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RESPONSE OF FOUR POTATO VARIETIES TO WATER DEFICIT STRESS UNDER FIELD CONDITION

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Abstract

An experiment was conducted at the Horticultural Research Field of Gazipur Agricultural University, Salna, Gazipur, during November 2016 to March 2017 to observe the responses of different potato varieties under different water deficit stress conditions and to find out the potential potato variety(ies) for achieving the maximum yield under water deficit stress condition. The experiment comprised four potato varieties, namely BARI Alu-7 (Diamant), BARI Alu-8 (Cardinal), BARI Alu-25 (Asterix) and BARI Alu-28 (Lady Rosetta) and three irrigations *viz*., Single irrigation at 30 days after planting (DAP) (Severe water stress), two irrigations at 30 and 45 DAP (Mild water stress) and three irrigations at 30, 45 and 60 DAP (Normal condition-no water stress). The results revealed that yield reduction under severe water stress condition was minimum in BARI Alu-25 (23.68%), followed by variety BARI Alu-28 (25.68%). The high yield maintenance ability of BARI Alu-25 and BARI Alu-28 under severe water stress was also supported by their higher stress tolerance indices of 0.82 and 0.74, respectively and their lower stress susceptibility indices of 0.58 and 0.55, respectively. BARI Alu-25 produced the highest fresh tuber yield, dry matter percentage, stress tolerance index (STI), lowest yield reduction and lowest stress susceptibility index (SSI) in well watered condition as well as the other two water deficit stress conditions.

Keywords: Potato, water deficit stress, dry matter, tuber yield, stress susceptible index, stress tolerance index.

Introduction

Potato (*Solanum tuberosum* L.), a member of Solanaceae family, is popularly known as 'Alu' in Bangladesh. It is the second largest food crop in Bangladesh next to rice and has recently occupied an important place in the list of major food and cash crops of Bangladesh (Ali and Haque, 2011). In the year 2022-23, total annual potato production was 10.431 million tons from an area of 0.455 million hectares and average yield was 22.90 t/ha (Anon., 2024). The area and production of potatoes are increasing day by day due to its higher demand and profitability. Potato is grown more or less in all districts of Bangladesh but better in the districts of Munshiganj, Bogra, Rangpur, Dinajpur and some parts of greater Cumilla (Anon., 2014). In the last few decades, several dozens of high yielding varieties (HYV) of potato were

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brought to Bangladesh and tried experimentally under local conditions before they were recommended for general cultivation (Khalil *et al*., 2013). The yield range of these released potato varieties is 20-40 t/ha (Azad *et al*., 2020).

Drought is commonly defined as a period without significant rainfall. Water deficit is a global issue that needs to be taken into consideration to ensure survival of agricultural crops and sustainable food production (Jaleel *et al*., 2009). Potato is a drought-sensitive crop and the detrimental effects of drought on potato tuber yield and other related traits are well documented (Hassanpanah, 2010). Water deficit (drought) is responsible for reduction of tuber yield, plant height, ground coverage and tuber number (Hassanpanah, 2010). Lahlou *et al*. (2003) and Hassanpanah (2010) reported the genotype-dependent differences of tuber yield under water deficit stress. Aliche *et al*. (2018) and Hill *et al.* (2021) reported that water restriction reduced leaf growth as well as having negative effects on growth, tuber formation, and tuber enlargement under drought stress. In Bangladesh, monsoon rains provide about 80% of annual rainfall, when this is reduced, drought becomes a significant problem. Every year Bangladesh experiences a dry period of seven months from November to May when rainfall is normally low. Though TCRC of BARI has been released more than 100 varieties of potato, most of the varieties did not get popularity due to several reasons among which abiotic stresses such as water deficit (drought). Performance of BARI potato varieties in the changed climate like water deficit stress needs to be studied to find out the adaptable varieties under water stress (drought) condition. Information regarding this aspect is scarce in Bangladesh. Considering the above facts in view the present study was conducted to study the responses of different potato varieties under water stress condition and to find out the suitable variety (ies) which can give high yield under this moisture stress condition.

Materials and Methods

The experiment was conducted at the Horticultural Research Farm of Gazipur Agricultural University (GAU). The area belonged to the Agro-Ecological Zone 28 (AEZ 28) i.e. the Madhupur tract which lies between 24^0 05ʾ N latitude and $90^0$25’ E longitude with an elevation of about 8.5 m above sea level. Weather data of GAU during the experimental period (2016-17) are presented in Fig. 1. The initial soil (0-30 cm depth) sample of experimental plot was analyzed as per standard methods (Table 1).During the cropping season (November-March), the maximum temperature ranged was 24.63-33.16 ºC while the minimum temperature range was 11.53-20.93 ºC and the average temperature range was 18.08-23.04 ºC (Fig.1). The average relative humidity (RH) percentage was 78.45-89.41% and total rainfall was 99.99 mm during the cropping season.

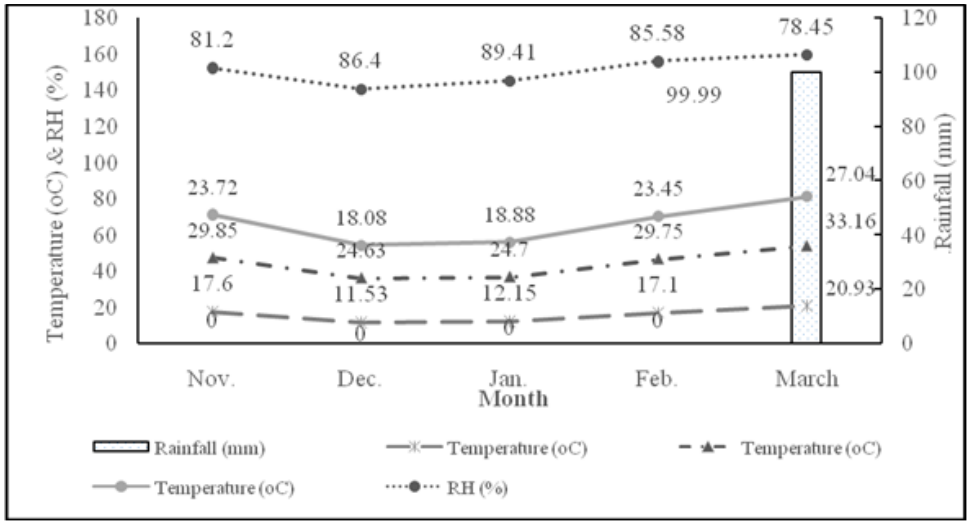

Fig. 1. Weather data (temperature, rainfall and relative humidity (RH)) during experimentation period in 2016-17.

Table 1. The initial physical and chemical properties of soil in the experimental field

Soil properties	Value	Remarks
Sand	21	-
Silt	42	-
Clay	37	-
Textural class	clay loam	-
Particle density (g cm^{-3})	2.61	-
Soil moisture at Field Capacity	28.5-29%	
Bulk density (g cm^{-3})	1.32	
Soil pH	6.20	Slightly acidic soil
Total nitrogen (%)	0.06	<0.12 (critical level), very low
Organic carbon (%)	0.72	low
Organic matter (%)	1.24	low
Available P (µg/g))	21.07	>7.0 (critical level), high
Available S (µg/g)	11.02	>10.0 (critical level), low
Available B (µg/g)	0.14	<0.2 (critical level), low
K (meq 100^{-1} g soil)	0.25	>0.12 (critical level), medium

The experiment was laid out in the field following Strip Plot Design with three replications. The experiment consisted of four potato varieties, namely V_1 = BARI Alu-7 (Diamant), V_2 = BARI Alu-8 (Cardinal), V_3 = BARI Alu-25 (Asterix) and V_4 = BARI Alu-28 (Lady Rosetta) that were allocated in horizontal plot and three irrigations viz. I_1= Single irrigation at 30 DAP (Severe stress), I_2 = 2 Irrigation at

30 and 45 DAP (Mild stress) and I3= Three Irrigation at 30, 45 and 60 DAP (Normal irrigation) that were allocated in vertical plots. The field was prepared thoroughly by plowing with power tiller followed by laddering to obtain a good tilt. The weeds and stubbles were removed from the field and bigger clods were broken into small pieces. The soil particles were pulverized and the land was leveled uniformly for the experimentation. There were five rows in each plot at 60 cm distance and twelve plants in each row at 25 cm distance. Total area of each plot was 9.0 m^2 (3.0 m × 3.0 m). Tubers of different varieties were kept in a well-ventilated room and allowed to sprouting in diffused light for obtaining healthy sprout prior to planting. Tubers of different varieties were kept in a well-ventilated room and allowed to sprouting in diffused light for obtaining healthy sprout prior to planting. Sprouted seed tubers were planted on 20 November, 2016. Sprouted whole tubers were planted following ridge method. Ridge was made by earthing up of side soils**.** Plant nutrients (N-P-K-S-Zn-B) were applied @ 150-44-130-22-3-1 kg/ha in the form of urea, TSP, Muriate of Potash, Gypsum, Zinc oxide and Boric acid, respectively. Cowdung was applied @ 10 t/ha during final land preparation. Full dose of P, S, Zn, B, and half of N were applied in furrows at the time of planting and then mixed with soil so that the tubers do not come in contact with fertilizers. The remaining half of N was applied as top dress at 35 days after planting (DAP).

Intercultural operations such as weeding, earthing up were done manually. After spading the soil between the rows, weeds were removed. Earthing up was done two times during growing period. First earthing up was done at 35 DAP when the plants attained a height of 15-20 cm from the ground, the second one was done after 20 days of first earthing up. Before first earthing up, the remaining half N was applied. Furadan 5G @ 10 kg/ha was applied during the final land preparation to control ant, mite, cutworm, aphid and other soil borne insects. Malathion (0.2%) was sprayed to the crops in two installments at 45 and 60 DAP to control insects. The crops were sprayed with Dithane-M 45 (a.i. Mancojeb) (0.2%) and Ridomyl Gold (a.i. Mancozeb + Metaloxyl) (0.2%) alternatively five times at 30, 40, 50, 65 and 75 DAP to prevent late blight infection and other diseases of potato. Haulm pulling was done before seven days of harvest. Hardening of tuber and setting up of skins were allowed for 8 days under the soil and there after tubers were harvested on 23 February, 2017. Tubers were collected carefully with the help of spade without any injury. Data were recorded on plant height (cm), number of stems/hills, foliage coverage (%), plant vigour, tuber dry matter (%), tuber fresh weight/plant, tuber fresh yield/ha, number of tubers/plants, individual tuber weight (g), Stress susceptibility index (SSI) and Stress tolerance index (STI). Foliage coverage (%) was recorded at 45 and 60 DAP with a 1 m x 1 m wooden frame having 100 gaps (10 cm x 10 cm). By placing the quadrant on the foliage of the crops and counting the blank gaps and then foliage coverage (%) were estimated by subtracting the blank gap value from 100 and expressed in percentage. The plant vigour was

recorded on the basis of phenotypic expression of plants on eye estimating using arbitrary CIP 1-9 scale, where, 1=poor, 9=vigorous (Moonsat, 2014). Tuber dry matter (%) was determined by drying the tuber slices at 70 ˚C for 72 hours in drying oven according to the method of Dogras *et al*. (1991).

Stress susceptibility index (SSI) was calculated according to the formula given below (Fischer and Maurer, 1978):

Stress susceptibility index (SSI) = $(1 - \frac{Y_{si}}{Y_{pi}})/SI$; (Fischer and Maurer, 1978)

Where, Y_{Si} and Y_{Pi} = yield of cultivar under stress and normal conditions, respectively and $(SI = \frac{Y_{si}}{Y_{pi}})$

Stress tolerance index (STI) was calculated according to the formulae given below (Fernandez, 1992):

Stress tolerance index (STI) = $\frac{Y_{si} \times Y_{SI}}{(Y_{mp})2}$

Where, Y_{Si} and Y_{Pi} = yields of cultivar under stress and normal condition, respectively. Y_{mp} = average yield of all varieties under normal condition.

The water amount used was regularly calculated according to the collected evaporation of a Class A Basin using the equation: IW/CPE = 0.8 where IW=the amount of irrigation water (mm) and CPE=the collected evaporation calculated from evaporation pan (mm). Application of measured amount of irrigation water (IW): A calibrated watering container of 100 liters volume was used to apply measured amount of irrigation water. Amount of precipitation was measured by a udometer and daily evaporation by a Class A evaporation pan. For monitoring soil moisture at a regular interval to find out the irrigation requirement and irrigation timing Electronic 4in1 Soil Survey Instrument was used. The collected data on various parameters were statistically analyzed using the Statistix 10 software program. Mean values were compared using the least significant difference (LSD) test at the 1% or 5% level of probability.

Results and Discussion

The results obtained from the experiment are presented and discussed character wise under separate headings in this chapter. Plant height, number of stems/hill, foliage cover and plant vigour were significantly influenced by various potato varieties and water stress treatments (Tables 2, 3 and 4)

Plant height (cm) at 60 days after planting

The longest plant (60.43 cm) was obtained from V_3 which was statistically similar to V_4 (51.53 cm). This corroborates the results of Amanullah *et al.* (2010) who

recorded similar increasing pattern in different potato varieties viz. Binella, Cardinal, Chamak and Heera. The influence of different levels of water stress treatments (levels of irrigations) on plant height was found significant at 60 DAP. The tallest plant (61.58 cm) was found in I_3 (no stress condition), while, the shortest plant (40.11cm) was found in I_1 (severe water stress) at 60 DAP. At 60 DAP, in severe water deficit stress (I_1) condition, the variety V_3 gave the maximum plant height (43.81 cm) which was statistically similar to V_4 and V_1 and the variety V_2 recorded the lowest plant height. In well watered condition (I_4), the variety V_4 produced the highest plant height (74.67 cm) followed by V_3 (65.33 cm) and V_1 (60.78 cm), and the V_2 gave the lowest plant height. Across varieties, plant height was decreased significantly with an increase in the water deficit. Water stress is known to suppress cell expansion and cell growth due to low turgour pressure. Our results confirm the findings of Jaleel *et al*. (2009).

Number of stems per hill at 60 days after planting

The maximum number of stems (7.08) per hill at 60 DAP was found in V_4, which was statistically similar to V_2. The larger seed tubers showed the trend to produce a greater number of sprouts than the smaller seed tubers correspondingly gave the greater number of stems per hill. The highest number of stems (7.24) per hill at 60 DAP was found in I_3 which was statistically dissimilar with other treatments. At 60 DAP the maximum number of stems/hill was recorded from V_4 (8.17/hill) which was identical with V_3 (7.60) and then followed by V_2 (6.63/hill) and V_1 (6.27/hill) with no significant difference between V_1 and V_2 at well watered condition (3). At mild water stress condition (I_2) the variety V_4 gave the highest number of stems (7.23/hill) which was statistically similar to the rest all three varieties (V_1, V_2 and V_3), whereas at severe water stress condition (I_1), the variety V_4 produced the maximum number of stems (5.83/hill) being identical with V_3 and V_1, and the variety V_2 gave the lowest number of stems/hills. Similar findings showing the effects of water deficit stress on number of stems per hill were also reported earlier by Deblode and Ladent (2001).

Foliage coverage (%) at 60 days after planting

The best foliage coverage 93.11% at 60 days after planting (DAP was found in both V_4 and V_3 followed by V_2 (74.11%) and V_1 (72.78%) with no significant difference between them. This deviation from our findings might be due to differences in climatic conditions. Foliage coverage is an important factor for a variety as it is directly related to the photosynthetic area. The highest coverage at earlier stage may ensure early bulking. Better foliage coverage resulted in increased photosynthesis rate and high total tuber yield (Saika and Deka, 2006).

The best foliage coverage 89.00% at 60 DAP was found in I_3 followed by I_2 (82.92%) and the lowest foliage coverage 76.42% was found in I_1 at 60 DAP. At 60 DAP, when well water condition was fulfilled, the topmost foliage coverage (97.67%) was recorded from V_4 which was statistically similar to V_3 (95.00%) and the lowest foliage coverage (65.00%) was obtained from V_1 which was statistically similar to V_2. At severe water deficit stress condition (60 DAP), the V_4 gave the highest foliage coverage (88.33%) followed by V_3 (86.67%). Fleisher *et al* (2008) reported that water deficit stress affected potato canopy architecture by decreasing leaf size and leaf expansion rate while limiting formation of new leaves and increasing the rate of senescence.

Plant vigor at 60 days after planting

The highest plant vigor (9.07) was observed in V_4 which was statistically similar to V_3 (8.77) and the lowest (6.04) plant vigor was observed in V_1. The best plant vigor (8.65) was found in I_3 which was statistically dissimilar with other treatments. At 60 DAP, the highest plant vigor (9.77) was found in V_4 which was identical with V_3 (9.70) and the minimum plant vigour was recorded in V1 at well watered condition (I_3). At 60 DAP, in severe water stress condition, the variety V_4 recorded the maximum plant vigour (8.27) which was closely followed by V_3 (7.63) and the variety V_1 had the lowest plant vigour (5.33) which was statistically similar to V_2 (7.13). The result indicated that the plant vigour of potato was influenced by the moisture present in the soil. Plant vigor also depends on the seed quality, seed size and potentiality of the genotypes, infection of virus, soil born and seed borne diseases.

Table 2. Main effect of variety on plant height, number of stems per hill, foliage coverage and plant vigor of potato at 60 DAP

Variety	Plant height (cm)	Stems/hill (no)	Foliage coverage (%)	Plant vigor
V_1	49.01	5.82	72.78	6.044
V_2	41.65	5.70	74.11	6.97
V_3	60.43	6.62	91.11	8.77
V_4	51.53	7.08	93.11	9.07
LSD	6.43	0.93	4.53	0.54
CV (%)	12.62	12.85	4.74	6.97

V_1= BARI Alu-7 (Diamant), V_2= BARI Alu-8 (Cardinal), V_3= BARI Alu-25 (Asterix) and V_4= BARI Alu-28 (Lady Rosetta).

Table 3. Main effect of irrigation on plant height, number of stems per hill, foliage coverage and plant vigor of potato at 60 DAP

Variety	Plant height (cm)	No. of Stems/hill	Foliage coverage (%)	Plant vigor
I_1	40.11	5.12	76.42	6.81
I_2	50.28	6.56	82.92	7.98
I_3	61.58	7.24	89.00	8.65
LSD	6.93	0.34	3.81	0.63
CV (%)	11.98	4.74	4.06	7.07

I_1= Single irrigation at 30 DAP (Severe stress), I_2 = Two irrigations at 30 and 45 DAP (Mild stress) and I_3= Three irrigations at 30, 45 and 60 DAP (Normal Condition-no water stress)

Table 4. Interaction effect of variety and irrigation on plant height, number of stems per hill, foliage coverage and plant vigor of potato at 60 DAP

Variety x Irrigation	Plant height (cm)	No. of Stems/hill	Foliage coverage (%)	Plant vigor
V_1 I_1	38.00	4.70	65.00	5.33
V_1 I_2	48.23	6.20	71.67	6.87
V_1 I_3	60.78	6.57	81.67	7.13
V_2 I_1	35.57	4.17	65.67	6.00
V_2 I_2	39.85	6.30c	75.00	6.90
V_2 I_3	49.53	6.63	81.67	8.00
V_3 I_1	43.81	5.80	86.67	7.63
V_3 I_2	59.52	6.47	91.67	8.97
V_3 I_3	65.33	7.60	95.00	9.70
V_4 I_1	43.05	5.83	88.33	8.27
V_4 I_2	50.00	7.23	93.33	9.17
V_4 I_3	74.67	8.17	97.67	9.77
LSD	10.50	1.17	6.52	0.93
CV (%)	4.73	8.48	2.93	3.33

V_1= BARI Alu-7 (Diamant), V_2= BARI Alu-8 (Cardinal), V_3= BARI Alu-25 (Asterix) and V_4= BARI Alu-28 (Lady Rosetta).

I_1= Single irrigation at 30 DAP (Severe stress), I_2 = Two irrigations at 30 and 45 DAP (Mild stress) and I_3= Three irrigations at 30, 45 and 60 DAP (Normal Condition-no water stress).

Variation in number of tubers per plant, tuber fresh weight (g)/plant, individual tuber weight (g), tuber fresh yield (t/ha) and Tuber dry matter percentage at 95 days

after planting was found significant (Table 5, 6 and 7). The maximum number of tubers/plant (10.78) was found in V_4 which was statistically similar to V_3 (9.61) and the minimum (8.51) was found in V_2 being identical with V_1 (8.53). Variation in number of tubers/plants was also found significant due to the influence of irrigation at 95 DAP. The highest number of tubers/plant (10.88) at 95 DAP was found in I_3 and the lowest tuber number/plant (8.10) was found in I_1. From the above results it is observed that a gradual increase in tuber number/plant was found with the corresponding increase in water supply in all the varieties.

At 95 DAP, in well watered condition, the maximum tuber number/plant (12.42) was found in V_4 followed by V_2 (10.58) which was statistically similar to V_3 (10.47) and V_1 (10.06) (Table 8). At 95 DAP, in severe water deficit water stress condition, the variety V_4 gave the maximum tuber number per plant (9.60), which was statistically similar to V_3 (8.90). From the above results it was observed that water deficit stress reduced the tuber number/plant of potato variety at 95 DAP. Similar results were reported by (Deblonde and Ladent, 2001).

Tuber fresh weight/plant (g) at 95 days after planting

The maximum (407.57g) tuber fresh weight/plant at 95 DAP was found in V_4 which was statistically similar to V_3 (382.40 g) and the minimum tuber fresh weight (291.65g/plant) was found in V_2 being identical with V_1 (302.08 g/plant. The maximum tuber fresh weight (440.01g/plant) at 95 DAP was found in I_3 followed by I_2 (337.25 g/plant) and the minimum tuber fresh weight (260.51g/plant) was found in I_1 (260.15 g/plant). At 95 DAP, in well watered condition, the maximum tuber fresh weight (461.17g/plant) was found in V_4 which was statistically similar to other three varieties (V_3, V_2 and V_1). At 95 DAP, in severe water deficit stress condition, the highest tuber fresh weight (342.84 g/plant) was obtained from V4 closely followed by V_3 (331.50) and the lowest tuber fresh weight was found in V_2 (171.23 g/plant) being identical with V_1 (196.47 g/plant). From the above results it was observed that water deficit stress reduced the tuber fresh yield/plant at 95 DAP in potato variety studied. Lahlou *et al*. (2003) reported that yields are frequently constrained by water deficit (drought) stress because drought stress affects the development and growth of shoots, roots and tubers.

Tuber fresh yield at 95 days after planting

The maximum tuber fresh yield at 95 DAP was found in V_4 (27.15 t/ha) which was statistically similar to V_3 (25.47 t/ha). The maximum tuber fresh yield at 95 DAP was found in I_3 (29.31 t/ha) which was identical with I2 (22.62 t/ha) and the minimum tuber fresh yield at 95 DAP was recorded in I_1 (17.35 t/ha).

At 95 DAP, in well watered condition, the highest tuber fresh yield was found in V_4 ((30.72 t/ha) which was statistically similar with V_3, V_1 and V_2. In severe water

deficit water stress condition, maximum tuber fresh was obtained from V_4 (22.83 t/ha) closely followed by V_3 (22.08 t/ha) and the minimum fresh yield was recorded in V_2 (11.40 t/ha) being identical with V_1 (13.08 t/ha). The findings are in agreement with Deblonde and Ladent (2001) and Hassanpanah (2010) who reported that drought treatment adversely affected tuber yield.

Individual tuber weight at 95 days after planting

Individual tuber weight (g) was significantly influenced by variety at 95 days after planting (DAP). The maximum individual tuber weight (39.79 gm) was found in V_3 closely followed by V_4 (37.76 g) and V_1 (34.60 g). There was no significant difference found among V_4, V_2 and V_1 in respect of individual tuber weight. The highest individual tuber weight was found in I_4 (40.64 g) closely followed by I_2 (36.82 g) and the least individual tuber weight was found in I_1 (31.49.g). At 95 DAP, in well watered condition, all the four varieties gave the identical individual tuber fresh weight where the maximum individual tuber weight was found in V_1 (42.27 g) and the minimum individual tuber weight was noticed in V_2 (25.00 g) (Table 8). Steckel and Gray (1979) reported that drought-tolerant potato cultivars produced fewer but larger tubers (>40 mm in length), making the yield more marketable than drought-sensitive cultivars.

Tuber dry matter at 95 days after planting

Across varieties, the tuber dry matter content increased as the water deficit stress increased. The highest tuber dry matter at 95 DAP was found in V_3 (22.80%) which was statistically different from other three varieties. The maximum tuber dry matter was found in I_1 (22.77%) which was statistically different from other irrigation treatments. The minimum tuber dry matter at 95 DAP was found in I_3 ((20.32%).

At 95 DAP, in normal condition, the maximum tuber dry matter was found in V_3 (21.37%) which was statistically different from other treatment combinations (Table 7), and the lowest tuber dry matter (19.24%) was found in V_2 (19.24%) which was statistically similar to V_1 (19.71%) and also no significant difference was found between V_4 and V_1 with regard to tuber dry matter content. At 95 DAP, in mild water deficit stress condition, At 95 DAP, in mild water deficit stress, the maximum tuber dry matter content was recorded from V_3 (22.36%) which was statistically similar to V_4 (21.37%) and the minimum tuber dry matter content was found from V_2 (19.99%). In severe water stress condition, the highest tuber dry matter content was found in V_3 (24.38%) followed by V_4 (23.21%) and the lowest dry matter content was recorded in V_2 (21.55%) which was identical with V1 (21.92%). Under water deficit stress condition, the plant might have used the water from the tuber that might increase dry matter content in potato 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. Due to the higher moisture content of the tubers and subsequently the significant decrease in the dry matter during drought exposure, the dry matter percentage of potato tubers decreased (Widuri *et al.,* 2020). However, dry matter content significantly increased in BARI Alu-25 (V_3) followed by BARI ALu-28 (V_4) when compared to BARI Alu-8 (V_2) and BARI ALu-7 (V_1).

Table 5. Main effect of varieties on number of tubers/plants, tuber fresh weight /plant, tuber fresh yield, individual tuber weight and tuber dry matter of potato at 95 DAP

Variety	Tubers/plant (no)	Tuber fresh weight/plant (g)	Individual tuber weight (g)	Fresh tuber yield (t/ha)	Tuber dry matter (%)
V_1	8.53	302.08	34.60	20.12	20.78
V_2	8.51	291.65	33.12	19.42	20.21
V_3	9.61a	382.40	39.79	25.47	22.80
V_4	10.78	407.57	37.76	27.15	21.74
LSD	1.21	44.15	5.51	2.94	0.92
Lev. of sig.	**	**	*	**	**
CV (%)	11.22	11.06	13.15	11.07	3.74

V_1= BARI ALU-7 (Diamant), V_2= ARI ALU-8 (Cardinal), V_3= BARI ALU-25 (Asterix) and V_4= BARI Alu-28 (Lady Rosetta); Lev. of sig. = Level of Significance

Table 6. Main effect of irrigations on number of tubers/plant, tuber fresh weight/plant, tuber fresh yield, individual tuber weight and tuber dry matter of potato at 95 DAP

Irrigation	Tubers/plant (no)	Tuber fresh weight/plant (g)	Individual tuber weight (g)	Fresh tuber yield (t/ha)	Tuber dry matter (%)
I_1	8.10	260.51	31.49	17.35	22.77
I_2	9.10	337.25	36.82	22.62	21.11
I_3	10.88	440.01	40.64	29.31	20.32
LSD	0.70	50.44	4.18	3.36	0.54
CV (%)	6.63	12.86	10.16	12.86	2.23

**= Significant at 1% level of probability; *= Significant at 5% level of probability.

I_1= Single irrigation at 30 DAP (Severe stress), I_2= Two Irrigations at 30 and 45 DAP (Mild stress) and I_3= Three Irrigations at 30, 45 and 60 DAP (Normal); DAP = Days after planting; Lev. of sig. = Level of significance.

Table 7. Interaction effect of variety and irrigation on number of tubers/plants, tuber fresh weight/plant, tuber fresh yield, single tuber weight and tuber dry matter of potato at 95 DAP

Variety X Irrigation	Tubers/plant (no)	Tuber fresh weight/plant (g)	Individual tuber weight (g)	Fresh tuber yield (t/ha)	Tuber dry matter (%)
V_1 I_1	7.02	196.47	27.86	13.08	21.92
V_1 I_2	8.53	286.09	33.67	19.05	20.71
V_1 I_3	10.06	423.68	42.27	28.22	19.71
V_2 I_1	6.86	171.23	25.00	11.40	21.55
V_2 I_2	8.08	262.80	32.65	17.50	19.99
V_2 I_3	10.58	440.92	41.71	29.37	19.24
V_3 I_1	8.90	331.50	37.44	22.08	24.38
V_3 I_2	9.47	381.43	40.38	25.41	22.36
V_3 I_3	10.47	434.28	41.54	28.93	21.67
V_4 I_1	9.60	342.84	35.67	22.83	23.21
V_4 I_2	10.33	418.71	40.56	27.89	21.37
V_4 I_3	12.42	461.17	37.04	30.72	20.64
LSD	1.53	74.69	7.67	4.97	1.12
CV (%)	5.77	8.48	8.13	8.48	1.44

V_1= BARI Alu-7 (Diamant), V_2= ARI Alu-8 (Cardinal), V_3= BARI Alu-25 (Asterix) and V_4= BARI Alu-28 (Lady Rosetta)

I_1= Single irrigation at 30 DAP (Severe stress), I_2 = Two Irrigations at 30 and 45 DAP (Mild stress) and I_3= Three Irrigations at 30, 45 and 60 DAP (Normal); DAP = Days after planting.

Stress susceptibility index (SSI) and Stress tolerance index (STI)

Stress indices were used to screen and identify the stress tolerant genotypes. In the present study, the maximum SSI (150) was recorded in the variety BARI Alu-8 (V_2) which was closely followed by the variety BARI Alu-7 (V_1) (1.32) under severe water deficit stress condition (I_1) (Table 8). The lowest value of SSI was found in BARI Alu-25 (0.58) which was statistically similar to BARI Alu-28 (V_4). The STI value was found maximum (0.82) in the variety BARI Alu-28 (V_4) which was closely followed by the variety BARI Alu-25 (V_3) (0.74) under severe water deficit stress condition (Table 8). Under mild stress condition (I_2) the highest SSI value was recorded in the variety BARI Alu-8 (V_2) (1.73) which was closely followed by the variety BARI Alu-7 (V_1) (1.39) and the lowest SSI value was found in the variety BARI Alu-28 (V_4) (0.39) which was statistically similar to

BARI Alu-25 (V_3) (0.52). Under mild water deficit stress condition (I_2), the maximum STI value was found in BARI Alu-28 (V_4) (1.00) which was identical with BARI Alu-25 (V_3) (0.86) and the lowest STI value was recorded in BARI Alu-8 (V_2) (0.60) closely followed by BARI Alu-7 (V_1). Differences in potato varieties for SSI and STI indices due to water deficit stress were earlier reported by several workers in different crops (Schafleitner *et al*., 2007 and Hassanpanah, 2010). Overall, BARI Alu-25 and BARI Alu-28 were identified as promising varieties for water stress tolerance based on their high stress tolerance index and low stress susceptibility index. Fischer and Maurer (1978) concluded that selection of stress tolerant genotypes should be based on stress susceptibility index (SSI). Deshmukh *et al.* (2004) reported that stress-resistant genotypes should have high stress tolerance index (STI) and minimum stress susceptibility index (SSI).

Yield reduction

The minimum yield reduction under severe water deficit condition (I_1) was recorded in the variety BARI Alu-25 (V_3) (23.68%), followed by the variety BARI Alu-28 (V_4) (25.68%) and the highest yield reduction was noticed in the variety BARI Alu-8 (V_2) (61.18%) followed by variety BARI Alu-7 (V_1) (53.65%) (Table 9). Under mild water stress condition (I_2), the lowest yield reduction was found in BARI Alu-28 (V_4 (9.21%) followed by BARI Alu-25 (V_3) (12.17%) and the highest yield reduction was obtained from BARI Alu-8 (V_2) (40.42%) followed by BARI Alu-7 (V_1) (32.49%). Lower yield reduction indirectly reflected the drought tolerance in varieties V_3 and V_4. Tuber yield reduction due to water stress has been reported in potato by many researchers (Tourneux *et al*., 2003; Schafleitner *et al*., 2007).

Table 8. Stress susceptibility index and stress tolerance index of potato varieties under moderate and severe water deficit

Variety	Stress susceptibility index (SSI)		Stress tolerance index (STI)	
	Severe water stress (I_1)	Mild water stress (I_2)	Severe water stress (I_1)	Mild water stress (I_2)
V_1	1.32	1.39	0.43	0.63
V_2	1.50	1.73	0.39	0.60
V_3	0.58	0.52	0.74	0.86
V_4	0.63	0.39	0.82	1.00
LSD	0.61	0.65	0.17	0.20
CV (%)	30.83	33.23	14.31	13.14

V_1= BARI Alu-7 (Diamant), V_2= ARI Alu-8 (Cardinal), V_3= BARI Alu-25 (Asterix) and V_4= BARI Alu-28 (Lady Rosetta); I_1= Single irrigation at 30 DAP (Severe stress), I_2 = Two Irrigations at 30 and 45 DAP (Mild stress) and I_3= Three Irrigations at 30, 45 and 60 DAP (Normal); DAP = Days after planting.

Table 9. Tuber fresh yield reduction percentage in severe and mild water deficit condition

Variety	Tuber fresh yield (t/ha) reduction (%) at 95 DAP	
	Severe water stress (I_1)	Mild water stress (I_2)
V_1	53.65	32.49
V_2	61.18	40.42
V_3	23.68	12.17
V_4	25.68	9.21
Mean	41.05	23.57

V_1= BARI ALU-7 (Diamant), V_2= ARI ALU-8 (Cardinal), V_3= BARI ALU-25 (Asterix) and V_4= BARI Alu-28 (Lady Rosetta); I_1= Single irrigation at 30 DAP (Severe stress), I_2 = Two Irrigations at 30 and 45 DAP (Mild stress) and I_3= Three Irrigations at 30, 45 and 60 DAP (Normal); DAP = Days after planting.

Conclusion

The results of the experiment revealed that almost all the physio-morphological and yield contributing characters were significantly influenced by variety as well as water deficit stress condition independently and their combinations. Reduction of fresh tuber yield, individual tuber weight and tuber number/plant at 95 days after planting were considerably higher in well watered condition than those in water deficit stress conditions. But higher tuber fresh weight/plant and tuber fresh yield) were produced by BARI Alu-25 (Asterix) followed by BARI Alu-28 (Lady Rosetta) in both severe and mild water deficit stress conditions as well as well watered condition. BARI Alu-25 (Asterix) showed the lowest stress susceptibility index (SSI) and the highest stress tolerance index (STI) followed by BARI ALu-28 (Lady Rossetta). Among the varieties, in terms of water use efficiency in severe and mild water deficit condition, the best performance was recorded in BARI Alu-28 followed by BARI Alu-25. Therefore, among the varieties, BARI Alu-25 (Asterix) and BARI Alu-28 (Lady Rosetta) may be considered for water deficit stress tolerant varieties as these showed better stability in yield and yield contributing characters under water deficit stress conditions.

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References

Aliche, E.B., M. Oortwijn, T.P.J.M. Theeuwen, C.W.B. Bachem, R.G.F. Visser, C.G. Linder. 2018. Drought response in field grown potatoes and the interactions between canopy growth and yield. Agric. Water Manag. **206**: 20-30.

Amanullah, A. S. M., S. U. Talukder, A. A. Sarkar, A.S.M. Ahsanullah. 2010. Yield and water use efficiency of four potato varieties under different irrigations regimes. Bangladesh Res. Publication J. **4**(3): 254-264.

Anonymous. 2024. Yearbook of Agricultural Statistics-2023. 35th series. Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh. www.bbs.gov.bd.

Azad, A. K., M. Miaruddin, M. A. Wahab, M. H. R. Sheikh, B. L. Nag. H. H. Rahman. 2020. Krishi Projukti Hatboi (Handbook on Agro-Technology), Edited. 9th edition, Banglaesh Agricultural Research Institute, Gazipur-1701.

Deblonde, P. M. K., 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.

Deshmukh D V, Mhase L B and Jamadagni B M. 2004. Evaluation of chickpea genotypes for drought tolerance. Indian Journal of Pulses Reseach **17**: 47–9.

Dogras, C., A. Siomos., C. Psomakelis, 1991. Sugar and dry matter changes in potatoes stored in a clamp in a mountainous region of northern Greece. *Potato Res*. **34**: 211-214.

Fernandez GCJ (1992) Effective selection criteria for assessing plant stress tolerance. *Crop Sci* **28**:13–16.

Fischer, R. A., R. Maurer. 1978. Drought resistance in spring wheat cultivars. I. *Grain yield responses*. *Aust. J. Agric. Res.* **29**: 897-912.

Fleisher, D. H., D. J. Timlin., V. R. Reddy. 2008. Interactive effects of carbon dioxide and water stress on potato canopy growth and development. *Agron. J.* **100**: 711-719.

Hassanpanah, D. 2010. Evaluation of potato advanced cultivars against water deficit stress under *in vitro* and *in vivo* conditions. *Biotech.* **9**: 164-169.

Hill, D., D. Nelson, J. Hammond., L. Bell. 2021. Morphophysiology of potato (Solanum tuberosum) in response to drought stress: paving the way forward. *Frontiers in Plant Sci.* Vol. 11: Article 597554. [https : // www .frontiersin .org /articles /10.3389 /fpls. 2020.597554/full].

Jaleel, C. A., P. Manivannan, A. Wahid, M. Farooq, R. Somasundaram., R. Panneerselvam. 2009. Drought stress in plants: a review on morphological characteristics and pigments composition. *International Journal of Agriculture and Biology* **11**: 100–5.

Khalil, M. I., M. E. Haque., M. Z. Hoque. 2013. Adoption BARI recommended potato (*Solanumtuberosum*L.) varieties by the potato farmers of Bangladesh. *The Agriculturists.* **11**(2): 79-86.

Lahlou, O., S. Ouattar., J. Ledent. 2003. The effect of drought and cultivar on growth parameters, yield and yield components of potato. *Agronomie* **23**: 257-268. levels of N and P fertilizers. Potato J. **33**: 170-172.

Levy, D., 1983**.** Varietal differences in the response of potatoes to repeated short periods of water stress in hot climates. II. Tuber yield and dry matter accumulation and other tuber properties. *Potato Research,* **26**: 315-321.

Moonsat, S. 2014. Effect of potash fertilizer on yield and chips quality of different potato varieties. An unpublished MS Thesis. Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur.

Saika, M.A., Deka. 2006. Yield maximization of potato by the use of bio fertilizers at two fertility levels

Schafleitner R, Gutierrez R, Espino R, Gaudin A, Perez J, Martinez M, Dominguez A, Tincopa L, Alvarado C, Numberto G and Bonierbale M. 2007. Field screening for variation of drought tolerance in Solanum tuberosum L. by agronomical, physiological and genetic analysis. Potato Research **50**: 71–85

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

Tourneux C, A. Devaux., M. R. Camacho, P. Mamani., J. F. Ledent. 2003. Effects of water shortage on six potato genotypes in the highlands of Bolivia (I): morphological parameters, growth and yield. *Agronomy* **23**: 169–79.

Widuri, L.I., B. Lakitan, J. Sakagami, S. Yabuta, K. Kartika., E. Siaga, 2020. Short-term drought exposure decelerated growth and photosynthetic activities in chili pepper (*Capsicum annuum* L.). *Annals Agricultural Sciences* **65**: 149-158. [https://www. sciencedirect.com/science/article/pii/S0570178320300403?via. %3Dihub].