rhizomes are not suitable for dry ginger due to their high moisture content which requires more time in drying resulting in poor quality dry ginger. The genotypes suitable for processing into dry ginger should possess high dry recovery percentage. The year effect on genotypes was found non-significant in almost all yield and yield attributing parameters except plant population/plot.

Character associationship is important to understand the relationship between dependent and independent variables as selection in one or more traits resulted in correlated responses in many other characters. The degree and direction of relationship between traits are measured by correlation coefficient (Table 5). The correlation coefficient between yield of rhizome with other quantitative traits (plant height, number of leaves/hill, number of tillers/plant at maturity; plant height, number of leaves/hill, number of tillers/plant, chlorophyll 'a', chlorophyll 'b', total chlorophyll, total carotenoid at 90 DAP; fresh weight of clump, number of rhizomes/plant, plant population/plot) showed that yield of rhizome has high positive significant correlation with fresh weight of clump ($r = 0.817^*$). This result suggested that rhizome yield can be increased with increase in fresh weight of clump. The number of leaves/hill at maturity has high positive significant correlation with number of tillers/plant at maturity ($r = 0.834^*$). This result is in conformity with the findings by other researchers (Ravi et al., 2017; Islam et al., 2008). Dry recovery (%) has exhibited high positive significant correlation ($r = 0.837^*$) with chlorophyll 'a' content in leaves at 90 DAP. Significantly high negative correlation coefficient between chlorophyll 'b' content in leaves at 90 DAP and total carotenoid content in leaves at 90 DAP ($r = -0.926^{**}$) was recorded. Similarly, number of tillers/plant at maturity exhibited significantly high negative correlation ($r = -0.801^*$) with plant population/plot.

4. Conclusion

Mizoram has been blessed with favourable climatic conditions suitable for ginger cultivation. Its cultivation in Mizoram is dominated by local cultivars with good quality traits but lower productivity. Therefore, selecting high yielding genotypes suitable for Mizoram conditions with quality at par with local cultivars could be the driving factor to achieving stable production, productivity and marketing of ginger. Three years of field experiment at ICAR Kolasib concluded that genotypes like Bhaise, PGS 102, Gorubathani and Bold Nadia exhibited significantly high fresh weight of rhizome and possessed higher yield and dry recovery are considered potential genotypes for large scale cultivation of ginger in Mizoram. However, reinvesting in proper management of rhizome rot of ginger combining with large scale screening of genotypes for resistance to the disease are also essential for stable ginger production in heavy rainfall areas.

5. Acknowledgement

The authors extended gratefulness to Director, ICAR Research Complex for NEH Region, Umiam, Meghalaya for providing all kinds of support to conduct field experiments. Also, we express our sincere gratitude towards AICRP on Spices (OXX02244) for providing financial support and ginger genotypes.

6. References

Abua MN, Iwo GA, Ittah MA, Obok EE, Edugbo RE (2021) Growth and yield performance of mutant ginger (*Zingiber officinale* Rosc.) lines in South-Eastern Nigeria. Journal of Applied Biology and Biotechnology 9(5):1-2.

AICRP (2020) Annual Report, 2020. All India Co-ordinated Research Project on Spices, ICAR p. 9.

Anonymous (2021a) Area, production and productivity of Ginger in India. Indiastat. Accessed on 1st April, 2022 from https://www.indiastat.com/table/ginger/area-%C2%A0production%C2%A0and%C2%A0productivity%C2%A0of%C2%A0ginger%C2%A0in%C2%A0ind/29193#

Anonymous (2021b) Selected state-wise area, production and productivity of Ginger in India. Indiastat. Accessed on 1st April, 2022 from https://www.indiastat.com/table/ginger/selected-state-wise-area-production-productivity-g/1220749#

Anonymous (2022) Crops and livestock products. FAOSTAT. Accessed on 22nd April, 2022 from FAOSTAT.

Aravind S, George J, Krishnamurthy KS, Radha E, Eapen SJ (2020). Annual Report, ICAR-All India Coordinated Research Project on Spices ICAR-IISR, Kozhikode, Kerala, India, p 112.

Bhuiyan MM, Roy S, Sharma PC, Rashid MH, Bala P (2012) Impact of multistoried agro-forestry systems on growth and yield of turmeric and ginger at Mymensingh, Bangladesh. Crop Production 1(1):19-23.

Dayankatti BS, Sulikeri GS (2000). Effect of plant population and nitrogen levels on growth, yield and quality of ginger-growth attributes. Karnataka Journal of Agricultural Sciences 13(4):1047-8.

Ghasemzadeh A, Jaafar HZ, Rahmat A (2010). Synthesis of phenolics and flavonoids in ginger (*Zingiber officinale* Roscoe) and their effects on photosynthesis rate. International Journal of Molecular Sciences 11(11):4539-55.

Hiscox JD, Israelstam GF (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. Canadian Journal of Botany 57(12):1332-4.

Hossain S, Rahman MS, Kona KN, Bari MS, Akter N, Ali MM (2019). Growth performance of two Ginger (*Zingiber officinale* Roscoe) varieties under different agroforestry systems in Bangladesh. Asian Plant Research Journal 3(3-4):1-0.

Islam KM, Islam AK, Rasul MG, Sultana N, Mian MA (2008). Genetic variability and character association in ginger (*Zingiber officinale* Rosc.). Annals of Bangladesh Agriculture 12(1):21-6.

Karthikeyan S, Anand M, Malathi S and Manonmani S (2018). Evaluation of ginger (*Zingiber officinale*) genotypes for high yield and resistance to soft rot suitable for Gudalur Regions in Nilgiris District. International Journal of Current Microbiology and Applied Sciences 7(7):2979-2985.

Martini DK, Paramita DP (2021). The effect of planting distance and bokashi from several types of organic fertilizers on the growth and yield of elephant ginger variety (*Zingiber officinale* var. Roscoe). Agriculture and Food Sciences Research 8(1):10-4.

Rahman H, Karuppaiyan R, Kishore K, Denzongpa R (2009) Traditional practices of ginger cultivation in Northeast India. Indian Journal of Traditional Knowledge 8(1):23-28.

Ravi Y, Narayanpur VB, Hiremath JS, Saraswati SS, Eragegowda M (2017) Correlation and path coefficient analysis in ginger (*Zingiber officinale* Rose.). International Journal of Current Microbiology and Applied Sciences 6(4):1224-30.

Ridwansyah Y, Yusraini E, Rahmawati N, Harahap MSM (2020) Growth performance of three ginger (*Zingiber officinale* Rosc.) varieties in crate system. In Proc Int Conf of Sci, Tech, Eng, Env and Ram Res (ICOSTEERR 2018), Research in Industry 4.0, pp 132-135.

Rymbai H, Jha AK, Talang HD, Deshmukh NA, Verma VK, Baiswar P, Firake DM, Laha R, Sinha PK, Devi MB, Deka BC, Prakash N (2018) Organic ginger cultivation in North Eastern Region. ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya. pp 35.

Sanwal SK, Singh SK, Yadav RK, Singh PK, Misra AK (2012) Yield and quality assessment of ginger (*Zingiber officinale* Rosc.) genotypes. Indian Journal of Plant Genetic Resources 25(3):281-6.

Shadap A, Hegde NK, Pariari A (2013) Performance of ginger var. Humnabad as influenced by planting dates under northern dry zone of Karnataka. The Bioscan 8(1):131-3.

Soni JK, Lalramhlimi and Shakuntala I (2022) Ginger cultivation in Mizoram: status, constraints, sustainable approaches and prospects. In Book Advances in Agricultural, Animal and Fisheries Sciences. Znan Publishers, Society for Technology, Environment, Science & People Kozhikode, India. (ISBN: 978-81-956227-2-6). pp. 47-58.

Utpala P, Johny AK, Parthasarathy VA, Jayarajan K, Madan MS (2006) Diversity of ginger cultivation in India- a GIS study Journal of Spices and Aromatic Crops 15(2): 93-99.

Verma VK, Patel RK, Deshmukh NA, Jha AK, Ngachan SV, Singha AK, Deka BC (2019) Response of ginger and turmeric to organic versus traditional production practices at different elevations under humid subtropics of north-eastern India. Industrial Crops and Products□136: 21-27.

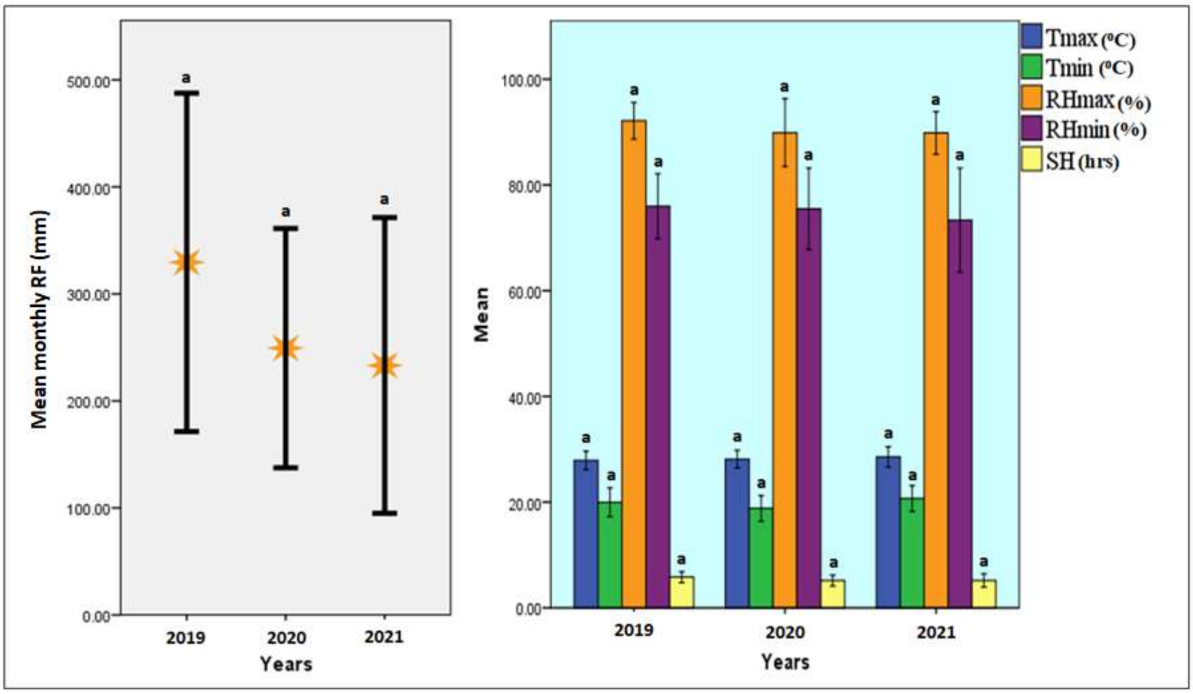

Figure 1. Crop seasonal mean values of weather parameters (April – December). Where RF= Rainfall (mm), Tmax= Temperature at maximum (^{O}C), Tmin= Temperature at minimum (^{O}C), RHmax= Relative humidity at maximum (%), RHmin= Relative humidity at minimum (%) and SH= Sunshine hours].

Table 2. Means of different growth parameters for seven genotypes of ginger for three consecutive years (2019, 2020 & 2021)

Treatments	Plant height @ 90 DAP (cm)	Plant height @maturity (cm)	No. of leaves/hill @ 90 DAP	No. of leaves/hill @ maturity	No. of tillers/hill @ 90 DAP	No. of tillers/hill @ maturity
			1. Genotypes			
Gorubathani	45.77^{a}	44.56^{NS}	17.04^{b}	30.57^{bc}	2.36^{a}	3.49^{ab}
Bold Nadia	41.18^{abc}	40.95^{NS}	17.47^{b}	38.36^{ab}	1.91^{c}	3.81^{ab}
Bhaise	27.31^{d}	44.06^{NS}	8.97^{c}	39.34^{ab}	2.32^{abc}	4.13^{a}

John's ginger	32.78^{cd}	40.94^{NS}	14.32^{b}	26.84^{c}	2.35^{ab}	3.13^{b}
PGS 121	35.13^{bcd}	45.38^{NS}	21.71^{a}	42.21^{a}	2.39^{a}	3.8^{ab}
PGS 95	45.29^{ab}	40.89^{NS}	9.86^{c}	35.11^{abc}	1.95^{bc}	3.62^{ab}
PGS 102	39.61^{abc}	43.46^{NS}	23.88^{a}	41.12^{a}	2.53^{a}	3.71^{ab}
Mean	38.15	42.89	16.18	36.22	2.26	3.67
C.V.	9.34	9.05	8.58	8.71	6.28	7.97
2. Years						
2019	34.15^{b}	41.19^{NS}	15.74^{NS}	33.28^{NS}	2.24^{NS}	3.55^{NS}
2020	33.92^{b}	42.09^{NS}	15.40^{NS}	36.38^{NS}	2.21^{NS}	3.59^{NS}
2021	46.38^{a}	45.39^{NS}	17.40^{NS}	39.01^{NS}	2.32^{NS}	3.88^{NS}
Mean	38.15	42.89	16.18	36.22	2.26	3.67
C.V.	3.33	11.73	14.27	9.90	9.80	8.34

The mean values of genotypes and years in column with similar alphabets are not significantly different (P = 0.05) for the traits according to Tukey's test.

Table 3. Means of different pigments from leaves of ginger for three consecutive years (2019, 2020 & 2021)

Treatments	Chlorophyll 'a' @ 90 DAP (mg/g)	Chlorophyll 'b' @ 90 DAP (mg/g)	Total Chlorophyll @ 90 DAP (mg/g)	Total carotenoid @ 90 DAP (mg/g)
1. Genotypes				
Gorubathani	1.13^{bc}	0.36^{ab}	1.5^{abc}	0.35^{ab}
Bold Nadia	1.30^{a}	0.37^{ab}	1.68^{ab}	0.30^{bc}
Bhaise	1.15^{abc}	0.47^{a}	1.77^{a}	0.22^{d}
John's ginger	1.09^{c}	0.33^{b}	1.5^{abc}	0.34^{ab}
PGS 121	1.12^{bc}	0.31^{b}	1.65^{abc}	0.38^{a}
PGS 95	1.26^{ab}	0.35^{b}	1.36^{c}	0.32^{b}
PGS 102	1.30^{a}	0.40^{ab}	1.42^{bc}	0.24^{cd}
Mean	1.19	0.37	1.55	0.31
C.V.	6.48	10.73	7.12	6.61
2. Years				
2019	1.26^{a}	0.37^{NS}	1.53^{NS}	0.31^{NS}
2020	1.21^{ab}	0.36^{NS}	1.65^{NS}	0.32^{NS}
2021	1.11^{c}	0.38^{NS}	1.49^{NS}	0.30^{NS}
Mean	1.19	0.37	1.55	0.31
C.V.	3.13	15.45	10.75	8.66

The mean values of genotypes and years in column with similar alphabets are not significantly different (P = 0.05) for the traits according to Tukey's test.

Table 4. Means of yield attributing, yield and quality traits for three consecutive years (2019, 2020 & 2021)

Treatments	Fresh weight of clump (g)	No. of rhizome/plant	Plant population/plot	Rhizome yield (t/ha)	Dry recovery (%)
			1. Genotypes		
Gorubathani	168.12^{ab}	4.73^{a}	27.11^{ab}	9.57^{ab}	19.56^{ab}
Bold Nadia	177.59^{a}	4.56^{a}	23.39^{abc}	9.16^{ab}	24.29^{a}
Bhaise	144.16^{bc}	4.12^{a}	30.39^{a}	10.20^{a}	16.50^{b}
John's ginger	120.11^{cd}	4.75^{a}	14.67^{c}	6.74^{c}	17.45^{b}
PGS 121	146.30^{bc}	4.55^{a}	27.78^{a}	8.50^{b}	19.69^{ab}
PGS 95	96.90^{d}	2.29^{b}	17.28^{bc}	6.70^{c}	20.10^{ab}
PGS 102	167.18^{ab}	4.20^{a}	26.11^{ab}	9.75^{ab}	23.63^{a}
Mean	145.77	4.17	23.82	8.66	20.17
C.V.	7.17	8.11	15.09	9.73	10.44
			2. Years		
2019	144.12^{NS}	4.04^{NS}	27.43^{a}	9.12^{NS}	19.92^{NS}
2020	141.29^{NS}	4.26^{NS}	23.36^{ab}	8.64^{NS}	20.29^{NS}
2021	151.88^{NS}	4.22^{NS}	20.67^{c}	8.22^{NS}	20.31^{NS}
Mean	145.77	4.17	23.82	8.66	20.17
C.V.	10.33	11.31	7.16	3.14	4.03

The mean values of genotypes and years in column with similar alphabets are not significantly different (P = 0.05) for the traits according to Tukey's test.

Table 5. Correlation matrix for ginger yield, quantitative and quality traits

Traits	[a]PH90	PHM	NLH90	NLHM	NTP90	NTPM	FWC	NRP	PPP	DR	CA90	CB90	TC90	TCA	YR
[a]PH90	1	-0.208	0.211	-0.168	-0.382	-0.295	0.087	-0.331	0.244	0.579	0.467	-0.403	-0.652	0.356	-0.17
PHM		1	0.386	0.429	0.678	0.409	0.404	0.372	0.1	-0.212	-0.399	0.142	0.333	0.054	0.622
NLH90			1	0.369	0.482	-0.091	0.614	0.499	0.465	0.624	0.192	-0.357	-0.123	0.203	0.288
NLHM				1	0.059	.834*	0.343	-0.115	-0.44	0.408	0.461	0.307	0.37	-0.372	0.518
NTP90					1	-0.103	0.238	0.501	0.481	-0.263	-0.447	0.107	-0.024	-0.099	0.357
NTPM						1	0.315	-0.148	-.801*	0.101	0.319	0.652	0.623	-0.555	0.669
FWC							1	0.685	-0.215	0.537	0.235	0.244	0.406	-0.197	.817*
NRP								1	0.198	-0.005	-0.43	-0.066	0.484	0.152	0.429
PPP									1	-0.071	-0.401	-0.749	-0.613	0.654	-0.49
DR										1	.837*	-0.129	-0.228	-0.092	0.204
CA90											1	0.235	-0.262	-0.464	0.161
CB90												1	0.391	-.926**	0.674
TC90													1	-0.197	0.525
TCA														1	-0.543
YR															1

[a]PH90: Plant height at 90 DAP (cm); PHM: Plant height at maturity (cm); NLH90: Number of leaves/hill at 90 DAP; NLHM: Number of leaves/hill at maturity; NTP90: Number of tillers/plant at 90 DAP; NTPM: Number of tillers/plant at maturity; FWC: Fresh weight of clump (g); NRP: Number of rhizomes/plant; PPP: Plant population/plot; DR: Dry recovery (%); CA90: Chlorophyll 'a' content in leaves at 90 DAP (mg/g); CB90: Chlorophyll 'b' content in leaves at 90 DAP (mg/g); TC90: Total chlorophyll content in leaves at 90 DAP (mg/g); TCA: Total carotenoid content in leaves at 90 DAP (mg/g); YR: Yield of rhizome (t/ha).