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EFFECT OF SPATIAL VARIATION ON THE PHYSICO-CHEMICAL CHARACTERISTICS AND QUALITY ATTRIBUTES OF MANGO (*MANGIFERA INDICA* L.) CV. ZARDALU

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ABSTRACT

The current experiment was carried out during the fruiting season in 2023 in the Department of Horticulture (Fruit Science), Bihar Agricultural University, with the objective to study the spatial variation in the physico-chemical composition of mango cv. Zardalu. Six blocks namely Jagdishpur, Kahalgoan, Sultanganj, Amarpur, Rajoun and Bhagalpur have been surveyed and collected Zardalu mango from different blocks. The experiment was laid out in a Randomised Block Design (RBD) with four replication and six treatments (Block) combinations. Results were observed that Sabour block was found maximum fruit weight (211.34 g) and fruit volume (204.19 cc) While, stone length was maximum (110.15 mm) found in Sultanganj block. Grade-A fruit (>225g based on weight) was maximum found in kahalgoan block 41.09 % followed by Sabour block 25.00%. In terms of grade-B fruits (200-225 g) was maximum found in Sabour block 51.08 % which is followed by Sultanganj block 43.37 %and Kahalgoan block 31.05 %. Minimum grade-D fruit (<175 g) fruit was found in sabour block 1.07 % followed by Kahalgoan block 1.36 and Sultanganj block 2.40%. The biochemical parameters of Zardalu mango like TSS (20.55° Brix) and total sugar (15.29 %) were found maximum in Sabour block with minimum acidity (0.22 % and 0.23 %) Sultanganj and Sabour block. While maximum vitamin-C (31.02 mg /100 pulp) was found in Jagdishpur block and the maximum beta-carotene, (3.82 mg/100 g) was recorded in Sultanganj block. Overall high-quality fruits were recorded in Sabour block followed by Kahalgoan and Sultanganj blocks.
Key words: Zardalu, Total Soluble Sugar, Brix, Vitamin-C, Pulp, Beta-carotene

Introduction

Mango (*Mangifera indica* L.), also denoted to as the "king of fruits," is the most important fruit crop in India is regarded as the national fruit of India under the family and order Anacardiaceae and Sapindales and native to the Indo-Burma region correspondingly with chromosome number 2n =40 (Nayak *et al*., 2023). It has been found that the mango has been grown in the Indian subcontinent for more than 4,000 years. Mangoes are an exceptional source of vitamin A (4850 IU in the ripening stage), Vitamin- B, vitamin- C, Protein, fat, carbohydrate, fibre and minerals like calcium, phosphorus, iron, and others (Hussain *et al*., 2021). Because of its delicious, sweetness and attractive aroma, mango has been a favorited of royalty and common alike since ancient times. Mango cultivars are the most diverse in the world and produce a wide range of phenotypic features. Mango is the third-most important tropical fruit crop after citrus and bananas. The mango tree, which is the national tree of Bangladesh, is also the national fruit of India, Pakistan, and the Philippines. According to Kostermans and Bompard (1993) and Mukherjee (1953), it has been grown in India for a very long time and is the most widely consumed fruit crop among the country's many millions of people.

In India, mango ranks first in area and second in production after banana. Uttar Pradesh is the leading producer of mango, and productivity is also high in UP, but AP has the highest area of mango. Zardalu

mango is a very suitable crop for Bihar's climate. The Bhagalpur district has embraced the unique mango cultivar Zardalu because the microclimate is ideal for the "Zardalu" mango's best performance (Rizwanullah *et al*., 2023). In recognition of the Zardalu mango's ideal size, lovely golden yellow color, and delicious flavor, the Bihar government has placed a strong emphasis on its popularization (Meena *et al*., 2022). Zardalu variety of mango, Bhagalpur, is the second most globally famous thing in Bihar after the "tussar silk" that has its GI tag (Kumar and Kumar, 2022). Zardalu varieties are famous around the world for their unique taste, distinct flavour, and aroma, which stem from their unique production location. Zardalu mangoes were granted a Geographical Identification (GI) tag in 2018 for Bhagalpur, Banka, and some parts of Munger districts due to their exclusive aroma, brilliant yellow color, sweetness, and other nutritional properties (Anand *et al*., 2023).

In Zardalu, mango physico-chemical properties are varied in fruit quality. This refers to the spatial variation of characteristics that define fruit quality acrossdifferent geographic areas. The change in the growing location of Zardalu mangoes has been observed to result in variations in their size, length, volume, diameter, flavor, sugar, antioxidants, etc. (Narvariya, 2016). Thus, it is essential to study the extent of variability among Zardalu mangoes grown in different districts of Bihar. The variation in quality in terms of size and shape of Zardalu mangoes has been noted with changes in growing places. The inconsistent fruit quality and attributes across various geographic locations are referred to as the problemof spatial variation in Zardalu mango (Nayak *et al*., 2023).

The quality of mangoes is notably influenced by varying climate conditions such as temperature, humidity, and precipitation. Mangoes grown in warmer climates tend to develop more intense Flavors and aromas, while those from cooler regions might exhibit milder tastes (Kalra and Tandon, 1995). Fluctuations in temperature can also affect the fruit's color, sweetness, and overall texture. The composition of the soil significantly affects the nutrients accessible to mango trees. For example, mangoes cultivated in soils rich in specific nutrients like potassium might display enhanced sweetness and overall quality (Ram *et al*., 2022). Mango treesat higher altitudes might experience cooler temperatures and shorter growing seasons, impacting fruit ripening and quality. Moreover, the drainage patterns on slopes can influence soil moisture levels, affecting fruit size and flavour (Van Leeuwen, 2022). Spatial variation adopts specific practices that influence factors like fruit size, appearance, and flavor. Different mango varieties possess unique genetic traits that contribute to their fruit's quality attributes. It is possible for variables to vary geographically, including soil composition, temperature, sunshine exposure, and microclimate conditions. The size, color, flavor, aroma, and nutritional value of the fruit can all vary due to these factors. Production of Zardalu mango and maintenance of uniform fruit quality throughout the geographic area Fruit quality control is crucial since it determines the fruit grade on the basis of their weight, and consequently, it gets a high market price. Fruit quality, however, is a complicated concept since it entails a variety of qualities, such as its look, flavor, and amount of nutrients (Abbott, 1999). The causes of the spatial variation in fruit quality are less well understood, despite the fact that many studies have concentrated on the factors influencing temporal changes in fruit quality. According to research on various crops, including mango (Lechaudel *et al*., 2010), variations in the fruit'ssugar and acid levels are related to heat days. Analysing the degree of physio-chemical Zardalu mango quality variability in relation to spatial variation may be helpful simultaneously. Spatial variation has a significant impact on the fruit quality of the Zardalu mango cultivar, according to studies. Variations in soil type and microclimatic conditions have an impact on the fruit's size, flavour, aroma and biochemical changes.

Materials and Methods

The current experiment was carried out during the fruiting season of 2023 in the Department of Horticulture (Fruit Science) at Bihar Agricultural University. The survey covered six blocks- Jagdishpur, Kahalgoan, Sultanganj, Amarpur, Rajoun, and Bhagalpur, where Zardalu mango samples were collected (**Figure 1**). The experiment was conducted in a Randomized Block Design (RBD) with six treatments corresponding to the six blocks, each replicated four times. This design facilitated the systematic evaluation of mangoes from different regions to assess their physico-chemical characteristics.

Figure 1: Zardalu mangos were collected from six different blocks

Different type of physical parameters was recorded *viz.* Fruit weight (g), Fruit diameter and length (mm), Length/Diameter (L/D) Ratio, Peel/Stone ratio, Pulp/Stone ratio, Fruit volume (cc), Stone Weight (gram), Stone length (gram), Stone diameter (mm) and Fruit weight (gram). Biochemical parameters were recorded *viz.* Total soluble solids (°Brix), Titratable acidity (%), Ascorbic acid (mg/100 g FW), Beta carotene (mg/100 g FW), Antioxidant activity (µmol trolox E/g FW) and Total sugar (%).

The total amount of soluble solid in the mango was determined using a digital hand refractometer. Titratable acidity was determined using the titration method, as specified by AOAC (2000). The ascorbic acid content was largely evaluated using the 2, 6-dichlorophenol indophenol colorimetric method, as described by Jones and Hughes (1983). Roy (1973) method for assessing the total carotene content of mango fruit peel was slightly modified. Apak *et al*. (2004) standardized the determination of antioxidant properties in mango using the CUPRAC method. Total sugar content was determined using Lane and Eynone's (1923) technique.

Formulas used:

$$Titratable\ acidity\ (\%) = \frac{\text{Titre value} \times \text{Normality of alkali i} \times \text{Vol. made up (ml)} \times \text{Eqv. wt. of acid} \times 100}{Vol.\ of\ sample\ taken\ for\ estimation\ (ml) \times Wt.\ or\ vol.\ of\ sample\ taken \times 1000}$$

$$Total\ Sugar\ (\%) = \frac{\text{Factor} \times \text{Dilution} \times 100}{50 \times \text{Titre value} \times \text{Weight of sample}}\ x\ 100$$

Results and Discussion

Zardalu mango, commercially grown in the Banka and Bhagalpur districts due to its microclimate conditions, is comparatively far better than other regions of the country. It was found that variation in fruit quality of Zardalu mango and physical parameters like fruit (length, diameter, and volume) stone (weight, length, and diameter) pulp/stone, pulp/peel, and fruit grading based on size. Chemical parameters like TSS, antioxidants, ascorbic acid, total sugar, and carotenoids have been discussed in work done by the previous worker.

Physical parameters of fruit cv. Zardalu Mango under spatial variation

The physical characteristics of cv. Zardalu ranged from 177.20 to 211.34 g, showing significant variation among the different blocks (Table 1). The maximum individual fruit weights were found in sabour (211.34 ± 2.00 g), while the minimum fruit weight was recorded in Rajoun block (177.32 ± 1.29 g). Such type of results

also observed by Parshant *et al*. (2013). According to Kumar *et al*. (2018), the wide range in fruit weight and volume among cultivars could be related to an individual cultivar that corresponds to fruit size, such as length and diameter. Many workers also observed such results, as Lal *et al*. (2017a) found in the CV of Kesar mango.

The fruit volume in Sabour block was assessed to be a maximum of 204.195 ± 2.45cc, whereas in Rajoun block, the minimum fruit volume was measured at 204.195 ± 2.45 cc. The variation in fruit volume is directly related to fruit size, and it is a completely varietal trait that is influenced by environments and locations (Anu *et al*., 2020). The fruit length/diameter ratio also ranged from 1.510 ± 0.00 to 1.678 ± 0.05. The highest fruit length/diameter ratio was found in Sultanganj block (1.678 ± 0.05), followed by Rajoun (1.568 ± 0.01) and Sabour block (91.540 ± 0.04). Fruit size is varied based on spatial variation, which is influenced by environmental conditions and locations (Ågren *et al*., 2008; Kostrakiewicz-Gierałt *et al*., 2022).

Physical parameters of Stone cv. Zardalu Mango under spatial variation

The physical parameters of Stone cv. Zardalu Mango under spatial variation showing significant variation among the different blocks (Table 2). The minimum stone weight is noted in Sultanganj block (33.148 ± 0.25 g); however, the maximum is found in Sabour block (38.030 ± 0.58 g), which is a significant variation from each other. Several workers have reported that the stone weight is variable. The stone length, stone weight, and stone diameter varied among the varieties, as reported by Lal *et al*., (2017b). The pulp/peel ratio varied from 10.228 ± 0.04 to 16.005 ± 0.11. Sultanganj has a maximum pulp/peel ratio of 16.005 ± 0.11, while the minimum was estimated at 16.005 ± 0.1.

Percentage of Zardalu mango under different grade at different locations

Percentage of Zardalu mango under different grade at different locations tabulated in (Table 3). The highest percentage of fruit Grade-A was observed in Kahalgoan block at 41.09 ± 0.31%, whereas the lowest percentage was recorded in Jagdishpur block at 5.43 ± 0.06%. The maximum Grade-B fruit was measured in the sabour block was 51.08 ± 0.35%, whereas the minimum was observed in the Jagdishpur block at the same percentage. The Garde-C fruit was observed minimally at the Sabour block (23.91 ± 0.21%), and the maximum was noted in Jagdishpur block (64.13 ± 0.48%). The lowest recorded percentage in the sabour block was (1.07 ± 0.01) in Grade-D. This variation could be attributed to spatial variation and adaptation to agro climatic conditions like temperature, rainfall, humidity, etc. Chakraborty and Dubey, 2017 and Shirodkar *et al*. (2001) reported that due to the increased uptake of water and nutrients and the accumulation of photosynthates from the source to the sink, the other probable reason might be due to the fertility status of the soil and microclimate. Further, effective photosynthetic activities and a higher availability of net photosynthates lead to an increase in fruit weight under varied agro climatic conditions.

Chemical composition of Zardalu Mango under spatial variation

The chemical characteristics of Zardalu mango (Table 4) exhibit TSS (total soluble solids) in the range of 16.02 to 20.55 °Brix. The maximum TSS content was recorded in Sabour block (20.55 ± 0.04 °Brix) with minimum was observed in Rajoun block (16.02 ± 0.07 °Brix) with each individual fruit varying TSS levels, which can be attributed to the distinct characteristics of these mango. Das, 2013, Parshant *et al*. (2013), and Nordey *et al*. (2014a and 2014b), all of whom have similarly noted variations in TSS levels among different mango varieties, supported the results. A number of studies have focused on the factors that influence the impact of temporal changes in mango fruit quality. The titratable acidity of Zardalu mango displayed a range from 0.22% to 0.33%.

These current results closely resemble the findings of Hada and Singh, 2018 and Mahayothee *et al*. (2020) documented acidity levels between 0.18% and 0.34%. The sugar content of Zardalu mango exhibits variation, ranging from 11.54% to 15.29% the fruit had higher TSS and lower acidity, and as the fruit matured from green to ripe, sugar content increased while acidity decreased. Kapilan and Anpalagan, 2015 found the similar results. In terms of beta-carotene content, the Amarpur block recorded the highest level at 3.82 mg/100 g of pulp and the lowest at 2.63 mg/100 g of pulp in the Kahalgoan block. Additionally, the highest antioxidant content, measuring 387.93 µmol Trolox E/g FW, was estimated in the Rajoun block, while the lowest was found at 274.92 in the Sabour block. The result is in agreement with the finding Lo'ay *et al*. (2021). The vitamin-C content in the Zardalu mango was notably lower, falling within the range of 25.09 to 31.02mg/100 g pulp weight.

The characteristics of Zardalu mangoes that affect consumer preference include the fruit shape, color, glossiness, uniformity, flavor, taste, the presence of

imperfections on the skin, and the quality of the flesh inside. These attributes collectively influence the spatial variation in whether consumers prefer the super quality of fruits.

Conclusion

From this investigation, the maximum fruit weight, fruit volume, fruit length/ diameter ratio was observed in sabour block followed by kahalgoan block. The maximum Grade-A fruit (>225 g) was maximum found in kahalgoan block 41.09 percent followed by sabour block 25.00 percent. In terms of grade-B fruits (200-225 g) was maximum found insabour block 51.08 percent which is followed by sultanganj block 43.37 percent and kahalgoan block 31.05 percent. The biochemical parameters of cv. Zardalu mango like TSS (20.55 °Brix) and total sugar (15.29 %) were found maximum in sabour block with minimum acidity (0.22 % and 0.23 %) sultanganj and Sabour block. While maximum vitamin-C (31.02 mg/100pulp) was found in Jagdishpur block and the maximum beta carotene (3.82 mg/100 g) was recorded in Sultanganj block. Finally, it would be concludedthat overall high-quality fruits were found in sabour block followed by kahalgoan and sultanganj blocks.

Table 1: Physical parameters of fruit cv. Zardalu Mango under spatial variation

Treatments/ Block (Districts)	Fruit-Weight (g)	Fruit-Length (mm)	Fruit-Diameter (mm)	Fruit Volume (cc)	Fruit L/D Ratio
Jagdishpur (Bhagalpur)	194.575 ± 0.97	94.700 ± 0.35	62.590 ± 0.37	187.113 ± 1.29	1.513 ± 0.01
Sultanganj (Bhagalpur	201.950 ± 0.86	110.153 ± 1.56	64.093 ± 0.60	191.513 ± 0.61	1.678 ± 0.05
Sabour (Bhagalpur)	211.340 ± 2.00	100.403 ± 0.73	65.000 ± 0.46	204.195 ± 2.45	1.540 ± 0.04
Kahalgoan (Bhagalpur)	206.280 ± 2.01	101.310 ± 1.24	65.798 ± 0.76	194.950 ± 2.10	1.533 ± 0.00
Amarpur (Banka)	185.780 ± 0.85	94.388 ± 0.89	64.245 ± 0.12	181.685 ± 1.51	1.510 ± 0.00
Rajoun (Banka)	177.320 ± 1.29	93.818 ±0.41	62.863 ± 0.41	163.745 ± 1.50	1.568 ± 0.01
C.D (P<0.05)	**4.666**	**3.209**	**1.542**	**5.538**	**0.069**
SE (± m)	**1.534**	**1.055**	**0.507**	**1.820**	**0.023**

Table 2: Physical parameters of Stone cv. Zardalu Mango under spatial variation

Treatments/ Blocks (Districts)	Stone-Weight (g)	Stone-Length (mm)	Stone-Diameter (mm)	Pulp/peel Ratio	Pulp/stone Ratio
Jagdishpur (Bhagalpur)	34.748 ± 0.46	78.133 ± 1.07	22.455 ± 0.18	10.228 ± 0.04	4.158 ± 0.05
Sultanganj (Bhagalpur	34.688 ± 0.18	74.403 ± 0.82	22.553 ± 0.15	16.005 ± 0.11	4.478 ± 0.05
Sabour (Bhagalpur)	38.030 ± 0.58	79.925 ± 0.87	21.938 ± 0.12	14.060 ± 0.17	4.238 ± 0.06
Kahalgoan (Bhagalpur)	36.348 ± 0.42	78.625 ± 0.70	21.983 ± 0.16	15.933 ± 0.05	4.313 ± 0.03
Amarpur (Banka)	34.178 ± 0.35	75.658 ± 0.81	17.270 ± 0.12	13.540 ± 0.15	4.243 ± 0.06
Rajoun (Banka)	33.148 ± 0.25	74.933 ± 0.68	21.255 ± 0.23	13.538 ± 0.02	4.058 ± 0.11
C.D (P<0.05)	**1.295**	**2.729**	**0.561**	**0.318**	**0.104**
SE (± m)	**0.426**	**0.897**	**0.185**	**0.105**	**0.034**

Table 3: Percentage of Zardalu mango under different grade at different locations

Treatments/ Blocks	Districts	Grade-A (%) (>250 g)	Grade-B (%) (200-225 g)	Grade-C (%) (175-200 g)	Grade-D (%) (<175 g)
Jagdishpur	Bhagalpur	5.430 ± 0.06	18.470 ± 0.23	64.130 ± 0.48	11.950 ± 0.10
Sultanganj	Bhagalpur	6.020 ± 0.02	43.370 ± 0.27	48.190 ± 0.39	2.400 ± 0.03
Sabour	Bhagalpur	25.000 ± 0.17	51.083± 0.35	23.910 ±0.21	1.078 ± 0.01
Kahalgoan	Bhagalpur	41.093 ± 0.31	31.500 ± 0.21	26.020 ± 0.13	1.360 ± 0.01
Amarpur	Banka	6.153 ± 0.08	18.460 ± 0.08	66.150 ± 0.60	9.228 ± 0.09
Rajoun	Banka	6.570 ±0.05	27.630 ± 0.10	56.570 ± 0.46	9.210 ± 0.11
C.D (P<0.05)		**0.487**	**0.768**	**1.350**	**0.242**
SE (± m)		**0.160**	**0.252**	**0.444**	**0.080**

Table 4 : Chemical composition of Zardalu Mango under spatial variation

Treatments/ Blocks (Districts)	TSS (°Brix)	Titrable Acidity (%)	Vitamin-C (mg/100 pulp)	Total Sugar (%)	Antioxidants (µmol trolox E/G FW)	Beta-carotene (mg/100 g)
Jagdishpur (Bhagalpur)	18.25 ± 0.08	0.32 ± 0.005	31.02 ± 0.32	13.14 ± 0.04	347.76 ± 2.08	3.50 ± 0.01
Sultanganj (Bhagalpur	19.32 ± 0.12	0.22 ± 0.003	25.09 ± 0.31	14.17 ± 0.12	323.77 ± 3.82	3.65 ± 0.04
Sabour (Bhagalpur)	20.55 ± 0.04	0.23 ± 0.002	28.37 ± 0.36	15.29± 0.20	274.90 ± 2.10	2.74 ± 0.01
Kahalgoan (Bhagalpur)	19.51 ± 0.29	0.24 ± 0.002	24.60 ± 0.13	15.14 ± 0.18	322.31 ± 1.92	2.63 ± 0.04
Amarpur (Banka)	17.40 ± 0.18	0.28 ± 0.003	26.42 ± 0.36	12.29 ± 0.09	347.53 ± 3.23	3.82 ± 0.03
Rajoun (Banka)	16.02 ± 0.07	0.33 ± 0.003	29.11 ± 0.21	11.54 ± 0.19	387.93 ± 3.23	2.64 ± 0.02
C.D (P<0.05)	**0.50**	**0.008**	**0.72**	**0.50**	**8.93**	**0.10**
SE (± m)	**0.16**	**0.003**	**0.23**	**0.16**	**2.93**	**0.03**

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