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RESPONSE OF POTATO VARIETIES TO DIFFERENT LEVELS OF IRRIGATION

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Abstract

The field experiment was conducted at the Tuber Crops Research Sub-Centre, Munshiganj during the *rabi* seasons of 2019-20 and 2020-21, to investigate the effect of different levels of irrigation on the growth, yield and yield contributing characters of potato. The experiment comprised of two factors: Factor A-four irrigation levels, viz. I_0= No irrigation, I_1= One irrigation at 30 days after planting (DAP), I_2= Two irrigations at 30 and 45 DAP and I_3= Three irrigations at 30, 45 and 60 DAP (Control) and Factor B: five potato varieties, namely V_1=BARI Alu-25, V_2=BARI Alu-28, V_3=BARI Alu-36, V_4=BARI Alu-37 and V_5=BARI Alu-40. Results revealed that BARI Alu-36 produced the highest tuber fresh yield under well-watered condition i.e. at three irrigations 30, 45 and 60 DAP (44.57 and 45.26 t/ha in 2019-20 and 2020-21, respectively) as well as under no irrigated condition (water stress) (25.54 t/ha and 28.92 t/ha in 2019-20 and 2020-21, respectively). On the contrary, though BARI Alu-37 was a good yielder (40.88 t/ha in 2019-20 and 44.86 t/ha in 2020-21) under well-watered condition i.e. at three times irrigated condition, this variety failed to give a reasonable yield under water stress condition. BARI Alu-36 showed the lowest yield reduction (42.70% and 36.10% in 2019-20 and 2020-21, respectively) in water shortage conditions. The more the water shortage the more the dry matter accumulation trend was found in both the seasons and the maximum tuber dry matter percentages of 23.66% and 23.46% were obtained from BARI Alu-28 and BARI Alu-25 varieties under no irrigation in 2019-20 and 2020-21, respectively. Therefore, considering the yield, percent yield reduction and dry matter percentages, BARI Alu-36, BARI Alu-28 and BARI Alu-25 may be cultivated under water shortage conditions in Bangladesh.

Keywords: Potato, water stress, dry matter, irrigation, variety.

Introduction

Irrigation development is an important means for achieving food self-sufficiency in many countries of the world including Bangladesh. In order to address the challenges associated with food insecurity and water scarcity (Yohannes *et al*., 2017), the knowledge of irrigation is very important. Many literatures also agree that development of irrigation can be taken as a strategy for reducing poverty and ensuring food security in the world's poorest regions (Magistro *et al.*, 2007). Potato is the fourth most important cultivated food crop and is believed to contribute significantly to sustain future global food security (Burlingame, 2009; FAOSTAT,

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2013). Potato cultivation holds significant potential in Bangladesh and plays a crucial role in Bangladesh's agricultural economy. Bangladesh with the annual potato production of over 10 million metric tons, stands 7th in terms of potato production in the world. Potato is the third most important food source in the country, following rice and wheat, and provide a rich supply of carbohydrates, vitamin C, potassium, and fiber, making a significant contribution to daily nutritional needs. Potato currently ranks second only to rice in terms of cultivated land area and yield in Bangladesh.

Among the vulnerable countries, the effects of climate change hold the top position by Bangladesh. The overall impacts of climate change may cause unstable agricultural productivity in the country to a large scale. It is often considered as a drought sensitive crop and its sustainable production is threatened due to frequent drought episodes. The shallow root system of potato makes the crop one of the most drought-sensitive species (Zarzynska *et al*., 2017). Drought, during the early growth stage, is considered to be the most harmful as it substantially reduces the total leaf area, photosynthetic rates, and assimilates partitioning to tubers leading to poor tuber initiation, bulking, and tuber yield (Evers *et al*., 2010; Obidiegwu *et al*., 2015). Drought limits the productivity of potato plants by affecting photosynthetic processes at the canopy, leaf or chloroplast level (Jones and Corlett, 1992). The sensitivity of potato to water stress is likely due to its shallow root system and complex physiological responses to moderate plant water deficits (Curwen, 1993). A total of 20 droughts already happened in Bangladesh since independence (Agarwala *et al*., 2003). Every year, 3 to 4 million hectares of land are affected by droughts of different magnitudes (Rashid and Salam, 2007). Hijman (2003) predicted that the worldwide yield production of potato would reduce 18 - 32% in the next 30 years (e.i. until 2033) due to water deficiency. Every year Bangladesh experiences a dry period of five to seven months between November and May when rainfall is normally low. During this period, about 2.7 million hectares of land in Bangladesh become vulnerable to annual drought. There is about 10% of probability that 41-50% area of the country experiences drought in a year (Tanner *et al*., 2007). English and Raja (1996) described three deficit irrigation case studies in which the reductions in irrigation costs were greater than the reductions in revenue due to reduced yields. Deficit irrigation can lead, in principle, to increased profits where water costs are high or where water supplies are limited. In these case studies, crop value was associated closely with yield, and crop grade and marketability were not germane. Under these circumstances, deficit irrigation can be a practical choice for growers. Tuber Crops Research Centre of BARI has released more than 104 varieties of potato but most of the varieties did not get popularity due to several reasons. Adaptability of the varieties in the changed climate was an important constraint. Therefore, physiological changes of BARI released potato varieties in the changed climate like water stress need to be studied to find out adaptable varieties. Information regarding this aspect is scarce in Bangladesh. The present study was, therefore, undertaken to find the response of selected potato varieties to different levels of irrigation.

Materials and methods

The experiment was conducted at the Tuber Crops Research Sub-Centre (TCRSC), Munshiganj during *rabi* season of 2019-20 and 2020-21. The 1st year Experiment was set on 27 November 2019 and the harvesting was done on 1 March 2020 and in the following year, the experiment was set on 30 November, 2020 and the harvesting was done on 5 March 2021. The soil of the experimental plot was sandy loam where sand, silt and clay are 35-50%, 45-60% and 20%, respectively. The soil pH was found 5.2-7.5. From November to March, there was no rainfall in both the years. The factorial experiment was executed with two factors, where Factor A: four levels of irrigation, namelyI_0 = No irrigation, I_1= One irrigation at 30 DAP, I_2= Two irrigation at 30 and 45 DAP and I_3= Three irrigation at 30, 45 and 60 DAP (Control) and Factor B: five potato varieties, viz. V_1=BARI Alu-25, V_2=BARI Alu-28, V_3=BARI Alu-36, V_4=BARI Alu-37 and V_5=BARI Alu-40. The experiment was laid out in a factorial Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3.0 m X 3.0 m. Tubers were planted following 60 cm line to line and 25 cm plant to plant spacing. Cow dung was applied @ 10 t/ha during final land preparation. Fertilizers were applied in the form of urea, TSP, MoP, gypsum, $ZnSO_4$ and boric acid @ 120-44-156-22-3-1 kg/ha of N-P-K-S-Zn-B. Half of urea and full dose of other fertilizers were applied immediately before planting the tubers in furrows and mixed properly with the soil. The rest amount of urea was side dressed at 35 days after planting (DAP). Weeding, earthing up and other intercultural operations were done as and when necessary for raising a good crop. Mancozeb (Active ingredient: Maneb and Metiram) and Secure (Active ingredient: Fluazinam) were sprayed 5 times to control diseases and Admire (Imidacloprid) was also sprayed 5 times at regular interval of 10 days to prevent insects like aphid and jassids. At the time of final land preparation, Carbofuran 5G was applied to the experimental soil to prevent the attack of cut worm and other soil pests. Data were taken on plant height, number of stems per hill, foliage coverage and plant vigor at 60 DAP, 60 DAP, 60 DAP, and 45 DAP, respectively (Kawochar and Uddin, 2015). Plant vigor was determined by the vigor codes(Kawochar and Uddin, 2015). Kawochar and Uddin (2015) reported that Code 1: Very weak - all the plants are small (< 20 cm), few leaves, weak plants, very thin stems and/or light green color. Code 3: weak plants, 75% of the plants are small (< 20 cm) or all the plants are between 20 and 30 cm, the plants have few leaves, thin stems and/or light green color. Code 5: medium, intermediate or normal plants. Code 7: vigorous plant growth, 75% of the plants are over 50 cm, robust with foliage of dark green color, thick stems and leaves very well developed. Code 9: very vigorous plants, all the plants are over 70 cm and ground coverage is complete, the plants are robust, with thick stems and abundant foliage of dark green color. Data on the number of tubers per plant at 95 DAP, weight of tubers (gm) per plant at 95 DAP, weight of individual tuber (gm) at 95

DAP, tuber fresh yield (t/ha) and tuber dry matter (%) at 95 DAP were recorded. Tuber fresh yield (t/ha) reduction percentage was calculated by the following formula:

$$\text{Tuber fresh yield reduction (\%)} = \frac{\text{Yield (t/ha) in } (I_3) - \text{Yield (t/ha) in } (I_0)}{\text{Yield (t/ha) in } (I_3)} \times 100$$

Quantity of approximate water supply: We used a siphon, record the time necessary for a siphon to fill a 100 liter container. Then water quantity was calculated from number of siphons and irrigation time.

Soil sample is collected in a moisture can and wet weight of the sample was recorded. The soil sample was dried in hot air oven at 105^{o} C until constant weight was obtained and dry weight of the sample was recorded.

$$\text{Post-harvest soil moisture content (on weight basis)} = \frac{\text{Soil wet weight} - \text{Soil dry wet}}{\text{Soil dry weight}} \times 100$$

Table 1. Approximate supplied water quantities assessment (litre) at 30, 45 and 60 DAP and post-harvest soil moisture (%) data at 95 DAP for each treatment

Treatment	Amount of approximate supplied water (Litre)			Total (litre)	Soil moisture (%) at 95 DAP
	30 DAP	45 DAP	60 DAP		
$V_1 I_0$	0	0	0	0	7.8
$V_1 I_1$	150	-	-	150	10.5
$V_1 I_2$	150	170	-	320	14.5
$V_1 I_3$	150	170	190	510	16.5
$V_2 I_0$	0	0	0	0	7.2
$V_2 I_1$	150	-	-	150	11.5
$V_2 I_2$	150	170	-	320	15.3
$V_2 I_3$	150	170	190	510	16.8
$V_3 I_0$	0	0	0	0	7.5
$V_3 3I_1$	150	-	-	150	11.75
$V_3 I_2$	150	170	-	320	14.78
$V_3 I_3$	150	170	190	510	17.5
$V_4 I_0$	0	0	0	0	6.8
$V_4 I_1$	150	-	-	150	10.55
$V_4 I_2$	150	170	-	320	14.80
$V_4 I_3$	150	170	190	510	17.30
$V_5 I_0$	0	0	0	0	7.4
$V_5 I_1$	150	-	-	150	10.85
$V_5 I_2$	150	170	-	320	15.75
$V_5 I_3$	150	170	190	510	16.75

Field data were analyzed statistically and means were separated by using Least Significant difference (LSD) test through Statistix10 statistical computer program.

Results and Discussion

The results obtained from the experiment are presented and discussed character wise:

Plant height

The interaction effects of varieties and irrigations were found significant on plant height of potato at 60 DAP in both 2019-20 and 2020-21 (Table 2). In 2019-20 and 2020-21 the tallest plant heights of 90.53 cm and 93.96 cm, respectively, were found in V_3I_3; while the shortest plant heights (51.20 cm) during 2019-20 were recorded in V_2I_0. The same was recorded as 50.67 cm in V_1I_0 during 2020-21 at 60 DAP (Table 2). The result was supported by the findings of Deblonde and Ladent (2001) where they stated that potato stem height was sensitive to drought and the effect was stronger on later cultivars especially when water shortage started early. Schittenhelma *et al*. (2006) also reported to have decreased plant height in water deficit condition.

Number of stems/hills

The interaction effect of variety and irrigation was non-significant on stem per hill at 60 DAP (Table 2). Similar results were reported by Lahlou *et al*. (2003) who stated that drought stress reduced the total stem number by 28%.

Foliage coverage

The effect of interaction between varieties and irrigations on foliage coverage percentage was significant (Table 2). The maximum foliage coverage, 93.33% in 2019-20, was recorded from V_3I_3 and 96.0% in 2020-21 from V_3I_2 while the minimum foliage coverage, 61.67% in 2019-2020 and 63.33% in 2020-21 were found from V_5I_0 at 60 DAP (Table 2). This result is in agreement with the findings of Schittenhelma *et al*. (2006) who found the decrease in ground coverage (i.e., foliage cover) with water deficit.

Plant vigor

Interaction effect of variety and irrigation on plant vigor at 45 DAP during 2019-20 and 2020-21 was non-significant (Table 2). The highest plant vigor (10.00) in 2019-20 was recorded both from V_3I_2 and V_3I_3 and also, 10.00 in 2020-21 from V_3I_2. The lowest plant vigor of 6.67 in 2019-2020 was frond from V_1I_0, V_2I_0 and V_4I_0 and that of 6.33 in 2020-21 was found from V_2I_0 and V_4I_0 (Table 2). In 'no irrigation condition' the best performances in both the years in terms of plant vigor were found 8.67 and 8.83 from V_3I_0 treatment (Table 3). Schittenhelma *et al*. (2006) also found similar effects from no irrigation treatments on plant vigor.

Table 2. Interaction effect of varieties and irrigations on plant height, number of stems/hill, foliage coverage and plant vigor of potato

Variety x Irrigation	Plant height (cm)		Number of stems/hill		Foliage coverage (%)		Plant vigor	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
$V_1 I_0$	51.68	50.67	5.50	5.00	71.67	69.17	6.67	6.67
$V_1 I_1$	71.60	73.67	6.13	5.33	85.00	80.00	7.50	7.67
$V_1 I_2$	77.07	79.11	6.57	5.97	88.33	85.00	7.67	8.33
$V_1 I_3$	77.98	78.12	7.47	6.07	91.75	90.00	8.95	8.33
$V_2 I_0$	51.20	53.33	5.63	5.03	71.67	65.00	6.67	6.33
$V_2 I_1$	63.59	58.33	6.20	5.67	80.00	75.33	7.67	6.67
$V_2 I_2$	69.33	69.00	7.00	6.00	83.67	84.00	8.00	8.33
$V_2 I_3$	71.42	70.63	7.27	6.30	89.62	90.33	8.75	8.67
$V_3 I_0$	64.33	72.17	6.07	6.00	73.33	74.00	8.67	8.83
$V_3 I_1$	69.00	75.84	6.23	6.57	85.00	85.67	9.00	9.00
V_3I_2	85.06	89.30	6.67	7.67	90.00	96.00	10.00	10.00
$V_3 I_3$	90.53	93.96	7.17	7.67	93.33	95.67	10.00	9.67
$V_4 I_0$	54.15	57.33	4.97	5.33	66.67	65.00	6.67	6.33
$V_4 I_1$	65.00	67.33	5.40	5.40	75.00	72.00	7.33	7.33
V_4I_2	72.87	72.33	5.67	5.83	83.33	80.00	8.33	8.00
V_4I_3	77.00	80.67	6.33	6.00	90.00	83.33	9.00	8.00
$V_5 I_0$	56.07	59.00	4.40	4.70	61.67	63.33	7.00	6.43
V_5I_1	61.57	61.33	4.53	4.80	76.67	75.00	7.67	7.17
V_5I_2	68.73	73.00	5.13	5.17	86.67	88.33	8.67	8.07
V_5I_3	70.42	76.33	5.73	5.30	90.00	90.33	9.00	8.33
LS	*	*	NS	NS	*	*	NS	NS
CV (%)	6.22	6.93	4.42	6.01	4.45	4.16	5.17	4.59

Means bearing same letter (s) do not differ significantly by LSD

*= Significant at 5% level of probability, NS= Non-significant, LS= Level of significance V_1= BARI Alu-25, V_2=BARI Alu-28 and V_3=BARI Alu-36, V_4=BARI Alu-37, V_5=BARI Alu-40; I_1= one irrigation at 30 DAP, I_2=two irrigations at 30 & 45 DAP, I_3=three irrigation 30, 45 & 60 DAP (Control); Y_1 = 2019-20, Y_2 = 2020-21

Tuber grade (% by number) at 95 DAP

The harvested potato tubers were separated into four grades, viz. <28 mm, 28-40 mm, 40-55 mm and >55 mm. In 2019-2020, the interaction effects of varieties and irrigations on tuber grades <28 mm, 28-40 mm and 40-55 mm showed that they did not vary insignificantly among treatment combinations. But significant variations were found on tuber grade >55 mm (Table 3). In 2020-21, tuber grades, <28 mm, 28-40 mm and >55 mm varied significantly but the variation was found insignificant for tuber grade 40-55 mm (Table 3).

In case of small size tubers (<28 mm), the maximum tubers of 41.19% and 36.68% in 2019-20 were produced by the treatment combinations V_4I_0 and V_2I_0, respectively, whereas the minimum values for small size tubers were found as 7.05% and 13.11% from the treatment combinations V_3I_2 and V_1I_3 in 2019-20 and 2020-21, respectively. In case of severe water shortage condition (no irrigation), the treatment combination V_1I_0 produced the lowest percentages of 13.85% and 23.38% of small tubers in 2019-20 and 2020-21, respectively (Table 3). The maximum percentages (44.72% and 43.95%) of tubers under grade, 28-40 mm, were found from the treatment combinations V_4I_2 and V_3I_2 in 2019-20 and 2020-21, respectively, whereas the lowest percentages 19.43% and 30.58% tubers for 28-40 mm grade were found from the treatment combinations V_2I_0 and V_4I_0 in 2019-20 and 2020-21, respectively (Table 3). In case of the least water receiving combination (no irrigation) treatment combinations, V_1I_0 and V_5I_0 performed well producing the highest percentages of 35.81% and 43.69% under the tuber grade, 28-40 mm, in 2019-20 and 2020-21, respectively (Table 4). Treatment combinations V_2I_3 and V_1I_3 produced the maximum of 47.14% and 36.24% tubers under grade 40-55 mm, whereas the lowest percentages (23.04% and 22.17%) of tubers for 40-55 mm grade were found from the same treatment combination V_5I_0 in 2019-20 and 2020-21, respectively (Table 3). Under no irrigation, treatment combinations, V_3I_0 and V_4I_0 performed well producing the highest percentages (36.53% and 30.25%) of tubers under grade 40-55 mm in 2019-20 and 2020-21, respectively (Table 3).

The maximum of 18.95% and 15.80%) of large sized tubers (>55mm), were produced by the treatment combinations V_1I_3 and V_5I_0, whereas the minimum of 4.56 and 5.55 were obtained from the treatment combinations V_3I_2 and V_5I_0 in 2019-20 and 2020-21, respectively (Table 3).

Under zero irrigation condition, V_1I_0 performed well yielding 44.11% and 43.69% of tubers to produce seed sized tubers (28-40 mm) in 2019-20 and 2020-21, respectively, whereas V_2I_0 and V_4I_0 showed very poor performance in producing only 19.43% and 30.58% seed sized tubers (Table 3). Similar results were reported by Deblonde and Ladent (2001).

Tuber grade (% by weight) at 95 DAP

In 2019-20, the interaction effects of variety and irrigation on the tuber grades, 28-40mm and >55m varied significantly but the effect was insignificant for tuber grades, <28mm and 40-55mm, whereas all the tuber grades (<28mm, 28-40mm, 40-55mm and >55mm) varied significantly in 2020-21 (Table 4). For small sized tubers (<28mm), the maximum of 8.53% and 7.82% tubers were produced by treatment combinations V_4I_0 in 2019-20 and V_5I_0 in 2020-21, respectively. The minimum of 0.98% and 1.21% tubers were produced for the same grade potato tubers respectively, in 2019-20 and 2020-21 from the same treatment combination V_3I_3. Treatment combination V_4I_0 performed well producing 2.87% and 3.26% small tubers (<28mm) in 2019-20 and 2020-21, respectively under no irrigation condition (Table 4). The maximum percentages of tubers, 27.50% and 27.94%, under grade 28-40 mm were obtained from treatment combinations V_4I_3 and V_1I_0 in 2019-20 and 2020-21, respectively. On the other hand, the lowest, 10.43% and 18.07% tubers for 28-40 mm grade were found from the treatment combinations V_2I_1 and V_3I_3 in 2019-20 and 2020-21, respectively (Table 4). Under no irrigation condition (least water receiving combination), the treatment combinations, V_1I_0 and V_5I_0 performed well producing the highest 27.94% and 21.90% tubers under grade 28-40mm in 2020-21 and 2019-20, respectively, as revealed from the same table. Treatment combinations V_3I_2 and V_4I_1 produced the maximum (60.68% and 51.06%) tubers for the grade 40-55 mm, whereas the lowest (41.85% and 34.69%) tuber percentages were found from the treatment combinations, V_4I_2 and V_4I_3 in 2019-20 and 2020-21, respectively for this grade. Under zero irrigation condition, the treatment combinations V_3I_0 and V_4I_0 performed well producing the highest percentages (58.28% and 50.74%) of tubers under grade 40-55mm in 2019-20 and 2020-21, respectively (Table 4). The treatment combinations V_1I_3 and V_3I_3 produced the highest percentages (40.51% and 40.82%) of large sized tubers under the grade, >55mm, in 2019-20 and 2020-21, respectively, whereas the lowest percentages (21.72% and 21.23%) were obtained from the combinations V_4I_1 and V_4I_2 in 2019-20 and 2020-21, respectively for this grade. In case of severe water stress (no irrigation), the highest (31.12% and 28.26%) tubers under grade >55mm were produced by V_1I_0 and V_5I_0 in 2019-20 and 2020-21, respectively (Table 4). From the above results it was found that water stress during tuber formation stage reduced the tuber size. Larger sized tuber formation was favored by well-watered condition. Similar findings were reported by Mackerel and Jefferies (1998), Struik and Voorst (1986) and Onder *et al.* (2005).

Number of tubers per hill

In both 2019-2020 and 2020-21, non-significant variation was found on number of tubers per hill at 95 DAP from the interaction effects of variety and irrigation (Table 5). In least water receiving combination, the highest (10.97 in 2019-2020 and 10.38 in 2020-21) number of tubers were produced by the treatment combination, V_3I_0, whereas the lowest (8.07 in 2019-2020 and 8.49 in 2020-21) number of tubers were produced by the treatment combination, V_5I_0. Eiasu *et al.* (2007) also found similar findings. They found that fewer stolons per stem reflected lower number of tubers and yields. Schittenhelma *et al*. (2006) also found that water deficit decreased tuber number.

Fresh weight of tubers per hill

The effect of interaction between varieties and irrigations on fresh weight of tubers/hill was significant (Table 5). The maximum fresh weight of tuber per hill in severe water stressed conditions were found 541 gm in 2019-20 and 541 gm in 2020-21 recorded from V_3I_0 while the minimum fresh weights of tubers/hill (299 gm in 2019-2020 and 304 gm in 2020-21) were found from V_5I_0 at 95 DAP.

Table 3. Interaction effect of varieties and irrigations of potato on tuber grade

Variety x Irrigation	(% by number)							
	<28 mm		28-40 mm		40-55 mm		>55 mm	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
V_1 I_0	13.85	23.38	44.11	43.69	31.85	26.06	10.20	6.87
V_1 I_1	28.04	19.31	20.44	41.14	41.51	30.51	10.01	9.05
V_1 I_2	19.98	16.98	28.33	35.50	36.37	34.47	15.32	13.06
V_1 I_3	23.35	13.11	20.38	35.89	37.32	36.24	18.95	14.76
V_2 I_0	38.97	27.63	19.43	37.56	35.57	28.98	6.03	5.84
V_2 I_1	31.66	21.95	20.57	38.31	40.11	31.96	7.65	7.78
V_2 I_2	27.18	18.44	24.34	40.41	38.64	32.41	9.84	8.73
V_2 I_3	20.54	15.15	21.07	38.65	47.14	30.90	11.26	15.30
V_3 I_0	26.58	26.47	31.07	39.87	36.53	27.72	5.82	5.93
V_33I_1	22.04	20.95	32.73	40.99	38.22	30.24	7.01	7.82
V_3 I_2	7.05	15.62	41.51	43.95	46.87	31.12	4.56	9.30
V_3 I_3	9.25	14.84	39.93	40.83	40.44	30.12	10.39	14.20
V_4 I_0	41.19	33.34	24.19	30.58	28.54	30.25	6.08	5.83
V_4 I_1	25.74	24.85	34.03	33.02	31.23	33.01	9.00	9.13
V_4 I_2	22.36	19.05	44.72	43.60	25.38	28.75	7.54	8.60
V_4 I_3	16.95	16.57	42.85	42.27	30.53	29.97	9.68	11.20
V_5 I_0	36.18	36.68	35.81	35.60	23.04	22.17	5.02	5.55
V_5I_1	27.03	26.18	23.03	35.99	39.68	28.19	10.26	9.64
V_5 I_2	17.67	17.97	29.02	37.41	40.82	32.54	12.48	12.07
V_5 I_3	12.41	13.76	33.56	38.81	39.43	31.64	14.60	15.80
LS	NS	*	NS	**	NS	NS	**	**
CV (%)	11.73	12.75	10.85	8.05	6.58	10.45	14.90	11.15

Means bearing same letter (s) do not differ significantly by LSD

*= Significant at 5% level of probability, **=Significant at 1% level of probability, NS= Non-significant, LS= Level of significance V_1= BARI Alu-25, V_2=BARI Alu-28 and V_3=BARI Alu-36, V_4=BARI Alu-37, V_5=BARI Alu-40; I_1= one irrigation at 30 DAP, I_2=two irrigations at 30 & 45 DAP, I_3=three irrigation 30, 45 & 60 DAP (Control); Y_1 = 2019-20, Y_2 = 2020-21

Table 4. Interaction effect of varieties and irrigations of potato on tuber grade

Variety x Irrigation	(% by weight)							
	<28mm		28-40mm		40-55mm		>55mm	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
$V_1 I_0$	6.72	3.94	11.42e-h	27.94	50.74	43.01	31.12cd	25.12ij
$V_1 I_1$	5.64	2.89	11.51e-h	27.77	52.36	40.51	30.49cd	28.83f-i
$V_1 I_2$	3.83	2.17	12.72e-h	21.36	44.58	40.26	38.87a	36.20bcd
$V_1 I_3$	2.24	1.57	11.46e-h	20.56	45.79	37.23	40.51a	40.63ab
$V_2 I_0$	7.22	5.08	10.63fgh	23.33	54.97	46.68	27.18c-g	24.90ij
$V_2 I_1$	5.63	3.97	10.43gh	21.46	58.00	47.55	25.94d-h	27.02g-j
$V_2 I_2$	4.30	2.80	11.01fgh	20.29	56.70	46.04	27.99c-f	30.87e-h
$V_2 I_3$	2.61	2.01	13.16e-h	21.30	59.95	38.47	24.28f-i	38.23abc
$V_3 I_0$	2.87	3.26	12.43e-h	22.46	58.28	47.82	26.41d-h	26.46g-j
$V_3 I_1$	2.04	2.28	13.47e-h	23.58	57.74	46.12	26.76c-h	28.02f-i
$V_3 I_2$	1.36	1.76	13.12e-h	19.25	60.68	41.57	24.84e-i	37.42abc
$V_3 I_3$	0.98	1.21	14.94d-g	18.07	56.67	39.90	27.40c-g	40.82ab
$V_4 I_0$	8.53	4.60	16.12de	23.07	51.71	50.74	23.63f-i	21.59j
$V_4 I_1$	5.06	3.05	23.80abc	21.97	49.41	51.06	21.72hi	23.92ij
$V_4 I_2$	3.81	2.56	26.30ab	25.34	41.85	40.87	28.05c-f	21.23d-g
$V_4 I_3$	2.63	1.79	27.50a	26.03	41.86	34.69	28.02c-f	37.50abc
$V_5 I_0$	6.66	7.82	21.90bc	22.83	46.30	41.10	25.13e-i	28.26f-i
V_5I_1	4.39	4.81	13.10e-h	23.49	52.52	35.68	29.98cde	36.02b-e
$V_5 I_2$	2.62	2.82	16.36de	22.66	49.23	41.17	31.79bc	33.35c-f
$V_5 I_3$	1.47	1.86	19.49cd	23.51	47.95	37.07	31.09cd	37.57abc
LS	NS	**	**	**	NS	**	**	*
CV (%)	11.66	12.13	14.63	9.06	5.18	6.02	10.45	9.07

Means bearing same letter (s) do not differ significantly by LSD

*= Significant at 5% level of probability, **=Significant at 1% level of probability, NS= Non-significant, LS= Level of significance V_1= BARI Alu-25, V_2=BARI Alu-28 and V_3=BARI Alu-36, V_4=BARI Alu-37, V_5=BARI Alu-40; I_1= one irrigation at 30 DAP, I_2=two irrigations at 30 & 45 DAP, I_3=three irrigation 30, 45 & 60 DAP (Control); Y_1 = 2019-20, Y_2 = 2020-21

Mean tuber weight

The effect of interaction between varieties and irrigations on mean individual tuber weight was non-significant in 2019-2020 but significant in 2020-21 (Table 5). The maximum mean tuber weight in severe water stressed conditions were 49 gm in

2019-2020 and also 49 gm in 2020-21) recorded from V_3I_0 while the minimum mean tuber weights of 37 gm in 2019-2020 from V_5I_0 and 35 gm in 2020-21 from V_4I_0 were recorded at 95 DAPS. From the same treatment combination, V_4I_3, the individual tuber weights in 2019-2020 and 2020-2021 were found 61 gm and 59 gm, respectively.

Fresh tuber yield

In 2019-2020, the fresh tuber yield (t/ha) at 95 DAP due to the interaction effect of variety and irrigation was found non-significant but significant variations were recorded in 2020-21 (Table 5). In severe water stressed condition, the treatment combition, V_3I_0 produced the highest fresh tuber yields of 25.54 t/ha in 2019-2020 and 28.92 t/ha in 2020-21. The lowest values of the same parameter were, 12.99 t/ha in 2019-2020 and 16.50 t/ha in 2020-21 produced by the treatment combination, V_5I_0. The results are in agreement with the findings of Lahlou *et al.* (2003). They reported that the yields were frequently constrained by drought in most environments. The drought stress affected the development and growth of shoots, roots and tubers. Water stress before tuber initiation reduced tuber set for certain varieties which was reported by van Loon (1981). Cavagnaro *et al*. (1971) also reported that drought stress at the beginning of the tuberization stage induced a longer period of tuber formation but decreased tuber number, growth and yield.

Tuber dry matter

In 2019-2020, due to interaction effect of variety and irrigation, the tuber dry matter percentage at 95 DAP was found significant but in 2020-21, it was non-significant variation (Table 5). In severe water stressed condition, the tuber dry matter (%) was found the highest (23.66% in 2019-2020) as recorded from V_2I_0 and in 2020-2021, it was recorded as 23.46% produced by the treatment combination, V_1I_0. The lowest tuber dry matter percentages in 2019-2020 was 19.86.86% and in 2020-21 was 20.09% obtained from the same treatment combination, V_3I_0. From the findings it was clear that gradual increase in dry matter was observed in all the genotypes with the shortage of irrigation water. Deficit water caused lowering the rate of photosynthesis and reduced other physiological activities. The main reason of dry matter increase was the shortage of water. Under stressed condition, the plant might have used the water from the tuber. These findings are in agreement with Levy (1983) who reported that tubers from water stressed plants had higher contents of total sugars and dry matter than well-watered plants. Steckel and Gray (1979) found similar findings that the dry matter content of potato tubers grown under low soil moisture was much higher than in tubers from well-watered plants

Table 5. Interaction effect of varieties and irrigations on number of tubers per plant, weight of tuber, individual tuber weight, fresh tuber yield and dry matter of potato at 95 DAP

Variety x Irrigation	No. of tubers/ hill		Fresh weight of tuber per hill (g)		Individual tuber weight (g)		Fresh tuber yield (t/ha)		Dry matter (%)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
V_1I_0	9.59	8.78	363	314	38	36	17.16	17.55	23.40	23.46
V_1I_1	10.08	9.75	444	411	44	42	22.03	23.64	22.15	22.26
V_1I_2	11.11	10.20	542	496	49	49	28.03	29.32	21.01	21.50
V_1I_3	11.83	11.05	617	583	53	53	33.74	35.56	20.29	20.04
V_2I_0	8.90	8.70	392	333	44	38	16.07	18.28	23.66	22.74
V_2I_1	10.09	9.26	498	441	49	48	23.29	25.29	22.29	21.70
V_2I_2	10.52	9.89	528	507	50	52	26.44	30.82	21.16	19.94
V_2I_3	11.40	10.82	598	571	52	53	32.28	35.74	20.47	19.19
V_3I_0	10.97	10.38	541	510	49	49	25.54	28.92	19.86	20.09
V_3I_1	12.00	11.11	620	565	52	51	31.38	33.11	18.77	19.10
V_3I_2	13.10	12.07	708	628	54	52	37.17	38.21	17.84	17.88
V_3I_3	14.13	12.98	816	721	58	55	44.57	45.26	17.41	16.98
V_4I_0	8.68	9.20	357	320	41	35	15.02	17.42	19.92	20.43
V_4I_1	10.11	9.22	506	407	50	44	22.75	23.37	18.54	19.41
V_4I_2	11.33	11.36	595	571	52	50	30.38	33.78	17.74	18.32
V_4I_3	12.32	12.19	748	721	61	59	40.88	44.86	17.38	17.15
V_5I_0	8.07	8.49	299	304	37	36	12.99	16.50	20.54	20.78
V_5I_1	10.60	8.78	445	431	42	49	19.88	24.48	19.37	19.08
V_5I_2	12.25	9.99	575	532	47	53	28.96	31.54	18.75	18.07
V_5I_3	14.46	11.01	775	639	54	58	44.17	40.43	18.25	16.99
LS	**NS**	**NS**	**	NS	NS	*	**	*	*	NS
CV (%)	5.70	6.82	5.67	11.58	6.79	8.29	4.96	9.24	2.12	1.95

Means bearing same letter (s) do not differ significantly by LSD

*= Significant at 5% level of probability, **=Significant at 1% level of probability, NS= Non-significant, LS= Level of significance V_1= BARI Alu-25, V_2=BARI Alu-28 and V_3=BARI Alu-36, V_4=BARI Alu-37, V_5=BARI Alu-40; I_1= one irrigation at 30 DAP, I_2=two irrigations at 30 & 45 DAP, I_3=three irrigation 30, 45 & 60 DAP (Control); Y_1 = 2019-20, Y_2 = 2020-21

Varieties and no irrigation interactions on yield reduction (%)

Under no irrigation condition, the highest yield reductions of 70.59% in 2019-20 and 61.17% in 2020-21 at final harvest (95 DAP) were found from the treatment combination V_5I_0 and V_4I_0, respectively. The combination V_3I_0 showed the best performance producing 42.70% yield reduction in 2019-20 and 36.10% in 2020-21at final harvest followed by treatment combinations V_1I_0 (49.14%) and V_2I_0 (48.85%) in 2019-20 and 2020-21, respectively (Table 6). The results are in agreement with the findings of Costa *et al*. (1997) and Stark and McCann (1992), where Costa *et al*. (1997) found that withholding water during tuberization severely penalized tuber yield. Stark and McCann (1992) observed the highest tuber yield reduction from water deficit during the mid-bulking period. Baghani (2009) investigated the effect of deficit irrigation on potato and concluded that under deficit irrigation conditions tuber yield of all potato cultivars studied reduced yields significantly compared to that of normal irrigation condition.

Table 6. Interaction effects of variety and no irrigation on tuber fresh yield reduction (%)

Variety x Irrigation	Tuber fresh yield (t/ha) reduction (%) at 95 DAP	
	2019-20	2020-21
$V_1 I_0$	49.14	56.27
$V_2 I_0$	50.22	48.85
$V_3 I_0$	42.70	36.10
$V_4 I_0$	63.26	61.17
$V_5 I_0$	70.59	59.19
Mean	55.18	52.32

V_1= BARI Alu-25, V_2=BARI Alu-28 and V_3=BARI Alu-36, V_4=BARI Alu-37, V_5=BARI Alu-40. I_1= one irrigation at 30 DAP, I_2=two irrigations at 30 & 45 DAP, I_3=three irrigation 30, 45 & 60 DAP (Control).

Pests and disease reaction

In case of no irrigation, some whitefly and aphids infestation were observed but not destructive. Regular spraying of insecticides minimized the damage due to whitefly and aphids infestation. This might cause as potato plants are water stressed, they produce fewer defensive compounds. Nutrients might be more concentrated in water deficient potato plants, providing a substantial food source for these pests. Some late blight disease symptoms caused by Phytophthora infestans were observed in case least water receiving combination which was under control with regular fungicide spraying. This fungal attack might be occurred due to fungal diseases that usually live on dead wood can invade living tissues when potato plants are moisture stressed. There were also some common scab infections occurred in case least water receiving combination. These might be caused because of water stressed soil condition was more favorable for potato common scab infection than well watered condition. Moreover, drought stress and pathogen infection simultaneously occur in the field.

Conclusion

The experimental results revealed that potato varieties differed significantly in their response to different levels of irrigation. In general, some varieties were considerably more tolerant to water stress treatments than others. Plant growth, dry matter and tuber yield were all reduced by water stress, and the reduction was much greater at the highest water stress level (no irrigation) of soil moisture content. BARI Alu-25, BARI Alu-28 and BARI Alu-36 varieties can be the good candidates for inclusion in breeding programs as they showed water stress tolerance.

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References

Agarwala S., T. Ota, A. U. Ahmed, J. Smith and M. Van Aalst. 2003. Development and climate change in Bangladesh: Focus on coastal flooding and the Sundarbans, OECOD, France.

Baghani, J. 2009. Effect of planting pattern and water quantity of potato cultivation with drip irrigation in Mashhad. *Water Soil. J.* **23**: 153-159. (Text in Persian with English Abstract).

Burlingame, B, B. Mouillé and R. Charrondière. 2009. Nutrients, bioactive non-nutrients and antinutrients in potatoes. *Journal of Food Composition and Analysis*. **22**:494– 502.

Cavagnaro J. B., B. R. De Lis and R.M.Tizio. 1971. Drought hardening of the potato plant as an after-effect of soil drought conditions at planting. *Potato Res.* **14**: 181-192.

Costa, L. D., G. D. Vedove, G. Gianquinto, R. Giovanard and A.Peressotti. 1997. Yield, water use efficiency and nitrogen uptake in potato: influence of drought stress. Potato Res. **40**: 19-34.

Curwen, D. 1993. Water Management. *In:* R.C. Rowe (edu). Potato Health Management. APS Press, St. Paul, Minn. pp.67-75

Deblonde, P. M. K. and J. F. Ladent. 2001. Effects of moderate water stress conditions on green leaf number, stem height, leaf length and tuber yield of potato cultivars. *Europ. J. Agronomy*. **14**: 31-41.

Eiasu, B. K., P. Soundy and P. S. Hammes. 2007. Response of potato *(Solanum tuberosum)* tuber yield components to gelpolymer soil amendments and irrigation regimes. *N. Z. J. Crop Hort*. **35**: 25–31. [doi: 10.1080/01140670709510164]

English, M. and S. N. Raja. 1996. Perspectives on deficit irrigation. *Agricultural Water Managemen*t. **32**: 1-14.

Evers, D., I. Lefèvre, S. Legay, D. Lamoureux, J. F. Hausman and R. O. Rosales. 2010. Identification of drought-responsive compounds in potato through a combined transcriptomic and targeted metabolite approach. *J. Exp. Bot*. **61**: 2327–2343. doi: 10.1093/jxb/erq060 PubMed Abstract | CrossRef Full Text | Google Scholar

FAOSTAT. 2013. FAO Statistical Database. Available:http://faostat3.fao.org/home/index.html#DOWNLOAD_ (Accessed 2013.08.23).

Hijman, R. J. 2003. The effect of climate change on global potato production. *Amer. J. Potato Res.* **80**: 271-280

Jones, H. G. and J. E. Corlett. 1992. Current topics in drought physiology. *J. Agric. Sci.* **119**: 291–296. 10.1017/S0021859600012144 [Cross Ref].

Kawochar, M. D. and M. J. Uddin. 2015. Field Data Descriptor of Potato (*Solanum tuberosum* L.). 10.13140/RG.2.1.1782.5761.

Lahlou, O., S. Ouattar and J. Ledent. 2003. The effect of drought and cultivar on growth parameters, yield and yield components of potato. *Agronomie*. **23**: 257-268.

Levy, D. 1983. Varietal differences in the response of potatoes to repeated short periods of water stress in hot climates. 2. Tuber yield and dry matter accumulation and other tuber properties. *Potato Research,* 26: 315–321 http://dx.doi.org/10.1007/BF02356152

MacKerron, D. K. Land R. A. Jefferies. 1988. The distribution of tuber sizes in droughted and irrigated crops of potato. Observation on the effect of water stress on graded yields from differing cultivars. *Potato Res*. **31**: 269-278.

Magistro J, M. Roberts, S. Haggblade, F. Kramer, P. Polak , E. Weight and R. Yoder. 2007. A model for pro-poor wealth creation through small-plot irrigation and market linkages. *Irrigation and Drainage.* **56**:321–334.

Obidiegwu, J., G. Bryan, G. Jones and A. Prashar. 2015. Coping with drought: stress and adaptive responses in potato and perspectives for improvement. *Front. Plant Sci.* 6: 542. doi: 10.3389/fpls.2015.00542 PubMed Abstract | CrossRef Full Text | Google Scholar

Onder, S., M. E. Caliskan, D. Onder, and S. Caliskan. 2005. Different irrigation methods and water stress effects on potato yield and yield components. Agric. *Water Manage.* **73**: 73-86.

Rashid, M. H. and M. S. Salam. 2007. Adaptation of climate for sustainable development of Bangladesh agriculture. Bangladesh country paper-presented in the 3rd session of Technical Committee of Asian and Pacific Centre for Agricultural Engineering and Machinery (APCAEM) on November Beijing, China. 20-21: 2007.

Schittenhelma, S., H. Sourell and F. J. Lopmeier. 2006. Drought resistance of potato cultivars with contrasting canopy architect. *Europ. J. Agronomy.* **24**: 193-202.

Steckel, J.R.A. and D. Gray. 1979. Drought tolerance in potatoes. *Journal of Agricultural Science.* **92**: 375-381 http://dx.doi.org/10.1017/S0021859600062900

Stark, J. C. amd I. R. McCann. 1992. Optimal allocation of limited water supplies for Russet Burbank potatoes. *Amer. Potato J.* **69**: 413-421.

Struik, P. C. and G. van Voorst. 1986. Effects of drought on the initiation, yield and size distribution of tubers Solanumtuberosum L. cv. Bintje. *Potato Research*. **29**: 487-500.

Tanner, T. M., A, Hassan, K. M. N. Islam, D. Conway, R. Mechler, A. U. Ahmed and M. Alam. 2007. ORCHID: Piloting climate risk screening in DFID Bangladesh. Detailed Research Report. Institute of Development Studies, University of Sussex, UK.

Van Loon, C.D. 1981. The effect of water stress on potato growth, development and yield. *Amer. Potato J.* **58**: 51-69.

Yohannes, D. F., C. J. Ritsema, H. Solomon, J. Froebrich, J. C. van Dam. 2017. Irrigation water management: Farmers' practices, perceptions and adaptations at Gumselassa irrigation scheme, North Ethiopia. *Agricultural Water Management.* **191**: 16–28.

Zarzynska, K., D. Boguszewska-Mankowska and A. Nosalewicz. 2017. Differences in size and architecture of the potato cultivars root system and their tolerance to drought stress. *Plant Soil Environ.* **63**:159–164. doi: 10.17221/4/2017-PSE Cross Ref Full Text | Google Scholar.