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Irrigation Management for Optimizing Onion Seed Production

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Onion is seen as a major horticultural crop in Bangladesh. Irrigation technologies that conserve water are necessary to assure the economic and environmental sustainability of commercial agriculture. This study was conducted in Lysimeter to observe the effect of different irrigation regimes on onion seed and bulb yield. Irrigation regime consisted of five irrigation treatments: Irrigation at pre-vegetative stage up to field capacity [T1]; Irrigation at pre-vegetative and vegetative stage [T2]; Irrigation at pre-vegetative, vegetative stage, and bulb formation stage [T3]; Irrigation at pre-vegetative, vegetative, bulb formation, and flowering stage [T4]; and Irrigation at pre-vegetative, vegetative, bulb formation, pre-flowering, and late flowering stage [T5] up to field capacity. The results revealed insignificant effect on seed and bulb yield, and yield attributes except plant height. The cultivars showed significant effect on all yield attributes and seed yield of onion. The highest seed yield (76.98 $gm.m^{-2}$) as well as water productivity (33.95 kg ha^{-1} cm^{-1}) was obtained from T4 treatment, which received four irrigations (total 11.06 cm). The onion mutants produced higher seed yield than the check cultivar Baripiaj 2. The highest seed yield was found under Bp2/75/2 mutant (73.93 gm/m^2). From the present results, it is revealed that irrigation at pre-vegetative, vegetative, bulb formation and flowering stages up to field capacity are required for higher seed yield of onion at Mymensingh area.

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1. INTRODUCTION

Onion (*Allium cepa L.*) is an important vegetable crop valued for its pungent or mild flavour and for being the essential ingredient of the cuisine of many regions. Onions may be grown from seeds, transplants, or sets, which are immature onion bulbs. Growing from sets is the easiest and most foolproof method. Onion sets are not as finicky about soil and are better for short growing seasons and cooler climates. The disadvantages are that there is less selection and sets are more expensive to buy than seed. Seeds can be started indoors and set in the soil as transplants or sown directly in the field. Transplants may also be purchased in bunches from garden centers or seed catalogues, but they are expensive.

Considering the production volume and importance, onion is seen as a major horticultural crop in many countries. During the last 25 years, continuous increase of onion acreage has been registered [1]. Onion (*Allium cepa L.)* is one of the chief horticultural crops of Bangladesh. It is grown on 126175 ha with an average yield of 8.43 $t.ha^{-1}$ [2]. In Bangladesh, onion is cultivated under both irrigated and nonirrigated conditions. The onion yield in Bangladesh is less than half of the world average (17 $t.ha^{-1}$) and four fold lower than those achieved in the European Union (30-35 $t.ha^{-1}$) [2]. The reasons for the lower yield of onion in Bangladesh are many including inadequate management practices, insufficient amount and unfavorable arrangement of precipitation in the growing season, as well as poor water management applied to onions grown from seed.

Water scarcity is an increasingly important issue in many parts of the world. Climate change predictions of increase in temperature and decrease in rainfall mean water will become even scarcer. This is also true for Bangladesh. Water as a natural resource is inadequate in most areas where onion production is prevalent. Its application must be done efficiently to ensure profitability, while at the same time maximizing yield.

The importance of analyzing ET_{wue} is illustrated by the efforts of numerous studies that consider the total water use for evapotranspiration towards transpiration use as to the productive part of water to plants [3,4]. The parameter ET_{wue} mostly depends on precipitation amount and distribution and establishes whether the growing period is favorable for plant production or not. Wang et al. [5] pointed out that crop yield depends on the rate of water use and that the factors that increase yield and decrease water used for ET favorably affect the water use efficiency. Howell [4] indicated that ET_{wue} generally is highest with less irrigation, implying full use of the applied water and perhaps a tendency to promote deeper soil water extraction to make better use of both the stored soil water and the growing-season precipitation. An even clearer estimation of irrigation effects and the applied irrigation regime can be obtained by the evaluation of irrigation water use efficiency (I_{wue}) [6]. If the irrigation regime is not synchronized with water needs of crops, water and physical properties of soil and weather conditions, the effect of irrigation can fail, that is the Iwue values can be bellow the optimum. The parameter, Iwue, generally tends to increase with a decline in irrigation if that water deficit does not occur at a single growth period [4].

The effects of irrigation frequency on yield, water productivity, etc., have been investigated for various crops as well for Onion [7,8,9,10,11] but rarely for onion in the context of seed yield.

The objective of the study was to investigate the effects of different irrigation regimes on Onion seed production.

2. MATERIALS AND METHODS

2.1 Experimental Location

The experiment was conducted in Lysimeter at the experimental farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh (24°43´´ North and 90°26´´ East). The rainfall distribution during the growing season in depicted in Fig. 1.

2.2 Irrigation Treatments

Fifty days old seedling of four mutants Bp2/100/1 (V1), Bp2/100/2 (V2), Bp2/75/2 (V3), Bp2/100/12(V4) and one cheek variety 'BARIpiaj 2' (V5) were transplanted in field Lysimeter (drainage type), on 4th December 2013. The layout of the plots in lysimeter is shown in Fig. 2. The seedlings were grown nearby the experimental plot, and the seed was supplied by the respective Breeder. The experimental design was RCBD having irrigation treatments in the main plots and onion mutants/ varieties in the sub-plots (Layout is presented in Fig. 2). The irrigation treatments were:

T1 = Irrigation at pre-vegetative stage (15-20 DAT) up to field capacity
T2 = Irrigation at pre-vegetative and vegetative stage (45-50 DAT)
T3 = Irrigation at pre-vegetative, vegetative stage, and bulb formation stage (65 DAT)
T4 = Irrigation at pre-vegetative, vegetative, bulb formation, and flowering stage (95 DAT)
T5 = Irrigation at pre-vegetative, vegetative, bulb formation, pre-flowering, and late flowering stage (115 DAT) up to field capacity.

Where, 'DAT' implies 'Date after transplanting'

There were two replications. Soil moisture was measured by Neutron Moisture Meter (NMM) up to 90 cm having 15 cm intervals at the time of transplanting, before irrigation and at harvest. Other cultural practices were followed as and when necessary. Onion seed were harvested on 5th May 2014.

2.3 Water Balance Components

Crop evapotranspiration was calculated from the simplified field water balance equation:

$$ET = I + P - D \quad (1)$$

where,

P = Effective rainfall
I = Irrigation water applied
ET = Evapotranspiration from cropped soil
D = Drainage

All quantities are expressed in the same unit (in terms of volume of water per unit area, or equivalent depth units) during the period considered. The effective rainfall was calculated following FAO guideline.

2.4 Water Productivity

Water productivity (WP) was calculated as [12]:

$$WP = Y/ET \quad (2)$$

Where Y is the seed yield, ET is the crop evapo-transpiration.

2.5 Analysis of Experimental Data

The analysis of variance technique (ANOVA) was carried out on the data for each parameter as applicable to the design. The significance of the treatment effect was determined using F-test, and to determine the significant difference among the means of the treatments, least significant difference (LSD) were estimated at 5% probability level.

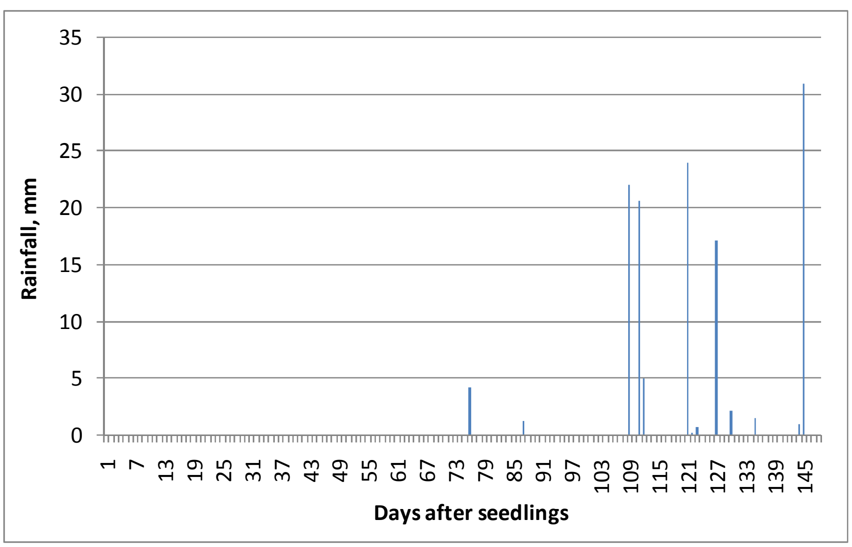

Fig. 1. Rainfall distribution during the growing season

	R1 3 m						R2					
T_1 1.5 m	V1	V2	V3	V4	V5		V1	V2	V3	V4	V5	T_5
T_2	V1	V2	V3	V4	V5		V1	V2	V3	V4	V5	T_4
T_3	V1	V2	V3	V4	V5		V1	V2	V3	V4	V5	T_3
T_4	V1	V2	V3	V4	V5		V1	V2	V3	V4	V5	T_2
T_5	V1	V2	V3	V4	V5		V1	V2	V3	V4	V5	T_1

Fig. 2. Layout of experimental plot in Lysimeter

3. RESULTS AND DISCUSSION

3.1 Mean Irrigation Effects on Yield Attributes, Seed and Bulb Yield

Table 1 shows the mean effects of irrigation on yield attributes, seed and bulb yield. The irrigation treatments showed insignificant effect on seed and bulb yield, and yield attributes except plant height. The highest seed yield was obtained from T_4 treatment (76.98 gm/m^2) followed by T_5. The cultivars showed significant effect on all yield attributes and seed yield of onion. The mean seed yield was highest under V_3 cultivar, followed by V_2.

3.2 Interaction Effects of Irrigation and Cultivar

The interaction effect of irrigation cultivar on seed yield is presented in Table 2. The interactions are not significant at 5% probability level. The variety V_3 produced the highest seed yield under treatment T_4 (i.e. T_4V_3) (96.39 g/m^2) followed by T_5 V_1 and T_5V_2.

3.3 Irrigation Water and Water Productivity

Table 3 shows the irrigation water applied, total water use, and water productivity under different irrigation treatments. The water productivity for onion seed yield was affected by irrigation treatments. The highest water productivity was found in T_4 treatment (33.95 kg ha^{-1}.cm^{-1}) which received four irrigations, followed by T_3. The T_5 treatment produced the third highest water productivity.

3.4 Discussion

Kumar et al. [10] studied the response of onion to different irrigation levels with microsprinkler irrigation system under semi-arid climate of India. The treatments comprised different ratio of irrigation water (IW) to cumulative pan evaporation (CPE) (0.60, 0.80, 1.0 and 1.20). Irrigation showed significant effect on growth parameters of onion and subsequently influenced the crop yield. They found higher yield of onion under IW/CPE ration of 1.0 and 1.20, for subsequent years. The results indicate that onion

Table 1. Mean effect of irrigation and cultivars on seed yield and yield attributing characters of onion

Treatments / variety	Plant height cm	Plants with flower (% of total plants)	Diameter of bulb (cm)	Bulb yield (tha^{-1})	Seed yield (gm.m^{-2})
T_1	70.84	90.00	3.46	6.79	48.44
T_2	65.28	78.57	3.12	8.14	40.49
T_3	72.98	89.29	3.50	8.98	57.83
T_4	74.44	95.00	3.43	7.23	76.98
T_5	76.28	92.14	3.50	9.25	68.09
LSD $_{0.01}$	***10.01***	***NS***	***NS***	***NS***	***NS***
Bp2/100/1	70.80	92.14	3.37	5.89	61.35 a
Bp2/100/2	72.58	95.00	3.15	6.79	66.20 a
Bp2/75/2	73.18	95.71	3.34	6.81	73.93 a
Bp2/100/12	71.82	93.57	3.21	7.23	61.12 a
Baripiaj2	71.44	68.57	3.94	13.69	29.19 b
LSD $_{0.01}$	***NS***	***17.79***	***0.51***	***2.40***	***20.6***

Table 2. Interaction effect of irrigation and cultivars on onion seed yield

Treatments	Onion seed yield (g/m^2)				
	V_1	**V_2**	**V_3**	**V_4**	**V_5**
T_1	46.1	57.9	75.0	47.4	15.8
T_2	30.1	42.3	56.5	49.6	23.8
T_3	60.3	67.0	74.1	62.4	25.4
T_4	78.1	76.9	96.4	85.1	48.1
T_5	91.9	86.9	66.7	60.9	32.9
LSD (5%)	NS	NS	NS	NS	NS

Table 3. Water requirement and water productivity of onion for seed production

Treatments	No. of irrigation	Irrigation water (cm)	Effective rainfall (cm)	Total water used (cm)	Seed yield (kgha^{-1})	Water productivity (kg. ha^{-1} cm^{-1})
T_1	1	3.66	11.6	15.3	484.4	31.7
T_2	2	6.21	11.6	17.8	404.9	22.7
T_3	3	8.12	11.6	19.7	578.3	29.3
T_4	4	11.06	11.6	22.7	769.4	33.9
T_5	5	12.10	11.6	23.7	680.9	28.7

needs optimum soil moisture throughout the growing period. The climate of the study area is closely similar to our study. But they only focused on onion bulb yield. In our study, the main focus was on seed yield.

Enciso et al. [13] studied the response of onion yield and quality to two irrigation scheduling strategies (soil moisture potential and ET_c based). They obtained higher total yields, and jumbo onion size yields when the soil moisture was kept above −30 kPa. Yields were not affected when water applications were reduced from 100% to 75% ET_c and from −20 to −30 kPa. The ET_c strategies of 100%, and 75% ET_c resulted in similar water usage to the soil moisture monitoring strategies of initiating irrigation at −20 and −30 kPa. Total yields dropped significantly when soil water stress increased below −50 kPa. For the ET based strategy, yields also dropped with the 50% ET_c treatment. This means that, onion is sensitive to moderate soil moisture stress. Pelter et al. [14] also concluded from three-year data that, total yield was reduced by soil-water stress imposed at any growth stage of onion. Based on results, obtained under different farming conditions, it is revealed that the onion crop reduced yield from mild to moderate soil moisture stress.

In our study, from the rainfall graph (Fig. 1), it is evident that sufficient rainfall occurred during the later stage of Onion, thus dismissed the effect of irrigation at this stage; which is evident from the seed yield of V_3, V_4 and V_5 (Table 2). The same effect is also evident in mean seed yield under treatment T_4 (Table 1). Irrigation water use efficiency (IWUE) declined in T_5 compared to T_1, T_2, and T_3 because, percentage improvement in yield was less than the percentage increase in irrigation water. In essence, IWUE is the function of yield and water applied, and decreases with increasing irrigation, unless percentage increase in yield supersedes the percentage increase in irrigation water.

4. CONCLUSION

Results of this study indicate that under the prevailing climatic condition (specially rainfall distribution), the irrigation application produced statistically similar seed yield of onion. However, four irrigations produced maximum seed yield. Considering the seed yield and water productivity, four irrigations at different growth stages can be applied for higher seed yield. Indeed, if the natural rainfall fulfills the crop demand, irrigation can be omitted at that stage.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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