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Effect of irrigation and fertigation schedules on yield of cabbage *(Brassica Oleracea var. Capitata)*

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Abstract
The field experiment was conducted during 2016-2017 and 2017-2018 to investigate the effect of irrigation and fertigation schedules on yield of cabbage during the winter season at AICRP on Water Management, VNMKV, Parbhani. Drip method with alternate day irrigation was adopted for all the plots with five irrigation levels as main plot *viz.,* 0.4 ETc (I_1), 0.6 ETc (I_2), 0.8 ETc (I_3), 1.0 ETc (I_4) and 1.2 ETc (I_5). Fertigation levels were 50% (F_1), 75% (F_2) and 100% (F_3) of recommended dose of fertilizers (120:60:60; N: P_2O_5:K_2O kg ha^{-1}) with eight splits during crop growth period. All the treatments were replicated thrice. The treatment combination of 1.0 ETc with 125% RDF, 1.0 ETc with 100% RDF and 0.8 ETc with 100% RDF give comparable and better cabbage yields. Hence the combination treatment of drip irrigation at 0.8 ETc and fertilizer level of 100% RDF may be adopted to obtain higher yields with net saving in water and fertilizers. The economic analysis of cabbage under drip fertigation also suggests that the drip irrigation at 0.8 ETc and fertilizer level of 100% RDF is more economical and feasible as compared to all other combinations.

Keywords: Drip irrigation, Irrigation scheduling, Fertigation

Introduction

Cabbage, one of the important vegetable crops, requires comparatively more water and nutrients in precise quantity and is very sensitive to moisture and nutrient stress. Conventional methods of irrigation and fertilization results in losses of water and nutrients through leaching, surface runoff, absorption on clay fraction and also create adverse condition for plant growth like water logging to some extent. Nevertheless, water scarcity and high input cost of fertilizer are other constraints in increasing the area, production and productivity of cabbage. Drip fertigation therefore is the most suitable option, which can efficiently use and save water and fertilizer in addition to increase in the area along with increasing productivity. Research on drip irrigation conducted so far in India and abroad has shown that this method leads not only the appreciable saving of water but also returns in achieving higher crop yields as compared to surface irrigation method. Much of work has been done on growth and yield response of various vegetable crops under drip including scheduling. Most of the field studies were conducted with irrigation levels based on pan evaporation data. However, the studies on irrigation schedule based on crop coefficient and real time evapotranspiration data and fertigation scheduling are limited. Similarly, the work on vegetable crop growth simulation under various full and deficit water and fertilizer conditions are scanty. In quest of the above considerations, a comprehensive field investigation was carried out in heavy black soil to evaluate the effect of various irrigation and fertigation levels on cabbage (*Brassica Oleracea var. Capitata)* crop growth and yield.

Material and Methods

Two field experiments were conducted on cabbage (*Brassica Oleracea var. Capitata)* during two growing seasons: January through May 2017 and 2018 in a split plot randomized block design at Research Farm of All India Coordinated Research Project on Irrigation Water Management, VNMKV Parbhani. The experimental plots were 7.2 x 7.5 m size with a buffer strip of 1 m and 2 m kept between two adjacent plots and within replications, respectively. Drip method with alternate day irrigation was adopted for all the plots with five irrigation levels as main plot viz., 0.4 ETc (I_1), 0.6 ETc (I_2), 0.8 ETc (I_3), 1.0 ETc (I_4) and 1.2 ETc (I_5).

Fertigation levels were 50% (F_1), 75% (F_2) and 100% (F_3) of recommended dose of fertilizers (120:60:60; N: P_2O_5:K_2O kg ha^{-1}) with eight splits during crop growth period. All the treatments were replicated thrice.

Irrigation scheduling

Irrigation water was applied as per the irrigation levels at 0.4, 0.6, 0.8, 1.0 and 1.2 times ETc. The daily crop water requirement for cabbage was estimated using crop coefficient and reference crop evapotranspiration. The crop evapotranspiration ETc was calculated using the following equation

$$ETc = Kc \times ETo$$

Where,

ETc - Crop evapotranspiration [mm d^{-1}]

Kc - Crop coefficient [dimensionless]

ETo - Reference crop evapotranspiration [mm d^{-1}]

The daily reference crop evapotranspiration (ETo) was estimated by using daily meteorological data collected from the meteorological observatory. The reference crop evapotranspiration was estimated using the FAO Penman-Monteith equation (Allen *et al.*, 1998) [2]. using the following equation

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,\frac{900}{T+273}\,u_2\,(e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)}$$

Where,

ETo - Reference evapotranspiration [mm day^{-1}]

Rn - Net radiation at the crop surface [MJ m^{-2} day^{-1}]

G - Soil heat flux density [MJ m^{-2} day^{-1}]

T - Mean daily air temperature at 2 m height [°C]

u_2 -Wind speed at 2 m height [m s^{-1}]

es - Saturation vapour pressure [KPa]

ea - Actual vapour pressure [KPa]

(es-ea) - Saturation vapour pressure deficit [KPa]

Δ - Slope vapour pressure curve [KPa °C^{-1}]

γ - Psychrometric constant [KPa °C^{-1}]

Crop coefficient

The crop coefficient varies according to crop type, growth stages and local climatic conditions. The FAO-56 curve method was used to estimate the local value of the crop coefficient. The stage wise crop coefficients of cabbage were derived from FAO 56 and were modified as per the climatic parameters of Parbhani by following the standard procedure and guidelines suggested in Allen *et al.*, (1998) [2].

Fertilizer application

For cabbage the recommended dose of fertilizers as 120:60:60 kg ha^{-1} N, P and K was used. In fertigation water soluble graded fertilizers such as (Urea, 19:19:19) were applied in 8 splits as per the treatment. The weighted quantity of fertilizers designed for the treatments were dissolved in water by continuous stirring and the fertilizer solution was injected through venturi in the main pipeline by creating the pressure difference.

Field data collection and analysis

In order to study the effect of irrigation and fertigation levels on growth and yield of cabbage crop, the data on the plant and growth attributes of the cabbage crop were collected periodically during the experimental periods (2016-17 and 2017-18). The collected data was analysed further for interpretations.

After transplanting 5 plants were randomly selected from each plot and were properly labeled. The crop growth parameters were recorded from these plants approximately at 15 days interval to monitor their growth. The observations at harvest such as weight of curd and curd yield were recorded for all the plants in the plot.

Curd yield of cabbage

Data pertaining to yield of cabbage (q ha^{-1}) as influenced by different irrigation and fertigation levels is presented in Table 1.

Table 1: Curd yield of cabbage (q ha^{-1}) as influenced by different irrigation and fertigation levels.

Treatment	Yield (q ha^{-1})		
	2016-2017	2017-2018	Pooled
Irrigation schedules			
I_1: 0.4 ETc	279.04	236.85	257.95
I_2: 0.6 ETc	346.80	296.19	321.49
I_3: 0.8 ETc	426.37	371.48	398.92
I_4: 1.0 ETc	438.79	386.65	412.72
I_5: 1.2 ETc	388.14	333.75	360.95
SE±	4.83	6.29	5.17
CD at 5%	14.24	18.56	15.24
Fertigation levels			
F_1: 75% RDF	351.09	303.16	327.13
F_2: 100% RDF	385.02	331.93	358.47
F_3: 125% RDF	391.37	339.86	365.61
SE±	3.09	3.67	3.28
CD at 5%	9.12	10.83	9.68
Interaction (IxF)			
SE±	4.56	5.18	5.04
CD at 5%	13.45	15.27	14.88
GM	375.83	324.98	350.41

Effect of irrigation schedules on curd yield

The data furnished in Table 1 revealed that application of irrigation through drip at 1.0 ETc (I_4) recorded significantly higher curd yield (438.79, 386.65 and 412.72 q ha^{-1}) over rest of the irrigation schedules. However, it was at par with irrigation at 0.8 ETc (426.37, 371.48 and 398.92 q ha^{-1}) during 2016-2017, 2017-2018 and in pooled results. Lower yields (279.04, 236.85 and 257.95 q ha^{-1}) were noticed in 0.4 ETc (I_1) treatment during these years.

The higher yield with 1.0 ETc (I_4) and 0.8 ETc (I_3) treatments might be due to availability of sufficient water to boost the overall vegetative growth and biological efficiency of plant whereas and the lowest yield under 0.4 ETc (I_1) may be due to water stress. An increase in cabbage yield with 0.8 ETc (I_3) treatment could be attributed to the optimum moisture content near to field capacity which helped roots to absorb optimum water and nutrient to satisfy the crop needs

The effective root zone of cabbage is reported to be 15-30 cm. Excess moisture tends to leach down the nutrients beyond the root zone. Hence treatment I_5 did not gave maximum yield of cabbage.

Effect of fertigation levels on curd yield

Fertigation at 125% RDF recorded significantly highest curd yields (391.37, 339.86 and 365.61 q ha^{-1}) which were at par with fertigation at 100% RDF (385.02, 331.93 and 358.47 q ha^{-1}). They were superior over fertigation at 75% RDF

(351.09, 303.16 and 327.13 q ha^{-1}) during 2016-2017 and 2017-2018 and in pooled results, respectively.

Higher yields under F_3 (fertigation at 125% RDF) and F2 (fertigation at 100% RDF) may be due to higher application of nutrients, their mobilization and availability at regular interval in required quantity resulting in better yields.

Interaction effects on curd yield of cabbage

The data presented in Table 2, 3 and 4 shows the interaction effects of irrigation schedules and fertigation levels on curd yield of cabbage during 2016-17, 2017-18 and in pooled results. These are also depicted in Fig. 1 through 3.

Data presented in Table 1 indicated that the combination I_4F_3 (drip irrigation at 1.0 ETc with 125% RDF) was superior showing highest curd yield (456.53 q ha^{-1}) over all other combinations of treatments during 2016-2017. This was at par with I_4F_2 (drip irrigation at 0.1 ETc with 100% RDF) and I_3F_2 (drip irrigation at 0.8 ETc with 100% RDF) which showed curd yield of 448.63, and 445.13 q ha^{-1}, respectively.

Similar results are also seen during 2017-18 where treatment combination of I_4F_3 (irrigation at 1.0 ETc and 125% RDF (I_4F_3) recorded significantly highest curd yield (407.62 q ha^{-1}) among all treatment combinations and was at par with I_4F_2 (irrigation at 1.0 ETc and 125% RDF) and I_3F_2 (irrigation at 0.8 ETc and 100% RDF) showing curd yield of 398.45, 395.38 q ha^{-1}.

The pooled results also indicated that the combination I_4F_3 is superior by recording curd yield of 432.07 q ha^{-1} over rest of the combinations and was at par with I_4F_2 (423.54 q ha^{-1}) and I_3F_2 (420.26 q ha^{-1}) (Fig. 4.15). The lowest curd yield of 259.97, 219.59 and 239.78 q ha^{-1} was recorded under I_1F_1 during 2016-2017, 2017-2018 and in pooled results.

The higher yields in I_4F_3, I_4F_2 and I_3F_2 combinations might be due to uniform distribution and adequate availability of nutrients and moisture in the root zone of the crop. On the other hand, the lowest yield under combination I_1F_1 might be due to low uptake of nutrients by the plants under inadequate irrigation and fertigation level (drip irrigation with 40% ETc and 75% RDF).

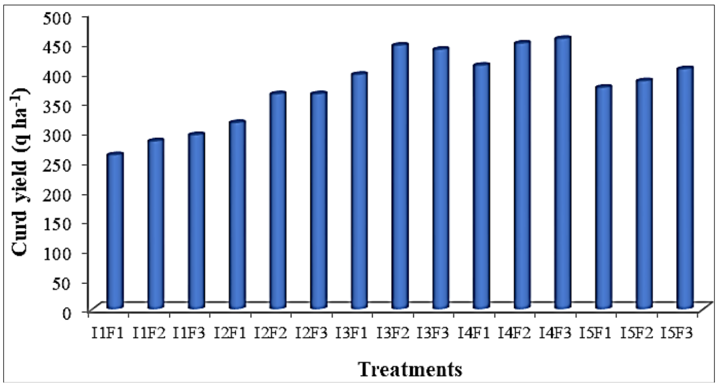

Fig 1: Interaction effect (IxF) on curd yield of cabbage during 2016-2017

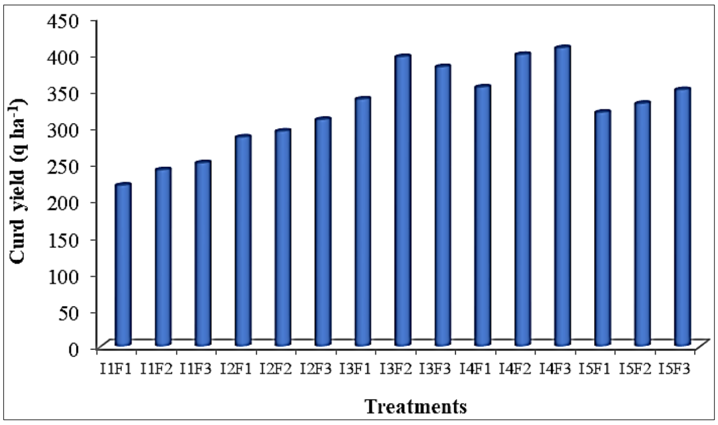

Fig 2: Interaction effect (IxF) on curd yield of cabbage during 2017-2018

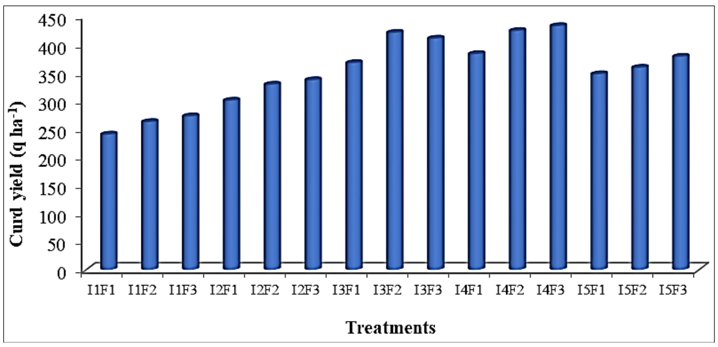

Fig 3: Interaction effect (IxF) on curd yield of cabbage (Pooled)

Table 1: Interaction effect (IxF) on curd yield of cabbage (q ha^{-1}) during 2016-2017

Treatment	Fertigation levels		
Irrigation schedules	F_1: 75% RDF	F_2: 100% RDF	F_3: 125% RDF
I_1: 0.4 ETc	259.97	283.37	293.80
I_2: 0.6 ETc	314.43	362.93	363.03
I_3: 0.8 ETc	395.80	445.13	438.17
I_4: 1.0 ETc	411.20	448.63	456.53
I_5: 1.2 ETc	374.07	385.03	405.33
SE±	4.56		
CD at 5%	13.45		

Table 2: Interaction effect (IxF) on curd yield of cabbage (q ha^{-1}) during 2017-2018

Treatment	Fertigation levels		
Irrigation schedules	F_1: 75% RDF	F_2: 100% RDF	F_3: 125% RDF
I_1: 0.4 ETc	219.59	240.71	250.25
I_2: 0.6 ETc	285.46	293.60	309.50
I_3: 0.8 ETc	337.45	395.38	381.60
I_4: 1.0 ETc	353.87	398.45	407.62
I_5: 1.2 ETc	319.42	331.51	350.32
SE±	5.18		
CD at 5%	15.27		

Table 3: Interaction effect (IxF) on curd yield of cabbage (q ha^{-1}) (Pooled)

Treatment	Fertigation levels		
Irrigation schedules	F_1: 75% RDF	F_2: 100% RDF	F_3: 125% RDF
I_1: 0.4 ETc	239.78	262.04	272.02
I_2: 0.6 ETc	299.94	328.26	336.26
I_3: 0.8 ETc	366.62	420.26	409.89
I_4: 1.0 ETc	382.54	423.54	432.07
I_5: 1.2 ETc	346.75	358.27	377.82
SE±	5.04		
CD at 5%	14.88		

Conclusion

The treatment combination of 1.0 ETc with 125% RDF, 1.0 ETc with 100% RDF and 0.8 ETc with 100% RDF give comparable and better cabbage yields. Hence the combination treatment of drip irrigation at 0.8 ETc and fertilizer level of 100% RDF may be adopted to obtain higher yields with net saving in water and fertilizers. The cost economics of cabbage under drip fertigation also suggests that the drip irrigation at 0.8 ETc and fertilizer level of 100% RDF is more economical and feasible as compared to all other combinations.

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