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# Response of *Rabi* Sweet Corn to Different Irrigation and Fertigation Levels in Konkan Region of Maharashtra

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**Sweet corn is one of the most important and versatile emerging cereal crop contributing to economic security of the farmers in the Konkan region of Maharashtra. It is a potential crop in *rabi* season where irrigation facility is available. An investigation was carried out to evaluate the response of sweet corn to irrigation and fertigation grown in *manad* soils of Raigad district during the *rabi* seasons of 2014-15, 2015-16 and 2016-17 at Agriculture Research Station, Repoli, Tal. Mangaon, Dist. Raigad (Maharashtra) with the objective of saving irrigation water and fertilizers. The experiment was laid out in a split plot design with fifteen treatment combinations of three drip irrigation and five fertigation levels. A treatment with recommended package of practice for sweet corn was maintained separately as control. N, $P_2O_5$ and $K_2O$ was applied through fertigation in six equal splits at 15 days interval in all fertigation treatments by using water soluble fertilizers. Analysis of the pooled data revealed that the number of cobs $ha^{-1}$ (71825) and cob yield (18.86 t $ha^{-1}$) of sweet corn was significantly higher at irrigation level of 80% $ET_c$, but was at par with irrigation level of 60% $ET_c$. While, fertigation level of 80% of recommended N, P and K recorded significantly higher number of cobs $ha^{-1}$ (74871) and cob yield (20.87 t $ha^{-1}$) of sweet corn, however it was at par with fertigation level of 100% of recommended N, P and K. The interaction between the treatments were non-significant except during the 2016-27 season. Based on additional net returns of ₹15844 with incremental cost benefit ratio of 0.44 over control, application of irrigation at 80% $ET_c$ along with fertigation of 80% of recommended N, P and K through drip may be recommended for growing *rabi* sweet corn in the irrigated areas of Konkan region in Maharashtra.**

(***Key words:*** *Drip irrigation, Fertigation, Konkan region, Rabi sweet corn*)

Water is one of the most important inputs essential for the production of crops. Plants need it continuously during their life cycle and in huge quantities. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients and cell division besides some other processes. Both its shortage and excess affect the growth and development of a plant directly and consequently, its yield and quality. Rainfall is the cheapest source of natural water-supply for crop plants and it is abundant in the region during monsoon but it is scare in the summer months. Studies carried out across different countries including India have confirmed that irrigation plays a paramount role in increasing the use of inputs and enhancing cropping intensity as well as productivity of crops (Dhawan, 1988; Vaidyanathan *et al*., 1994). With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries located in arid and semi-arid regions, the problems of water scarcity are expected to be aggravated further (Biswas, 2001; Rosegrant, 1997; Rosegrant et al., 2002). Considering the water availability for future use and the increasing demand for water from different sectors, it is necessary to increase the water use efficiency, especially in the use of irrigation water. Uses of micro irrigation system helps to save water and increase water use efficiency.

Fertigation is the application of fertilizers and other water-soluble products through an irrigation system. It is practiced extensively in commercial agriculture and horticulture. As the fertilizers are applied in the root zone and at the right amounts as per the crop requirement, fertigation increases nutrient availability and improves the fertiliser use efficiency. There is saving of fertilizer up to 20 to 40% without affecting growth and yield of crop (Anonymous, 2001). Besides, it saves labours and energy in application of fertilizer and reduce environmental contamination by reducing leaching of nutrients.

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Sweet corn is newly introduced profit earning crop in the coastal area of Maharashtra state *i.e.* Konkan region. It is an exhaustive crop in both nutrient and water requirement. There is water scarcity in the region during summer months and sweet corn as *rabi* crop requires more water. Under such condition use of micro-irrigation such as drip will help in reducing irrigation water use while fertigation will save fertilizers. Keeping in view the above facts, the present study was conducted to study the performance of sweet corn crop under drip irrigation system at different irrigation regimes and fertigation levels.

## MATERIALS AND METHODS

Field experiments were carried out during the *rabi* seasons of 2014-15, 2015-16 and 2016-17 at Irrigation Research Scheme, Agricultural Research Station, Dr. B. S. Konkan Krishi Vidyapeeth, Repoli, Tal. Mangaon, Dist. Raigad, Maharashtra, India located at 18° 10′ 48″ N latitude and 73° 19′ 12″ E longitude having altitude of 12 m above mean sea level. The experiment was conducted in split plot design with three replications. The treatments comprised of three irrigation regimes, namely, $I_1$ - Irrigation level of 40% $ET_c$, $I_2$ - 60% $ET_c$ and $I_3$ - 80% $ET_c$, through drip as main plot treatments and five fertigation levels as sub plot treatments *viz.* $F_1$-100% recommended fertilizer dose through soil application, $F_2$-100% N through fertigation + 100% P and K through soil application, $F_3$-80% N through fertigation + 80% P and K through soil application, $F_4$-100% N, P and K through fertigation and $F_5$-80% N, P and K through fertigation. Besides a control treatment was maintained separately out of the experimental area which comprised of soil application of recommended fertilizer dose @ 200:60:60 kg of N, P and K ha$^{-1}$ and flood irrigation at 50 mm depth. Out of the recommended dose, full amounts of P and K, and half of N were applied as basal dose at the time of planting. The remaining half dose of nitrogen was applied in two equal splits at 30 and 60 DAS. Fertigation of N, P and K was done in six equal splits at 15 days interval in all the fertigation treatments by using water soluble fertilizers. The soil in the region is black locally known as *manad* soils. The soil of the experimental site was clay loam in texture with neutral pH having 0.70% organic carbon (Black, 1965), 236 kg ha$^{-1}$ available N (Subbiah and Asija, 1956), 21.30 kg ha$^{-1}$ available P (Bray and Kurtz, 1945) and 266 kg ha$^{-1}$ available K (Jackson, 1973). The field capacity and permanent wilting point values of the soil were estimated to be 32 and 16%, respectively by using field method. All recommended package of practices was followed uniformly across the treatments during the experiment period except irrigation and fertigation. In order to ensure better germination and initial crop stand two common irrigations were given to all the treatments. Observations were recorded on randomly selected 5 plants and on plot basis for yield contributing characters and yield.

Statistical analysis of the data regarding the characters studied during the course of investigation was carried out by analysis of variance as described by Gomez and Gomez (1983), Panse and Sukhatme (1967) and Rangaswamy (2010). The significant difference between the treatments was tested by 'F' test at 5% level of significance. The critical difference was calculated when difference among the treatments was found to be significant by 'F' test.

## RESULTS AND DISCUSSION

### Quantity of water applied and water use efficiency

Data regarding average monthly evaporation and monthly water applied in the different irrigation regimes are presented in Table 1. Data revealed that less water (97.12 ha-cm) was applied in irrigation regime of 40% of $ET_c$, which resulting in saving of about 73% of water over control. In the control treatment where flood irrigation was followed more water was applied *i.e.* 359.41 ha-cm. The water saving in drip irrigation varied from 50 to 73% over that used in flood irrigation.

The data regarding water use efficiency and estimated additional area that can be brought under sweet corn due to saving of water is presented in Table 2. The highest water use efficiency (159.29 kg ha-mm$^{-1}$) was recorded in the treatment $I_1$ (Drip irrigation given at 40% of $ET_c$) as compared to other irrigation treatments under study. Lowest water use efficiency was recorded in the control. The water saved under drip irrigation could be used to bring additional area under cultivation of sweet corn. It was estimated that under the treatment

***Table 1.*** *Average monthly evaporation and volume of water applied to sweet corn crop under different treatments (2014-15-2016-17)*

| Month | Evaporation (mm) | $ET_c$ (mm) | Water applied (ha-cm) | | | |
|---|---|---|---|---|---|---|
| | | | $I_1$ | $I_2$ | $I_3$ | Control |
| February | 103.10 | 31.42 | 20.39 | 23.92 | 27.45 | 75.27 |
| March | 169.03 | 77.80 | 31.13 | 46.71 | 62.29 | 126.33 |
| April | 196.43 | 99.66 | 39.86 | 59.80 | 79.71 | 130.41 |
| May | 32.40 | 14.39 | 5.75 | 8.62 | 11.51 | 27.40 |
| Total | 500.96 | 223.27 | 97.12 | 139.05 | 180.96 | 359.41 |
| Percent water saving over control | | | 72.98 | 61.31 | 49.65 | - |

***Table 2.*** *Estimated area can be brought under sweet corn due to effect of different irrigation treatments*

| Particulars | $I_1$ | $I_2$ | $I_3$ | Control |
|---|---|---|---|---|
| Water used (mm) | 97.12 | 139.05 | 180.96 | 359.41 |
| Yield of sweet corn (t ha$^{-1}$) | 15.47 | 17.76 | 18.86 | 21.44 |
| Input cost (₹) | 109517 | 109637 | 109757 | 90428 |
| Gross return (₹) | 154660 | 177647 | 188627 | 214400 |
| Net income (₹) | 45143 | 68005 | 78870 | 123973 |
| Additional area respect to water saving (ha) | 0.73 | 0.61 | 0.50 | - |
| Additional input cost (₹) | 79947 | 66879 | 54879 | - |
| Additional yield of sweet corn (t ha$^{-1}$) | 11.29 | 10.83 | 9.43 | - |
| Additional gross return (₹) | 112900 | 108300 | 94300 | - |
| Additional net income (₹) | 32953 | 41422 | 39421 | - |
| Total Net income (₹) | 78096 | 109427 | 118291 | 123973 |
| Total yield of sweet corn (t ha$^{-1}$) | 26.76 | 28.59 | 28.29 | 21.44 |
| WUE (kg ha-mm$^{-1}$) | 159.29 | 127.72 | 104.22 | 59.65 |

$I_1$ (Drip irrigation treatment given at 40% of $ET_c$) more additional area can be brought under sweet corn crop as compared to other treatments even though its estimated additional income was less as compared to rest of drip irrigation regimes under study. While, with water saving in irrigation treatment $I_3$ (Drip irrigation given at 80% of $ET_c$), additional 50% area can be brought under sweet corn crop which is less than treatment $I_1$, and the estimated total net income was highest as compared to other drip irrigation regimes. The total estimated net income was highest in the control treatment consisting of flood irrigation.

**Effect of irrigation regimes on cob number and yield**

A perusal of the data on number of cobs ha$^{-1}$ under different irrigation regimes (Table 3) revealed that during the first two years of study (2014-15 and 2015-16), the number of cobs ha$^{-1}$ was not significantly different among the three irrigation regimes. However, treatment $I_2$ (drip irrigation given at 60% $ET_c$) recorded numerically higher number of cobs (71010) during year 2014-15, while during 2015-16, the highest number of cobs ha$^{-1}$ (75573) was recorded in treatment $I_3$ (drip irrigation given at 80% $ET_c$) over rest of irrigation regimes under study. The numbers of cobs ha$^{-1}$ during the year 2016-17 of study and in pooled analysis was influenced significantly due to different irrigation regimes. Significantly higher number of cobs ha$^{-1}$ (69094 and 71825) was recorded in the treatment $I_3$ (drip irrigation given at 80% of $ET_c$) during year 2016-17 and in poled analysis, respectively. However, in treatment $I_2$ (drip irrigation given at 60% of $ET_c$), statistically at par number of cobs ha$^{-1}$ (63448 and 69791) was observed during 2016-17 and in pooled analysis.

The data on cob yield recorded in different irrigation

***Table 3.*** *Effect of different irrigation regimes and fertigation levels on number of cobs*

| Treatments | Number of cobs ha$^{-1}$ | | | |
|---|---|---|---|---|
| Main plot: Irrigation levels | 2014-15 | 2015-16 | 2016-17 | Pooled |
| $I_1$: Drip irrigation at 40% $ET_c$ | 70637 | 74259 | 40668 | 61855 |
| $I_2$: Drip irrigation at 60% $ET_c$ | 71010 | 74916 | 63448 | 69791 |
| $I_3$: Drip irrigation at 80% $ET_c$ | 70808 | 75573 | 69094 | 71825 |
| SE± | 318 | 941 | 3359 | 2022 |
| C.D. at 5 % | NS | NS | 13190 | 6232 |
| Sub plot: Fertigation levels | | | | |
| $F_1$: 100 % recommended fertilizer through soil application | 70679 | 72503 | 38933 | 60705 |
| $F_2$: 100% N through fertigation +100% P and K through soil application | 70679 | 75252 | 56469 | 67467 |
| $F_3$: 80% N through fertigation +80% P and K through soil application | 70567 | 73626 | 48231 | 64141 |
| $F_4$: 100% N, P and K through fertigation | 71151 | 76515 | 68135 | 71934 |
| $F_5$: 80% N, P and K through fertigation | 71016 | 76684 | 76915 | 74871 |
| SE± | 448 | 1509 | 2165 | 2023 |
| C.D. at 5 % | NS | NS | 6318 | 5702 |
| Interactions | | | | |
| SE± | 776 | 2614 | 3749 | 3504 |
| C.D. at 5 % | NS | NS | 10944 | NS |
| Control ($I_0$) | 68939 | 75421 | 53932 | 66097 |

***Table 3a.*** *Number of cobs as affected by interaction effect of various treatments (2016-17)*

| Treatments | $I_1$ | $I_2$ | $I_3$ | Mean |
|---|---|---|---|---|
| $F_1$ | 30812.33 | 42093.00 | 43894.67 | 38933.33 |
| $F_2$ | 39663.33 | 57026.00 | 72717.00 | 56468.78 |
| $F_3$ | 32989.33 | 51629.00 | 60073.33 | 48230.56 |
| $F_4$ | 45708.67 | 86450.33 | 72246.67 | 68135.22 |
| $F_5$ | 54167.00 | 80039.33 | 96538.00 | 76914.78 |
| Mean | 40668.13 | 63447.53 | 69093.93 | |

regimes are presented in Table 4. During the first year of study (2014-15) irrigation regimes did not influence the cob yield. However, different irrigation regimes through drip irrigation had significant effect on cob yield during the years 2015-16, 2016-17 of study and also in pooled analysis. The treatment $I_3$ (Drip irrigation given at 80 % of $ET_c$) recorded significantly higher cob yield during the years 2015-16 (21.39 t ha$^{-1}$) and 2016-17 (22.82 t ha$^{-1}$) of study, and in pooled analysis (18.86 t ha$^{-1}$). However, it was statistically at par with treatment $I_2$ (Drip irrigation given at 60% of $ET_c$) which recorded cob yield of 19.66, 20.93 and 17.76 t ha$^{-1}$, respectively during 2015-16, 2016-17 and in poled analysis.

Due to adequate and optimum moisture supply in higher irrigation regimes under drip irrigation the plants tend to become physiologically more active leading to increase in yield and yield attributes. The lower irrigation regimes might be responsible for water stress which resulted in poor plant growth due to restriction imposed on nutrient translocation, photosynthesis and metabolic activities of plant system. Bibe *et al*. (2017) reported decreasing trends in yield and yield attributes of maize with subsequent decrease in irrigation regimes. Similar findings have also been reported by Bahadur *et al*. (2009), Bharati *et al*. (2007) and Patil *et al*. (2011).

**Effect of fertigation levels on cob number and yield**

The data on number of cobs at different fertigation

***Table 4.*** *Effect of different irrigation regimes and fertigation levels on cob yield*

| Treatments | Cob yield (t $ha^{-1}$) | | | |
|---|---|---|---|---|
| Main plot: Irrigation levels | 2014-15 | 2015-16 | 2016-17 | Pooled |
| $I_1$: Drip irrigation at 40% $ET_c$ | 13.66 | 18.88 | 13.86 | 15.47 |
| $I_2$: Drip irrigation at 60% $ET_c$ | 12.70 | 19.66 | 20.93 | 17.76 |
| $I_3$: Drip irrigation at 80% $ET_c$ | 12.38 | 21.39 | 22.82 | 18.86 |
| SE± | 0.36 | 0.44 | 0.90 | 0.62 |
| C.D. at 5 % | NS | 1.73 | 3.55 | 1.90 |
| Sub plot: Fertigation levels | | | | |
| $F_1$: 100 % recommended fertilizer through soil application | 13.28 | 16.80 | 12.69 | 14.25 |
| $F_2$: 100% N through fertigation +100% P and K through soil application | 12.52 | 19.55 | 18.65 | 16.90 |
| $F_3$: 80% N through fertigation +80% P and K through soil application | 12.93 | 19.21 | 15.78 | 15.97 |
| $F_4$: 100% N, P and K through fertigation | 12.49 | 20.91 | 23.06 | 18.82 |
| $F_5$: 80% N, P and K through fertigation | 13.35 | 23.43 | 25.83 | 20.87 |
| SE± | 0.49 | 0.83 | 0.57 | 0.73 |
| C.D. at 5 % | NS | 2.42 | 1.66 | 2.09 |
| Interactions | | | | |
| SE± | 0.85 | 1.44 | 0.98 | 1.26 |
| C.D. at 5 % | NS | NS | 2.87 | NS |
| Control ($I_0$) | 16.80 | 23.75 | 23.77 | 21.44 |

***Table 4a.*** *Cob yield as affected by interaction effect of various treatments (2016-17)*

| Treatments | $I_1$ | $I_2$ | $I_3$ | Mean |
|---|---|---|---|---|
| $F_1$ | 9.54 | 15.14 | 13.39 | 12.69 |
| $F_2$ | 13.87 | 18.26 | 23.81 | 18.65 |
| $F_3$ | 11.93 | 16.17 | 19.24 | 15.78 |
| $F_4$ | 15.16 | 28.85 | 25.18 | 23.06 |
| $F_5$ | 18.79 | 26.23 | 32.48 | 25.83 |
| Mean | 13.86 | 20.93 | 22.82 | |

levels are presented in Table 3. During 2014-15 as well as 2015-16, it was observed that the number of cobs was not influenced significantly by the fertigation levels. However, it was significantly influenced by fertigation levels during the year 2016-17 and in pooled analysis. The treatment $F_5$ (80% N, P and K through fertigation) registered significantly higher number of cobs during 2016-17 (76915) and in pooled analysis (74871) over rest of the treatments except treatment $F_4$ (100% N, P and K through fertigation) which was found to be statistically at par with in pooled analysis.

During the first year (2014-15) of study, fertigation levels did not significantly influence the cob yield, However, it has a significant influence on the cob yield during the years 2015-16, 2016-17 and in pooled analysis. Significantly highest cob yield was registered during 2015-16 (23.43 t $ha^{-1}$) and 2016-17 (25.83 t $ha^{-1}$) in the treatment $F_5$ consisting of 80% N, P and K through fertigation as compared to rest of the treatments.In pooled analysis,this treatment alsorecorded significantly highest cob yield than rest of the treatments except treatment $F_4$ (100% N, P and K through fertigation) which recorded at par yield.

The increase in yield and yield attributes may be ascribed to better availability of the nutrients to the plants under drip fertigation through the water soluble fertilizers. Application of water soluble fertilizers in splits through drip fertigation results in lower losses and better uptake of the nutrients by the crop plants (Ibrahim *et al*., 2016; Patil *et al*., 2012). These findings are in conformity with those reported by Basava *et al*. (2012), Bibe *et al*. (2017) and Patil *et al*. (2011).

**Interaction effect**

The interaction effect between irrigation regimes and fertigation levels was found non-significant for both the number of cobs and cob yield of sweet corn except during the year 2016-17 (Tables 3 and 4). The treatment combination of $I_3F_5$ (Drip irrigation given at 80% of $ET_c$ with application of 80% N, P and K through fertigation) recorded significantly highest number of cobs over the other treatment combinations (Table 3a). Similarly, significantly highest cob yield was recorded in the treatment combination of $I_3F_5$ (Drip irrigation given at 80% of $ET_c$ with application of 80% N, P and K through fertigation) compared to rest of the treatment combinations.

**Economics**

The economics of sweet corn under different treatments is presented in Table 5. It is revealed from the data that the treatment $I_3F_5$ (Drip irrigation given at 80% of $ET_c$ with 80% N, P and K applied through fertigation) recorded higher gross return (₹ 2,30,244) as well as additional gross returns over control (₹ 15,844)as compared to rest of treatment combinations under study. In case of net return alsothe same treatment $I_3F_5$ recorded higher net return (₹ 1,04,022) as compared to rest of the treatment combinations. However, highest net return (₹ 1,23,973) was recorded in the control treatment. Highest incremental cost benefit ratio (0.44) was recorded in the treatment $I_3F_5$ *i.e.* drip irrigation given at 80% of $ET_c$ with 80% N, P and K applied through fertigation over rest of the treatment combinationsand control.

***Table 5.*** *Economics of the different treatments*

| Sr. No. | Treatments | Cob yield (t ha$^{-1}$) | Gross return (₹) | Additional gross return over control | Input cost (₹) | Additional input cost over control | Net return (₹) | Incremental cost benefit ratio |
|---|---|---|---|---|---|---|---|---|
| 1 | $I_1F_1$ | 12.86 | 128615 | -85785 | 95926 | 5498 | 32689 | -15.60 |
| 2 | $I_1F_2$ | 15.52 | 155236 | -59164 | 95926 | 5498 | 59310 | -10.76 |
| 3 | $I_1F_3$ | 15.47 | 154692 | -59708 | 94460 | 4033 | 60232 | -14.81 |
| 4 | $I_1F_4$ | 15.38 | 153817 | -60583 | 135294 | 44867 | 18523 | -1.35 |
| 5 | $I_1F_5$ | 18.09 | 180941 | -33459 | 125982 | 35555 | 54959 | -0.94 |
| 6 | $I_2F_1$ | 14.59 | 145909 | -68491 | 96046 | 5618 | 49863 | -12.19 |
| 7 | $I_2F_2$ | 17.10 | 170988 | -43412 | 96046 | 5618 | 74942 | -7.73 |
| 8 | $I_2F_3$ | 15.50 | 155030 | -59370 | 94580 | 4153 | 60450 | -14.30 |
| 9 | $I_2F_4$ | 20.13 | 201325 | -13075 | 135414 | 44987 | 65911 | -0.29 |
| 10 | $I_2F_5$ | 21.50 | 214963 | 563 | 126102 | 35675 | 88861 | 0.02 |
| 11 | $I_3F_1$ | 15.31 | 153126 | -61274 | 96166 | 5738 | 56960 | -10.68 |
| 12 | $I_3F_2$ | 18.09 | 180883 | -33517 | 96166 | 5738 | 84717 | -5.84 |
| 13 | $I_3F_3$ | 16.95 | 169462 | -44938 | 94700 | 4273 | 74762 | -10.52 |
| 14 | $I_3F_4$ | 20.94 | 209421 | -4979 | 135534 | 45107 | 73887 | -0.11 |
| 15 | $I_3F_5$ | 23.02 | 230244 | 15844 | 126222 | 35795 | 104022 | 0.44 |
| 16 | control | 21.44 | 214400 | - | 78428 | - | 123973 | - |

Rate of cob ₹ 10.00 per kg

In the present study, the treatment combination consisting of irrigation regime of 80% $ET_c$ with drip irrigation and fertigation with 80% of recommended N, P and K dose recorded higher cob yield of sweet corn (23.02 t ha$^{-1}$) with additional net profit of ₹ 15,844 and incremental cost benefit ratio (0.44) over rest of treatment combinations under study. In addition, there was saving of irrigation water to the tune of 50% over control. Therefore, it may be recommended that for obtaining higher yield and returns in the Konkan region, *rabi* sweet corn may be irrigated at 80% $ET_c$ with drip irrigation along with fertigation of 80% of recommended N, P and K dose.

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