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VALIDITY OF DRIP IRRIGATION REGIMES FOR RICE CULTIVATION ON KASTANOZEMS SOILS

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Abstract

With increasing demand for rice production and a severe shortage of water, it is necessary to develop innovative water-saving technology of rice cultivation which would allow reducing water consumption and increasing rice productivity. Therefore, field experiment was conducted at Agricultural Research Station of Russian Research Institute of Irrigated lands (Volgograd, Russia) over three years (2013-2015) to study the effect of different water regimes viz I_1 *[80% FC & h = 0.6 m],* I_2 *[80% FC & h = 0.4 and 0.6 m] &* I_3 *[80-70% FC & h = 0.4 and 0.6 m] in combination with three levels of mineral fertilizers (NPK) such as;1- (*$N_{109} P_{62} K_{75}$*); 2 – (*$N_{131} P_{74} K_{90}$*) and 3 – (*$N_{157} P_{90} K_{108}$*) kg* ha^{-1} *under drip irrigation system on growth, yield of aerobic rice and water-saving capacity of this technology. The obtained results revealed that, average rice grain yield was 6 ton/ha, while the volume of required irrigation water varied within 499–538 mm/ha which decreased by 60–80% compared to those consumed under the flooding technology of rice cultivation. Therefore, it can be concluded that drip irrigation is characterized by great water saving capacity along with high productivity of aerobic rice varieties.*

Key words: *aerobic rice, drip irrigation, water regime, water consumption, mineral fertilizers, yields.*

Introduction:

Rice is one of the most important food crops for developing countries. It's grown in 120 countries over the world a proximally on 165 million ha. Although rice is grown worldwide, the global rice production and consumption are dominated at South-East Asia.

According to FAO (2014) rough rice production reached more than 745 million tons. However, the demand for rice continues to rise due to population growth and its increased consumption in countries outside the Southeast Asia. It was estimated that by the year 2025 it will be necessary to produce more rice by 60% compared to current production to meet the food needs of the growing world population. In addition, the area of lands available for crop production is steadily decreasing because of urban growth and land degradation. Hence, increase in rice production is supposed to be obtained from the same or even less land areas. This means that appropriate rice production practices should be adapted to increase rice yield per unit area. the rice production areas can be classified into irrigated, which accounts for nearly 55% of the total rice cultivation area, and rainfed, which consist of upland rice territories (approximately 14 Mha — 11% of the total rice cultivation area), rainfed lowland rice territories (nearly 46 Mha concentrating mainly in Asia, representing 30% of the total rice cultivation area), and deep-water rice and floating rice areas (about 4 Mha in Asia).

Egypt's arable area totals about 3.3 million hectares about one-quarter of which is land reclaimed from the desert. About 90 percent of the agricultural area is concentrated in the Nile delta, and the rest falls within a narrow ribbon along the Nile between Aswan (Upper Egypt) and Cairo. Even though only 3% of the land is arable, it is extremely productive and can be cropped two or even three times per year.

After wheat, rice is the second priority cereal crop; approximately 95% of all rice is grown in the six governorates that constitute the northern part of the Nile delta. Rice consumes about 10 billion m^3 of water or about 18% of the total water resources.

The importance of rice crop emanates from the fact that it occupies a large area, estimated at 743,000 hectares, representing 31% of the 2008 summer planted area, which yields some 7240 thousand tons and the Average Per Capita Share (kg/year) 59.8. The National average yield of rice increased from 5.71 tons/ha during the base period 1984-1986 to 7.09 tons/ha during 1989-1991 period. It reached 7.71 tons/ha in 1993 and 8.9 tons/ha in 1999 which may be the world highest. Because of fertile soil of the Nile Delta, high intensity of sunlight, few diseases and insect pests, warm weather and good irrigation system, and well organized National Rice Research

Program and National Campaign, the Egyptian national average rice yield at 10.00 tons/ ha, is more than three times the world average.

Egypt has been facing several challenges such as the growing demand for water, drought waves, the expected global and Arab water scarcity, the current and expected climate changes, in addition to the rising conflicts between the Nile basin countries and the attempts some of these countries are making to reduce Egypt's water share of the Nile water. So that, the Ministry of irrigation and Water Resources' plan to reduce the total rice planted area, which it does not exceed 462,000 ha. FAO Rice Market Monitor (2010) Reported that, according to official assessments in Egypt , plantings of the summer crop 2010, which account for nearly all of production, contracted to 450 800 hectares this season, 22 percent below an already low extension of 576 000 hectares in 2009 and nearly 40 percent under the 745 000 hectare high in 2008. The retrenchment would be in line with a Government set target to limit rice plantings to 462 000 ha, which authorities estimate would allow between 5 and 6 million cubic meters of water to be saved for other purposes.

In Egypt like most countries of the world, traditionally, rice is grown under continuously flooded condition so the most conventional water management practices which are used aimed to maintain the constant water layer above the soil surface throughout the season. Under flooded cultivation system, water consumption is more than 2000 mm/ha which significantly excesses the biological needs of rice from water (which ranges within the interval 600–800 mm/ha). However, this system of rice cultivation is limited by water shortage. Therefore, there is a necessity to find ways to reduce water consumption and increase water use efficiency in rice production and at the same time to maintain higher yields. More than 75% of rice production comes from 79 million ha of irrigated lowlands. By 2025 over 39 million ha of irrigated rice areas in Asia may experience water scarcity. Reducing water input in rice production can have a high societal and environmental impact if the saved water can be diverted to areas where water deficiency is high. The reduction by 10% of water used for rice irrigation would save 150,000 million m^3, which corresponds to about 25% of the total fresh water globally used for non-agricultural purposes.

Recently, the term ‘water-saving irrigation techniques’ has been introduced to denominate irrigation strategies, aimed at reducing seepage and percolation (s) rates by: i) reducing the depth of ponded water; ii) keeping the soil just saturated or iii) alternate wetting/drying, i.e., allowing the soil to dry out to a certain extent before re applying the irrigation water. Rice is not an aquatic plant so achieving economy in water use without affecting the crop yield seemed to be the hit world in rice cultivation considering the fact that farmers irrigate their paddy crop more than it is required. It is reaffirmed that flooding was not the best practice to produce rice.

Aerobic rice is the latest technology that reduces water inputs due to growing rice as any other irrigated upland crop, which consists of dry-seeded rice cultivation under non flooded conditions with irrigated upland rice cultivation, and which is being developed to increase water-use efficiency. In this system plants are grown on non - puddled, unsaturated and well-drained soils. Water requirements can be lowered by reducing water losses due to seepage, percolation, and evaporation.

Drip irrigation is a promising system for economizing on available irrigation water. However, there are still many things unclear about the applicability of this irrigation system for rice cultivation in terms of water use efficiency, yield ability and impact on environment and production costs.

Materials and Methods:

Field Experiment was carried out over three years (2013- 2015) at the agricultural research station of Russian research institute of irrigated lands (Volgograd, Russia).

Three soil moisture regimes and three levels of mineral fertilizers (NPK) were established in a split-plot design with three replications.

The studied water regimes i.e. I_1, I_2 and I_3 were applied as the following:

I_1 — Soil moisture content was maintained at the level not lower than 80% FC (field capacity) at soil layer h = 0–0.6 m during the whole growing period of rice plants (from sowing to the stage of fully mature grain) [80% FC & h = 0.6 m].

I_2 — Soil moisture content was kept not lower than 80% FC at the soil layer 0.0 - 0.4 m during the vegetative period (from sowing to stage of panicle initiation), then during reproductive and ripening phases (from panicle initiation to the stage of fully mature of grain) the wetting depth was increased to 0.6 m [80% FC & h = 0.4 and 0.6 m].

I_3 — Soil moisture content was maintained as mentioned above at I_2, but from the dough phase to the phase of fully mature of grain soil moisture content was slightly reduced and kept at the level not lower than 70% FC at soil layer 0.0–0.6 m [80-70% FC & h = 0.4 and 0.6 m].

The second factor was three levels of mineral fertilizers viz. – (N_{109} P_{62} K_{75}); 2 – (N_{131} P_{74} K_{90}) and 3 – (N_{157} P_{90} K_{108}) kg ha^{-1}. Doses of fertilizer treatments were calculated to obtain the planned productivity of 5, 6 and 7 t/ha of grain. Nitrogen fertilizer was applied in 3 splits — 50% at sowing, 25% at tillering and the remaining 25% at flowering stages, while both phosphate and potassium fertilizers were applied at sowing.

Physical properties of the experimental site were characterized by heavy loamy textured soils, low organic matter content –1.29, 1.87% in 0.00–0.28 m and 0.00–0.6 m soil layers, respectively. Soil bulk density was 1.27 and 1.29 t/m^3 measured as average at depths 0.0–0.4 and 0.0–0.6 m, respectively. Field capacity was 24.7 and 23.8% by weight, total porosity ranged from 47.06 to 51.59% and soil particle density –2.52–2.54 t/m^3 at the same depths, respectively. The determined chemical properties were, soil PH ranged from 7.2 to 7.7 at the soil depth 0.0–0.6 m. The content of available in nitrogen is 1.45 mg/1kg soil, phosphorus (P_2O_5) – 26.73 mg/1kg soil and exchangeable potassium (K_2O) -201 mg/1kg soil

Dry direct seeding by drilling method was performed when the soil temperature at the seeding depth reached 14°C, seeding rate being at 5 million seeds/ha, on the 28th of April (2013–2014) and 8th May -2015.

Irrigation water was supplied through PVC pipe after filtering, under maintained pressure 1 atm., the lateral lines were laid with space interval of 0.6 m and distance between emitters 0.33m which characterized by discharge rate 2.2 L/h. irrigation was applied according to the maintained soil moisture levels at the studied soil depths. Soil moisture content was measured by the digital soil moisture meter (Aquaterr — M350).

Daily meteorological parameters (daily rainfall, air temperature and relative humidity) were collected from the weather station at the experimental site. The amount of precipitation during the period from April to September in 2013, 2014 and 2015 were 306.9, 104.9 and 235.4 mm, respectively. The sum of daily air temperatures reached 3605.7, 3637.3 and 3574.7 ^{0}C. The growing seasons in 2013, 2014 and 2015 were characterized as wet, hemi arid, hemi wet, respectively.

Evapotranspiration calculated by the water balance formula Kostyakov (1960):

$$E = M + 10\mu P \pm \Delta W + W гр ,$$

где: E – total water consumption, m^3 / ha;

M – total water applied by irrigation , $м^3$/га;

P – precipitation, mm;

μ – precipitation use coefficient ;

ΔW – the change in storage soil moisture content during the studied period, m^3 / ha;

$W_{гр}$ – recharge of the active layer of the soil by groundwater m^3/ ha.

Irrigation rate under drip irrigation was calculated using the formula Kostyakov(1961) modified by Kruzhilin et.al.(2003).

$$m = 100 \cdot S \cdot h \cdot \alpha \cdot (Wfc - \lambda \cdot Wfc),$$

Where:

m– Irrigation rate m^3/ha $S = \frac{S\,wet}{S\,total}$

$S_{total.}$ – total area, $м^2$;

$S_{wet.}$ – wetted area, $м^2$;

h – depth, м;

α – bulk density $т/м^3$;

W_{fc} – field capacity;

λ – Coefficient corresponding to the pre-irrigation moisture content.

Bioclimatic evaporation coefficient

$$K_t = \frac{E}{\Sigma T},$$

: K_t - Bioclimatic evaporation coefficient , mm / ^{0}C;

E –calculated evapotranspiration for the growing period, m^3 / ha;

ΣT – the sum of the daily air temperatures for the growing period ^{0}C.

***K_c* – water consumption coefficient**

$$Kc = \frac{E}{Y},$$

where: K_c – water consumption coefficient, m^3/t;

E – total water consumptions for the growing period, m^3 / ha;

Y – grain yield t/ha

Results and Discussion

Grain Yield

The effect of the studied water regimes and mineral fertilizers and their interactions on grain yield of aerobic rice was estimated. The results indicated that, grain yield was significantly affected due to the applied treatments, average grain yield ranged from 4.88 to 6.95 t ha^{-1} in, while higher grain yields of 5.29 to 6.95 t ha^{-1} were obtained when the second water regime was applied. The lower yield of rice 4.88 ton/ha grains was obtained when the first water regime combined with the level of mineral Fertilizer N_{109} P_{62} K_{75} has been applied. By maintaining soil moister content according to the third water regime grain yield decreased by 80 kg ha^{-1} compared with the second variant of irrigation treatment, but it was higher by 230 kg/ha than obtained in the first water regime.

The higher yield obtained at second water regime in combination with a dose of mineral fertilizer (N_{157} P_{90} K_{108}) was attributed to the achieved favorable conditions for growing rice plants (Table 2).

High productivity of rice crop variety (Volgograd) under drip irrigation it can be explained by, the amount of water supplied by drip irrigation was sufficient to saturate the soil during reproductive stage resulted in better spikelet fertility and finally the yield and/or may ascribed to combined favorable conditions (water and nutrient regimes) enhanced photosynthetic rate, increased filled grain percentage then productivity. Similar trend was observed by Soman (2012), and Vanitha (2012)

Soil moisture dynamics and scheduling of irrigations.

Results revealed that, the time and number of the applied irrigation rates were varied according to the maintained soil moisture regimes during the studied period of rice.

By maintaining soil moisture content according to the first water regime, the total number of irrigations applied by rate 370 m^3/ha, reached to 12, 15 and 13, with irrigation water consumption by 4440, 5550 and 4810 m^3 /ha in 2013, 2014 and 2015, respectively, and intervals between irrigations as affected by growth phases and climatic conditions were varied from 2 to 26 days.

However, when the second water regime was applied, in 2013, during the vegetative period (from sowing to stage of panicle initiation) the number of applied irrigations rate by 250 m^3/ha totaled 4, in 2014- 5 and 2015 – 2, during subsequent phases (reproductive and ripening) by irrigation rate of 370 m^3/ha, 10, 13 and 13, respectively, with irrigation intervals from 2 to 19 days.

According to the third water regime, the total number of irrigations rate of 250 m^3/ha during the vegetative period was 4, 5 and 2 irrigations respectively, and by rate of 370 m^3/ha was applied 8, 10, and 10 irrigations, however, during the period (phase wax ripeness of grain) was applied the last irrigation on 9, 6 and 19 August with irrigation rate by 550 m^3/ha, with irrigation water consumption by 4510, 5500 and 4750 m^3/ha.

Water consumptive use or evapotranspiration

Total water consumptive use by aerobic rice as influenced by the applied water regimes under drip irrigation system have been investigated under the current study conditions.

The total consumptive water use values or actual evapotranspiration of aerobic rice were find to be 6672 m^3/ha, which recorded at treatment of the maintained soil moisture content before irrigation not less than 80% Fc at depths 0.4 and 0.6 m with total water input by irrigation 5357 m^3/ha. The Lowest value evapotranspiration was observed when soil moisture kept not lower than 80% Fc in the layer of 0.6 m, which amounted to 6184,0 m^3/ha with irrigation water input 4933,0 m^3/ha. The maintenance of the differentiated water regime (70 and 80% Fc) at the studied soil layers (h = 0.4 and 0.6 m) total water consumption was decreased and amounted 6529 m^3/ha, and accompanied by the lowest value of the used irrigation water input which amounted 4920 m^3/ha.

In planning for a water supply by irrigation, it is necessary to estimate not only the total water demand but also water consumptive during growth stages of rice is needed for getting the optimal growth and yield of rice plants.

Water consumptive use at different growth stages of rice crop was varied depending upon the studied irrigation treatments. When I_2 and I_3 were applied, the maximum amount of water consumed by aerobic rice was recorded at the growth stage "**from Booting- to flowering** " and amounted 2708 m^3/ha. While the consumptive use of water at the same stage of growth period was decreased under the first water regime I_1 and amounted 2515 m^3/ha.

Minimum water consumptive use of aerobic rice at all variants of the studied water regimes was estimated at growth phase "sowing-germination" which amounted 121 m^3/ha

Evaporation (bioclimatic) rate

Evaporation rate мм/^{0}C was calculated by Ligov (1966). The estimated evaporation rate allows us to predicate schedule of successive occurrence timing of irrigations. Results of evaporation or bioclimatic rate were indicated that, values of bioclimatic rates were varied as affected by the studied water regimes and growth stage of rice plants.

Bioclimatic or evaporation rates during the life cycle of rice amounted to 0,250 mm/^{0}C their lowest value of 0.064 mm/^{0}C, was obtained in the period "sowing-germination", and the largest, 0,412 mm/^{0}C in the period of " Flowering –milk ripeness stage ". Under the second water regime (80% Fc, h = 0.4 and 0.6 m) and the third water regime (80- 70 % Fc, h = 0.4 and 0.6 m) values coefficients of evaporation as average during life cycle of aerobic rice, and 0,255 0,254 mm/0C, respectively.

Water use coefficient

Water use coefficient Kc was expressed as m^3/ton of grains; it has been used to evaluate efficiency of the consumed water per unit of the obtained yield.

According to the results of the experiment it can be expressed the equation which describe the relation between the coefficient of water consumption (Kc, m^3/ton) and the obtained yield of aerobic rice (t/ha) figure -5:

$$K_c = 21,623У^2 - 432,13У + 2895,5$$

This equation allowed us to determine values of Kc at different levels of rice productivity. Then for obtaining grain yield of rice at level 5 t/ha, water consumption coefficient =1275 m^3/t. By increasing productivity of grain to 6 t/ha, value of Kc was decreased to 1081 m^3/t and to obtain yields of 7 t/ha, Kc = 930 m^3/t.

According to the above mentioned results, generally it can be concluded that, irrigation water input in drip irrigated aerobic rice was 513mm ha^{-1} (the average 2013–2015) which saved by 60–80% when compared with that consumed under flooded conditions. Water requirements under aerobic conditions were decreased by reducing water losses (seepage, percolation, and evaporation). Moreover, it can be demonstrated that, the higher water use efficiency had been achieved when the irrigation regime I_3 was applied. In addition, under drip irrigation was found to create better conditions for growth and yield of aerobic rice. Thus it can be concluded that drip irrigation has greater water saving capacity compared with the flooding irrigation, and therefore is a better water-saving technology in areas of water scarcity.