Deficit Irrigation Management Practice for Major Crops in Kunigal Command Area

R. Shreedhar, Dr. A.V.Shivapur & Nithya B.K.

ABSTRACT: The increase in water demand has resulted in new methods of saving water worldwide with about 70% of water being used in agriculture globally, water saving techniques has to be practiced. Irrigation technologies and irrigation scheduling may be adopted for more effective and rational uses of limited supplies of water. Deficit irrigation is one of the methods designed to ensure the optimal use of allocated water. It maximizes water use efficiency for better yields per unit of irrigation water applied through by exposing the crops to a certain level of water stress either during a particular period or throughout the growing season. A study is carried out to review the crop yield responses to deficit irrigation in Kunigal command areas. The major crops taken for study include rice, pulses, groundnut, sugarcane and millet (ragi). Simulation are carried out using agro-climatic data development of irrigation schedules under deficit irrigation and evaluation of current irrigation practices were done by crop growth simulation software CROPWAT 8.0 developed by FAO. From the simulation, it is evident that deficit irrigation incurs yield reductions in proportional to water stress magnitudes but saves substantial amount of water. The recommended deficit irrigation practice is to water stress the crop during mid stage of crop cycle thus saving more water & incurring acceptable yield reductions to the farmers.

Index terms: Deficit irrigation, water stress, yield reduction, rainfed, full irrigation, evapotranspiration

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1. Introduction

Irrigation supply under deficit irrigation is reduced relative to that needed to meet maximum evapo-transpiration. Therefore, water demand for irrigation can be reduced and the water saved can be diverted for alternative uses. Even though deficit irrigation is simply a technique aimed at the optimization of economic output in limited water , the reduction in the supply for irrigation to an area imposes many adjustments in the agricultural system. Thus, deficit irrigation practices are multipurpose, inducing changes at the levels of socio-economical technical, and institutional.

Among traditional methods of irrigation system, the deficit irrigation practice is different. The manager is required to know the amount of allowable transpiration deficiency without causing any significant reduction of yield. The water use efficiency for a crop has to be increasing by adopting deficit irrigation practices and eliminate such irrigations which has less impact on the yield of the crop. The benefits gained by utilizing the saved water to irrigate other crops by compromising with reduction in yield may be taken into account. For successful deficit irrigation practice, it is necessary to consider the soil's

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water retention capacity. Also it is essential to know the yield response of a crop when subjected to water stress. The crop varieties also play a significant role when the crop is subjected to water stress. Generally low yielding varieties are less sensitive to water stress than high yielding varieties. For example, yield reduction in case of new maize varieties as compared to traditional varieties when deficit irrigation is applied. Crops of short growing season are more effective for deficit irrigation and are also tolerant to drought. CROPWAT [1] is practical tool to help agrometeorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. Ali Abdzad Gohari adopted the CROPWAT model to appropriately estimate the yield reduction caused by water stress and climatic impacts. The simulation results analysis suggest that in both condition rainfed and irrigated, the largest yield reduction occurred in the stage three (developmental stage) [2]. Kirda concluded that the proper application of deficit irrigation practices can generate significant savings in allocation of water in irrigation. Among field crops, groundnut, banana, vegetables, common bean and sugarcane show proportionately less yield reduction obtained under various levels of reduced evapotranspiration[3]. Dhanapal et al conducted that the proper application of deficit irrigation practices can generate significant in irrigation water allocation. Among filed crops, groundnut, soybean, common bean and sugar cane show proportionately less yield reduction [4]. Li and Barker introduce the research on practices to increase water productivity for paddy irrigation in China and summarize the experience on implementation of the alternate wetting and drying (AWD) irrigation technique. Considerable benefits have been realized from the adoption of AWD. However, farmers must be persuaded through demonstration and training that yields can be maintained with application of less water [5]. A study was carried out by Nithya et al to determine the crop water requirement of some selected crops for the command area in Kunigal taluk. These crops include rice, pulses, groundnut, sugarcane and millet (ragi). Crop water requirement for each of the crops was determined using 30-year climatic data in CROPWAT. Reference crop evapotranspiration (ETo) was determined using the FAO Penman Monteith method [6]. Hence a study was carried out to review the crop yield responses to deficit irrigation for the major crops in Kunigal command area and presented in this paper.

2. Study area

Kunigal as shown in Figure 1.0 is located around 35 km south of Tumkur on the Bangalore-Hassan road, and 75 km from Bangalore city‖. Kunigal is situated at a latitude of 12.45°N and longitude of 76.20°E. It has a normal altitude of 726 m. The Annual normal precipitation of the kunigal is 593.0 mm. Tumkur area comes under farming—zone 4 (Central dry zone), zone 5(Eastern dry zone) and zone 6 (Southern dry zone)‖.—The Zone 4 comprises of 6 taluks to be specific Chikkanayakanahali, Tiptur, Koratagere, Sira, Madhugiri and Pavagada. The Zone 5 comprises of Gubbi and Tumakuru taluks and the Zone 6 comprises of Kunigal and Turuvekere taluks‖. The south west storm begins ordinarily from 1st week of June and maximum precipitation is in mid September.

Close to Marconahalli, a dam has been constructed across the Shimsha River which is the biggest reservoir in the district‖. Marchonahally Dam, (Markonahalli Reservoir) is the life-saving water source as it irrigates more than 6,000 hectares of land in and around Kunigal. It is situated around 50 km from Tumkur town. Markonahalli reservoir is considered to be the best water resources project because of its automatic siphon spillways which efficiently controls the flood thus requiring no operation of gates manually.

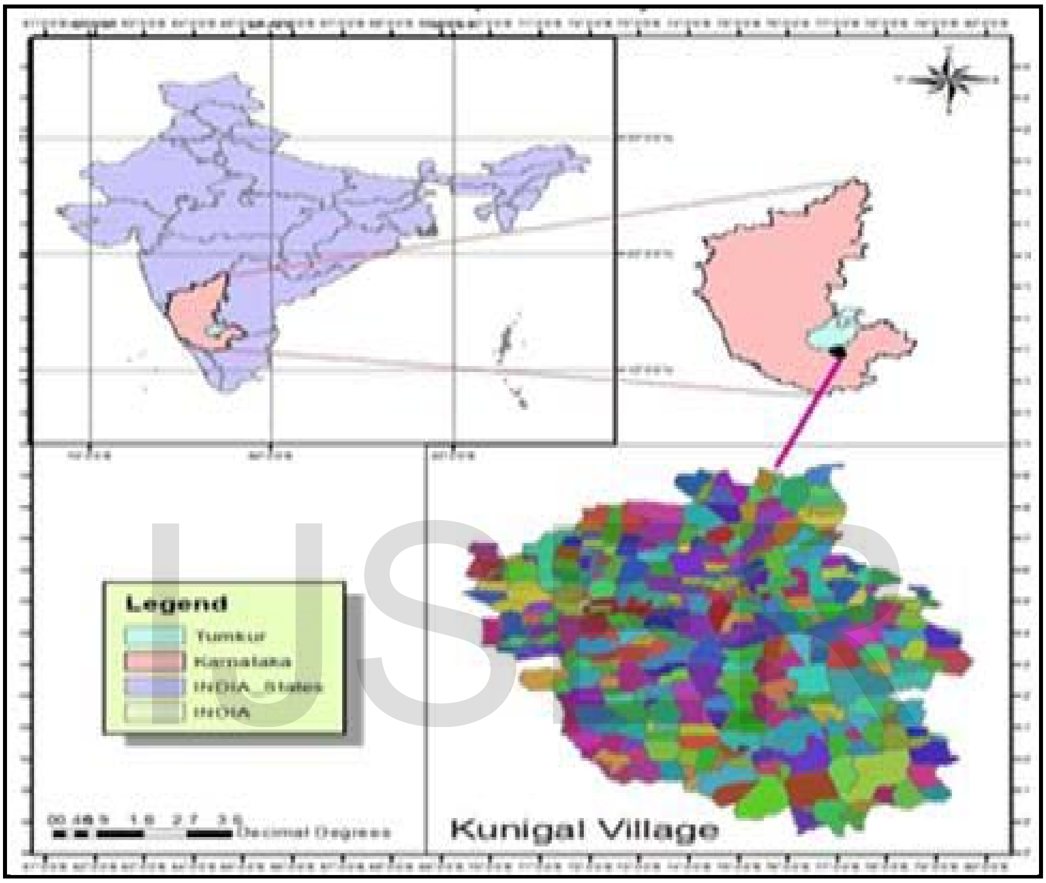

Figure 1.0 Location Map of Kunigal Study area

3.0 Results and discussions

3.1 Stage wise irrigation requirement of crop

Each crop life cycle can be divided into four growth stages namely initial, development, mid season and late season. These growth stages respond differently to water stress. Each stage has its own duration and its own irrigation requirement as given in Table 1.0

Table 1.0 Irrigation requirement for the whole crop cycle and each growth stage

Crops	Initial season		Development season		Mid season		Late season		Total	
	Duration (Days)	Irrigation Requirement (mm)	Duration (Days)	Irrigation Requirement (mm)	Duration (Days)	Irrigation Requirement (mm)	Duration (Days)	Irrigation Requirement (mm)	Duration (Days)	Irrigation Requirement (mm)
Sugarcane	30	31.7	60	168.7	180	526.8	95	135.6	365	862.8
Ragi	20	0	40	4.5	30	2.6	30	1.5	120	8.5
Groundnut(Rabhi)	20	11.7	30	76.8	35	116.9	25	87.6	110	293.1
Groundnut(Kharif)	20	0	30	18.4	25	21.6	35	6.9	110	46.9
Rice	75	400	30	94.3	40	190.7	30	80.2	150	765.4
Pulses	20	27.5	30	40	40	106.3	20	57.3	110	231.1

The mid-season stage requires more water as the crop is at grand growth stage, which end up in the first yield formation phase. Sugarcane requires more than 60% water during mid-season stage and 16% more during late-season stages. The crops like Groundnut (Rabi), Groundnut (Kharif) and pulses require more than 40% water during mid-season growth stages and more than 30% water during late stage. As Rice requires 50% water during nursery and land preparation stage, the water required for the mid-season stage is around 25%.Since the yield formation continues until the early phases of the late stages, water requirement for each crop is around 25% to 30% average. However the irrigation requirement for Ragi is not much as it is rain fed crop. The irrigation requirement for all the crops for each growth stages and whole cycle is also shown in the figure 2.0

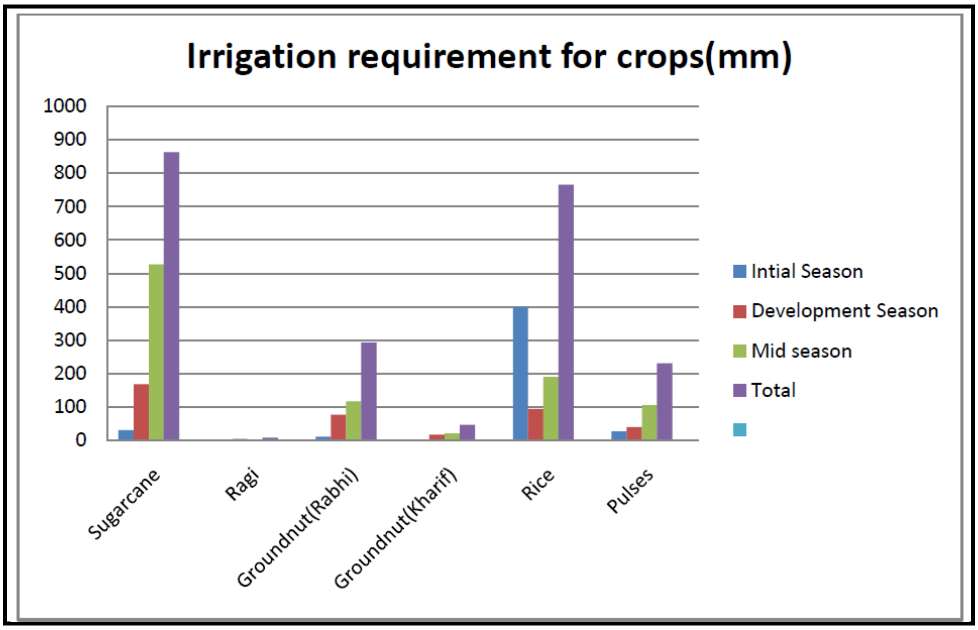

Figure 2.0 Irrigation requirement of crops for each growth stage

3.2 Rainfed and full irrigation

The scheme module of CROPWAT calculates the irrigation requirement on a daily time step using the following equation:

$$\text{Irrigation Requirement} = ET_a - P_{eff} \pm SW \ldots\ldots 1.0$$

where,

ETa is actual evapotranspiration

SW is soil water

ETa is also referred to evaporation under non standard conditions. It is evapotranspiration from crops grown under management and environmental conditions that differ from those of ETc due to non-optimal conditions of water shortage. Presence of water stress reduces the ETa rate below ETc. ETa is computed using the following formula:

$$ET_a = K_s \times ET_c \ldots\ldots 2.0$$

Where,

Ks is the water stress factor.

Ks describe the effect of water stress on crop evapotranspiration. The water stress causes reduction in evapotranspiration resulting in ETa deviating from ETc"

Simulations are carried out for all the crops in Kunigal command area for both ran fed and full irrigation conditions and given in Table 2.0

Table 2.0 Comparison of yield under rain fed and full irrigation condition

Crops	Rain Fed Condition				Full Irrigation Condition			
	Yield Reduction (%)	ET_a (mm)	ET_c (mm)	GIR (mm)	Yield Reduction (%)	ET_a (mm)	ET_c (mm)	GIR (mm)
Sugarcane	40.10	993.60	1493.20	0.00	0.00	1493.20	1493.20	1019.60
Ragi	0.00	299.80	299.80	0.00	0.00	299.80	299.80	0.00
Groundnut (Rabi)	35.90	161.10	331.10	0.00	0.00	331.10	331.10	367.00
Groundnut (Kharif)	0.00	334.80	334.80	0.00	0.00	334.80	334.80	0.00
Rice	58.30	189.80	404.10	332.00	0.00	538.70	538.70	1464.50
Pulses	46.40	168.90	292.30	0.00	0.00	292.30	292.30	238.50

The estimated yield reduction percentage is found for all crops. The response of yield to water supply is quantified through the yield response factor known as Ky. It relates relative yield decrease $\left(1 - \frac{Y_a}{Y_m}\right)$ to relative evapotranspiration $\left(\frac{ET_a}{ET_c}\right)$ given by the following formula:

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y \times \left(\frac{ET_a}{ET_c}\right) \quad \text{..3.0}$$

Where,

Ya=Actual yield

Ym=maximum yield

ETa=Actual evapotranspiration

ETc=Maximum eavapotranspiration

The Ky factor values are derived on the assumption that the relationship between relative yield and relative evapotranspuiration is linear and are valid for water deficits of up to 50% of the crop water requirement (FAO1986) "

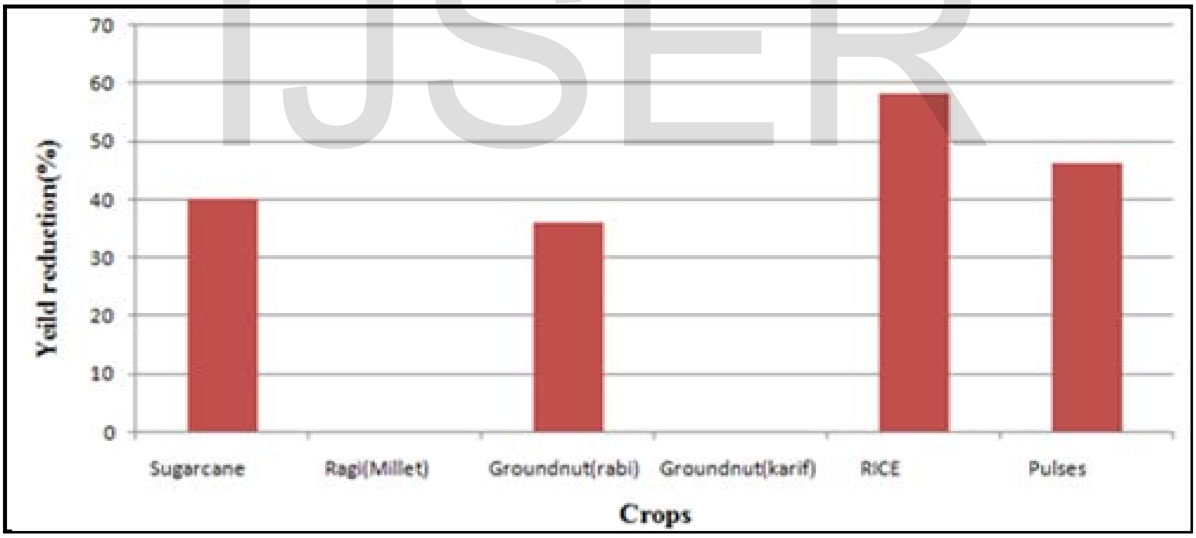

Figure 3.0 Yield reductions in % for various crops

Under Rain fed conditions, the yield reduction for sugarcane, groundnut (Rabi), rice and pulses are 40.1%, 35.90%, 58.30% and 46.40% respectively as given in Figure 3.0. Ragi and groundnut (Kharif) does not show any yield reductions as they are not subjected to any water stress. The yield reduction in case of sugarcane, groundnut (rabi), rice and pulses is strongly linked to low rainfall received.

3.3 Deficit irrigation scheduling

In order to successfully meet the objective of deficit irrigation practice, there is a need to know the level of actual crop evapo-transpiration deficiency allowable that can cause acceptable reduction in crop yield. The water stress that can be simulated by CROPWAT either by distributing uniformly over the entire life cycle or can be concentrated on specific phase of crop cycle (FAO, 1986) .

3.3.1 Water stress uniformly spread over the crop cycle

By using CROPWAT, water deficit of different magnitudes occurring simultaneously over the total growing period is simulated as shown in Table 3.0. The simulations are carried out allowing irrigation at above critical soil moisture depletion of RAM. Irrigation at 100% depletion of RAM is taken as the benchmark, which that the irrigation water is applied whenever the entire RAM has been depleted such that the crop will never be exposed to water stress.

Table 3.0 Yield reductions obtained over different deficits spread uniformly over the crop cycle

Crops		0	10	20	30	40	50
Sugarcane	Yield Reduction (%)	0.00	0.40	4.50	11.80	21.30	40.10
	ETa (mm)	1493.20	1488.10	1436.80	1346.90	1228.70	993.60
	GIR (mm)	1019.60	833.20	908.60	655.10	351.40	0.00
Ragi	Yield Reduction (%)	0.00	0.00	0.00	0.00	0.00	0.00
	ETa (mm)	299.80	299.80	299.80	299.80	299.80	299.80
	GIR (mm)	299.80	299.80	299.80	299.80	299.80	299.80
Groundnut (Rabi)	Yield Reduction (%)	0.00	0.30	0.70	2.30	4.10	4.80
	ETa (mm)	331.10	329.10	327.70	320.30	311.90	308.60
	GIR (mm)	367.00	419.70	328.90	367.20	260.70	281.70
Groundnut (Kharif)	Yield Reduction (%)	0.00	0.00	0.00	0.00	0.00	0.00
	ETa (mm)	334.80	334.80	334.80	334.80	334.80	334.80
	GIR (mm)	334.80	334.80	334.80	334.80	334.80	334.80
Rice	Yield Reduction (%)	0.00	0.00	0.10	0.20	0.40	0.50
	ETa (mm)	461.40	461.50	461.50	459.50	460.10	457.60
	GIR (mm)	1109.30	1109.10	1111.10	1112.70	1112.70	1114.10
Pulses	Yield Reduction (%)	0.00	0.30	1.20	2.80	5.00	9.40
	ETa (mm)	292.30	291.50	289.10	284.80	278.90	261.30
	GIR (mm)	238.50	266.90	291.60	210.10	227.70	245.50

Different water deficit magnitudes were used as shown in Table 3.0 thus allowing depletion to go beyond the RAM level also known as critical depletion point. By doing so, the crops suffered some stress that ultimately leads to yield reduction. These different deficits are spread uniformly over the entire cycle. The simulations was done at intervals of 10% of exceedance of critical depletion (100%) and indicated that higher the degree of exceedance, greater is the yield reduction.

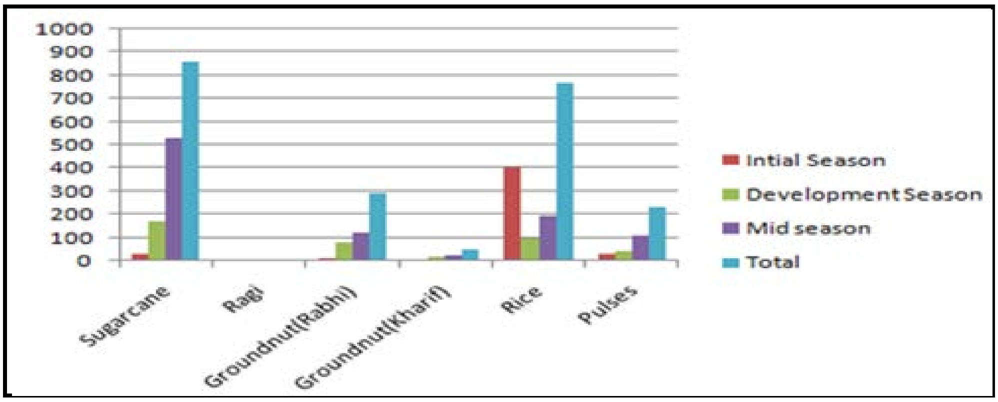

Figure 4.0 Yield reduction over different water deficits spread uniformly over the crop cycle

Figure 4.0 shows that irrigating at 100% of critical moisture depletion renders no yield reduction and requires more water use (Table 5.12). In contrary, irrigation at 150% of critical moisture depletion incurs high yield reduction. Sugarcane suffers maximum water stress leading to maximum yield reduction of 40.1%.Groundnut(Rabi),Pulses and rice are not much exposed to water stress thus leading to yield reductions of 4.80%,9.40% and 0.50% respectively. Ragi and Groundnut (Kharif) does not suffer any water stress and has no effect on yield reduction.

The actual water used by the crops ETa are plotted for different water deficits spread uniformly of crop as shown in Figure 5.0

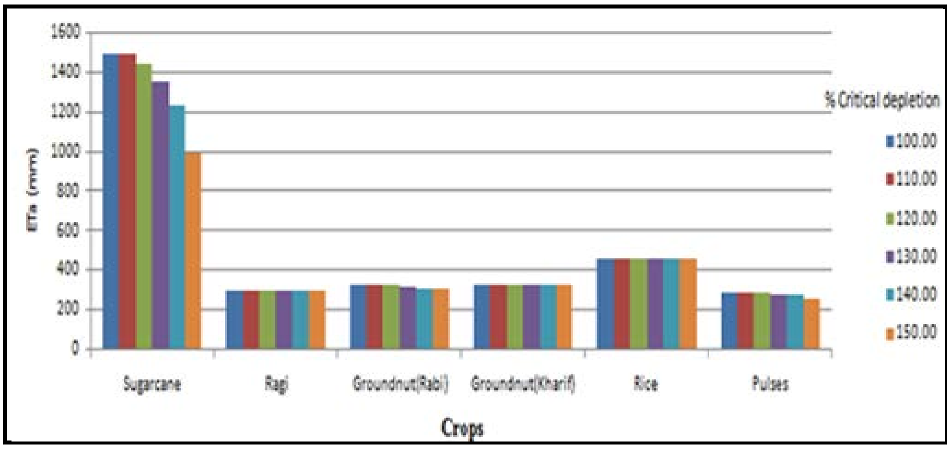

Figure 5.0 Actual water used (ETa) over different water deficits spread uniformly over the crop cycle

As shown in Figure 5.0, irrigating at 100% of critical moisture depletion requires more water use. It utilizes much less water when irrigated at 150% of critical depletion. The yield reductions for the crops stressed against the actual water used by the crops (ETa) are as shown in Figure 6.0

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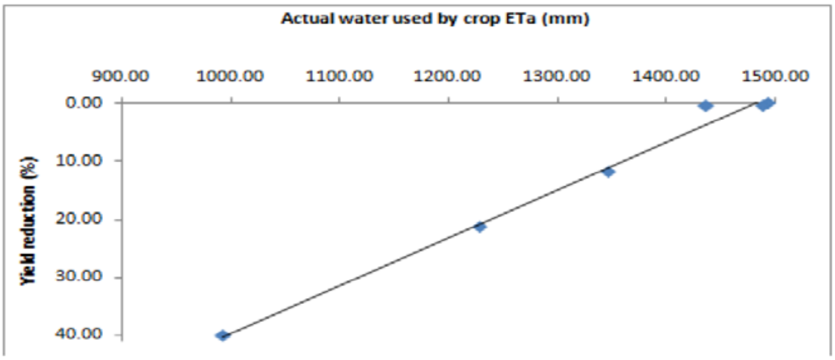
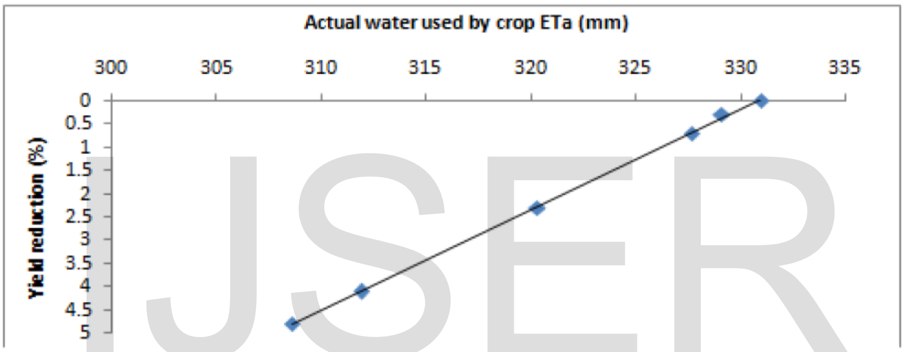
Yield reduction versus ET_a for water stress uniformly spread over the whole cycle.

SUGARCANE



GROUNDNUT(RABHI)



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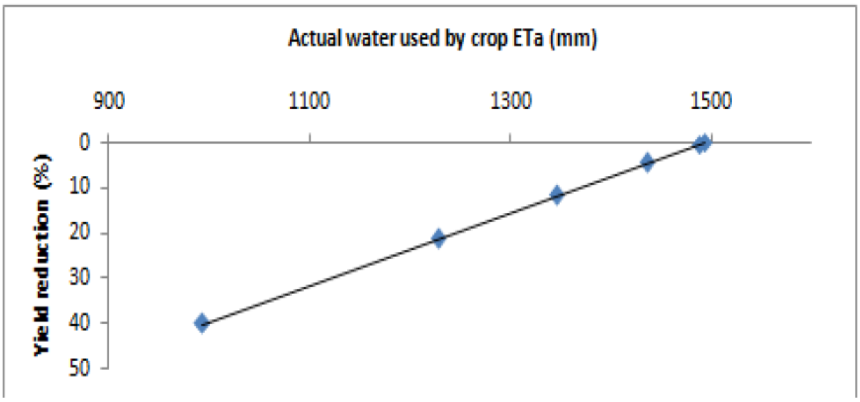

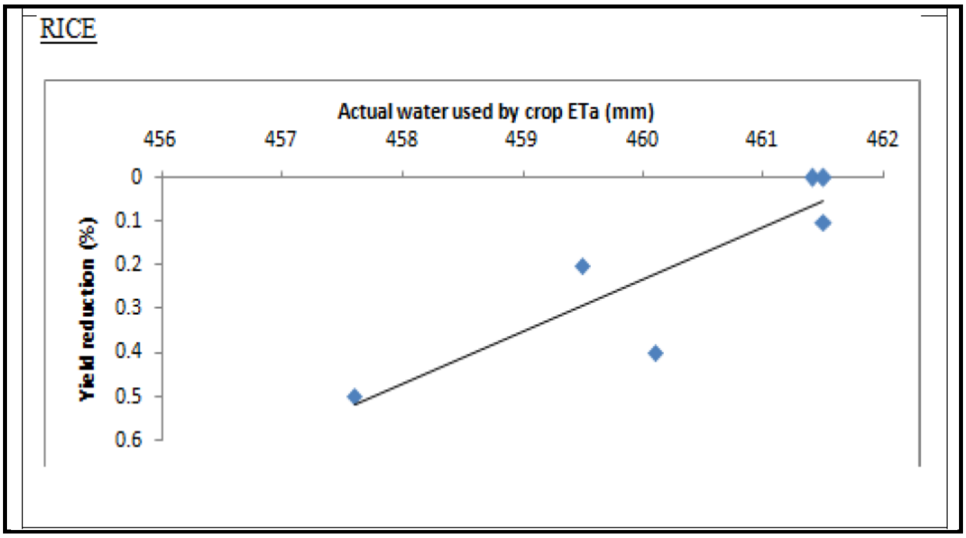

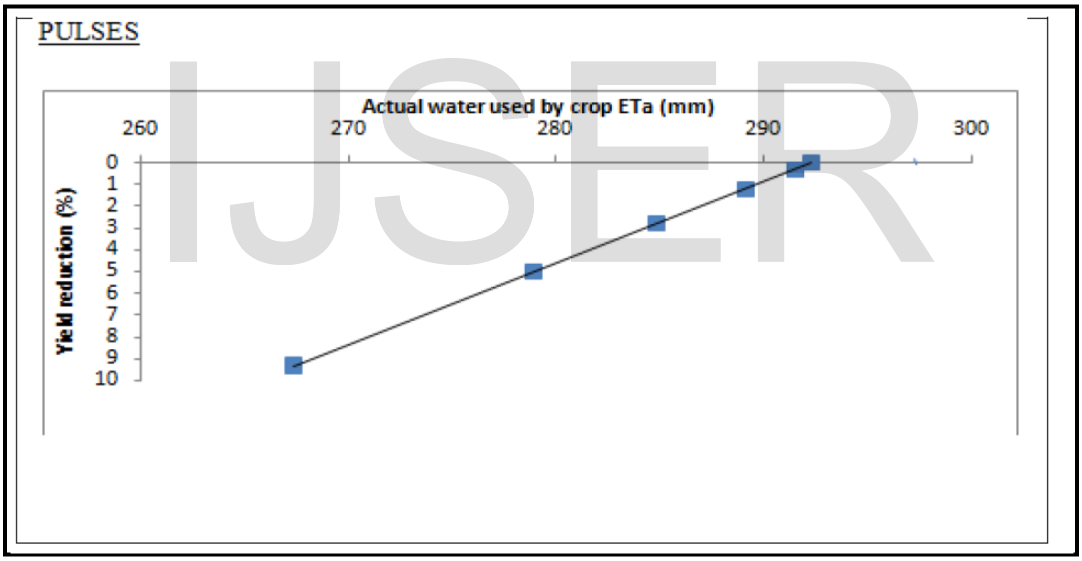

Figure 6.0 Yield reductions versus ETa for water stress spread uniformly over the crop cycle

The yield reduction increases linearly with decrease in water used under the condition of water stress uniformly spread over the whole crop cycle.

3.3.2 Water stress concentrated over one phase of crop cycle

Crop response to water deficit can also vary as a function of the phase of the crop cycle during which the stress occurs. The ETc reduction per stage in the CROPWAT option is selected for the irrigation

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timing. Table 4.0 shows simulation results for 10%, 20% and 30% ETc reduction per stage for all the crops.

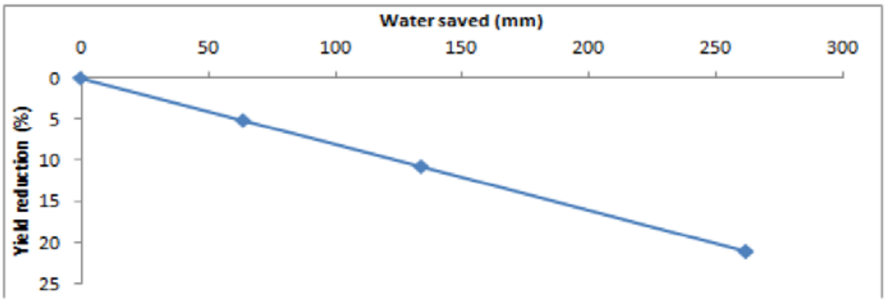
At initial and development stages, there is negligible yield reduction. Compared to full irrigation, there is rather no water saved when stressing on either of these stages. In case of sugarcane, the ETa for full irrigation is 1493.20 mm compared to 1482.4 mm and 1481.7 mm in the initial and development stages giving a yield reduction of 0.9%. However the maximum yield reduction in case of sugarcane is 21% with ETa for 30% ETc reduction during mid-stage is 1231.8 mm comparing the results, if the farmers accept high yield reduction they can stress at mid-season stage as it saves more water than stressing at initial, development or late season stages in case of sugarcane.

Table 4.0 Yield reductions obtained at different growth stages at various water deficits

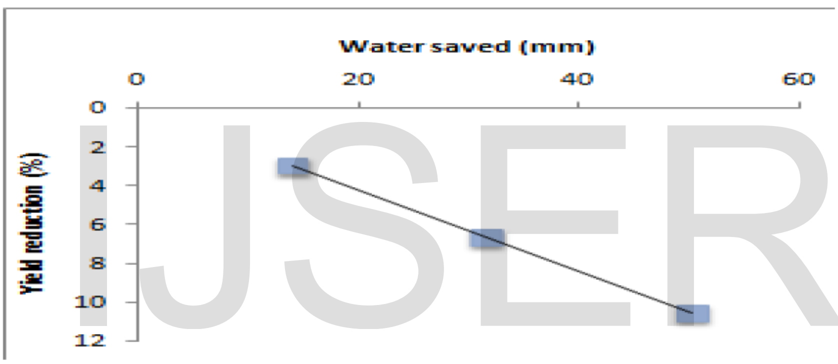
Crops	Growth Stage	10% Etc reduction			20% Etc reduction			30% Etc reduction		
		Yield (%)	ETa	GIR	Yield (%)	ETa	GIR	Yield (%)	ETa	GIR
Sugarcane	I	0.90	1482.40	850.40	0.90	1482.40	850.40	0.90	1482.40	850.40
	D	0.90	1481.70	854.20	0.90	1481.70	854.20	0.90	1481.70	854.20
	M	5.10	1429.70	914.10	10.70	1359.40	600.30	21.0	1231.80	550.70
	L	0.90	1482.40	850.40	0.90	1482.40	850.40	0.90	1482.40	850.40
Ragi	I	0.00	299.80	299.80	0.00	299.80	299.80	0.00	299.80	299.80
	D	0.00	299.80	299.80	0.00	299.80	299.80	0.00	299.80	299.80
	M	0.00	299.80	299.80	0.00	299.80	299.80	0.00	299.80	299.80
	L	0.00	299.80	299.80	0.00	299.80	299.80	0.00	299.80	299.80
Groundnut (Rabhi)	I	0.70	327.70	328.90	0.70	327.70	328.90	0.70	327.70	328.90
	D	2.20	320.80	359.30	2.20	320.80	359.30	2.20	320.80	359.30
	M	3.00	317.00	362.40	6.70	299.60	263.20	10.6	281.0	274.44
	L	0.70	327.70	328.90	0.70	327.70	328.90	0.70	327.70	328.90
Groundnut (Kharif)	I	0.00	334.80	0.00	0.00	334.80	0.00	0.00	334.80	0.00
	D	0.00	334.80	0.00	0.00	334.80	0.00	0.00	334.80	0.00
	M	0.00	334.80	0.00	0.00	334.80	0.00	0.00	334.80	0.00
	L	0.00	334.80	0.00	0.00	334.80	0.00	0.00	334.80	0.00
Rice	I	1.70	441.00	1121.1	1.70	441.00	1121.1	1.70	441.00	1121.10
	D	2.90	428.70	1115.6	2.90	428.70	1115.6	2.90	428.70	1115.60
	M	4.50	423.10	915.60	8.70	405.80	1115.6	8.70	405.80	1115.6
	L	2.80	431.20	915.10	2.80	431.20	915.10	2.80	431.20	915.10
Pulses	I	1.20	289.10	289.50	1.20	289.10	289.50	1.20	289.10	289.50
	D	3.80	282.30	217.00	3.80	282.30	217.00	3.80	282.30	217.00
	M	5.00	278.90	208.00	8.70	269.10	219.90	8.70	269.10	219.90
	L	4.50	280.40	185.10	4.50	280.40	185.10	4.50	280.40	185.10

Figure 7.0 shows the variation of yield reduction with water saved as compared to full irrigation for water stress concentrated over mid-season stages.

SUGARCANE



GROUNDNUT(RABHI)



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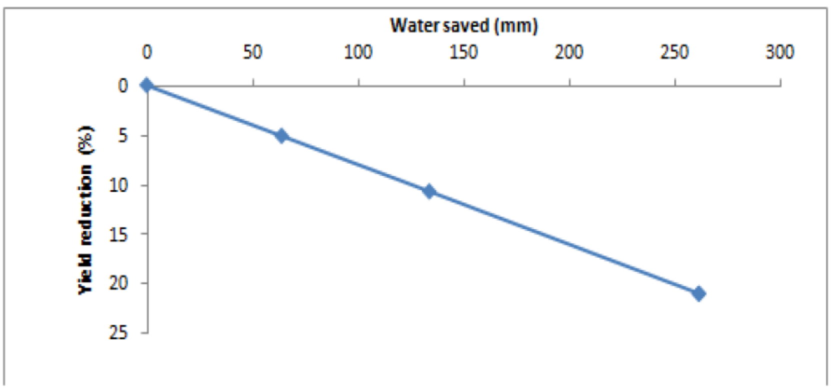

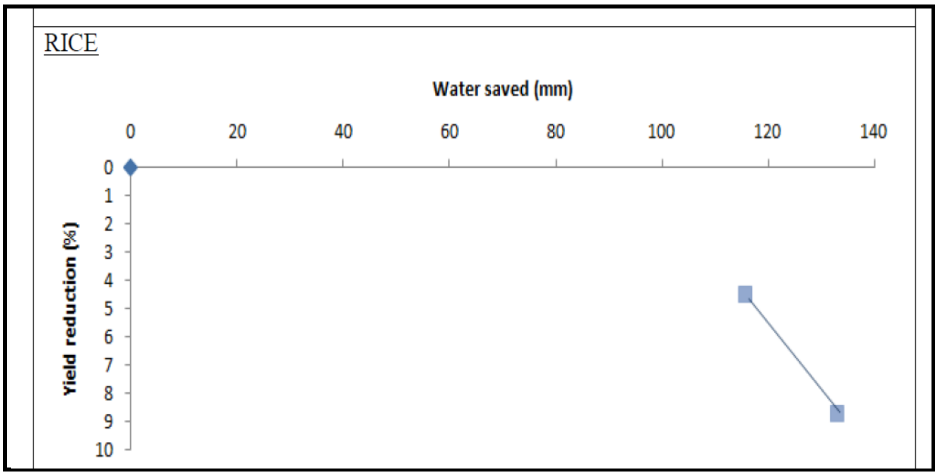

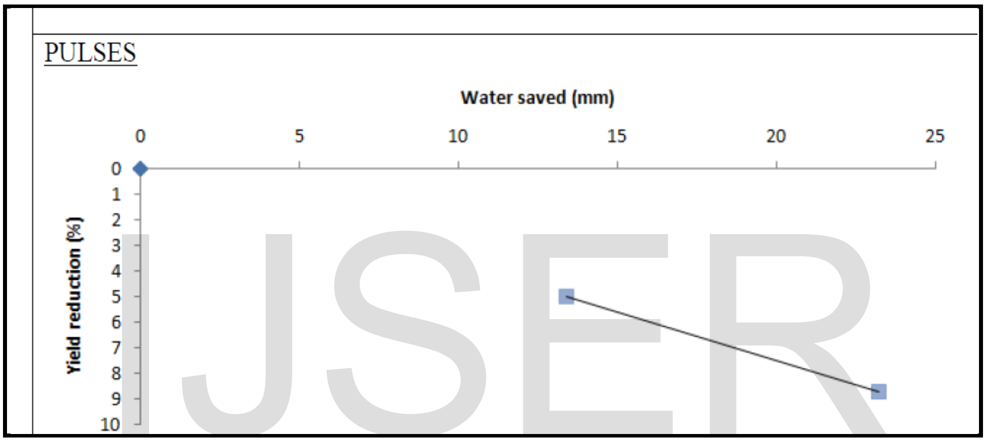

Figure 7.0 Yield reduction versus water saved as compared to full irrigation for the water stress concentrated over mid-season stage

The linearity of yield reduction verses water saved shown in Figure 7.0 is due to the assumption that the relationship between relative yield and relative evaporation is linear and is valid for water deficits of up to 50% of the crop water requirement. "

Ragi and groundnut (Kharif) does not suffer any water stress and no effect on the yield reduction. Groundnut (Rabi), pulses and Rice are not much exposed to water stress thus leading to maximum yield reductions of 10.6%, 8.70%, and 8.70% respectively during midseason stage (Table 4.0).

4.0 Conclusions

The deficits irrigation practice generates significant savings in irrigation water allocation though it incurs yield reductions. To meet this objective of deficit irrigation practice successfully, there is a need to know the level of evaporation deficiency allowable that can cause acceptable crop yield reduction. Though deficit irrigation practice assists in conserving limited available water resources for irrigation, the practice however requires precise knowledge of yield response to water function and also involves economic risk. The water stress that can be simulated by CROPWAT either can be distributed uniformly over the entire life cycle or can be concentrated in specific phase of the crop cycle.

From the simulations carried out for the Kunigal command area, the following conclusions can be drawn.

i. The crop evapotranspiration 'ETo' were higher for crops with longer growing season than those with short ones. Also ETo was more during the dry season than the rainy season. The crops such as Groundnut(Rabi),Rice and Pulses grown in dry season needs more water than those crops such as Groundnut(Kharif) and Ragi grown during the rainy season.
ii. The mid-season stage of the crop life cycle requires more water as the crops are at grand growth stage. Sugarcane requires more than 60% water during Midseason stage and 16% water during late season stage. The crops like Groundnut(Rabi),Groundnut(Kharif) and Pulses requires more than 40% water during midseason stage.
iii. The yield reduction for Sugarcane, Groundnut (Rabi), Rice and Pulses are 40.1%, 35.90%, 58.30% and 46.40% respectively under rain fed conditions. Ragi and Groundnut(Kharif) does not show any yield reductions as they are not subjected to any water stress.
iv. The yield reduction in case of Sugarcane, Groundnut (Rabi), Rice and Pulses is strongly linked to low rainfall received. These four crops suffer water stress almost though out the whole cycle of growth stage during rain fed conditions.
v. Irrigating at 100% critical moisture depletion render no yield reduction and requires more water. In contrary, irrigation at 150% of critical moisture depletion incurs high yield reduction.
vi. Sugarcane suffers maximum water stress leading to maximum yield reduction of 40.1.Groundnunt(Rabi), Pulses and Rice are not much exposed to water stress thus leading to yield reductions of 4.80%,9.40% and 0.50% respectively.
vii. The yield reductions for the crops are negligible when water stress is concentrated at initial and development stages. The yield reductions are much greater at mid-season stages and substantial amount of water is saved.
viii. The maximum yield reduction in case of Sugarcane is 21% .The ETa for full irrigation is 1493.2 mm and 30% ETc reduction during mid-stage is 1231.8 mm
ix. Comparing the two deficit practices, it is better to spread the water stress concentrated over mid stage growth cycle as it saves more water and incurs less yield reduction compared to water stress spread uniformly over the crop cycle.

5.0 Recommendations

Farmers are recommended to practice deficit irrigation for sugarcane, Groundnut (Rabi), Pulses and Rice in Kunigal command area in order to save water. They should have knowledge on the crop varieties used so as to know the best time to stress the crops, expected yield under full irrigation and all proper agronomic practices to be adopted.

Farmers are encouraged to fully protect their crops against diseases, pests and weeds. Diversification and inverse crop production can be practiced in command areas of Kunigal through deficit irrigation. Agronomic measures such as varying tillage practices and mulching can reduce the demand for irrigation water.

Before implementing a deficit irrigation programme, it is necessary to know the crop yield responses to water stress either during defined growth stages or for the whole season.

It is also recommended to decrease the plant populations as compared to those used under full irrigation and apply less fertilizer especially ammonium based ones to reduce during ill to the plants under water stress conditions.

For best results, deficit irrigation should be practiced in the area with heavy clays than with light soils. It is because, fine textured soils have high water retention capacity such that plants have ample time to adjust to low soil water pressure and remain unaffected by low soil water content.

The drought tolerant crop varieties should be selected as they are most suitable for deficit irrigation. The farmers should be made aware of economic analysis to find out the exact deficit magnitude which saves more water and simultaneously entails acceptable yield reduction percentage. Thus the farmers can profitably use the saved water to expand the area cropped or irrigate other valuable crops using the same quantum of water.

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