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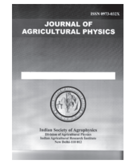

Research Article

Appraisal of Soil and Climatic Impacts on Variability of Fruit Germplasms

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ABSTRACT

Long-term orchard management had impacts on soil, tree and fruit quality *vis-à-vis* production. The aim of preset study was to assess the impacts of soil and climatic factors on the fruit production of germplasms at subtropical condition. Experimentation conducted at research field of ICAR-CISH, Lucknow suggested changes in flowering, fruiting behaviour as a function of soil-tree-environment. Higher evaporation (>7 to 8 mm/day) coupled with temperature (>35°C) influences fruit sets. Statistical histographic distribution indicated mango germplasms had experienced maximum temperature ranges of 35 to 40°C with highest frequency level of 47 per cent while withstand the minimum temperatures of 25 to 27.5°C with highest frequency level of 26 per cent. A heat map of exiting orchard at subtropical climatic condition was developed. Recent information of soil organic carbon (0.41 ± 0.09 per cent), phosphorus (34.53±12.57 kg/ha), potassium (190.1±47.41 kg/ha), zinc (0.91±0.31 mg/kg), Cu (1.79±0.56 mg/kg), Fe (4.36±1.96 mg/kg) and Ca (1245.32±321.99 mg/kg) was recorded from the soils of mango germplasms maintained at subtropical climatic condition. Recent scientific analysis included recent information of interactions across indicators and concluded that resource conservation practices are to be adopted sincerely for ensuring sustainability.

Key words: Soil factors, Weather factors, Quality, Production, Conservation technology

Introduction

Soil and climate had positive impact on the conservation of fruit germplasms. It has been observed that the influence of soils on the maintenance of fruit germplasms becomes very much relevant and important was given for improving the nutritional characteristics of soils to support optimum productivity. Adak and Kumar (2020) inferred significant role of soil nutrients for germplasms conservation to enhance future resource use efficiency. Adoption of conservation technologies significantly improved farmers' income (Babu *et al.,* 2022) and application of natural organic resources also encouraged Langra production in subtropical soil and climate (Adak and Shukla, 2023). Srivastava *et al.* (2017) emphasized health care improvement in Citrus through soil fertility. Bao *et al.* (2006) scientifically explained the importance of soil nutrient status *vs* fruit quality in Newhall orange. The significance of boron and potassium for supporting mango germplasms production system was also systematically and scientifically assessed under subtropical climatic situation (Adak *et al.*, 2018a). It was felt that many a time fruit growers were harvesting lesser fruit with low quality fruits that fetch lower prices in the market. In many arid, tropical, temperate and coastal regions wherein specific management is needed, farmers grow fruits with difficulty but lesser amount of quality fruit fetched higher prices. In rainfed and subtropical zones, growers had to follow scientific practices for

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improving the fruit production and quality of fruits to support their livelihood. Climate in turns environmental factors significantly affect the reproductive phases of fruits across various agroecological region. Adak *et al.* (2013) noted severe vulnerability of mango production as a function of rapid weather dynamics in Lucknow. In subtropical area, mango and guava significantly impacted by the extreme changes in weather variables. Mishra *et al.* (2014) observed changes in guava phenology due to weather factors affecting its production. It has been observed that fruit germplasms act as a function of soil and climate based management to support its production. Mango germplasms undergone various changes, sometimes shifts in phenology was noted. Rajan *et al.* (2021) reported the impacts of climate variability on the shifts of phenophases *vis-à-vis* thermal heat accumulation in Dashehari mango. It was noted that flowering in mango germplasms were shifted over the seasons and fruit set pattern got impacted. The fruit load in different mango accessions was thus act as a dependant factor and climate *vis-à-vis* soil management acts as independent factors. Bearing habits in these germplasms had significant influence by its genetic characters, orchard practices involved. Since, over the years or decades of cultivation, there is changing pattern of soil fertility cum weather vagaries, scientific innovation to improve sustainable fruit production from germplasms maintained orchards needs to be followed. In this context, indexing of orchards and control measures were developed for the benefit of growers, stakeholders, scientists, farmers and policy planners. Adak and Pandey (2020) found significant role of soil nutrient index to correlate mango orchard productivity in Lucknow. Gundappa *et al.* (2016) disseminated dynamics of mango hoppers and their management under subtropical climates while Shukla *et al.* (2017a) developed a robust humid thermal ratio for managing anthracnose disease in mango orchards. Government initiatives to restore soil fertility and also avail tree insurances to support the farming family in case of adverse weather aberrations are praiseworthy. Henceforth, soil health optimization is very crucial for profuse flowering and higher production; tree health monitoring is important and climactic management is also essential to support fruit production even at severe limited resources cum climatic hazards.

Materials and Methods

The location of the current study was at the latitude of 26°54N and longitude of 80°45E. It was situated in the Experimental research farm of ICAR-CISH, Rehmankhera, Lucknow, UP. Mango germplasms fields were being scientifically maintained for long-term experimentation. The fruit growing blocks have undergone several weather variances like extreme heat to cold periods; sometimes frost occurrences were also recorded within the fields. Generally, summer season had 35 to 45°C temperature variations while minimum temperature showed as low as 0 to 10°C. Rainfall recorded only after harvesting of majority of fruits in the months from July to September periods. Absence of rainfall during fruit production rendered orchard management. Soil management was done each year. Each year ploughing was done. Recommended fertilizer doses were applied to the tree basins. Irrigation was applied at the fruit developmental stages for the retention of fruits. Pest management practices were practiced sincerely to avoid higher pest load and thereby to reduce fruit loss. Soil samples were collected systematically from the tree basin of mango orchards for their analysis. Samples were air dried and processed as per the standard procedures. Analysis of soil organic carbon, soil available P, K, Ca and micronutrients like Zn, Cu and Fe was completed in the soil science laboratory of the institute. Statistical frequency distribution of nutritional data was developed to present the frequency levels of each nutrient at variable class contents. This is the most scientific ways of representing datasets to indicate which nutrients falls in which category; either maximum or minimum class intervals with highest or lowest frequency distribution. Each day climatic data was recorded systematically from the observatory of the institute. All these datasets were considered for the entire vegetative and reproductive phase of fruit production representing existed climatic situation on real time basis. Histographic distribution was generated to indicate the level of frequency distribution with class intervals of each weather parameter. Vegetative and reproductive stages were noted. Variability of flowering, fruit set and yield pattern was depicted pictorially. Each parameter was correlated to find out the impacts. Heat map for subtropical climatic condition was generated. Soil factors to support fruit germplasms were included in detailed. Quality and production as well were considered for this scientific analysis.

Results and Discussions

Scientific role of soils to support fruit germplasms

Recent analyzed data of soil nutrients in mango orchards showed statistically variable contents. It has been recorded that soil organic carbon varied between 0.23 to 0.58 per cent; soil phosphorus and potassium had ranges of 17.63 to 73.00 and 131.65 to 296.40 kg/ha respectively. Soil micronutrients like Zn content were 0.47 to 1.54 and Cu content of 0.92 to 2.92 mg/kg was noted. The maximum and minimum Fe and Ca contents were recorded as 2.14 to 10.06 and 13.09 to 1713.0 mg/kg respectively across these orchards. The histographic distributions of all these soil nutrients were depicted in the Fig. 1 and 2. The distribution pattern indicates maximum soil organic carbon of 0.3 to 0.5 per cent in the frequency distribution of 11 per cent; highest P and K in the class intervals of 10 to 15 and 60 to 80 mg/kg with frequency distribution of only 12 and 14 per cent. Similarly, soil zinc and Cu had highest class contents of 0.6 to 0.8 and 1.5 to 2.0 mg/kg in the frequency levels of 8 and 11.5 per cent. The maximum Fe and

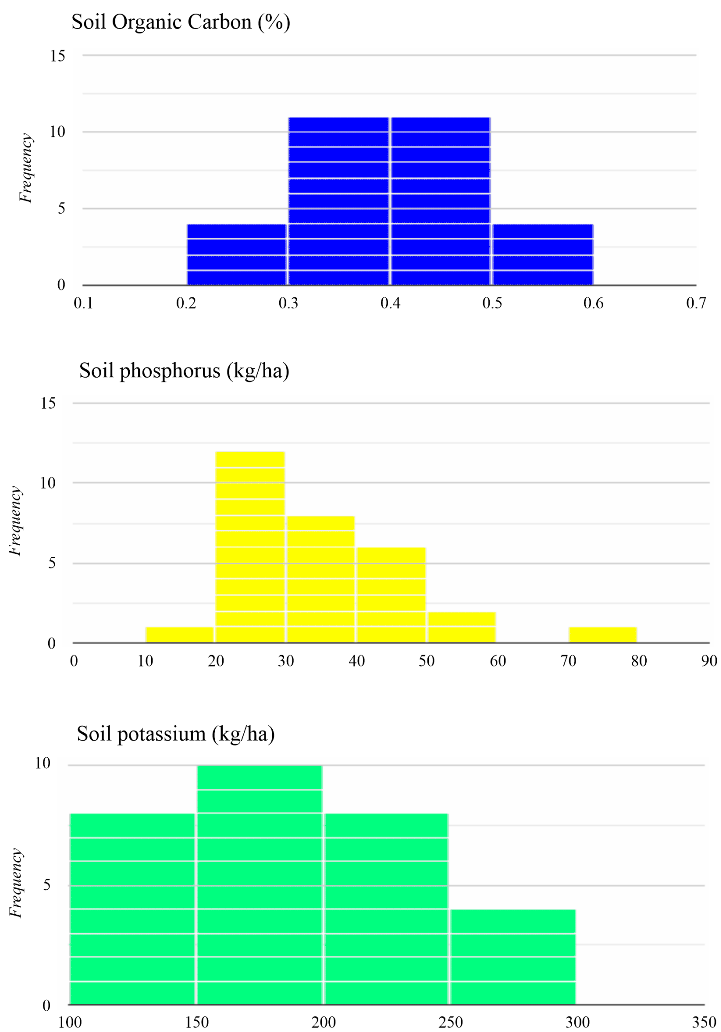

Fig. 1. Histographic distribution of soil organic carbon, phosphorus and potassium in soils of mango germplasms maintained at subtropical condition of Lucknow, UP, India

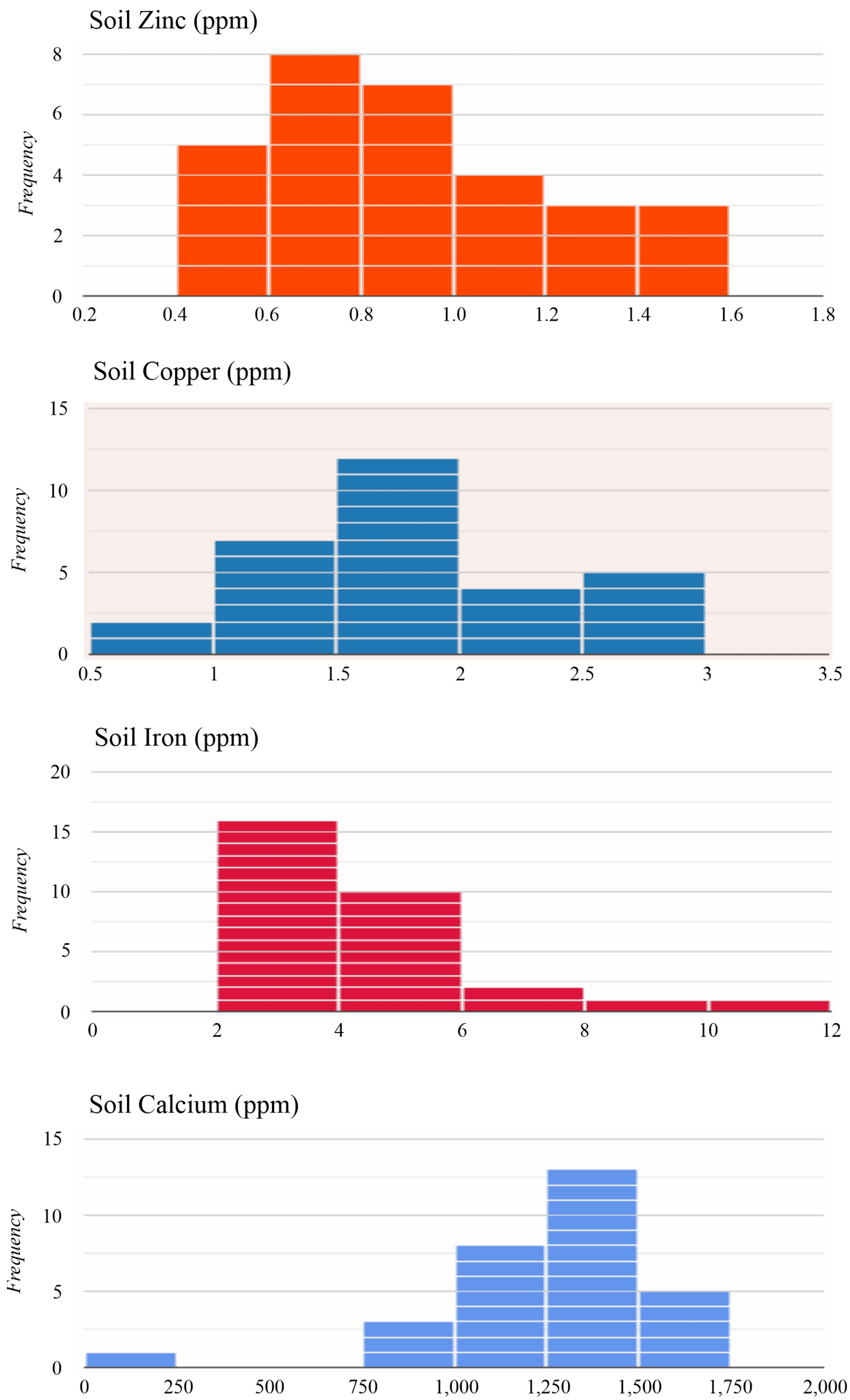

Fig. 2. Histographic distribution of soil zinc, copper, iron and calcium in soils of mango germplasms maintained at subtropical condition of Lucknow, UP, India

Ca were of course noted in the ranges of 2 to 4 and 1250 to 1500 mg/kg with 16 and 13 per cent frequency distribution levels. It was inferred from the study that there is a need to improve the soil nutrient status to support the improved productivity through optimized nutrient management modules. Soils of different category had wider adaptability to sustain various fruit germplasms. Different types of fruits or similar traits when cultivated in one or more types of soil, the characteristics of soils, its texture, structure, aggregate stability, hydraulic conductivity, moisture contents, pore characteristics, water holding and aeration capacity etc impacts on the hydrological dynamics *vis-à-vis* fruit productivity. Therefore, suitability of fruit trees on a particular location based on its soil and climate is very much important. Scientific evidence suggested many crops grown on problematic soils does not suitability offer further scope to grow similar or more crops as beneficial fruit crop. Even, fruit grown on compacted or hard pan or stony soil often perform lesser than sandy loam or alluvial soils due to restricted root growth. Adak *et al.* (2018b) observed 0.16±0.06 to 1.14±0.19 ìgTPFg^{-1}h^{-1} (dehydrogenase), 161.11±9.27 to 386.89±33.80 ìg fluorescein g^{-1} h^{-1} (fluorescein diacetate activity) and 0.34 ±0.02 to 0.45± 0.04 per cent soil organic carbon across 0-30 cm soil depth in Langra orchard for correlating lower yields. Finn *et al.* (1993) recorded significant differences in potassium (2.83 g/kg), Ca (12.87 g/kg), Mg (2.03 g/kg), Zn (36 mg/kg) and B (21 mg/kg) nutrient contents in blueberry germplasms screening at variable soil pH (5.0 and 6.5). Helalia *et al.* (2021) experimentally found the variability of water use in almond orchards having sodium adsorption ratio of 1.33 to 13.31 and 0.9 to 16.6 mmolc/L with saturated hydraulic conductivity of 2.05 to 26.59 and 1.01 to 16.71 cm/day across locations. Similarly, under pistachio orchards, saturated hydraulic conductivity of 7.02 to 21.85 and 11.2 to 50.95 cm/day was noted with 0.3 to 34.48 and 0.3 to 8.0 mmolc/L salinity levels. Torkashvand *et al.* (2019) and Yu *et al.* (2021) predicted kiwifruit yield using neural networking protocols with leaf nutrients concentration. The soil and foliar nutrient dynamics may be optimized through soil management systems and enhanced yield can be obtained in Dashehari (Adak *et al.*, 2019a). Therefore, soil functionality is very important as it directly related with the soil indicators. Physical and biological indicators do statistically alters the chemical indicators and therefore soil processes had immense role on the sustainability of fruit germplasms. There are evidence that mango quality, nutraceutical and other nutritive parameters are impacted by the soils and its quality. Akin-Idowu *et al.* (2020) observed variability of nutrient concentrations across Ogbomoso, Madoe, Palmer, Saigon, Lipen, Kent, Edward, Julie, Haden and Alphonso mango genotypes. It was inferred that the K concentrations varied from 6.88±4.33 to 20.15±0.01 mg/100g, Zn of 10.75±0.09 to 32.95±0.14 mg/100g, Cr of 0.09±0.02 to 0.47±0.04, Ca and Mg concentrations of 21.50±1.15 to 51.5±0.00 and 1.10±0.029 to 7.79±1.73 mg/100g respectively. The P concentration of 176.50±1.44 to 298.5±2.02 mg/100g was recorded across these ten mango genotypes. O'Neil *et al.* (2013) opined of nutritional health as mangoes are normally associated with better nutrient intake and diet quality. Bello *et al.* (2016) noticed variability of â-carotene (0.026 to 0.080 mg/100g) and vitamin C (21.18 to 26.40 mg/100g) across Julie Mango, Normal mango, Peter mango, Sheri mango and Golden nugget. The potassium, magnesium, iron and calcium concentrations of 20.8 to 62.2, 0.6 to 1.2, 1.4 to 9.4 and 0.6 to 1.4 mg/100g respectively were also noted across these five mango cultivars. Anti-oxidants variability in mango cultivars was found by Dars *et al.* (2018) and it was noted that total polyphenol of 102.7 to 145.52 mg GAE/100g, total carotene of 578 to 2771 µg/100 g and Lutein content of 0.111 to 0.816 mg/100 g existed in mango.

Eradication of malnutrition through scientific approaches is praise worthy job. The task of ensuring nutritional security through food production is challenging and it has become national priority to safeguard people of a nation from hidden hunger also. Therefore, sincere efforts are put in place to achieve the goal of nutritional security as national importance. In this direction, fruits play significant role to supply and ensure required nutrients to human health. The dietary requirements through cereals, pulses of course supply nutrition to human body but fruits being rich in several vitamins, proteins, phenols, flavonoids, carotenoids, anti-oxidants etc. are easily digestible and bio-available to human system. Ribeiro *et al.* (2007) recorded variable quantity of antioxidants in pulp of mango while Sankaran *et al.* (2020) based on genetic analysis of 400 mango genotypes, recorded 27.54 to 87.16 percentages of pulp and 11.23 to 19.36°B TSS. Satisha and Ganeshamurthy (2015) observed that soils of mango growing region had 40 to 60 per cent deficiency in N, P and K. Rampant Zn deficiency in soil to the tune of 45 to 75 per cent hampering mango productivity across mango growing regions. Sometimes deficiency in one or more soil minerals significantly responsive to quality component and often showed deprived symptoms on the fruit outside and inside. De Oliveira *et al.* (2001) observed the spongy tissues impacts on the contents of sugar and amylase starch in tommy atkins. Based on mineral nutrient content, Huang *et al.* (2021) concluded that artificial neural networking is better in predicting soluble solids and acid content in loquat as compared to multiple linear regressions. The nutrient contents in loquat were estimated as 14.82% soluble solids, 65% acidity, 0.011, 0.006, 0.027, 0.063 g/kg Zn, Cu, Mn and Fe respectively. Soil quality also differs and decides the soil nutrients *vis-à-vis* production in peach orchard (Zhu *et al.,* 2019). Nutritional practices were foremost to support the improvement in quality parameters. Scientific analysis often also suggested variable anti-oxidant contents in similar or various cultivars based on comparable soil types or same soils. The value addition of fruits even after fresh consumption is another ways to support several fruit waste based healthy products for use and profit earning. Berardini *et al.* (2005) expressed that polyphenolics and pectin can be obtained from mango peels. Recently, variable TSS of 11.00±0.20 to 19.47±0.12°B, titratable acidity of 1.12±0.01 to 4.43±0.02% and pulp yield of 13.01±2.54 to 46.75±1.62% in various passion fruit germplasms was found by Viera *et al.* (2022). The nutrient concentrations of 818.68±50.39 to 1270.96±13.11 of nitrogen, 88.56±0.64 to 170.03±1.27 phosphorus, 1471.28±58.85 to 2816.00±76.46 of potassium, 41.96±0.61 to 139.71±0.62 of sulphur and 8.81±0.07 to 12.48±0.11 mg/100 g dry pulp of sodium was observed in passion fruit germplasms. In this context, the natural habitat of mango germplasms in subtropical climate offers great scope for scientific conservation and regulation to improve the nutraceutical composition. Innovations in soil management were thus given national importance to support the mechanisms of fruit functionality.

Scientific climate analysis cum sustainability in fruit germplasms

The variability of mango germplasms showing its flowering pattern, fruit set and production pattern under subtropical environmental condition is being depicted in Fig. 3 to 6. The variability of fruit phenological responses due to genetic *vs*

Fig. 3. Variability of flowering pattern in mango germplasms at Lucknow, UP, India

Fig. 4. Variability of fruit set pattern in mango germplasms at Lucknow, UP, India

Fig. 5. Variability of fruit production pattern in mango germplasms at Lucknow, UP, India

Fig. 6. Variability of fruit production pattern at subtropical condition of Lucknow, UP, India

environmental and soil factor as well. It was recorded that trees experienced maximum temperature ranges of 40 to 44°C between 138 to 147 Julian days with highest minimum temperature of 25.5°C and pan evaporation of 9.7 mm/day. Mango germplasms undergoing maximum frequency level of 47 per cent in the maximum temperature ranges of 35 to 40°C followed by 42 per cent frequency distribution in the class intervals of 30 to 35°C (Fig. 7). Maximum frequency level of 26 per cent in the class intervals of 25 to 27.5°C of minimum temperature was recorded followed by 21.5 per cent frequency level in 20 to 22.5°C class contents. Evaporation of 7 to 8 mm/day was noted as highest in 35 per cent frequency level. Heat map showed inter dependency of parameters impacting on exiting orchards under subtropical climatic condition (Fig. 8). The scanty rainfall during the vegetative cum reproductive stages shown needs for resource management to produce optimum yield. Insects and disease dynamics on the fruit trees had a thrust to save the fruit from infestation. In this direction, systematic data was generated and recommendation issued to farmers for efficient controls. Shukla *et al.* (2017b) reported the interaction of weather parameters to sooty moulds in mango orchards and their remedies. Weather based indices was developed to correlate with thrips dynamics in mango (Gundappa *et al.,* 2016) and management of powdery mildew in subtropics was also developed following interactions of soil-tree-weather factors (Shukla *et al.,* 2016). Further, it was recorded that flowering in mango often delayed, extended during cold period, fruits had to suffer severe heat stress, trees got exhausted over period of higher temperature and moisture stress condition (Babu *et al.,* 2020). Under such situation, even a smaller amount of irrigation and mulching can avoid heat stress and reduce the mortality of newly bearing trees. Climatic adaptation of germplasms was thus should be adapted with scientific care. In this context, cost effective polytunnel technology can be adapted to acclimatize strawberry germplasms even in subtropical condition (Kumar *et al.,* 2016). Tulipani *et al.* (2011) found 0.2 to 0.7 mg vit C/g fruit weight and 0.24 to 2.46 mg Protein/g fruit weight in strawberry. Adak and Pandey (2019) described in detailed about hydrology *vis-à-vis* production under tree and agroforestry related ecosystem. Soil micronutrients also indicate the sustainability measurement for which Adak *et al.* (2019b) studied over 250 samples also recorded the spatial variability of important micronutrients across mango orchards related to lower production. Fad´on *et al.* (2021) found rising temperatures impacts during dormancy on flowering in sweet cherry with 4994 to 7315 mean growing degree hours accumulation as cultivar-

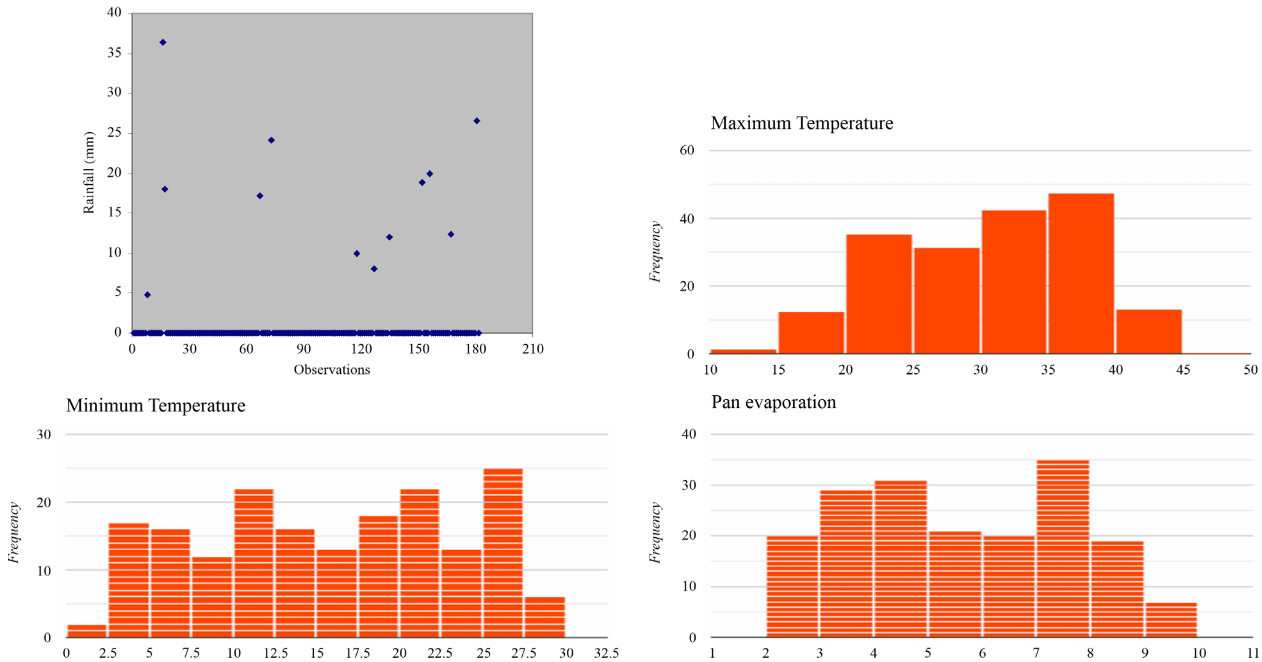

Fig. 7. Mango germplasms experiencing variability of climatic factors at Lucknow, UP, India

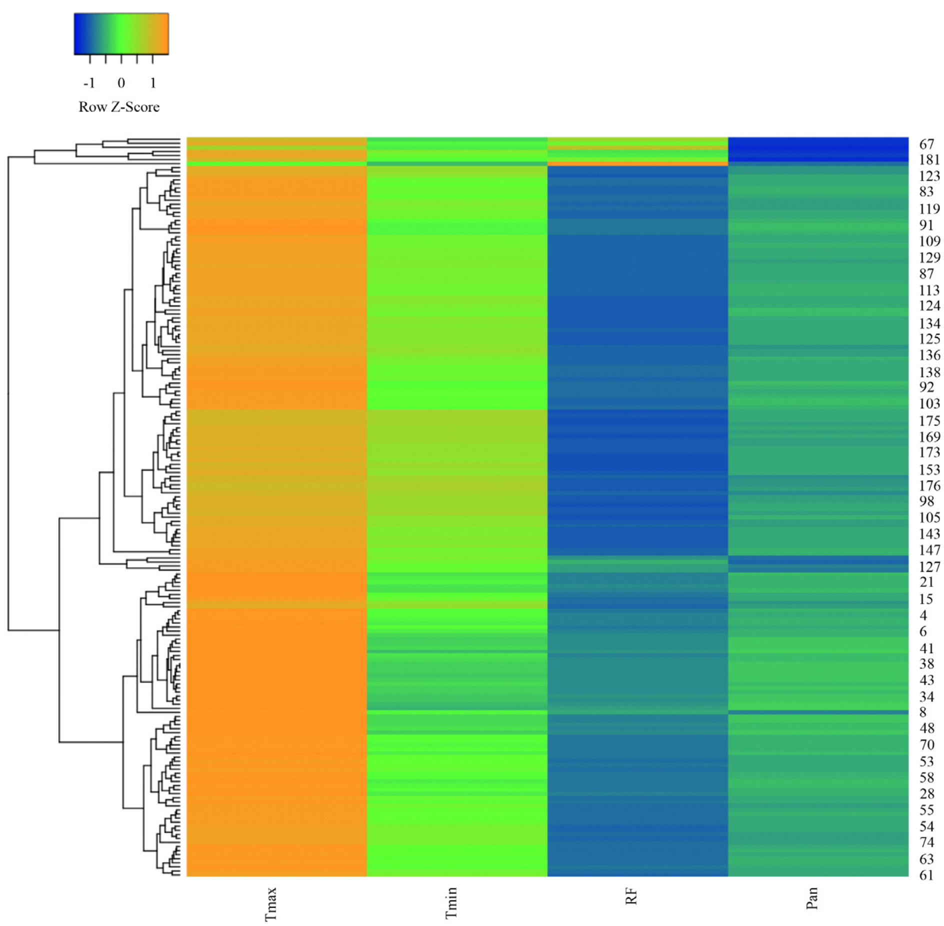

Fig. 8. Heat map of exiting orchard at subtropical climatic condition

specific response. Adaptation of newly introduced fruit like papeno can also be suitably performed through resource management. Quality of such fruit germplasms ensures in such a way that growers get benefited and confidence build up to grow more such newly introduced fruits in non-traditional areas under climatic management *vis-à-vis* resource conservation practices.

Fruit germplasms adaptive to a particular location undergoes severe overhaul owing to change in climatic factors. The impression of atmospheric demand was such a magnitude that trees often prone to draught and yield lesser. In contrast, heavy rainfall all of sudden cause flood and leads to succumbs to flooding for prolonged period. Recently Wang *et al.* (2022) screened water-tolerant kiwifruit genotypes that can maintain root activity during water logging stress. All these weather vagaries resulted in loss of fruit yield. Even within season moisture stress at fruit set to maturity, cause havoc loss of quality product. The quality component of fruit depends on number of dynamic factors out of which climatic component play significant role. Apart from genetic ability, environmental factors statistically alter contents of number of phenols, anti-oxidants, vitamins, TSS, acidity, carotenoids, flavonoids etc. Durán-Zuazo *et al.* (2005) nicely described the nutrient status in Mango whereas Carolyn *et al*. (2015) showed 8 to 21.33°B TSS, diversity index of pulp thickness of 0.84, maximum frequency levels of 13.98 to 15.23°B and 79.25 to 83.28 per cent edible portion across 208 mango accessions grown in Philippines. Ribeiro *et al.* (2008) observed variable *mangiferin* content in mango pulp (2.9±0.01, 2.2±0.1 and 12.4±0.3 mg/kg dry matter in Haden, Tommy Atkins, and Uba cultivars respectively). Moreover, it was noted that Uba variety had higher radical scavenging activity (94.2%) as compared to popular Tommy Atkins (52.6%). Under subtropical climatic condition of Lucknow, Veena *et al.* (2019) exhaustively analyzed total carotenoids and total anti-oxidants in various mango germplasms. It was recorded that Amrapali (10.37 mg/100 g pulp) had highest content of total carotenoids followed by Kesar (9.62), Arunika (7.55) and Zardalu (6.58) while some of the commercial cultivars had lower content like Banganpalli (2.30), Alphonso (2.66), Fazri (1.83), Mallika (3.77) and Lucknow Safeda (3.0). Total anti-oxidants in Lagra (1.51 µmol/100 g pulp), Mallika (1.28), Neelum (1.03), Alphonso (1.21), Elaichi (0.93) and Lucknow Safeda (0.82 µmol/100 g pulp) whereas Kesar (0.42 µmol/100 g pulp), Vanraj (0.49), Himsagar (0.65), Baramasi (0.56) and Dashehari (0.67 µmol/100 g pulp). The seasonal stability in quality parameters is an important issue. Verdugo-Vasquez *et al.* (2018) reported that under semi-arid climatic situation, temporal stability of TSS in grape may be obtained around forty days before harvesting to parameterize the within-field variability. Avendaño-Arrazate *et al.* (2017) described the morphological characterization of mango in Mexico. Diamanti *et al.* (2012) noted 1363.16 to 1964.33mg GA/kg fruit weight total phenols content and 288.94 to 505.69 mg PEL-3-GLU/kg fruit weight of anthocyanins content in Strawberry. Lower anthocyanin content (1.00 to 2.57 in 1100 to 1500m vs 1.77 to 3.02 in 900m) at higher altitude in strawberry indicated the role of altitude as an important factor in phenolic synthesis and accumulation in strawberry (Guerrero-Chavez *et al.,* 2015). Conservation practices like drip irrigation or fertigation, mulching, zero tillage, organic, foliage treatments may alters the scope of sustainability in any orchard production systems. Adoption of organic protocols also served as an excellent practice under subtropical climate (Shukla and Adak, 2024). Senthilkumar *et al.* (2016) explained combining fertigation and consortium of bio-fertilizers may improve yield of banana. Even, zinc nutrition technology offers a great scope to improve pulp nutrient enrichment *vis-à-vis* yield sustainability in Dashehari mango (Adak *et al.,* 2022). Thus, soil indicators may suitably be employed for scientific characterization of mango orchards (Adak and Singh, 2023) and thereby resource management needed to improve soil productivity. Therefore, scientific analysis is very much needed to ascertain the role of soil-environmental indicators on the fruit phenology *vis-à-vis* production.

Conclusion

The present scientific analysis consisting of soil and climate indicators on the influence of fruit germplasms showed variability was existed across fruit nutrition. Latest information from the orchard soils indicated highest and lowest soil organic carbon (0.58 and 0.23 per cent with coefficient of variation of 21.1 per cent); soil phosphorus (73.00 and 17.63 kg/ha with coefficient of variation of 36.4) and potassium (296.40 and 131.65 kg/ha having coefficient of variation of 24.9 per cent) respectively. Being utmost important for nutrition, micronutrients like Zn and Cu content of 1.54 and 0.47; 2.92 and 0.92 mg/kg was noted. Likewise, Fe and Ca contents were recorded as 10.06 and 2.14; 1713.0 and 13.09 mg/kg respectively across these orchards. Higher coefficient of variation in the ranges of 33.9, 31.2, 45.0 and 25.9 per cent was recorded. Conservation practices involving mulching should be used to reduce the nutrient variability across orchards. The impact of soil nutrients was included to compare the changes in fruit quality. Environmental indicators affect the fruit germplasms on its reproductive stages. Flowering, fruit set and fruit load act as a function of tree cum environmental indicators. Greater temperature (40 to 44°C) and higher evaporation (9.7 mm/day) was observed during reproductive phase. Statistical histographic distribution suggested there is a need to improve the soil nutrient concentrations to higher frequency levels. Relevant information of conservation practices adopted for production and quality of various fruit germplasms maintained across agroecologies was also discussed. Thus, the scientific analysis explained sustainability of fruit production is the priority for growers and planners.

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