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PRODUCTION AND QUALITY ENHANCEMENT OF MANGO USING FAN JET SPRAYER IRRIGATION TECHNIQUE

Peningkatan Produksi dan Kualitas Mangga Melalui Teknik Irigasi Curah

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ABSTRACT

Lack of water in reproductive phases (flowering, fruit formation and maturation) of mango can reduce fruit production and quality. In these phases the plant must be protected from water stress. The aim of the research was to assess the effect of irrigation on the productivity and quality of mango fruits. The study was conducted at the Cukurgondang Experimental Station, Pasuruan, East Java, from April to December 2013, using 40 mango trees of 21 year-old Arumanis variety. Mangoes were planted on five rows with eight plants for each row and 6 m x 6 m spacing within the row. Fan jet sprayer irrigation was installed using hose according to plant diameter. The irrigation technique of fan jet sprayer with four nozzles per plant was applied at 125, 100, 75, 50 and 0% of crop water requirements or equal to 828, 663, 497, 331 and 0 liters of water per tree, every seven days. The parameters observed were the number and weight of fallen fruits and the number, weight and quality of mangoes harvested. The results showed that irrigation of 50% and 75% of crop water requirement had the highest and lowest number of fallen fruits (26% and 14% of total production), respectively. The highest and lowest total number of mangoes were 3.108 and 1904 fruits, respectively, which were achieved at irrigation of 50% and 75% of crop water requirement. Further, the highest and lowest total weight of mango fruits were 1036.2 and 677.9 kg respectively which were achieved at irrigation of 50% and 125% of crop water requirement. Mango fruits produced were dominated by grades 2 and 3 with A quality.

[***Keywords***: Mango, production, quality, fan jet sprayer]

ABSTRAK

Kekurangan air pada fase reproduksi (pembungaan, pembentukan buah, dan pematangan) dapat menurunkan produksi dan kualitas mangga. Dengan demikian pada fase-fase tersebut tanaman harus terhindar dari cekaman air. Tujuan penelitian adalah mengukur pengaruh pemberian irigasi terhadap hasil dan kualitas buah mangga. Penelitian dilaksanakan di Kebun Percobaan Cukurgondang, Pasuruan, Jawa Timur, pada April–Desember 2013 menggunakan 40 pohon mangga varietas Arumanis umur 21 tahun, dengan jarak tanam 6 m x 6 m. Teknik irigasi curah (fan jet sprayer) *menggunakan selang dipasang sesuai diameter pohon dengan empat buah* nozzle *per pohon. Lima perlakuan irigasi yang diaplikasikan yaitu 125, 100, 75, 50, dan 0% dari kebutuhan air tanaman atau berturut-turut setara dengan 828, 663, 497, 331, dan 0 liter air per tujuh hari per pohon. Parameter yang diamati yaitu jumlah dan berat buah rontok, jumlah dan berat buah yang dipanen, serta kualitas buah. Hasil penelitian menunjukkan bahwa perlakuan irigasi 50% dan 75% dari kebutuhan tanaman masing-masing menghasilkan jumlah buah rontok terbanyak dan terendah, yaitu berturut-turut 26% dan 14% dari total produksi. Jumlah buah total tertinggi dan terendah masing-masing terdapat pada perlakuan irigasi 50% dan 75% dari kebutuhan air tanaman, berturut-turut 3.108 dan 1.904 buah. Total berat buah tertinggi dan terendah terdapat pada perlakuan irigasi 50% dan 125% dari kebutuhan air tanaman, yaitu berturut-turut 1036,2 dan 677,9 kg. Berat buah mangga yang dihasilkan umumnya termasuk kelas 2 dan 3 dengan kualitas A.*

[***Kata kunci***: Mangga, produksi, kualitas, irigasi curah]

INTRODUCTION

Mango (*Mangifera indica* Linn.) is widely grown in tropical regions, while in the subtropical regions it is grown in the irrigated semiarid region. Most of the fruit development phase during fruit season occurred in dry season and farmers have to irrigate mango trees to ensure high yields and good quality of fruit. Out of several biotic and abiotic factors, optimum water management is one of the most important factors that significantly influence productivity and fruit quality (Adak *et al.* 2012; Bhriguvanshi *et al.* 2012). Pongsomboon (1991) *in* Bithell *et al.* (2010) reported that mango plant is tolerant to drought, while a water deficit during the critical period of reproductive phase (flowering, fruit formation and maturation) would decrease fruit production (Lechaudel and Joas 2007; Schaffer *et al.* 2009). In the ratio of crop evapotranspiration and potential evapotranspiration (ET/ETP) of 0.8, mango tree still has successfully maintained yields (Spreer *et al.* 2007, 2009; Da Silva *et al.* 2009).

In Australia and Pakistan, irrigation on mango trees previously used a drip irrigation, but at present, microsprinkler irrigation is commonly used for mango trees. Drip irrigation is considered costly for the installation of equipment, and spare parts are expensive while farmers generally do not have cash capital for a large scale irrigation (Lu 2005). According to Perry *et al.* (2009), sprinkler irrigation could save water usage by 30% compared with flooded or furrow irrigation, even reaching 50% compared to drip irrigation.

Irrigation application up to 100% of the ETc could ensure crop productivity (Spreer *et al.* 2009). Water application under the evapotranspiration requirements of the plant is called deficit irrigation or limited irrigation. Deficit irrigation is a strategy to stabilize yields and maximize water productivity while maintaining or increasing farmers' profits (Fereres and Soriano 2007). In the limited water conditions, deficit irrigation can improve water use efficiency because water is allocated properly. Deficit irrigation is very interesting when it comes to an efficient allocation of scarce resources like water. This technique can maximize water productivity with good harvest quality (Spreer *et al.* 2007). It is particularly suitable for crops in which flowering and fruit development (like in mango) take place in the dry season. Due to the application of relatively small amounts of water, the harvest can be stabilized over time thus it can improve economic planning for farmers, which is increasingly interesting under climate change conditions where water resources are becoming scarce and rain is erratic.

The principle of deficit irrigation is to enhance water use efficiency by reducing irrigation from the full requirement of one or more of crop growth phases with the smallest impact on crop growth and yield (Kirda *et al.* 1999). Understanding on the different stages of crop growth is required to arrange irrigation schedule according to crop water requirement. Deficit irrigation techniques could save considerable amounts of water without affecting the yield to a large extend, possibly increasing the average fruit weight apparently without negative long-term effects (Speer *et al.* 2009). Bezerra (2012) reported that this irrigation technique was more efficient and gave the maximal yield with the minimal water loss.

Determination of the optimal irrigation for several mango cultivars had been studied by de Azevedo *et al.* (2003), while the research on the effect of different irrigation regimes on the quality and store-ability of mango fruits was reported by Abdel-Razik (2012). Fukuda *et al.* (2013) stated that irrigation increased fruit size and marketable fruit. Therefore, it is important to understand the effect of irrigation timing on mango trees to get better production systems. Limited irrigation on several horticultural crops to enhance water use efficiency has been widely applied worldwide, such as on grape (Chavez *et al.* 2007; de la Hera *et al.* 2007), apples (Zegbe *et al.* 2008; Zegbe and Serna-Pérez 2011), pear (Kang *et al.* 2002) and raspberries (Grant *et al.* 2004).

In Indonesia, irrigation requirement for mango was not well established, both plant response to lack of water availability and its impact on the quantity and quality of fruits. Therefore, the aim of the research was to assess the effect of irrigation on the productivity and quality of mango fruits. The study is expected to increase the yield and quality of mango fruits through the provision of irrigation scheduling and best irrigation application according to crop water requirement.

MATERIALS AND METHODS

The study was conducted at the Cukurgondang Experimental Station, Pasuruan District, East Java (7° 44' 30.95" N, 113° 01' 34.15" W) from February to December 2013. The Cukurgondang Experimental Station belongs to the Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture. Since 1938 the station has functioned as a collection orchard of mango and has a complete mango germplasm collection in the Southeast Asia. There were 1148 mango trees consisting of 208 varieties at the station. The mango collections were obtained from various regions in Indonesia or introduced from other countries.

The 21-year old mango trees of Arumanis variety and jet spray irrigation techniques were used for the study. The five water irrigation regimes applied were equal to 125%, 100%, 75%, 50% and 0% of crop water requirements. Irrigation amount for mango trees was analyzed based on the crop coefficient (Kc), soil characteristics and climate conditions. Value of Kc applied in this study was according to research results on mango trees in Brazil (Coelho and Filho 2007). Irrigation amount was represented by the duration of irrigation according to crop water requirement and irrigation technique.

Irrigation Amount and Schedule

The amount of water and the application period were determined using a water balance analysis based on crop water requirement according to the FAO method (FAO 1998). The crop water requirement was indicated through the water requirement in the deficit periods from the ratio of real evapotranspiration and maximum evapotranspiration (ETR/ETM) of less than 0.65 (Baron *et al*. 1995). If the ETR/ETM ratio is nearly 1, it means that the water is effectively used by plants, and higher production is expected. Conversely, if the ETR/ETM is less than 0.65, it means that plants experience water shortages and lead to low production (CIRAD *in* Irianto 2000). The maximum water requirement of plant (ETM) was calculated based on the ETP and crop coefficient (Kc). The ETP was calculated based on the Penman-Monteith method (Allen *et al.* 1998) as follows:

$$ETM = Kc \times ETP$$

Actual/real water requirement (ETR) was calculated using the Eagelman equation (Forest and Reyniers *in* CIRAD 1995), as follows:

$$ETR/ETM = A + B(HR)^1 + C(HR)^2 + D(HR)^3 \quad \text{...............(i)}$$

$A = -0.050 + 0.732/ETP$ $C = -8.57 + 1.56*ETP$
$B = 4.97 - 0.661*ETP$ $D = 4.35 - 0.880*ETP$

HR is soil relative humidity, calculated by the equation as follows:

$$HR = (HM - HPF)/(HCC - HPF) \quad \text{..................................(ii)}$$

HM = soil moisture content measurement
HPF = soil moisture content at permanent wilting point (pF = 4.2)
HCC = soil moisture content at field capacity (pF = 2.54)
(HM - HPF)/groundwater reserve = rainfall + last reserve + irrigation + water logged
(HCC - HPF)/water availability = rooting depth x total available water
Total available water = (soil moisture content at pF 2.54 - soil moisture content at pF 4.2) x bulk density

Irrigation was applied after the mango fruit size reaching 2–5 mm diameter until the maximum fruit development and at an early maturation phase. Five irrigation levels were applied for eight mango trees, so there were 40 mango trees. Amount of water and duration of irrigation are given in Table 1, while the schedule of irrigation application at several development phases is given in Table 2.

Design of Fan Jet Sprayer Irrigation Technique

The fan jet sprayer irrigation technique was installed using PE pipe with 13 mm diameter and 12 m length. It was located around the mango tree and connected to a sprayer with four nozzles and a capacity of 50 liters per hour. The pump installed was a Grundfos SP 8A 10 type, used 1.5 kW of electric power, resulted 2 liters per second of discharge capacity. The water was distributed evenly in four directions to all areas of the plant roots using pipelines. Irrigation treatments were applied to the eight mango trees of Arum Manis variety. The design of irrigation networks on experimental plots is presented in Fig. 1. The last of rain before irrigation applied occurred on July 14 with 1.2 mm. Design of fan jet sprayer irrigation technique on mango tree is shown in Fig. 2.

Table 1. Amount of water applied by fan jet sprayer irrigation technique on mango trees.

Irrigation	Amount of water (%)				
	A	B	C	D	E
Amount/7 days (litre)	828.5	662.8	497.1	331.4	0
(mm)	29	23	18	12	0
Duration (hour, minute)	1.53	2.50	3.47	4.45	0

A, B, C, D and E were 125%. 100%, 75%, 50% and 0% of crop water requirement

Table 2. Period of fan jet sprayer irrigation technique at several growth phases of mango trees.

Week	Date	Development phase	Irrigation	Rainfall (mm)
1	August 5, 2013	Blooming flower	-	0
2	August 12, 2013	Blooming flower	-	0
3	August 19, 2013	Early fruit formation	-	0
4	August 26, 2013	Early fruit formation	1st irrigation	0
1	September 2, 2013	Fruit growth	2nd irrigation	0
2	September 16, 2013	Fruit growth	3rd irrigation	0
3	September 23, 2013	Fruit growth	4th irrigation	0
4	September 30, 2013	Fruit growth	5th irrigation	0
1	October 7, 2013	Fruit growth	6th irrigation	0
2	October 14,2013	Maximum fruit growth	7th irrigation	0
3	October 21,2013	Maximum fruit growth	8th irrigation	0
4	October 28,2013	Ripening	-	0
1	November 4, 2013	Ripening	-	0
2	November 11, 2013	Ripening	-	0
3	November 13, 2013	Mature	Harvest	0.2

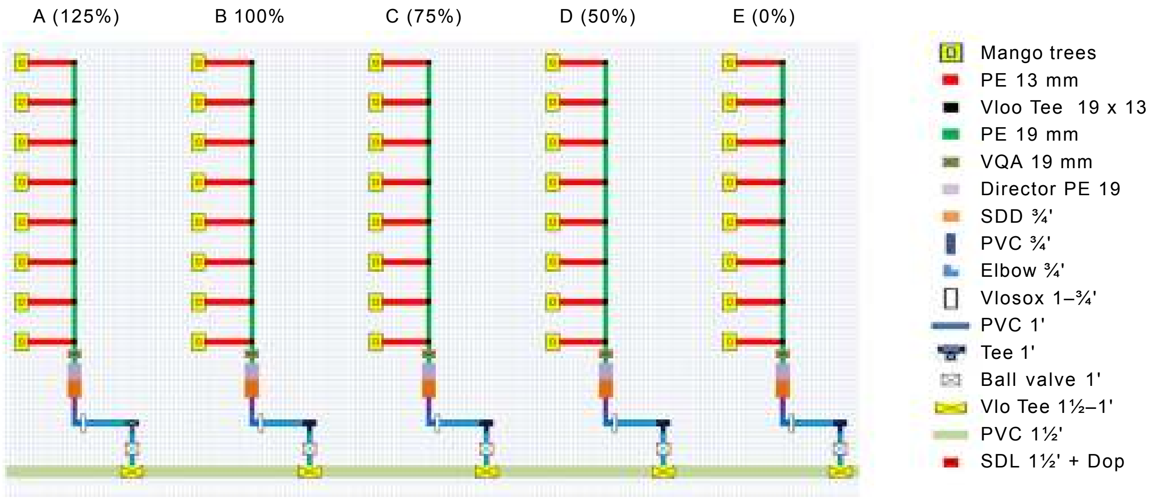

Fig. 1. Design of experimental plots of fan jet sprayer irrigation technique on mango trees at Cukurgondang Experimental Station, Pasuruan, East Java.

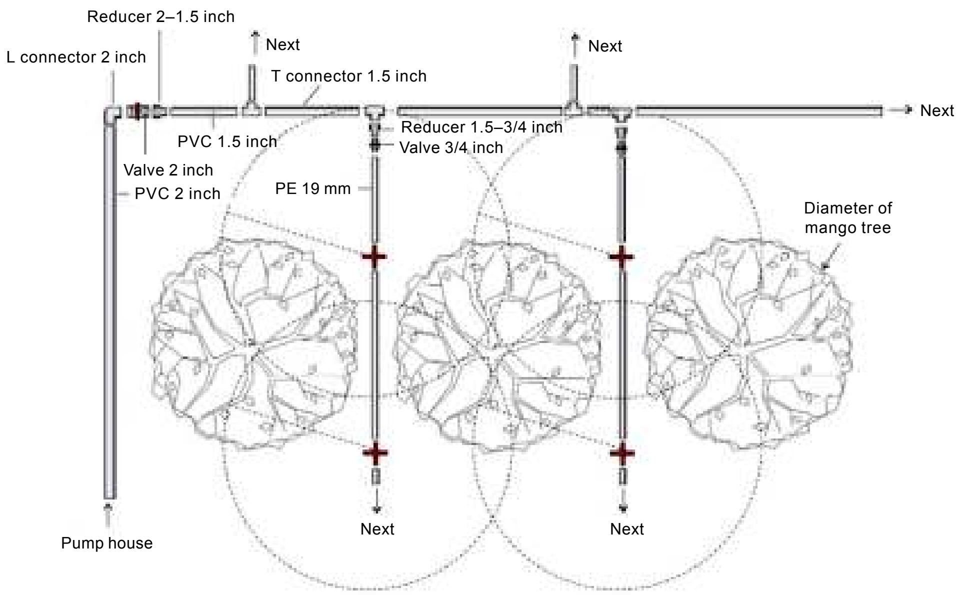

Fig. 2. Fan jet sprayer irrigation technique on mango trees at Cukurgondang Experimental Station, Pasuruan, East Java.

Observed Parameters

The parameters observed were early age of flower initiation, number of fallen fruits, number of fruits, fruit weight, fruit size and fruit quality at harvest. Observations of fallen fruits were begun when the fruit size achieved 5 mm until harvest. Observations were carried out by collecting fallen fruits under trees using net container, then the fruits were calculated and weighed. To assess fruit quality, mango fruits were classified by size appearance at the harvest. Fruit weight was divided into five classes as follows: class 1 (>450 g), class 2 (351–450 g), class 3 (251–350 g), class 4 (151–250 g), and class 5 (<151 g), while fruit quality was classified into three classes (Super, A, and B), resulting the combination of 15 classes (Table 3).

Super Class. Mangoes in this class must be of superior quality, free from defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package. *Class A*. Mangoes in this class must be of good quality. The following slight defects, however, may be allowed, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package: (1) a

Table 3. Classification of mango fruit classes based on fruit weight and quality.

Fruit classification	Fruit weight classification	Quality class
1 S	Class 1 (> 450 g)	S
1 A		A
1B		B
2 S	Class 2 (351–450 g)	S
2 A		A
2B		B
3 S	Class 3 (251–350 g)	S
3 A		A
3B		B
4 S	Class 4 (151–250 g)	S
4 A		A
4B		B
5 S	Class 5 (< 151 g)	S
5 A		A
5B		B

Source: SNI 3164:2009. ICS 67.080.10 Indonesian National Standard Agency.

slight defect in shape, (2) slight skin defects due to rubbing or sunburn and suberized stains due to resin exudation not exceeding 2 cm^2 for size groups 5 and 4; 3, 4, 5 cm^2 for size groups 3, 2, 1 respectively, (3) slight bruising, (4) scattered rust-colored lenticels, (5) a yellowing of green varieties due to exposure to direct sunlight not exceeding 40% of the fruit surfaces, excluding necrotic stains. *Class B*. This class includes mangoes that do not qualify for inclusion in the higher classes, but satisfy the minimum requirements specified above. The following defects may be allowed, provided the mangoes retain their essential characteristics as regards the quality, the keeping quality and presentation: (1) defects in shape, (2) skin defects due to rubbing or sunburn and suberized stains due to resin exudation not exceeding 4 cm^2 for size groups 5 and 4; 5, 6, 7 cm^2 for size groups 3, 2, 1 respectively, (3) bruising, (4) scattered rust-colored lenticels, (5) a yellowing of green varieties due to exposure to direct sunlight, not exceeding 40% of the surface of the fruit, excluding necrotic stains.

RESULTS AND DISCUSSION

Biophysical Characteristics of Cukurgondang Experimental Station

The Cukurgondang Experimental Station is located 20 km from Pasuruan District and + 50 m above sea level (asl), has Latosol soil type, flat topography and soil pH between 6–7. Based on Schmidt Ferguson classification, the type of climate at the station is D (annual rainfall of 1332 mm and 99 rainy days), with an average temperature of 27° C and a relative humidity of 65%. Based on climate data from the climate station at the experimental station of Indonesian Sugar Research Institute in Pasuruan for the periods of January to December 2010–2012, the highest monthly rainfall occurred in January and the lowest was in June, July and August. While the average of the maximum and minimum temperatures were 31.7° C and 23.5° C, respectively.

Fallen Fruits

Fallen fruits were observed frequently on 5 mm fruit size until just before harvest. It was observed on 40 trees as much as 21 times, two times a week. The total number of fallen fruits during plant growth was 20,877 with the largest number occurred in 50% of crop water requirement treatment, i.e. 5,490 fruits or 26% of the total fallen fruits. While the lowest fallen fruits was 2,922 fruits (14%) occurred in 75% of crop water requirement treatment (Table 4). Lack of nutrients and plant hormones (auxin and gibberellin) when the plant enters the reproductive phase resulted in a high loss of fruits (Ram 1983, 1992 *in* Chattha *et al.* 1999; Nkansah *et al*. 2012).

Fruit Harvesting

Fruit harvesting was done for 40 mango trees in five irrigation treatments. The number of fruits at 50% of water requirement treatment was 25.4% higher than other irrigation treatments. This treatment also produced fruit size of 351–450 g (class 2), higher than other irrigation treatments. All irrigation treatments generally produced high fruit quality (grade A). The

Table 4. Number and weight of fallen fruits of mango at different irrigation treatments.

Irrigation (% of crop water requirement)	Number of fallen fruits		Weihgt of fallen fruits (kg)	
	Total	%	Total	%
125	3,374	16.2	304.3	16.2
100	3,915	18.8	396.5	21.2
75	2,922	14.0	301.7	16.1
50	5,490	26.3	467.7	25.0
0	5,176	24.8	403.1	21.5
Total	20,877	100.0	1,873.4	100.0

fruits of super quality mostly reached 29% of total fruits produced at 50% of crop water requirement (Fig. 3).

The highest total weight of fruit production was achieved by irrigation treatment at 50% of crop water requirement (1,036.2 kg) or 25% of total production. The result of the present study agrees with Kumar *et al.* (2008) that 3–5-year old mango tree irrigated at 50% of crop water requirement combined with mulch produced fruits greater than that irrigated at 75% of crop water requirement. In this research, mango fruits were dominated by class 2 (351–450 g) and class 3 (251–350 g) (Fig. 4). The quality of fruits was dominated by A quality (58%) followed by the super quality (29%).

Deficit irrigation was a good practice to increase crop water productivity. In the present study, the highest fruit yield was obtained at 50% of crop water requirement treatment, which was similar to Fereres and Soriano (2007) without yield decrease. Geerts and Raes (2009) showed that deficit irrigation technique could increase mango productivity. The increase in harvest yield obtained was due to more fruits as associated with less fallen fruits, rather than bigger fruit size (Pavel and de Villiers 2004; Spreer *et al.* 2009), while fruit ripening and internal quality parameters were not affected by the irrigation method (Spreer *et al.* 2007).

Table 5 confirms the finding that the total fruit weight was mainly correlated to the number of fruits harvested ($R^2 = 0.85$), but was not correlated to the average of weight fruit ($R^2 = 0.001$). According to Spreer *et al.* (2007, 2009), weight and number of fallen fruits correlated to fallen fruits ($R^2 = 0.96$ and 0.93 respectively), while fallen fruit was not correlated to fruit weight.

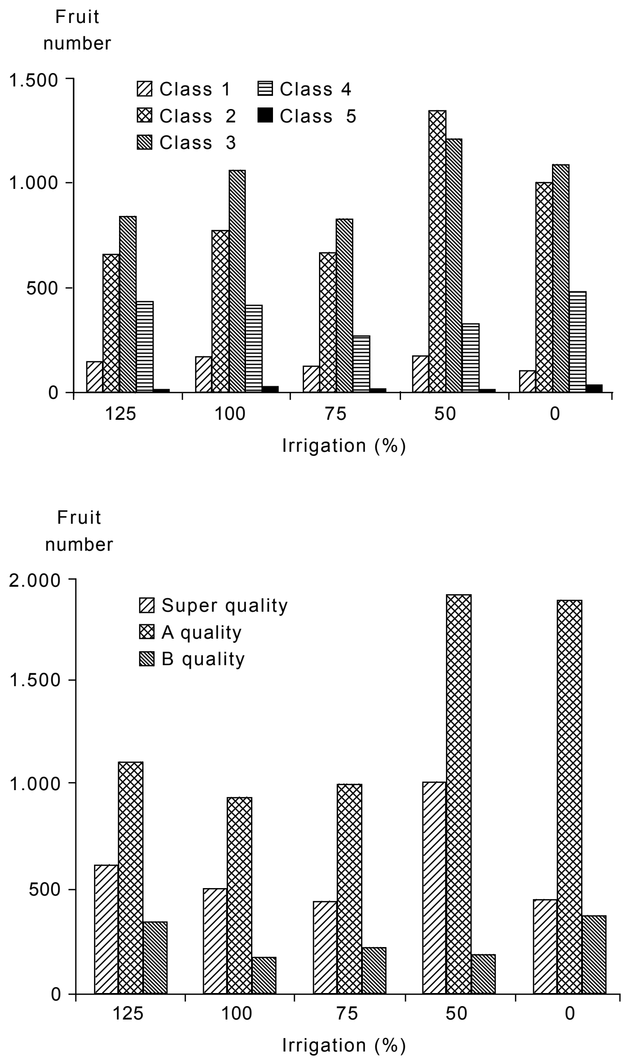

Fig 3. Number and quality of mango fruits produced from various irrigation treatments.

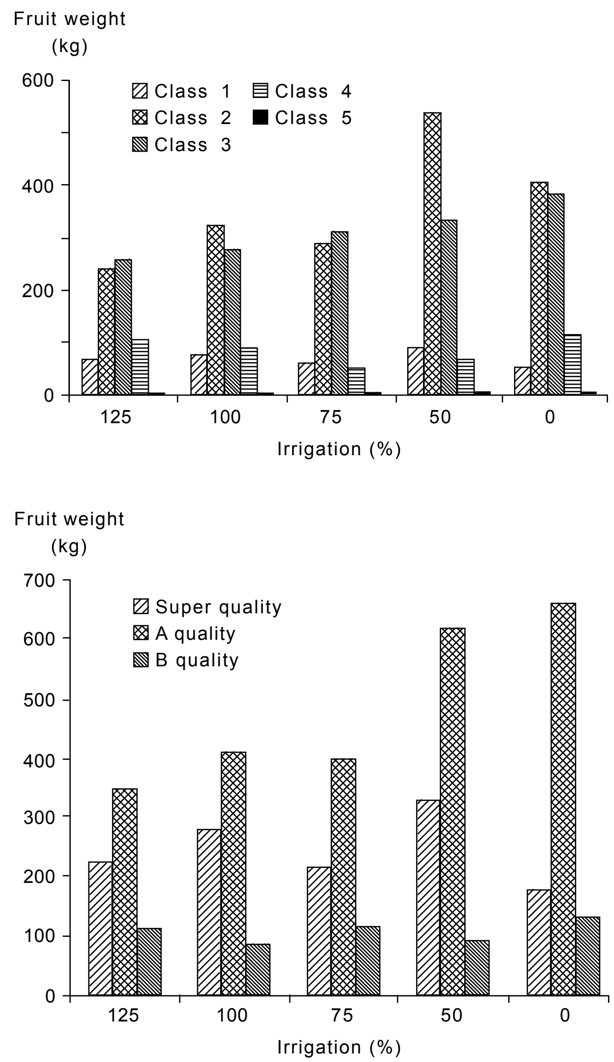

Fig 4. Weight of mango fruits at different irrigation treatments.

Table 5. Correlation matrix between total fruit weight, fruit number, average fruit weight, and number of fallen fruits on mango.

Parameter	Fruit number	Average fruit weight	Number of fallen fruits
Fruit weight	$y = 1.0009x^{0.862}$ $R^2 = 0.85$	$y = 527.1x^{0.0766}$ $R^2 = 0.001$	$y = 7.7854x^{0.7461}$ $R^2 = 0.96$
Fruit number	-	$y = 527102x^{-0.923}$ $R^2 = 0.13$	$y = 17.37x^{0.7896}$ $R^2 = 0.93$
Average fruit weight		-	$y = 65716x^{-0.436}$ $R^2 = 0.02$
Number of fallen fruits			-

Water Use Efficiency

Since water is a limiting factor of production, limited irrigation can enhance water use effciency (WUE), so that the available water is better allocated. The WUE was calculated per tree as the harvested yield (kg) per volume of irrigation water (m^3) according to FAO recommendations (Doorenbos and Kassam 1979). The WUE of 50% and 75% of crop water requirement was higher than that of 100% of crop water requirement, while WUE of 125% of crop water requirement was lower compared to that of 100% of crop water requirement. WUE of 50% of crop water requirement was the highest as presented in Table 6. Out of several biotic and abiotic factors, optimum water management is one of the most important factors that significantly influence productivity and quality of the product (Bhriguvanshi *et al.* 2012).

To obtain a water use efficiency, the relationship between environmental factors and water use in various plant developmental stages needs to be understood properly. Thus, the necessary of water saving efforts and understanding of its relationship with crop management and irrigation techniques are crucial (Bithell *et al.* 2010). To enhance water use efficiency, a few key things needed are as follows: (1) water requirement information of mango to achieve high production and good quality of fruit, and (2) establishing water management through (a) scheduling irrigation application based on water requirement, (b) composing efficient irrigation method, and (c) monitoring soil water availability conditions to support water use efficiency.

The development of irrigation technology is highly prospective on crops with high economic value such as horticultural crops, supported by adequate market access for marketing the product. Agus *et al.* (2003) reported that the use of irrigation pumps in horticultural crops such as water melons in Central Lampung provided economic benefits. Further, implementation of automatic disc irrigation systems by solar powered on mango trees in Pringgabaya, West Nusa Tenggara at laboratory and field scales was economically feasible, with an average return of capital in fourth year (Rejekiningrum and Saptomo 2015).

Table 6. Fruit yield and irrigation efficiency at different water treatments on mango.

Irrigation (% of crop water requirement)	Yield (kg per plant)	Irrigation (m^3 per plant)	WUE[1)] ($kg\ m^{-3}$)
125	6.21	6.63	0.94
100	8.56	5.30	1.61
75	8.48	3.98	2.13
50	15.49	2.65	5.84
0	11.04	0.00	0.00

[1)]WUE = water use efficiency

CONCLUSION

Application of proper water irrigation on mango is essential to ensure high production and good quality of fruits. Limited irrigation (50% of crop water requirement) could save considerable amounts of water without affecting fruit number and fruit weight as indicated by high yield and water use efficiency. Application of fan jet spray irrigation to fulfill 50% of crop water requirement provided the highest fruit weight. Water use efficiency of 50% and 75% of crop water requirement was higher compared to that of 100% of crop water requirement, while water use efficiency of 125% of crop water requirement was lower compared to that of 100% of crop water requirement treatment. The present study is useful for area with limited water conditions which could improve fruit yield and water use efficiency.

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