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SOIL MOISTURE RETENTION AND PRODUCTIVITY OF ZERO-TILL LADY'S FINGER UNDER DIFFERENT CROP-WASTE MULCHES AND IRRIGATION REGIMES

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Abstract: In India, lady's finger/okra planted during *kharif* and summer seasons, suffers from moisture stress due to hot-and-dry weather conditions, thus produce low yields. Improved water management with proper irrigation scheduling and using crop residues mulch could reduce negative effects of water stress in this crop. Hence, a two year field experiment consisting of 16-treatment combinations of 4-types of crop residue mulches (applied to preceding vegetable pea and continued in okra) and 4-irrigation schedules, *viz.*, recommended irrigation, and irrigation at 30, 50 and 70% depletion of available soil moisture (DASM) was conducted in spring-summer season (March-June) of 2017 and 2018 at research farm of Division of Agronomy, ICAR-IARI, New Delhi to assess the productivity of zero-tilled lady's finger under different crop residues and irrigation regimes in sequence with garden pea. The yield of lady's finger was comparable between recommended irrigation and irrigation at 30% DASM. Application of maize, soybean and paddy crop residues as mulch @ 5 t/ha each increased zero tilled-lady's finger yield by 14, 25 and 19%, respectively. However, delaying irrigation till 50% DASM reduced yield considerably and when irrigations were further delayed upto 70% DASM, the yield fell drastically (>60% reduction). Under frequent irrigations (recommended and 30% DASM), soybean and maize residue mulches were better but under stressed irrigation (50 and 70% DASM), paddy straw mulch was better. All mulches improved yield over no-mulch. Overall, it could be concluded that summer lady's finger may be irrigated at 30% DASM under adequate moisture availability and at 50% DASM with yield penalty under inadequate irrigation water availability. Use of mulches like soybean, maize and rice residues could further improve water productivity and yields.

Keywords: Crop residue mulch, Irrigation regime, Lady's finger, Water saving, Zero-tillage

INTRODUCTION

In India, lady's finger (*Abelmoschus esculentus* L.) is extensively grown during *kharif* and summer season due to its high adaptability over a wide range of environmental conditions (Haris *et al.*, 2014). *Okra* belongs to the malvaceae family and have adopted to tropical, subtropical and warmer temperate region (Farinde *et al.*, 2007). It suffers from moisture stresses due to hot-and-dry weather conditions, especially during summer season resulting in low yields. Achieving higher agricultural growth this a priority of many countries, including India. Use of appropriate technology helps not only to improve productivity, quality and economics of production, but also has a salutary impact on

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the environment. One of the major constraints of achieving higher agricultural productivity is limited water availability. Water stress during critical growth periods reduces yield and quality of crops (Al-kaisi and Broner, 2009). Rekha and Mahavishnan (2008) reported that when water use efficiencies of different irrigation methods were compared in okra, the efficiency under flood irrigation was the lowest (106kg/ha-cm) and drip irrigation recorded the highest (252 kg/ha-cm). Scientific methods of cultivation and judicious use of water is called upon to become cost competitive. Higher efficiency of input- utilization can be achieved by introducing advanced methods of water application. Adoption of zero tillage worldwide has shown favourable results in terms of water use efficiency and fertilizer use efficiencies, and quality of produce, besides environmental advantages. Proper scheduling is also needed to provide nutrients at the time when plants require them. Due to ever growing paucity of irrigation water as a consequence of depletion and pollution of water resources, and also due to completing demands of other sectors, meeting full crop water requirement of *Okra* during scarcest supply season (summer) is not possible. The agronomic practices that conserve soil moisture, prolong soil moisture retention, and enhance moisture tolerance in plants by facilitating absorption of moisture from greater soil depths can help cut down irrigation water supplies and improve productivity and water-use efficiency (WUE).

Frequent irrigation with small amounts of water can lead to stress, while heavy, less frequent irrigation can lead to excessive deep percolation (Hill *et al*., 1983). Mulching of the soil surface has been shown to reduce runoff and increase infiltration and yield of crops (Adekalu *et al*., 2007). Thus, it is essential to develop an efficient irrigation scheduling under prevailing local conditions. Soil moisture depletion approach is greatly used for scheduling irrigation in okra under field conditions (Home *et al*., 2000). Covering soil surface with mulching materials *viz.* crop residues mulches, grass mulching, various coloured mulches have been found to have multiple benefits like improving crop yields and saving/improving natural resources (Ahmad *et al*., 2020; Balasubramanian *et al*., 2013; Arora *et al*., 2011; Awodoyin *et al*., 2007; ALlbu-Gouch and El-Balla, 2003). Mulching is effective in reducing evaporation, conserving soil moisture and has been known to modify the hydrothermal regime of soil (Jha *et al*., 2018). Parte *et al*. (2020) found significant results in okra yield improvement with organic and plastic mulches. Walter (1988) reported that the bad effects of water deficit could be overcome by irrigation or adopting in-situ moisture conservation techniques, such as use of mulches. Mulching has also been identified by many workers as a method to provide a favorable soil environment by minimizing crusting at the soil surface and keep it stable (Mehta and Prihar, 1973). Optimised irrigation scheduling with various crop residues could be promising technology to minimise the water stress in lady's finger. Thus the current investigation was carried out to study the influence of different crop residue mulches on soil moisture retention and productivity of zero-tilled lady's finger.

MATERIALS AND METHODS

Effects of different crop residues applied as mulches in preceding vegetable pea crop and retained further in *okra,* and irrigation regimes were investigated by conducting a field experiment during spring-summer season (March-June) of 2017 and 2018 at Research Farm of Division of Agronomy, ICAR-IARI, New Delhi-12. The experimental soil was sandy clay loam in texture, organic carbon 0.48% with available N (180.2 kg/ha), P (17.5 kg/ha) and K (236.5 kg/ha) (Table 1). There were 16-treatment combinations of 4-types of crop residue mulches (applied to preceding vegetable pea) and 4-irrigation schedules as shown below. The main plot treatments included 4-crop-residue mulches (5 t/ha), *viz*., maize (M), Rice (R), Soybean (S) and no-residue (NR). The sub-plots had 4-Irrigation regimes including I_1:Recommended irrigation (weekly), I_2: Irrigation at 30% Depletion of available Soil Moisture (DASM), I_3: Irrigation at 50% DASM and I_4: Irrigation at 70% DASM. The experiment was conducted in a split-plot design replicated three times. Each experimental unit size was 2.7m × 4.5 m. A popular lady's finger variety 'Pusa A4' was used in this study. This variety has green fruits that are 12-15 cm long and first picking comes after 45 days of sowing. It is tolerant to aphids and jassids and has average yield of 140q/ha.

The crop was sown on 3rd week of March each year at a row spacing of 45×30cm using 20 kg/ha seed, and fertilized with 100 kg N, 50:kg P_2O_5 and 50 kg K_2O kg/ha. Other agronomic cultivation practices were adopted as per recommendations. Fruits were harvested five times by hand at 5-day intervals and weighed after each harvest.

At various growth stages, the volumetric water content (v/v) was determined in each plot using a soil moisture metre (Diviner-2000). Soil moisture sensors were used to monitor changes in soil moisture in each plot on a volumetric basis at 0–10, 10–20, 20–30, and 30–40 cm depth increments. A post-hole auger was used to install 1.0 meter long soil moisture sensor tubes between the crop rows in one of the replications. The soil moisture content was measured using the DL-6: PR 2 soil moisture probe (Delta-T Devices Ltd, Burwell, Cambridge, CB5 0EJ, UK). The instrument was calibrated before its use in the field. Water productivity of the crops under different treatments was computed using yield with total amount of water consumed in each plot. The collected data was subjected to analysis of variance and analyzed by using SAS software. The significance differences among the means were tested using least significance difference (LSD) at 5% level of significance.

Table 1: Initial soil characteristics of the experimental field

Soil texture	*Sandy loam*
Sand (%)	63.5
Silt (%)	16.0
Clay (%)	20.5
Organic C (%)	0.48
Available N (kg/ha)	180.2
Available P (kg/ha)	17.5
Available K (kg/ha)	236.5

RESULTS AND DISCUSSION

Soil moisture

Sensor-based moisture access tubes were used to conduct soil moisture profile studies up to 0.6 m soil depth in 2017 and 2018. Figs. 1 and 2 show the profile moisture content under various tillage techniques from 0–10, 10–20, 20–30, 30–40 and 40–60 cm. The percentage of moisture content between 0.10 and 0.60m soil depth increased as irrigation frequency was increased. There was a slight variation in soil moisture content among different mulches at all stages of okra. Soil moisture was in the order of paddy > maize> soybean residue mulch > no-mulch for 0–60 cm soil depth. However, the difference between paddy and maize and between maize and soybean was small. In 0–10 and 10–20 cm soil layers, moisture content was more than twice higher under conventionally recommended irrigation (weekly interval) and irrigation at 30% DASM compared to stressed irrigation (at 50 and 70% DASM). Difference among irrigation regimes for lower soil depths (20-60 cm) narrowed down gradually. This increase in soil moisture content might be due to reduced evaporation and enhanced soil moisture utilization by the okra crop. Organic mulches can suppress annual weeds and offer other important benefits, such as organic matter, nutrients, moisture conservation, soil protection, and moderation of soil temperature (Jha *et al*., 2018). Similarly, Bahadur *et al*. (2020) also observed maximum soil moisture content of 12.2% and 13.5% under organic mulch, respectively at 20 and 30 cm depths. Likely, plants grown under organic and black-silver mulch have registered 52.5% and 35% higher chlorophyll content than control. Contrastingly, Dagore *et al*. (2016) opined that soil moisture extraction was higher in plastic mulch (9.82%) followed by wheat straw, grass and no mulch (9.82, 8.60 and 6.77%, respectively).

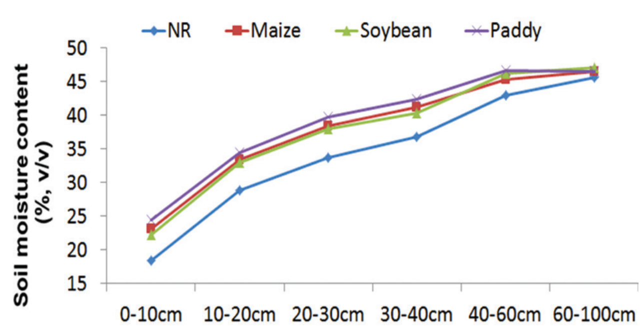

Figure 1: Effect of crop residue mulch on soil profile moisture content

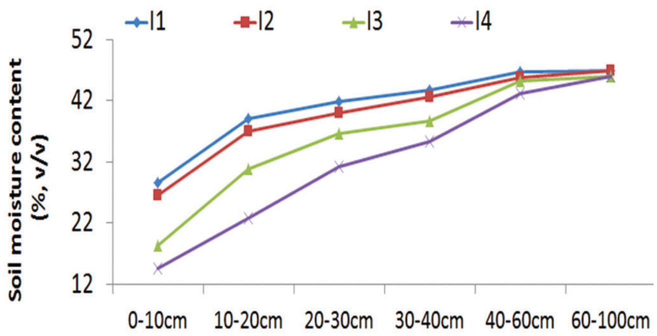

Figure 2: Effect of irrigation regimes on soil profile moisture content

Okra fruit yield

Mulching and irrigation schedules affected okra yield (Figure 3). The yield of lady's finger was comparable between recommended irrigation and 30% DASM irrigation schedule. Delaying irrigation till 50% DASM reduced yield considerably and when irrigations were further delayed to 70% DASM, the yield fell drastically (>60% reduction). Under frequent irrigations (recommended and 30% DASM), soybean and maize residue mulches were better but under stressed irrigation (50 and 70% DASM), paddy straw mulch was better. Maize, soybean and paddy crop residue mulch (5 t/ha) increased ZT-lady's finger yield by 14, 25 and 19%, respectively, in 2017; a similar enhancement in yield due to mulches were observed in 2018 too. Dagore *et al.* (2016) opined that mulching with plastic sheet in okra proved the best mulching practices which produced superior growth, yield attributing characters, WUE (101.39 kg/ha/cm) and seed yield (486.11 kg/ha) over mulching with wheat straw and grass mulching. Contrastingly, the okra yield was highest (8104 kg/ha) under silver plastic mulch followed by control (5161kg/ha), *Panicum repens* (3901kg/ha) and *Lantana camera* (3701kg/ha), respectively (Jha *et al.*, 2018). Bhadauria and Vijay (2006) found that application of mulches (50 micronblack plastic mulch and sugarcane trash mulch @10 t/ha) have had significant effect on photosynthesis, pod length and pod yield of okra crop as compared to no-mulch treatment. Similarly, Parte *et al.* (2020) found better *okra* growth and pod yield under wheat straw, grass and plastic mulches over the control.

However, interaction of mulches with irrigation schedules had been profound effect on okra fruit yield. The maximum yield of 113 q/ha was reported with irrigation at 30% depletion of available Soil Moisture (DASM) with soybean mulch as compared to 75% DASM with all the crop residue mulching treatments.Naik*et al.* (2011) observed that scheduling of irrigation at 1.0 IW/CPE ratio with application of black plastic mulch gave significantly higher fruit yield of okra than their respective lower level / control.

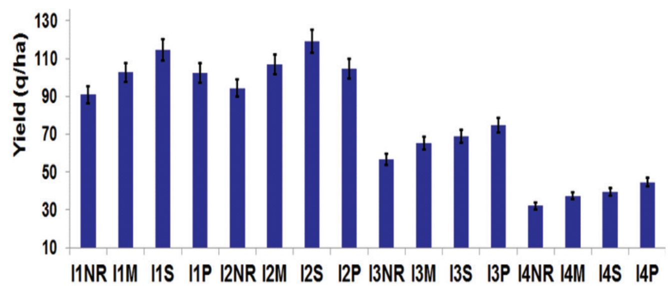

Figure 3: Yield of zero-till okra under different irrigation regimes and crop residue mulches (mean of two years)

Water productivity (WP)

During the 2017–2018 growing season, mulching and irrigation schedules had an effect on okra water productivity (Figs 4 and 5). In soybean crop residue applied plots, water productivity was substantially ($P \leq 0.05$) higher in all the study years, with increase being 20% and maize and paddy straw mulches by more than 15%, over no-mulch. Enhanced fruit yields under mulching plots results in increased water productivity (WP) in okra. All the practices of mulching increased the WP significantly over no mulch. Minimum WP was noted under no mulching, which was significantly less than noted under any of the treatment. The maximum WP was recorded under soybean mulching followed by mulching with paddy and maize, but it was at par with all the straw mulching treatments. The reason for this increased WP is contributed to more extraction of water due to greater root density and proliferation (Rekha *et al.*, 2009). Similarly, Dagore *et al.* (2016); Jha *et al.*, 2018; Bahadur *et al.* (2020) also observed significantly higher water productivity under crop residue mulch applied plots than no crop residue applied plots (Figure 4). Researcher have found that mulching reduces the overall water requirement of a crop by conserving soil moisture through reducing evaporation and runoff loses in addition to deep percolation and more water retention, and weed suppression (Kader *et al*. 2019; Iqbal *et al*. 2019; Ahmad *et al*. 2020).

Among irrigation schedules, applying irrigation as 30% DASM returned the highest water productivity which was significantly greater than all other irrigation regimes. Water-stressing the lady's finger crop to 70% DASM reduced WP to less than half of the WP recorded with irrigations scheduled at 30% DASM due to drastic yield reduction (Figure 5). Likewise, Adekalu *et al.* (2007); Jha *et al.* (2018) also observed that lower water productivity in okra under water stress plots/no irrigation applied plots.

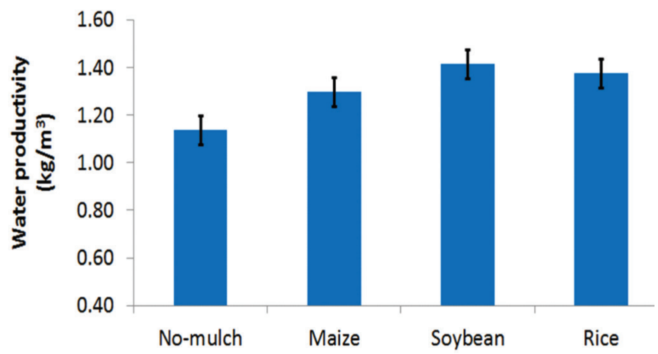

Figure 4: Water productivity of zero-till lady's finger under different crop residue mulches (mean of two years)

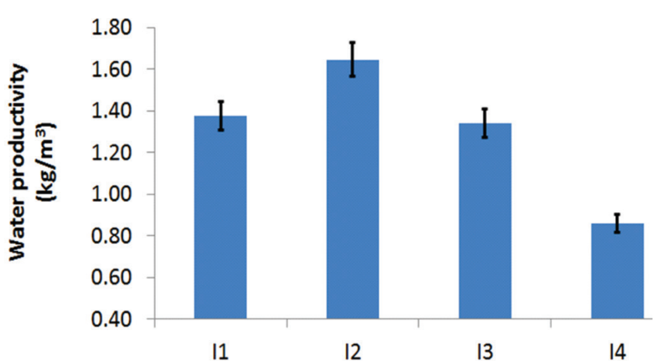

Figure 5: Water productivity of zero-till lady's finger under different irrigation regimes (mean of two years)

CONCLUSION

Overall, it could be concluded that summer lady's finger may be irrigated at 30% DASM under adequate moisture availability and at 50% DASM with yield penalty under inadequate irrigation water availability. Use of mulches like soybean, maize and rice residues could further improve water productivity and yields in okra.

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