Deficit Irrigation for Wheat Cultivation Under Limited Water Supply Condition

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Deficit Irrigation for Wheat Cultivation Under Limited Water Supply Condition

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By

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Declaration

I declare that, except where otherwise stated, this dissertation is entirely my own work and has not been submitted in any form to any other University for any degree.

Date: 11.03.2008 (Md. Hossain Ali)

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The author

Biographical Sketch

The author was born on 31st December, 1966 in Jamalpur District, Bangladesh. He is the second son of Md. Abdur Rahim and Joygun Nesa. He passed his Secondary School Certificate (SSC) examination securing first division in 1982 from Battala High School, Jamalpur and Higher Secondary Certificate (HSC) examination securing first division in 1984 from Nandina College, Jamalpur, Bangladesh. He completed his B.Sc.Ag.Engg. (Hons) degree (securing first class, 5th position in merit) from 'Bangladesh Agricultural University, Mymensingh, Bangladesh' in 1988. He also completed his M.Sc.(Agril. Engg.) in Irrigation & Water Management from the same University in 1995. He did his M. Engg. Sci. degree from 'The University of Melbourne, Australia', in 1999. He joined at 'Bangladesh Rural Electrification Board (REB)' as Assistant General Manager (Member Service) in 1993. Later, he joined at 'Bangladesh Institute of Nuclear Agriculture (BINA)' in 1994, as Scientific Officer. He was promoted as Senior Scientific Officer in 2001. He has published 47 research papers in different national and international journals, one text book (*Agricultural Meteorology*, from Bangla Academy, Dhaka, Bangladesh, ISBN: 984-07-4586-7), and seven popular articles. He is member/life-member of several national /foreign professional societies.

The author is married to Anjumanara Begum and blessed with one daughter, Sanjida Afiate, and one son, Irfan Sajid.

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Abstract

Vertical and horizontal expansion of irrigated agriculture to feed the increasing population has contributed to excessive groundwater withdrawal and affected the availability of water in terms of both quality and quantity. To sustain agricultural growth, strategic measures should be adopted to reduce water consumption while minimizing adverse effect on yield. The effect of deficit irrigation on wheat yield was studied in three consecutive years (2002-03 to 2004-05) in field and pot at the experimental farm of Bangladesh Institute of Nuclear Agriculture, Ishurdi, Bangladesh. Ten irrigation treatments were imposed in a randomized complete block (RCB) design covering full deficit, no deficit at all, single deficit at different stages, and alternate deficits. Water deficit was created by withholding irrigation at different growth stages. The results indicate that deficit irrigation strategies affected all aspects of plant growth (leaf area index, chlorophyll content, root growth, nutrient uptake, plant height) adversely. Yield attributes were affected by deficit irrigation treatments although they are not statistically significant in all cases. Differences in yield attributes among the partial deficits (i.e. single stage or alternate stage deficits) and no deficit treatments were small, but there was a sharp difference between partial or no deficit, and full deficit treatment. The grain and straw yields were significantly affected by treatments. Differences in grain and straw yield among the partial- and no-deficit treatments were small, and statistically insignificant in most cases. The greatest effect on yield was observed with the addition of first increment of water at CRI stage. Within all treatments, the well-irrigated treatment produced the highest grain yield. When compared within single-deficit treatments, the grain yield reduction was in the order to water deficit at phases: CRI> maximum tillering > booting – heading >flowering- soft dough. Within two deficit strategies, the treatment having alternate irrigation at CRI and booting –heading phase produced higher grain yield over the other one; and this treatment produced statistically similar yield to those of single-deficit and no-deficit treatments. This strategy showed the highest harvest ratio, indicating higher proportional accumulation of assimilates to grain. The crop coefficient (k_c) under different ET_0 methods for early, crop development, middle, and late period ranged from 0.54 to 0.96, 0.95 to 1.36, 1.2 to 1.62, and 0.68 to 1.05, respectively. The Penman-Monteith method resulted in relatively higher k_c value than those of other methods. Non-significant differences were observed by pair '*t*' test between k_c values determined by various ET_0 methods. When the values were averaged over years and methods, a

k_c value of 0.77, 1.17, 1.41, and 0.89 were found for early, crop development, middle and late period, respectively. The yield response factor (k_y) varied with the growth phase and also among seasons. On average, the k_y for early, maximum tillering, booting-heading, and flowering-soft dough stages was 0.27, 0.21, 0.25, and 0.17, respectively. The sensitivity index (λ_i, of Jensen model) for early, vegetative, booting-heading, and flowering-soft dough phases was 0.35, 0.22, 0.31, and 0.14, respectively. A more sensitive growth stage had a higher value of λ_i, and therefore water supply is more important at early and booting-heading phases. Deficit irrigation effectively boosted water productivity. On average, the single irrigation at early stage (T_{10}) in addition to post-sowing irrigation saved about 68 % water in comparison to well-irrigated plot (T_9) with a yield reduction of 19 %. Between two alternate deficit strategies, treatment having irrigation at early and booting-heading stages (T_7) saved 39 % water coupled with 16% yield reduction compared to well- irrigated plot. Marginal productivity of irrigation water associated with treatment T_{10} and T_7 was about two folds of the others. Within the single deficit treatments (T_3 to T_6), relative water savings were almost similar (27 – 31 %), but had differences in relative yield reduction (6 - 2 %). The highest relative yield reduction was associated with deficit at CRI, followed by tillering, and then booting-heading stage. The highest net financial return from both land- and water-limiting condition was obtained from alternate deficit treatment (treatment T_7). From the evaluation of yield, irrigation amount, irrigation water productivity, relative water savings, relative yield reduction, and maximum profit under limited water resource condition, it can be concluded that when limited quantities of water is available, preference should be given to irrigate first at CRI (if one irrigation is available), then at CRI and booting-heading (if two irrigations are available), and next at CRI, maximum tillering and booting-heading (if three irrigations are available) stages of growth.

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List of Abbreviations

ASM	Available soil moisture
BARI	Bangladesh Agricultural Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
CHU	Crop heat unit
cm	centimeter
CRI	Crown root initiation
CSF	Crop susceptibility
CWR	Crop water requirement
DAS	Days after sowing
DF	Dilution factor
DMRT	Duncan's new multiple range text
ET	Evapotranspiration
ETD	Cumulative evapotranspiration deficit
FAO	Food and Agricultural Organization
FC	Field capacity
g	gram
GDD	Growing degree days
HUE	Heat use efficiency
IW	Irrigation water
kg	Kilogram
LAI	Leaf area index
LSD	Least significant difference
m	meter
ml	milliliter
mm	millimeter
nm	nanometer
P-M	Penman-Monteith
PTU	Photothermal unit
RCB	Randomized complete block

RLD	Root length density
TSM	Total profile soil moisture
UNESCO	United Nations education, science and cultural organizations
vol.	Volume
WP	Wilting point
WUE	Water use efficiency

List of Symbols

^0C	Centigrade temperature
A_{645}	Absorbance at 645 nm wave length
A_{663}	Absorbance at 663 nm wave length
cm/hr	Centimeter per hour
c_p	Specific heat of air
E_0	Evaporation of a free water surface
E_{ET}	Water productivity
E_{ir}	Productivity of irrigation water
ET_0	Reference evapotranspiration
ET_a	Actual crop evapotranspiration
ET_c	Crop evapotranspiration
ET_m	Maximum evapotranspiration
gm/cc	Gram per cubic centimeter
ha	Hectare
IW/CPE	Ratio of irrigation water to cumulative evapotranspiration
K	Potassium
k_c	Crop coefficient
K_y	Yield response factor
kg/ha	Killogram per hectare
kg/ha/day	Killogram per hectare per day
kg/m^3	Killogram per cubic meter
kP_a	Killo Pascal
log	Logarithm to the base 10
m/sec	Meter per second
m^3/m^3	Cubic meter per cubic meter
mg/gm	Milligram per gram
MP_{ir}	Marginam productivity of irrigation water
N	Nitrogen
P	Phosphorus

P^H	Soil reaction indication
R^2	Coefficient of determination
R_a	Extra-terrestrial radiation
R_s	Global radiation
Sm^{-1}	Second per meter
t/ha	Metric ton per hectare
TB	Base temperature
T_{max}	Maximum temperature
T_{mean}	Mean temperature
T_{min}	Minimum temperature
v/v	ratio of volume to volume
Wm^{-2}	Weiber per square meter
Y	Crop yield
Y_a	Actual yield
Y_{max}	Maximum yield
Zn	Zinc
θ_i	Soil moisture content at ith layer
λ	Sensitivity index of crop to water stress
Π	Multiplication
ψ	Leaf water potential

Chapter I

Introduction

1.1 General concept of irrigation

Plants need water for its proper growth and development. The demand for water by the crop must be met by the water in the soil, via the root system. Application of water to meet the crop water demand at proper time in proper way is termed as irrigation. If the crop water demand is meet by other ways (such as rainfall, capillary rise from groundwater table, etc.), there is no need of irrigation. Irrigation water requirement for cereals and non-cereals are not same. Among cereals, irrigation water requirement of rice is the highest. On the contrary, irrigation requirement of wheat is less compared to rice. Proper irrigation scheduling also affects the irrigation requirement of different crops.

1.1.1 Irrigation scheduling

The problem of irrigation scheduling consists of: (i) when to irrigate, (ii) how much to irrigate, and (iii) how to apply irrigation water. The amount of irrigation is obtained through field measurement or predicted through indirect method. The amount of irrigation is defined as the depth of water needed to meet the crop water loss through evapotranspiration under the growing environment. Although both timing and amount of water applied affect irrigation water productivity, timing has the greatest effect on crop yield and quality because at some growth stages, excessive soil moisture stress caused by delayed irrigation can irreversibly reduce the potential yield or quality or both. Different