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MANGO PRODUCTION AND FRUIT QUALITY UNDER PROPERLY MANAGED DRIP IRRIGATION SYSTEM

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ABSTRACT

In Pakistan, mango orchards are traditionally irrigated through basin flooding method. Basins are made around a mango tree and flooded through a small channel. A huge quantity of water is lost in these basins as well as in these channels. To minimize water losses, modern micro-irrigation methods such as drip and sprinkler irrigation are introduced. They save precious water, produce quality fruits and higher yields. Several progressive farmers have installed drip irrigation systems in their orchards. This study describes, the water distribution pattern, irrigation frequency, required number of emitters and their orientation under drip irrigated mangoes. Each mango tree was irrigated by four drippers installed at a distance of about 50 to 80 cm from the trunk. They did not provide sufficient moisture around the canopy hence trees were under dry stress. To cover entire canopy, the system should be operated for additional hours. Also, the placement of the drippers was inappropriate which failed to irrigate the outer edges of the tree canopy. The lateral could be placed with circular orientation around the canopy to provide moisture and avoid dry stress. Several operational problems were observed that need to be locally resolved. The frequency and time of application should be set according to the daily consumptive use of the mango tree. The plant growth was almost similar under drip and basin irrigation methods. However, the signs of leaf wilting were observed under drip irrigated trees whereas lush green leaves were seen under basin irrigated trees. The fruit drop was higher under drip method; while the fruit quality and yield was better under basin irrigation method; this is attributed to dry stresses due to limited availability of water around the tree canopy.

Keywords: Canopy, drip irrigation, dry stress, fruit drop, fruit quality, mango growth.

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INTRODUCTION

Mango trees are the specimens of handsome landscapes with round shaded canopy. The canopy is broad and rounded, or more upright, with a relatively slender crown. They are very fast growing trees under hot climate. Its leaves are dark green on the top side and pale at the bottom, usually red while young. The midrib is pale and obvious with distinct horizontal veins. The fruit grows at the end of a long, string like stem (the former panicle), with sometimes two or more fruits to a stem. The fruit is nutritionally rich in carbohydrates and vitamin A and C. It is relished and liked due to its flavor, color, dietary and medicinal importance. The young, immature fruit is an effective antidote for mild sunstroke, while the mature fruit provides energy to weak and old ones (Jiskani *et al.,* 2007).

Mango is native of Indian subcontinent but also grown in almost all continents of the world like North, South and Central America, South, West and Central Africa, Australia. It is grown in countries like China, India, Pakistan, Bangladesh, Philippine, Burma, Thailand, Malaya, Mexico, Brazil, United States of America, etc. In Asia, it is grown on over 1.0 million ha area and produces over 12.42 million tons per year (Chadha and Pal, 1993). In Pakistan mango is not only a source of employment in the countryside, but is also an important foreign currency earning fruit. It is grown in various southern districts of Sindh, Pakistan such as; Hyderabad, Tando Allahyar, Matiary, Mirpur Khas, Sanghar and Nawabshah. Several commercial varieties of mango are popular in these districts which are exported to generate foreign earnings. For successful growth and development of mango orchard, proper irrigation is required during critical stages such as flowering, fruiting and maturity. Irrigation of mango orchards, whether it is young, non-bearing and/or bearing, is closely related to soil and climate of the orchard. The fine textured deep and well drained soils with high retention capacity of water require less irrigation, while very fine textured and sticky soil, like black cotton requires no irrigation. Other groups of soils like light and medium textured require adequate surface irrigation, provided they are well drained. No irrigation is required for soil having water tables located within three meters from the soil surface as mango tree roots travel to this depth in search of water. Climatic factors such as humidity, rainfall and temperature can also affect the irrigation requirements of the mango orchards. The orchards situated in humid tropics do not require irrigation irrespective of soil type while under dry climate having low humidity and high temperature; irrigation is needed at 15 days interval. Mangoes grown in Brazil consume about 55.5 cm during a productive cycle (Azevedo *et al*., 2003).

Mango trees have very well spread, deep, and extensive root system. In deep soil the taproot may descend to about 7 meter depth, while copious of wide-spreading feeder roots also extend many anchor roots which penetrate by few meters. The main root develops secondary roots that go to sub-soil layer. This extensive root system of mango draws and gets the moisture from far and wider areas. Under extensively spread root system, only light surface irrigation is sufficient. In some odd conditions, the extensive root system development is

checked by hard pan rock. In this situation root zone is kept restricted and ultimately it restricts the vegetative growth of plant. Trees grown in such environment require rather frequent irrigation for better yield and quality fruits. A well spread, deep and extensively rooted system of mango trees requires more moisture as compared to shallow and horizontally spread roots. The irrigation requirements of young and non-bearing orchards differ from the bearing orchards. The young and non-bearing orchards require light and frequent irrigation to boost fast and vigorous growth of plants. At the initial stage, the root spread of the plants is limited hence light irrigation at frequent intervals is required to wet the soil. The non-bearing trees 4-5 years of age are usually irrigated at weekly interval while the bearing orchards are irrigated at regular intervals of 10 to 15 days. This interval is a prime requirement during fruit set and for full fruit development. This would help attain full sized fruits and avoid fruit drop. For better flowering and flower bud differentiation the irrigation needs to be stopped at least for 2-3 months during winter month, because, the irrigation during this period promotes vegetative growth, which might have detrimental effects on flowering. Evidences from recent past have shown that the mango plant suffers from a number of pests and diseases, which affect different of parts plant at the growth, development, flowering and fruiting stages. A mango quick decline (MQD) due to mango sudden death syndrome (MSDS) or mango tree mortality (MTM) is a newly emerging problem (Jiskani *et al.,* 2007). The scientists have successfully conducted many experiments to discover the exact causes and suggested several control measures. They prepared recommendation for growers, to face the problem and improve the productivity of mango orchards (Khuhro *et al*., 2006). Some progressive growers have adopted their suggestions and achieved fruitful results, while most of the growers are still facing disease problems as they have failed to follow the recommendations made by the scientists. In some cases the insecticides and pesticides were ineffective and did not provide any solution; hence growers are still facing an unknown dilemma and waiting for the solution. The water shortage at critical flowering and fruiting stages of mangoes has further added into their desolation.

Despite having such a well- established irrigation system in the country, it does not meet total agricultural requirements. The limited or unavailability of surface water supply at critical stages of mangoes is another problem faced by the growers. It has been reported by the Asian Development Bank “Asian Water Development Outlook, 2007”, that Pakistan has almost surpassed the water stressed level and will soon turn into a water scarce country. The country is now ranked among the worst performers in Asian Nations. This is because of huge amounts of water lost in the conveyance system, which limits its availability to the growers especially those at the tail-reaches. Also, the farming community continues to use water in extravagant and indiscreet way through traditional flooding methods. They have an overall efficiency of not more than 30% (Ishfaq, 2002). The water use efficiency is very poor while the capacity is weakening by every passing day and quality always keeps worsening. All these indicators suggest that our agriculture will be suffering through a disastrous phase, if appropriate measures were not taken on urgent basis to address these issues. Water application efficiency needs to be enhanced so that water could be saved

and additional lands could be brought under cultivation, which otherwise remain barren due to water storage. This could be done through proper management of current irrigation application methods and through adaptation of modern irrigation methods. The more emphases should be focused on the improvement of irrigation efficiency of application methods. To make efficient use of water for agricultural production, a precise amount required by the plants be applied at the right time and at right place with minimal water losses. The modern micro irrigation methods such as sprinkler, drip, subsurface, pitcher and bubbler stand a great potential to water saving. These methods not only have high application efficiency but they produce higher yields. According to Yildrin and Korukcu (2000) drip irrigation generally achieves better crop yield and balanced soil moisture in the active root zone with minimum water losses. On the average, drip irrigation saves about 70 to 80% water as compared to conventional flooding or furrow irrigation methods (Ishfaq, 2002). Some of the progressive growers have changed irrigation strategies and now they are applying modern micro irrigation methods.

The drip irrigation is regarded as one of the highly efficient methods that allows limited water resource to be properly utilized. The method not only saves water but also applies fertilizer through emitters. The drip irrigation allows water near the plant roots either onto the soil surface or beneath the soil surface directly to the root zone area. This method has several advantages such as plant attains quick growth, controls weed, saves labor, applies direct nutrient to plants, increases yield with quality fruits. The drippers operate at a very slow rate; usually the discharge matches the soil infiltration rate which neither allows the surface flooding nor the runoff. Deep percolation is out of question hence, water losses or minimal. The fertilizer and nutrient losses are minimal due to localized application and reduced percolation. It has high water application efficiency, can irrigate irregular shaped fields without proper land leveling, as is necessary in case of basin, border and furrow irrigation methods. The drip irrigation allows safe use of recycled water; maintains moisture within the root zone near to the field capacity. Even, the soil type plays less important role in frequency of irrigation in this method. It also minimizes the soil erosion. The other advantages of drip irrigation include high uniform distribution of water i.e. controlled by output of each nozzle. The water system is regulated through valves and drippers hence labor cost is minimum. Fertigation can easily be included with minimal waste of expensive fertilizers. The foliage remains dry thus reduce the risk of diseases. This method usually is operated at lower pressure than other types of pressurized irrigation systems such as sprinkler, thus energy costs are reduced (Wikipedia, 2010 and 2011; Infonet-Biovision, 2010).

Despite having several benefits, drip irrigation method also has certain disadvantages. The initial cost of the system is very high thus poor growers cannot afford to install it on their own. The lateral pipes are made from polyethylene tubes, which are vulnerable to high temperatures due to continuous and extended sunshine hours. Hence, the usable life of these pipes is less particularly in the semi-arid and arid regions. The longevity is variable, it can result in clogging, if the water is impure and not properly filtered and the

equipment is not regularly checked and properly cleaned. The herbicides and top dressed fertilizers need sprinkler irrigation for activation; hence, drip irrigation might be unsatisfactory. The drip tape winding, disposal, recycling or reuse is needed; otherwise drip tape will require extra cleanup costs after harvest. In order to install an economical and efficient system one must consider the important relevant factors viz. topography, soil type, crops, their water requirement, agro-climatic conditions, and suitability of drip irrigation system and its components. The subsurface drip may be unable to wet the soil surface for germination in lighter soils. Therefore, a careful consideration is required to install a drip system in these soils. Almost all the drip systems are designed for high efficiency; hence one can expect neither deep percolation nor runoff. The salts applied with the irrigation water may build-up in the root zone, usually at the edges of the wetting front (Wikipedia, 2010 and 2011).

A number of irrigation methods such as basin, flood, ring, furrow, sprinkler and drip are used to irrigate mango orchards in Pakistan and elsewhere. Each system has advantages and disadvantages as one system may be suitable for a set of conditions but unsuitable for another. Therefore, proper selection of an irrigation method is vital for the better management of mango orchards. The drip irrigation system is usually applied in those areas where the water supplies are limited and water available needs to be judiciously used. In this study, a drip irrigation system has been evaluated in terms of water distribution pattern around the crop canopy, irrigation frequency, number of emitters and their orientation. The fruit size, fruit quality, and yield under drip and furrow irrigation were also compared.

MATERIALS AND METHODS

Drip irrigation system installation

Study was carried out at the Talpur Farm located on the South of Kotri city at a distance of about 15 kilometers. The farm is owned by a progressive farmer and is spread over an area of about 16 hectares. The farm is irrigated by the Kalri Baghar Canal also known as 'Karachi Canal' that off takes from the Kotri Barrage. A drip irrigation system was installed on a 6.5 ha piece of the mango orchard farm (plate 1). The system comprises of a water tank, pumping unit, chemical mixing chamber, flow release pipe, water cleaning system and network of pipes that supplies water to mango trees. Each mango tree is irrigated through 4 drippers/emitters connected through micro-tubes to the lateral lines (plate 2). The laterals are connected to sub-mainline which receive water from the main line in which water is supplied through a pumping unit from the source. Two lateral lines have been provided to irrigate each tree. While, two drippers on each lateral line are fixed at a distance of one meter between them. Depending on the operating pressure, the drippers can discharge between 50 and 60 liters per hour. A fully grown mango tree requires about 120 liters day^{-1}, so the irrigation application time is to be fixed according to discharge through each emitter.

Plate 1. View of drip irrigated mango orchard

Plate. 2. A mango plant with four drippers

Plate 3. View of mango orchard irrigated with basin irrigation

Plate 4. Fruit drop from drip irrigated mango tree

RESULTS AND DISCUSSION

Farmers' perception

A team of experts visited Talpur Farm, located at the outskirts of city of Kotri, in the command of Karachi Canal on the complaint of growers. It was observed that a significant portion of the mango orchard was irrigated by a well established drip irrigation system while, the rest of the orchard was irrigated by flooding method (plate 3). The grower and the mango contractor were interviewed for the specific problems related to drip irrigated mangoes. The grower/contractor had concerns that a significant fruit drop (falling fruits) and defoliation (falling leaves) problem was observed under drip irrigated mango/ trees as compared to those irrigated by flooded basins. The grower/contractor also informed that the quality of drip irrigated fruit was inferior compared to the basin irrigated trees. At maturity, the drip irrigated mangoes lost their freshness and quality within few hours after harvest. Under the circumstances they did of exporters, thus their market value is significantly affected. According to them, a sound of the stone inside the fruit could easily be heard with a small shake/movement at maturity. The team investigated the possible causes of fruit drop and leaf defoliation.

General observations

On the average, a tree had canopy radius between 2.8 to 3.2 m. Each mango tree an irrigated by four drippers (work as low pressure jet sprinklers). They were installed at a distance of about 0.5 to 0.6 m from the trunk/stem. Significant moisture was observed within a one meter radius, while beyond this, the moisture reduced towards the outer sides of the tree canopy. The number of drippers was not enough to provide adequate water to meet water requirements of tree. It was further observed that the orientation of the drippers was inappropriate as a consequence outer edges of the canopy of tree/plant

remained under irrigated. This caused dry stress in the plant roots located in that vicinity, which could be avoided by increasing the number of drippers and through their proper placement around the canopy. The lateral pipes should run along the circumference around the canopy. If required, the system should be operated for longer periods so that water could reach the dry areas around the canopy.

The continuous dripping in the surrounding of the main trunk causes excessive wetting that may result in a problem of root rot/wilt in long run. This may also result in root death that ultimately will affect fruit quality and reduce the yield. It may also be recalled that the drippers are installed near the main trunk at a distance of about 45 to 60 cm from the stem only which cause such wet stresses (plate 3). While designing a system, a due consideration needs to given to the placement of the drippers.

Further, a water application and management problem at farm level was apparent. Due to power crises/failures the system sometimes did not operate for a specified period, hence the tree's water requirements were not properly met. The problem could be resolved by introducing new irrigation schedules and irrigation frequencies could be devised in such a way that each tree gets the required amounts as per its consumptive use. The trees could neither be under stressed nor over stressed. Also, the operational hours should be fixed in such a manner that both excessive flooding and deep percolation are avoided.

Plate 5. Showing branches with suffering fruit

It is the beauty of drip irrigation that it only irrigates the crop canopy area, the rest of area remains uncultivated and dry. It was apparent that most of the area between mango rows was very dry hence weed growth was restricted. Consequently, the dry soil surface increased the temperatures as compared to basin/flood irrigated wet areas. Also, the temperatures during this time of the year are pity high; they expedite evapo-transpiration which cause quick

differential in the moisture gradients between roots and leaves. The water taken by the roots does not meet the transpiration demands due to sharp moisture gradient thus plant leaves appear wilted. It was obvious that the plant leaves were rather yellow (wilted), particularly during afternoon hours, while they were lush and green in nearby area irrigated by basins. The leaves of plants seemed dirty under drip irrigated mangoes as compared to basin flooded ones. In order to reduce the dryness effects, either the entire area is flooded during few times of the year or small channel/furrows between rows are made. The channels may be flooded at least once a month during fruiting and maturity periods. The drip irrigated plants may be washed once a year to remove the dirt sitting in the leaves this would help increase stomatal activity.

Fruit drop, size, quality and yields related to irrigation

Under normal moisture conditions, the fruit set in mango remains unaffected; however, the prolonged soil moisture deficit has the serious consequences. The soil moisture deficiency reduces the fruit size and its quality and increases the drop of immature mango fruit. During fruit development period, under hot and dry climate, the irrigation prevents the drop of immature fruits. Early maturity of fruits was observed under drip irrigated trees that could be attributed to dry stresses under drip irrigation method. The drop rate was higher under drip irrigated trees than basin flooded ones (plate 4). The dropped immature mangoes were collected under drip and basin irrigated trees. The total number and weights were recorded. The results suggest that the drop rate was higher by about 25% under drip irrigated trees as compared to basin flooded ones. The mangoes dropped under drip irrigated trees have less weight as compared to basin flooded dropouts. The fruit quality and mango yield under drip irrigated mangoes was slightly affected. While the basin flooded mangoes has higher weight with a fresh appearance. It was further observed that the basin irrigation provided sufficient moisture to the plants during fruit development and maturity period hence the fruit quality was better than the drip irrigated mango trees. The better sized mango fruit with a juicier flavor was observed under basin irrigated tree's than those from tree under deficit soil moisture under drip irrigation.

These findings suggest that a regular and timely irrigation is necessary for bearing plants than a deficit and untimely one. Slightly higher yields were observed under basin irrigated mango trees. The differences in the total yield between two irrigation methods could be attributed to water stresses experienced by the drip irrigated trees. A properly managed drip system can provide uniform water application around the canopy and avoid stresses; ultimately mango yields will increase with properly irrigated trees. Similar results have also been reported in a study conducted by Spreer *et al.* (2007). Their results showed reduced yields under deficit irrigation as compared to the fully irrigated mango trees. However, development and post-harvest quality of fruits grown under deficit irrigation were not adversely affected. They further reported that fruit size was increased and fruits had a higher fraction of edible parts under partial root zone deficit. According to them, in areas where water becomes a limiting factor, partial root zone deficit may be applied; this would increase the mango production. In a

recent study Spreer *et al.* (2009) determined yield response and fruit size distribution for partial rootzone drying (PRD), regulated deficit irrigation (RDI) and irrigated control trees. They reported that during normal years the yields of the two deficit irrigation treatments (RDI and PRD) do not differ significantly, while in a dry year yield under PRD is higher than under RDI and in a year with early rainfall, RDI yields more than PRD. In all years PRD irrigated mango trees had a bigger average fruit size and a more favorable fruit size distribution. They concluded that deficit irrigation strategies saved considerable amounts of water without affecting the yield to a large extent, possibly increasing the average fruit weight, apparently without negative long term effects.

Insect pests and diseases

No serious problem of any insect pest or disease was observed in the mangoes. Rarely mango midge and scale insect infestation were noticed. Few leaves were found infected with tips die back and bacterial leaf spot diseases (plate 5). Such symptoms may be attributed to inadequate water and nutrition deficiency.

CONCLUSION

Study was carried out at the Talpur Farm located on the South of Kotri city at a distance of about 15 kilometers. A significant section of the mango orchard is irrigated by a well established drip irrigation system while, the rest is irrigated by flooding method. Investigations were made to evaluate the performance of drip irrigation in terms of water distribution, frequency, fruit size, fruit quality, and yield. Following conclusions were drawn from this study:

- About half of canopy radius had sufficient moisture, while the outer sides remained under watered and stressed. This was because of improper orientation of the drippers. The dry stresses could be avoided by increasing the number of drippers and through their proper placement/orientation around the canopy.

- Due to power crises/failures, a problem related to water application timing and frequency was apparent. This disturbed the irrigation schedules hence crop's water requirements were not properly met. The problem could be resolved by introducing new irrigation schedule, frequency and operational hours. Operational times should be worked out in such a way that both excessive flooding and deep percolation are avoided.

- Most of the area between the rows of mango trees was very dry hence weed growth was restricted. Consequently the dry soil surface increased the air temperatures as compared to basin/flood irrigated wet areas. Also, the temperatures during maturity period become too high; which caused speedy moisture gradients between roots and leaves. The water taken by the roots could not meet the transpiration demands due to sharp moisture gradient thus plant leaves appear wilted under drip irrigation compared to flood irrigation.

- The fruit drop rate was higher by 25% under drip irrigated trees than basin flooded ones. Similarly, the fruit quality and mango yield under drip irrigated mangoes was slightly affected. While the basin flooded mangoes has higher yield with a fresh appearance. The better size mango fruit with a juicier flavor was observed under basin irrigated trees than those under deficit soil moisture under drip irrigation.

- A problem of root rot/wilt could be expected due to continuous dripping and excessive wetting in the nearby surrounding of the main trunk. The wet stresses results in root death which ultimately affects fruit quality and yield.
- Our qualitative observations suggest that a detailed study at the site could be initiated for quantitative and solid conclusions. The study should focus on soil characteristics, soil profile texture, water application timing, application rate, soil infiltration, hydraulic conductivity, moisture distribution pattern, soil fertility level, fruiting behavior, and other relevant parameters. The impact of these factors along with water through drip system could then be related to the yield and quality of mango and a final conclusion could be drawn.

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