Effect of climate on physiological and quality parameters of Kinnow mandarin under north western Himalayan region

ABSTRACT

Climatic factors are normally important in the development, yield and quality of fruits leading to commercial value. A field experiment was executed to evaluate the impact of weather parameter on physiological aspect and quality aspect of Kinnow mandarin, these were subjected to drip-irrigation starting from the first year of planting. Results showed positive correlationof peel per cent, peels thickness and pulp percent of kinnow mandarin fruit with minimum temperature and rainfall at K_4 stage while evaporation was the only climatic factor that showed positive correlation withpeel per cent and pulp per cent of kinnow mandarin fruit at K_4 stage. Similarly maximum and minimum of both temperature at K_1 and K_3 stage along with relative humidity at K_1stage positively favour the content of number ofseed per kinnow mandarin fruit moreover evaporationalso exhibited a positive effect on number of seed per kinnow mandarin fruit at K_2 and K_3 stage.Stock: Scion ratio were found positively influence by only evaporation at K_4 stage.

Key words: Kinnow mandarin, Climate, Physiological, Quality

Introduction

Global climate change is the alteration in the statistical distribution of atmospheric conditions trends that have far-reaching ecological, agricultural, and economic consequences. Weather patterns on Earth has changed many times throughout the history of our planet, ranging from the glacial period to the phase of warmth and has a profound impact on growth development and output of various crops, there are various environmental factors influence life span of both annual and perennial plants, such as elevated temperature, heat-waves, water scarcity, low temperatures, freezing conditions, and increasing carbon dioxide concentration (CO_2) levels. Climate change represents a dangerous challenge for mankind, there need for an efficient strategy to guarantee adequate crop production for humanity.

"Climate change and agriculture are related processes and have an effect on in many ways. Climate is interrelated with citrus quality and quantity (Dolkar *et al*., 2017). Citrus fruits are one of the imperative and foremost fruit crops of the world. Among the different commercially grown citrus fruits, cultivation of kinnow mandarin, a first generated hybrid of King Orange (♂) and Willow Leaf (♀) developed by Dr. H. B. Frost in 1915 in California (USA) has gained the highest value among citrus growers in the North-Western regions of the India. Given its nutritional value, Kinnow has been utilized in the production of a diverse range of products for beverages, industrial applications, and medicinal purposes. It is commonly processed into juices, squashes, jams, jellies, and marmalade. Despite of such qualities and scope, Kinnow cultivation globally faces numerous environmental challenges. Crop productivity is often impacted by various stress factors, and potential yields are rarely realized under such stress conditions" (Dolkar *et al*. 2017)

Citrus is a major fruit globally and can thrive in various climate regions, extending from tropical to subtropical, dry, and semi-dry areas ranging from 12.8˚C to 37˚C, which is regarded as the ideal temperature for citrus growth and fruit production. However, extremely high temperatures (exceeding 44-45˚C) halt citrus growth entirely.

"Over the past few decades, climate variability has been and remains a major driver of fluctuations in global food production, particularly in developing countries" (Oseni and Masarirambi 2011). "Low temperatures are regarded as a major constraint for the distribution of citrus fruits across regions. Low temperature can halt metabolic processes, while cold stress and frost conditions can cause significant injuries and destroy the whole tree. Temperature fluctuation have a detrimental effect on growth, development, reducing overall production and fruit quality particularly when occurred during fruit maturation stage. affects negatively growth, decreases total yield, and reduces fruit quality particularly when occurred during the maturity stage. Moreover, extreme heat events negatively impact the production of various varieties particularly seedless varieties like Navel orange, and some Mandarin and lemon cultivars" (Dolkar et al. 2017). Also it was reported by Dolkar *et al*., 2018 that the climate of a particular area is a crucial determinant in producing high-quality fruit of marketable size. Chelong and Sdoodee (2013) reported that "decrease in rainfall and soil moisture of two areas viz., Yala and Pattani affected the fruit development, yield & quality and the quantity ofshogun (*Citrus reticulata* Blanco) fruit was better in Pattain than in Yala based on fruit diameters, fruit weight, peel, juice and peel thickness whereas, the total soluble solids in Pattani were lower than in Yala. Furthermore, the color of the rind in Pattani was greener than that in Yala".

"On another side, rising carbon dioxide has positive effects on the growth of citrus seedlings and trees productivity.Current forecast with the continuing raise in universal average temperature and its impact on Earth's climate system are anticipated to alter the climate in the traditional fruit tree cultivation region. Restricted exchange of air with concomitant increase in relative humidity may cause alters in plant development, growth and diseases incidence, that possibly will have adverse effects on yield of crops" (Grange and Hand, 1987). Therefore, the recent investigation was carried out to find out the impact of weather parameters on physiological aspect at different phenological stages and quality during fruit developmental stages of kinnow mandarin under sub-tropical foot-hill Himalayas conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted for two consecutive year 2014 and 2015 at Research Farm Chatha, Division of Fruit Science, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu, India. The experimental orchard is situated in the sub-tropical zone at latitude 32^o 43' North, longitude of 74^o 54' East and altitude 332 meters above mean sea level. “Annual rainfall is about 1110 mm, out of which most of the rains are received during July to October. The mean annual maximum and minimum temperatures are 29.7 and 16.3 ^{o}C, respectively. Summer months are hot with temperature and humidity ranging from 23.5to 35.5^{o}C and 53.0 to 73.5%, respectively. The winter months experience mild to severe cold conditions with an average temperature ranging from 6.5 to 21.7^{o}C. December is the coldest month, when minimum temperature touches to 4^{o}C. The highest temperature is recorded in the month of June (45^{o}C). Daily maximum and minimum values of temperature, evaporation rate rises from February onwards up to June drop during July to September with a slight peak in October and then drop progressively up to December” (Dolkar et al. 2017).

Experimental design and treatments

The experiment was conducted on 08 year-old Kinnow mandarin trees, which were uniformly growing and bearing fruit habit and had been drip-irrigated since the first year of planting. The experiment was laid out according to randomized block design with plant to plant spacing of 5 meters both within the row and between rows. Three plants from each replication were randomly selected for the periodic observation of phenological events. The stages were identified based on critical phases necessary for this study, using the external morphological characteristics of 'Kinnow' mandarin which included (i) Pre-flowering stage (K_1),(ii) Flowering to first fruit set (K_2), (iii) First fruit set to maximum fruit set (K_3)and (iv) Maximum fruit set to fruit harvest (K_4).

Plant sampling and analysis

In the experiment, the phenophasewise correlation studies of growth and quality with various parameters were carried out separately withthe help of methodology described by Gomez and Gomez (1984) for the crop on first, second, third and four stages. The meteorological parameters included were maximum temperature (Tmax), minimum temperature (Tmin), maximum relative humidity (RHmax) and minimum relative humidity (RHmin), rainfall (Rf) and Evapotranspiration (Ev) whereas physiological aspect and quality parameters *viz*., Peel thickness, no. of seed, peel per cent . The stock as well as scion girth thus measured was expressed as ratio.

For determining the fruit pulp was cut into pieces and boiled in hot water for 15 minutes and the seeds were separated by using ordinary sieve (< 20 mm) and then number of seeds per fruit were counted.The juice per cent, pulp per cent and peel per cent in fruits was determined according to Romero *et al*. (2006) where fruit pulp and fruit peel was manually separated and juice, pulp, peel per cent was estimated on weight basis with respect to the fruit weight. Whereas peel thickness of randomly selected 10 fruits from each treatment in each replication was recorded with the help of Digital Vernier's Caliper. And the values were expressed in centimeters (cm).

Data analysis

The statistical correlation analysis of data was done using SPSS 16.0 software. The test of significance was done at $p<0.01$, 0.05 and 0.005 level.

RESULTS AND DISCUSSION

Climate of crop cultivated region influence the physiological aspects of the crops and quality of the fruits, but itsimpact on crop is complex and is combined with otherfactors and hence, it become very difficult to single out anyparticular meteorological parameters for describing itsinfluence. However, the emphasis was given on mainclimatic factors that influenced either individually or jointlythe growth and quality of kinnow mandarin. These factors includemaximum temperature, minimum temperature, maximumrelative humidity and minimum relative humidity, rainfall, evaporationduring both the crop growing seasons 2014 and 2015, which are depicted inFig 1 and 2.

Effect of climatic factors on kinnow mandarin fruit

The data regarding the impact of climatic factor on the stock: scion ratio of kinnow mandarin fruit crops are presented in Table 1 which clearly showed that the stock: scion ratio were positively influence by rainfall at K_4 stage (r = 0.87**), while negatively influence by climatic factor as maximum and minimum temperature at K_1 and K_3 stage (r = –0.74*, –0.76* and –0.75*, –0.80**, respectively), maximum and minimum relative humidity at K_1 stage (r = –0.76* and –0.77*, respectively), maximum relative humidity at K_4 stage (r = –0.78* and –0.75*) and evapo-transpiration at K_2 and K_3 stage (r = –0.83** and –0.83**, respectively). These results are in consonance with the finding of Mounzer *et al*. (2008) who reported that in peach cv. "Flordastar" the maximal trunk growth rate being reached approximate 30 days after full bloom. "Tree maintains a balance between the surface for water uptake in the root system and the surface for transpiration in the shoot system. This limitation of water absorption stops shoot growth and production" (Borchert, 1973). High humidity reduced the transpiration and heavy rain during experiment time created excessive moisture conditions near root zone, which interfered in water uptake. High humidity reduced the transpiration and heavy rain during experiment time created excessive moisture conditions near root zone, which interfered in water uptake. These findings are consistent with the findings of Higuchi *et al*. (1999) that warmer temperature decreased Cherimoya trees shoot growth, while it increased at cool temperature

Number of seeds

Both maximum and minimum temperature and maximum relative humidity at K_1 stage (r = 0.67* each) positively favour the content of number of seeds per kinnow mandarin fruit. In addition to that, both maximum and minimum temperature at K_3 stage (r = 0.68* and 0.75*), maximum and minimum relative humidity at $K_4$and K_1stage (r = 0.69* and 0.68*, respectively) and evapo-transpiration at K_2 & K_3stage(r = 0.86** and 0.79*) also showed positive correlation whereas, at K_4 stage the number of seeds per kinnow mandarin fruit were negatively influenced by minimum temperature, evapo-transpiration (r = –0.82**and –0.76*, respectively) and rainfall at bothK_3 and K_4 stage (r = –0.79* and–0.74*). Higuchi *et al*. (1998) reported that warm temperature produced asymmetrical and small fruit containing a small number of seeds in cherimoya fruit, due to low-viability of pollen. While maximum temperature at K_4 stage, evapo-transpiration at K_1 stage and rainfall at K_4 stage did not show any correlation.Inverse relationship has been reported by Gucci *et al*. (2009) between cell size and water potential presumably due to the direct effect of turgor on cell expansion under low water availability

Juice per cent

Further the data indicated that maximum and minimum temperature at K_1 stage and K_3 stage (r = 0.75*, 0.77* and 0.71*, 0.77*, respectively) showed positive impact on the juice per cent of kinnow mandarin. However, juice percent was negatively favoured by the minimum temperature during the K_4 stage (r= –0.73*). On the other hand, the maximum and minimum relative humidity at K_1 stage (r = 0.76* and 0.77*, respectively) and the maximum relative humidity at K_4 stage (r = 0.75*) positively influenced the juice percent in kinnow mandarin. Similarly, Reddy and Venkateswarlu (2015) observed that fruits grown in moist climate tend to have more juice than those grown in drier climate. This is might be due elevated temperatures influence plant morphology, anatomy, and physiological processes, impacting plant growth, gametic fertilization, fruit set, fruit weight, size, and overall fruit quality (Gora *et al*., 2019). Likewise, evapo-transpiration at K_2 and K_3 stage (r = 0.84** and 0.82**, respectively) also exerted positive impact. While rainfall at K_3 and K_4 stage (r = –0.73* and –0.81*, respectively) were negatively associated with juice content of kinnow mandarin. Similarlly Makhmale S. *et al*., 2016 reported that unseasonal rain can also escalate pest infestations, leading to reduced fruit quality and yield.

Pulp per cent

Pulp per cent of Kinnow mandarin was positively affected by minimum temperature at the K_4 stage (r = 0.79*), while it was negatively influenced by both maximum and minimum temperature at K_1 and K_3 stage (r = –0.70*, –0.72* and –0.68*, –0.74*, respectively). Maximum and minimum relative humidity at the K_1 stage (r = –0.72* and –0.73*, respectively), as well as maximum relative humidity at K_4 stage (r = –0.71*), showed a negative correlation. In contrast, rainfall at K_3 and K_4 stage (r = 0.76* and 0.80*, respectively) showed positive correlation with the pulp per cent of Kinnow mandarin. Evapo-transpiration at K_4 stage (r = 0.73*) also showed a positive correlation with pulp per cent, whereas the K_2 and K_3 stage (r = –0.85** and – 0.79*, respectively) showed negative correlation with the pulp per cent of kinnow mandarin.

Peel per cent

The peels per cent as influenced by various climatic factors are presented in Table 1. Among all the climatic factors, peel per cent of kinnow mandarin were positively influenced by minimum temperature at K_4 stage (r = 0.77*) and negatively influenced by both maximum and minimum temperature at K_1 and K_3 stage (r = –0.71*, –0.73* and –0.71*, –0.77*, respectively). Similarly, maximumand minimum relative humidity also showed negative correlation with peel per cent at K_1 stage (r = –0.73* and –0.74*, respectively) and maximum relative humidity at K_4 stage (r = –0.71*) while, rainfall at K_3 and K_4 stage (r = 0.75* and 0.81**) exhibited a positive correlation with peel per cent of kinnow mandarin. Furthermore, evapo-transpiration at K_4 stage (r = 0.71*) also showed a positive correlation with peel per cent, while K_2 and K_3 stage (r = –0.86** and –0.82**, respectively) showed negative correlation with peel per cent of Kinnow mandarin fruit. Chelong and Sdoodee (2013) reported that decrease in rainfall and soil moisture of two areas viz., Yala and Pattani affected the peel, juice and peel thickness of shogun (*Citrus reticulata* Blanco).

Peel Thickness

The perusal data presented in Table 1 revealed that peel thickness per cent in fruit of kinnow mandarin were positively influenced by minimum temperature at K_4 stage (r = 0.67*and 0.94***, respectively) and rainfall at K_3 and K_4 stage (r = 0.70* and 0.83*, respectively) and influenced negatively both by maximum and minimum temperature at K_1 and K_3 stage (r = –0.74*, –0.76* and –0.68*, –0.74*, respectively). Further, maximum and minimum relative humidity at K_1 stage (r = –0.75* and –0.77*, respectively) and maximumrelative humidity at K_4 stage (r = –0.78* and –0.76*, respectively)also showed negative correlation with per cent peel thickness. In addition to that evapo-transpiration also exerted negative impact on per cent peel thickness atK_2 and K_3 stage (r = –0.83** and –0.78*, respectively). Similarly, Reddy and

Venkateswarlu (2015) observed that fruits grown in moist climate tend to have thinner peel than those grown in drier climate.

CONCLUSION

Based on the aforementioned study, it can be concluded that a robust correlation exists between weather parameters and the quality of Kinnow mandarin fruit. Further, the climate of a specific region is a decisive factor in achieving fruit of desirable high quality fruit with marketable size. Based on this study we can provide the optimum crop environment at distinct phenological stage of kinnow mandarin fruit crops by implementing precise crop management strategies, adapted to varying climatic factors. This research is particularly important for developing strategies to mitigate climate-related challenges in fruit cultivation benefiting both scientific research and agricultural industries since it explores the impact of climatic factors on the physiological and quality parameters of Kinnow mandarin in the North Western Himalayan region. It identifies key weather variables affecting fruit quality and growth, providing insights for optimizing cultivation practices. Furthermore, it serves as a crucial resource for future studies aimed at enhancing crop resilience and sustainability. Moreover these approaches will facilitate the production of high-quality fruits with elevated market demand and increased economic worth.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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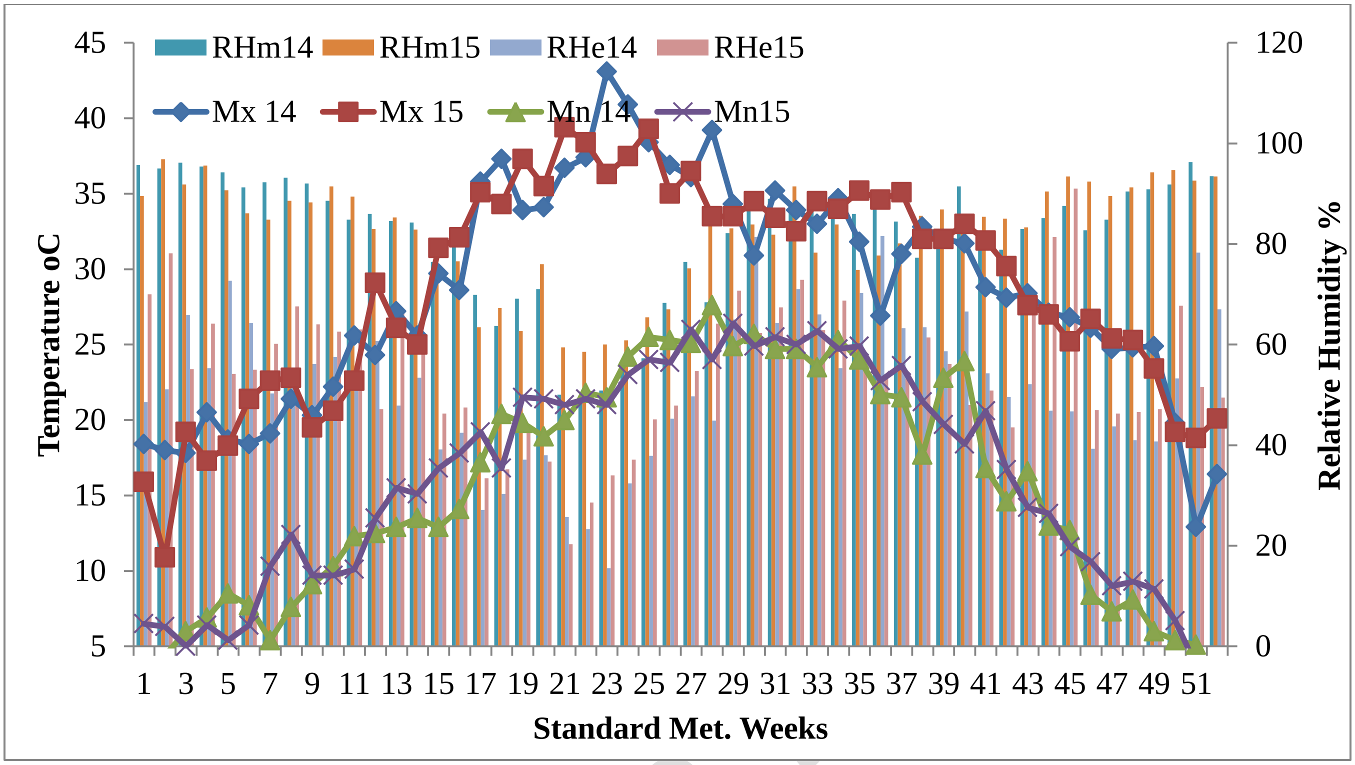

Fig. 1: Temperature and relative humidity recorded during the study period (2014 & 2015)

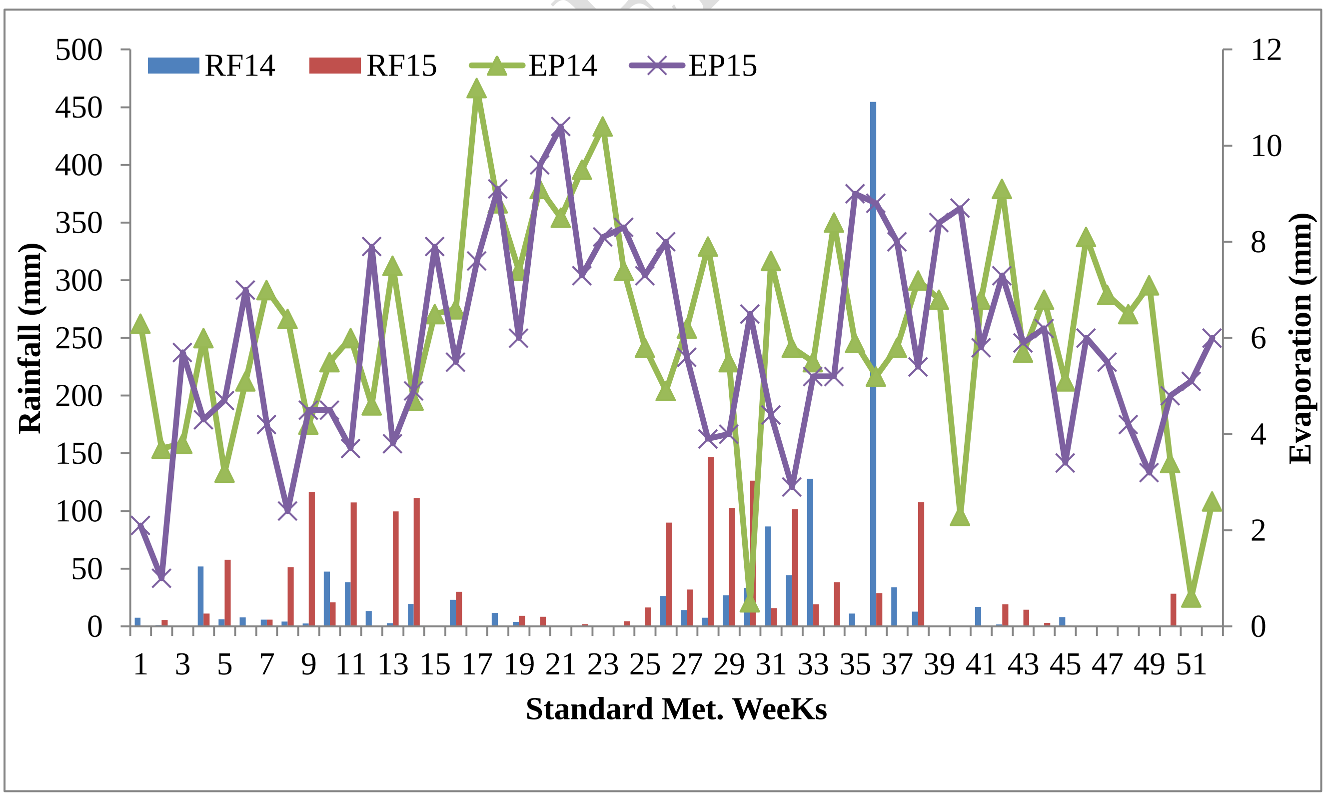

Fig. 2: Rainfall and evaporation recorded during the study period (2014 & 2015)

Table1: Correlation between climatic factors and growth and qualityat different stage of kinnow mandarin fruit crops during 2014

	St-G: Sc-G	No. Seed	Pulp %	Juice %	Peel %	Peel T
Max Temp K1	-0.74*	0.67*	-0.70*	0.75*	-0.71*	-0.74*
Max Temp K2	-0.15	0.24	-0.20	0.16	-0.21	-0.17
Max Temp K3	-0.75*	0.68*	-0.68*	0.71*	-0.71*	-0.68*
Max Temp K4	0.03	-0.22	0.19	-0.12	0.17	0.03
Min Temp K1	-0.76*	0.67*	-0.72*	0.77*	-0.73*	-0.76*
Min Temp K2	-0.48	0.57	-0.53	0.50	-0.54	-0.50
Min Temp K3	-0.80**	0.75*	-0.74*	0.77*	-0.77*	-0.74*
Min Temp K4	0.66	-0.82**	0.79*	-0.73*	0.77*	0.67*
Max RH K1	-0.76*	0.67*	-0.72*	0.76*	-0.73*	-0.75*
Max RH K2	0.25	-0.15	0.19	-0.23	0.18	0.22
Max RH K3	0.11	-0.10	0.09	-0.15	0.10	0.16
Max RH K4	-0.78*	0.69*	-0.71*	0.75*	-0.71*	-0.78*
Min RH K1	-0.77*	0.68*	-0.73*	0.77*	-0.74*	-0.77*
Min RH K2	0.20	-0.09	0.14	-0.19	0.13	0.18
Min RH K3	-0.18	0.02	-0.03	0.09	-0.07	-0.08
Min RH K4	-0.48	0.33	-0.35	0.40	-0.35	-0.45
Rain Fall K1	-0.58	0.49	-0.59	0.58	-0.58	-0.58
Rain Fall K2	0.39	-0.24	0.35	-0.36	0.35	0.37
Rain Fall K3	0.63	-0.79*	0.76*	-0.73*	0.75*	0.70*
Rain Fall K4	0.87**	-0.74*	0.80*	-0.81**	0.81**	0.83*
Epan K1	-0.64	0.63	-0.61	0.66	-0.60	-0.64
Epan K2	-0.83**	0.86**	-0.85**	0.84**	-0.86**	-0.83**
Epan K3	-0.83**	0.79*	-0.79*	0.82**	-0.82**	-0.78*
Epan K4	0.59	-0.76*	0.73*	-0.67	0.71*	0.60

Significant at $p < 0.01$*, 0.05**, 0.005*** level;

K1: Pre-flowering stage, K2: Flowering to first fruit set , K3: First fruit set to maximum fruit set, K4: Maximum fruit set to fruit harvest; Max: maximum, Min: Minimum, Temp=Temperature, RH=Relative humidity, RF=Rainfall;