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Studies on Crop Water Balance and Yield of Mango (Cv. Mallika) as Influenced by the Weather Parameters

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Abstract

A field study was conducted to know the influence of weather parameters on growth, yield and crop water balance in Mallika Mango hybrid at "C" and "I" block, UAS, GKVK, Bengaluru during 2020-21. The plantations of Mallika hybrid of different ages (20 and 28 years), with and without plant protection chemicals were selected and data was analysed using FRBD with five replications. Among the different age of trees, mango trees with 20 years of age had shown significantly higher mango yield (60.30 kg/ tree) compared to 28 years old plantation (40.90 kg/ tree). But, among the spray treatments, with spray treatment recorded significantly higher yield (58.02 kg/tree) compared to control (43.19 kg/ tree). Fruit retention percentage had shown similar trend at different mango fruiting stages. Water requirement satisfaction index was more than 80 % upto 13th SMW where the chances crop failure is less, but at the fruiting stage the values are in decreasing trend where the per cent deficit was higher which is unfavourable for the fruiting mango.

Keywords : Mango, Crop weather relationship, Fruit retention, Water requirement

Climate and weather play a significant role in growth and productivity of any crop in a region. While climate decides the suitability of a crop or variety to a location, the weather decides its performance in that particular location. This stresses the role of short term weather variability on crop performance. Weather parameters have proven influence on the performance of a crop through their sole and interactive effects. For example, variabilities in air temperature and rainfall influence vegetative and phenological phases in several horticultural crops. The influence of weather parameters on crop yield depends on the magnitude and distribution of weather variables during crop growth period. Mango is growing well in areas receiving annual rainfall of 25 to 250 cm. High humidity, rainfall and frost during flowering period is harmful for the crop. Rainfall during flowering adversely affects fruit set, fruit development and yield. Excessive vegetative growth and flower drop occurs due to heavy and prolonged rainfall. Fruits develop better colour and are less affected by diseases where the air is comparatively dry during flowering,

Mango (*Mangifera indica* L.) is one of the important tropical fruits of the world belongs to the family Anacardiaceae and is native to Indo-Burma region. it

is rich source of nutrients and has been rightly described as 'King of fruits' owing to its delicious taste. Mallika (hybrid developed from IARI, New Delhi. Neelum x Dashehari) is a regular bearer, good colour, uniform fruits and moderate keeping quality (Vidya *et al.,* 2014). It can be grown from sea level to an altitude of about 1400 meters. The favourable temperature is 18°C to 35°C. but can however tolerate temperature as high as 48°C with protective irrigation. India ranks first among mango producing countries in the world with 20.9 million metric tonnes accounting for about 50 per cent of the global mango production. In India, mango crop occupies an area of 2.3 million hectare, with productivity of 9.1 tonnes per hectare (Anonymous, 2021).

Even the regular-bearing types, if they carry a heavy load of flowers in a year, they show a tendency towards reduced yield in the following year. Hence the basic tendency of bienniality exists even in the so-called regular-bearing varieties of mango. The potential of shoot to form flower buds will depend on the floriferous condition of the tree, which in turn will be determined by the amount of fruit load carried by the tree in the previous year (Singh *et al.,* 1997). Generally, moderate blossoming is one of the chief conditions of annual fruit bearing in fruit trees. Fruit drop in mango is a serious problem causing heavy losses to the farmers. About 99 per cent of the mango crop is lost due to hermaphrodite flowers drop and immature fruits. Increasing demand of water for agriculture and domestic purposes necessitates study on water resource availability and water balance to assess the potential for their use over space and time in attaining higher productivity (Shailendra Rajan, 2012). Time and peak period of flowering, sex ratio, flowering behaviour, insect pests, diseases and weather parameters like temperature and relative humidity influences flowering and fruit set in mango (Anonymous, 2017). The pest status does not remain static throughout the year, but uninfluenced by the abiotic factors like temperature, humidity, rainfall and light etc. Hence a study was conducted to establish relationship of soil moisture and rainfall with the fruit retention and yield of mango using soil moisture index, moisture availability index and water requirement satisfaction index. Climatic and crop water balance has been computed to know the water requirement of a mango crop.

Material and Methods

The present investigation was executed at 2 locations/ orchards with two management levels (M_1: control and M_2: With Plant Protection Chemicals) with sample size of 5 plants each in 2 locations with different age groups (20 and 28 years old plantation) located at Dry land Agriculture Project, Zonal Agricultural research station, UAS, GKVK, Bengaluru belonging to Eastern dry zone of Karnataka (Zone 5) at 12^0 N latitude and 77^0 35' E Longitude, at an altitude of 930 m above mean sea level. Mallika hybrid developed by IARI was selected for the study in this experiment.

Daily meteorological data recorded at the observatory at AICRP on Agrometeorology unit, Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, GKVK, Bengaluru for the crop growth period during 2020-21 and 2021-22 was collected. The normal and actual of weather parameters *viz.,* rainfall, mean temperature (maximum and minimum), relative humidity, bright sunshine hours and wind speed were collected. The field was cleaned at the starting of the mango season to avoid contamination from the host plants in and around the orchard trees and basins were done for each tree. To manage the major diseases and pests like powdery mildew, anthracnose, fruit fly and mango hoppers two sprays were given to the spray treatment trees with Hexaconazole @ 5 per cent SC, Lambda Cyhalothrin @ 5 per cent EC and Sulphur @ 80 per cent WP at the time of flower bud initiation and fruiting stage.

Soil moisture status was studied on weekly basis. Available Water holding capacity of the soil where the experiment was conducted is considered as 97.8 mm for every 100 cm depth of the soil. The total water available to the plant at its root zone obtained using,

$$Sai = \frac{(Si - Sw) * D}{100}$$

Where,

Si - Soil moisture at field capacity (mm)

S_w - Soil moisture at wilting point (mm) and

D - Normal rooting depth of the tree (100 cm).

Weekly Water Balance- (Thornthwaite and Mather, 1955 – Weather Cock)

Soil moisture storage (ST) : If the value of P-PE is positive, then soil moisture storage value is the same as the Available water capacity (AWC). On the other hand, if the value of P-PE is negative, then soil moisture storage is calculated by equation

$$ST = AWC\ e^{APWL/AWC}$$

Where,

APWL - Accumulated potential water loss

Actual evapotranspiration (AE) : When the precipitation (P) is higher than the potential evapotranspiration (PE), it means that soil moisture storage still saturated from the excess precipitation.

$$P > PE,\quad AE = PE$$

$$P < PE,\quad AE = P - \Delta ST$$

Where,

ΔST - Difference in soil moisture between weeks

Maximum evapotranspiration by the trees has been computed using the equation.

$$ET_i = K_{ci} \times PET_i$$

Where.

ETi - Evapotranspiration by the tree during i^{th} week

Kc_i - Crop coefficient during i^{th} week

PET_i - Potential Evapotranspiration during i^{th} week

Moisture availability index : It is a relative measure of the adequacy of precipitation in supplying moisture requirements (Hargreaves, 1975) and are categorized as under,

$$MAI = \frac{AE}{PE}$$

Where,

AE is the actual evapotranspiration and PE is the potential evapotranspiration.

MAI	Category
0.00-0.33	Very deficient
0.34-0.67	Moderately deficient
0.68-1.33	Deficient
1.01-1.33	Adequate moisture
>1.34	Excessive moisture

Water requirement satisfaction index (WRSI) :It is the ratio of seasonal actual crop evapotranspiration (AETc) to the seasonal crop water requirement, based on WRSI values the severity of the moisture deficit condition suffered by the crop during the growth period was categorized as below,

$$WRSI = 100 - \frac{\text{Total deficit}}{\text{Total water requirement}}$$

WRSI	Category
80-90	Mild rainfall deficit
70-80	Moderate rainfall deficit
Below 70	Severe rainfall deficit

A case of 'no deficit' will result in a WRSI value of 100, which corresponds to the absence of yield reduction related to water deficit. A seasonal WRSI value less than 50 is regarded as a crop failure condition (Smith, 1992).

The experiment data were analysed using ANOVA technique at 0.05 level of significance.

Results and Discussion

Climatic water balance has been worked for mango growing period from the flower bud initiation to harvest during 2020-21. During the year crop had received 232 mm of rainfall and 922.4 mm potential evapotranspiration and had experienced the stress period at the initial stages (Anonymous, 2016). The flowering period is coincided with moisture stress for one to two weeks and there was severe moisture stress

TABLE 1

Climatic water balance for experimental site during the mango growing season

SMW	PPT (mm)	PET (mm)	Actual soil moisture (mm)	Evop. Trans. (mm)	Surplus (%)	Deficit (%)	Moist. Avail. index	Deviation
51	0	24	34.1	9.5	0	14.5	0.40	0.60
52	0	29	25.3	8.8	0	20.2	0.30	0.70
1	11.4	23	22.4	14.2	0	8.8	0.62	0.38
2	0	23	17.7	4.7	0	18.3	0.21	0.79
3	0	27	13.4	4.3	0	22.7	0.16	0.84
4	0	31	9.8	3.7	0	27.3	0.12	0.88
5	0	29	7.2	2.5	0	26.5	0.09	0.91
6	0	33	5.1	2.1	0	30.9	0.06	0.94
7	0	33	3.7	1.5	0	31.5	0.05	0.95
8	40	30	13.7	30	0	0	1	0
9	0	38	9.2	4.4	0	33.6	0.12	0.88
10	0	38	6.2	3	0	35	0.08	0.92
11	0	39	4.2	2.1	0	36.9	0.05	0.95
12	0	42	2.7	1.5	0	40.5	0.03	0.97
13	0	42	1.7	0.9	0	41.1	0.02	0.98
14	0	43	1.1	0.6	0	42.4	0.01	0.99
15	0	41	0.7	0.4	0	40.6	0.01	0.99
16	31.8	39	0.7	31.9	0	7.1	0.82	0.18
17	35.2	40	0.6	35.2	0	4.8	0.88	0.12
18	0	39	0.4	0.2	0	38.8	0.01	0.99
19	0.60	37	0.3	0.7	0	36.3	0.02	0.98
20	15.8	34	0.2	15.9	0	18.2	0.47	0.53
21	3	35	0.2	3.1	0	31.9	0.09	0.91
22	5	37	0.1	5	0	32	0.14	0.86
23	74.2	36	38.3	36	0	0	1	0
24	15.0	30	32.9	20.5	0	9.5	0.68	0.32
25	0	31	23.9	9	0	22	0.29	0.71
	232	922.4		251.7				

SMW : Standard meteorological week ; PPT : Precipitation (mm) ; PET: Potential evapotranspiration (mm) ; Evop. Trans. : evapotranspiration (mm) ; MAI : moisture availability index

at the fruiting period for about six to seven weeks. Moisture availability index was less than 0.33 from second to seventh SMW and ninth to fourteen SMW, the index values represents very deficient condition during crop growth period (Table 1). Excess rainfall during the fruit maturity in south Karnataka is a common phenomenon due to active premonsoon shower (Lingaraj *et al.,* 2021).

Crop Water Balance: Crop water balance has been worked using crop coefficient (Kc) values developed by Doorenbos and Pruitt (1977). During 2020-21 the crop has received the rainfall of about 232 mm (from 51th SMW of 2020 to 25th SMW of 2021) and 922.4 mm potential evapotranspiration. Crop water requirement was 862.8 mm and the crop has used about 277.05 mm of water throughout the crop growth

TABLE 2

Weekly water balance for mango growing season in 2020-21

SMW	PPT (mm)	PET (mm)	KCR	WR (mm)	WU (mm)	PPT - WR (mm)	SMR (mm)	SPL (mm)	DEF (%)	WRSI
51	0	23.6	0.85	20.4	20.4	-20.40	22.50	0	0	70.42
52	0	29.5	0.85	24.65	24.65	-24.65	0	0	2.15	70.28
1	11.4	23.2	0.8	18.4	11.4	-7	0	0	7	100
2	0	22.7	0.8	18.4	0	-18.4	0	0	18.4	98.85
3	0	26.9	0.8	21.6	0	-21.6	0	0	21.6	97.49
4	0	30.6	0.8	24.8	0	-24.8	0	0	24.8	95.94
5	0	28.7	0.8	23.2	0	-23.2	0	0	23.2	94.49
6	0	32.5	0.8	26.4	0	-26.4	0	0	26.4	92.83
7	0	33.3	0.8	26.4	0	-26.4	0	0	26.4	91.18
8	40	30.1	0.8	24	24	16	16	0	0	91.18
9	0	37.7	0.85	32.3	16	-32.3	0	0	16.3	90.16
10	0	37.6	0.85	32.3	0	-32.3	0	0	32.3	88.13
11	0	39.3	0.85	33.15	0	-33.15	0	0	33.15	86.05
12	0	41.9	0.85	35.7	0	-35.7	0	0	35.7	83.82
13	0	42.5	0.95	39.9	0	-39.9	0	0	39.9	81.32
14	0	42.6	0.95	40.85	0	-40.85	0	0	40.85	78.76
15	0	41.2	0.95	38.95	0	-38.95	0	0	38.95	76.32
16	31.8	39.4	0.95	37.05	31.8	-5.25	0	0	5.25	75.99
17	35.2	40.4	0.95	38	35.2	-2.8	0	0	2.80	75.81
18	0	39.1	1.05	40.95	0	-40.95	0	0	40.95	73.25
19	0.6	36.8	1.05	38.85	0.6	-38.25	0	0	38.25	70.85
20	15.8	34.4	1.05	35.70	15.8	-19.9	0	0	19.9	69.60
21	3	34.6	1.05	36.75	3	-33.75	0	0	33.75	67.49
22	5	37.5	1.15	42.55	5	-37.55	0	0	37.55	65.13
23	74.2	36	1.15	41.4	41.4	32.8	32.8	0	0	65.13
24	15	29.6	1.15	34.5	34.5	-19.5	13.3	0	0	65.13
25	0	30.7	1.15	35.65	13.3	-35.65	0	0	22.35	63.73
	232	922.4		862.8	277.05					

SMW : Standard meteorological week ; PPT : Precipitation (mm) ; PET : Potential evapotranspiration (mm) ; KCR : Crop coefficient ; WR: water requirement (mm) ; WU : water used (mm) ; SMR : soil moisture retention (mm) ; SPL : Special needs (mm) ; DEF : Deficit (%) ; WRSL : water requirement satisfaction index

period (soil moisture and rainfall). Crop has experienced moisture scarcity for long period during the crop growth period which has been shown in Table 3. During flowering for one to two weeks and there was moisture stress at the fruiting period for about six to seven weeks. A prerequisite for successful mango production is the absence of rain during the flowering period. Moist and humid atmosphere washes pollen and encourages insect pests and diseases and also interferes with the activity of pollinators. Rain, heavy dew or foggy weather during the blooming season stimulate tree growth but interfere with flower

TABLE 3

Soil moisture scarcity period during the mango growing period

Growth stage	Date of occurrence(Dry period)	Duration (Days)	Soil moisture scarcity period
flowering period	11-02-2021 to 19-02-2021	9	>5 days
fruiting period (marble stage of fruit)	02-03-2021 to 19-04-2021	50	>10 days
lemon stage of fruit	02-05-2021 to 12-05-2021	11	>15 days
lemon stage of fruit	17-05-2021 to 20-05-2021	4	<5 days
maturity stage	23-05-2021 to 01-06-2021	10	>10 days

production and encourage inflorescence diseases. Plant water stress has been presumed to provide the stimulus for flowering (Singh, 1960). The developmental fate of mango buds is strongly influenced by cool night temperatures (15°C) followed by <20°C day temperature. Dry weather, excessive rainfall and high humidity during the period of fruit maturity results in severe menace of fruit fly, anthracnose and mango stone weevil. Conversely, fruits that are well exposed to the sun become well coloured and are relatively

TABLE 4

Fruit retention percent at different stages and yield as influenced by different ages and management practices of Mallika mango hybrid

Parameters	Fruit retention atmarble stage (%)	Fruit retention at Lemon stage (%)	Fruit retention at Maturity (%)	Yield (kg /tree)
Treatments	2020-21	2020-21	2020-21	2020-21
A_1 - 20 years of age	44.26	20.88	13.27	60.30
A_2 - 28 years of age	42.37	20.41	12.47	40.90
F - test	NS	NS	NS	*
S.Em.±	0.75	0.37	0.28	3.01
CD at 5%	NS	NS	NS	9.26
M_1 - control	41.71	19.73	12.43	43.19
M_2 - with PPC	44.92	21.56	13.31	58.02
F - test	*	*	*	*
S.Em.±	0.75	0.37	0.28	3.01
CD at 5%	2.31	1.15	0.87	9.26
A1M1	43.35	20.43	12.71	55.58
A1M2	45.17	21.32	13.82	65.03
A2M1	40.08	19.03	12.14	30.79
A2M2	44.66	21.79	12.80	51.01
F - test	NS	NS	NS	NS
S.Em.±	1.06	0.53	0.40	4.25
CD at 5%	NS	NS	NS	NS

Note: * Significant at 5 % level, NS : Non significant PPC : Plant protection chemicals

free from diseases. Highly climate sensitive crops like mango (Roemer *et al.,* 2011).

Water Requirement Satisfaction Index : The water requirement satisfaction index (WRSI) is a crop performance indicator based on the availability of water to the crop during a growing season. It expresses the percentages of the crop's water requirements were actually met (Guled *et al.,* 2013). WRSI values values are more than 80 per cent upto 13th SMW where the chances crop failure is lower, but at the fruiting stage the values were observed in decreasing trend from the 14th to 25th week moderate to severe deficit moisture condition is observed, which is unfavourable for fruiting. The index below 50 per cent signifies a crop failure as the water requirements were not met, an index ranging between 50 per cent and 75 per cent signifies the yield would be moderate while an index above 75 per cent is an indicator of a good harvest. At fruit maturity stage rainfall was excess than normal (Shivaramu *et al.,* 2022).

Fruit Retention (%) : The average fruit retention in different cultivars ranges from 0.5 to 2.25 fruits per panicle in mango varieties and which is 2.2 in Mallika. The differences in the ultimate number of matured fruits per panicle till harvest may be attributed to differences in cultivars, age of the tree and the crop load. If the crop load is heavy, lower fruit retention is expected because of the competition among fruits for mobilization of carbohydrates (Dod *et al*., 1999).

Fruit retention percentage was higher at marble stage compared to lemon and at maturity. Among the different age groups, trees of 20 years of age has shown higher retention percentage at marble stage, lemon stage and maturity (44.26, 20.88 and 13.27 per cent, respectively) compared to 28 years of age trees (42.37, 20.41 and 12.47 per cent, respectively). But among the spray treatments, with PPC spray recorded significantly higher fruit retention percentage at marble stage, lemon stage and maturity (44.92, 21.56 and 13.31 per cent, respectively) compared to control (41.71, 19.73 and 12.43 per cent, respectively) (Table 4). These results are in line with findings of Kumar *et al*. (2015); Kanzaria *et al.* (2015) and Singh *et al*. (1998).

As the availability of water becomes lower, the index (WRSI) values decreases along with decrease in fruit retention percentage which has been graphically represented (Fig. 1.). this might be due to the insufficient soil moisture at the fruiting stage leads to higher fruit drop less retention capacity as the stress level increased there will be formation of abscission layer which leads to fruit drop along with dry weather, high temperature, strong winds and insect pests also affects on the retention capacity of the tree.

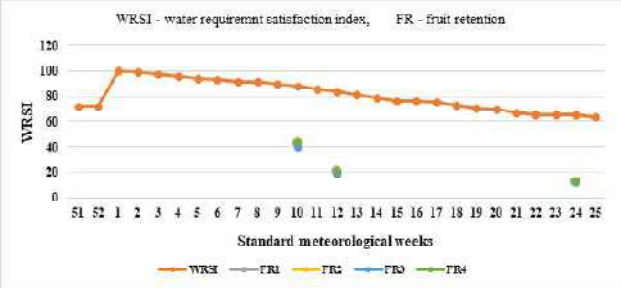

Fig. 1 : Water requirement satisfaction index and fruit retention (%) at different fruiting stages of mango growing season

Yield (Kg/tree) : Mango tress of 20 years of age has shown significantly higher mango yield (60.30 kg/tree) as compared to 28 years of age trees (40.90 kg/tree). But among the spray treatments, PPC spray treatment recorded significantly higher yield (58.02 kg/tree) compared to control (43.19 kg/tree). Increased yield in the 20 years of aged trees due to increased yield attributing factors like panicle number, fruit set percentage, number fruits per tree and fruit weight. Increased fruit yield with moderate tree age may be due to increase in bearing capacity so they produce more fruits (Minor and Kobe, 2019). The trees with good canopy and productive age might have greater ability to gain and store nutrients and carbohydrates, the higher assimilation and the larger fruit mass (Aregay *et al.,* 2021). Ozeker (2000) also reported similar finding, in that 20-year-old trees of seedless grape fruit to have bigger fruit when compared to 34-year-old trees.

Tree age and plant height are important factors affecting yield. The mango yield is lower at the early stage of bearing fruit and increases with time, reaching the highest stage of fruit production in 10 to 20 years. Then, yield begins to decline in the later stage of

fruiting, as the trees shade each other and begin ageing. However, as tree age increases, height also increases, which leads to greater management challenges and affects mango yield. In the traditional planting patterns, tall trees have been found to be less productive than dwarfing cultivars (Dong *et al.,* 2019). Timely application of plant protection chemicals supresses insect pests *viz.,* hoppers, fruit fly and diseases like powdery mildew, anthracnose and stem end rot (Sudha and Narendrappa, 2015). Mean damage on mangoes due to fruit flies for the two seasons and orchards increased from 17 per cent in early April to 73 per cent at mid-June (Vayssieres *et al.,* 2009). There is no significant difference among the interaction treatments (Table 4). These results are in confirmation with the findings of Kavitha *et al.* (2022), Kumar *et al*. (2015) and Meena & Asrey (2018).

Present study on impact of weather variability during different phenological phases of mango (2020-21) reveals the importance of rainfall and soil moisture on flowering and fruiting behaviour. As the soil water balance indicates hydrological variations in soil with respect to climate, crop water balance paves the way to understand moisture variability in the crop field. The outcomes of the investigation indicated moisture stress during fruiting setting and further development phases. Impact of this moisture variability was clearly observable by parameters like fruit retention percentage, which decreased upon each next stage of fruit development. This outcome envisages use of measures to supply moisture to the crop by external means for bringing out sustainability in the mango productivity in the region. Further, such long term analysis of soil and crop water balance for other horticultural crops needs to be studied for achieving higher production goals to meet out food security.

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