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Original Article

Stress tolerance attributes and yield based selection of potato genotypes for water stress environment

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Abstract

Twenty potato genotypes were assessed for water stress sensitivity during 2009 and 2010 at Horticulture Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh. The experiment was carried out in completely randomized design (CRD) comprising two factors with four replications. Selection of the genotypes for water stress condition was done following different stress tolerance attributes likes; relative performances, stress susceptibility index, tolerance and stress tolerance index. Local cultivars Indurkani, Shilbilati and Sadaguti showed high degree of tolerance to water stress with low productivity in both conditions. CIP genotype CIP 396244.12 had the highest yield under water stress condition followed by CIP 393371.58. Under water stress condition, as genotype with higher yield is desirable. So, considering yields and different stress attributes, CIP genotypes CIP 396244.12 and CIP 393371.58 were found suitable for water stress condition.

Keywords: potato, yield, relative performance, tolerance, stress susceptibility index and stress tolerance index

1. Introduction

Potato is very sensitive to water stress (Ekanayake & de Jong, 1992). Part of the reason is due to poor soil water extraction (Weitz *et al.,* 1994) as well as narrow and ineffective rooting system. Water stress resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same magnitude of water stress. It is considered as a production constraint of potato worldwide. Both yield and quality of potatoes may be affected even by a brief period of water shortage. Every year, 3 to 4 million ha of land are affected by water stress of different magnitudes in Bangladesh (Rashid & Islam, 2007).

Water stress-adopted plants are characterized by deep and vigorous root systems. Plants experience water stress by excessive transpiration and/or by a limitation of water supply (French, 1997). Although water stress reduces plant water potential; it affects root and leaf growth differently. It has been documented that water stress reduces plant growth (Weitz *et al.,* 1994), marketable yield, tuber number per stem and average tuber yield (Lynch and Tai, 1989), carbohydrate accumulation and partitioning (Ekanayake & de Jong, 1992), yielding capacity of plants, and subsequent performance of the seed tubers (Karafyllids, 1996). Significant effect of water stress on potato growth and yield suggests the need for genotypes adapted to water stress (Maldono *et al.,* 1998). In fact, there have been major efforts to develop water stress tolerant potato cultivars.

A complete mitigation of water stress is impossible. The development of potato genotypes that are more tolerant to water stress is a practical and economical approach to

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lessen the negative effects of water stress on the productivity of the crop. Under such circumstances, there is plenty of scope to find out genotypes that have inherent capability of producing relatively higher yield by withstanding the stress conditions. Under CIP-CPRI collaborative recent survey, farmers have also elicited their preference for having heat and water stress tolerant potato cultivars in parts of India (Rana *et al.*, 2011, 2013). In order to develop water stress tolerant potato cultivars, the efforts were initiated in the subcontinent (Sharma *et al.*, 2011). At present, researchers have chosen a mid-way and believed in selection under both favorable and stress conditions (Bazzaz *et al.,* 2015). Besides, to distinguish drought tolerant genotypes several selection indices such as tolerance, mean productivity, stress susceptibility index, geometric mean productivity, stress tolerance index, yield stability index etc., have been employed under various conditions. Hence, the study was commenced for assessing potato genotypes for water stress condition and to test the effectiveness of different drought tolerance indices for selecting potato genotypes in the target environment.

2. Materials and Methods

Twenty potato genotypes were assessed for water stress sensitivity in Bangladesh at the Horticultural research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh in 2009 and 2010. Tolerance of the genotypes subjected to water stress throughout the growing period was estimated by comparing the quantitative values of the characters of water stressed plants with those of non-stressed ones. The experiment was designed in a two factor completely randomized design (CRD) with four replications where five plants considered as one replication. Water stress treatments and 20 potato genotypes were considered as two factors for this study. The treatments were; water stress (ws) and non- stress (ns) condition. Twenty potato genotypes from different sources were used in the experiment (Table 1) and were selected on the basis of their growth, leaf size; stem characters and yielding potentiality under non-stress condition (Tuber Crops Research Centre [TCRC], 2009)

Disease free planting materials were collected from Tuber Crops Research Sub-Centre (TCRSC) of Bangladesh Agriculture Research Institute (BARI), Bogra, Bangladesh. Well sprouted potato tubers were placed in plastic pots (30 cm diameter x 24 cm height) and the plants were grown inside a plastic vinyl house under natural light conditions. The potting mixture was prepared with sandy loam soil and well rotten dried cow dung (5:1 ratio) and held about 30% moisture at field capacity (FC). The pots were fertilized uniformly with

Table 1. List of the 20 potato genotypes with their source of collection, plant characters and yield potentiality.

Source of collection	Name of the variety/ TCRC/CIP code/BARI released number	Plant Characters	Yield potentiality (ton/ha)	Remarks
Group-1 (TCRSC, BARI)	Diamant(BARI Potato-7) Granola (BARI Potato-13), Asterix (BARI Potato-25), Courage (BARI Potato-29), Sagita (BARI Potato-31)	Leaf type, medium to broad leaf, high yielding, medium to long stem	25-35	Released by Bangladesh Agricultural Research Institute (BARI)
Group-2 (TCRSC, BARI)	Saline,Smart, Burren, Banba and Elgar	Leaf type, medium to broad leaf, high yielding, medium to long stem	30-40	Exotic promising germplasm with high yield potential
Group-3 (TCRSC, BARI)	LB-1 (CIP 391004.18) , LB-2 (CIP 391046.14), LB-3 (CIP 391058.175), LB-7 (CIP 393371.58), LB-12 (CIP 396031.119), LB-14 (CIP 396244.12)	Leaf type, medium to broad leaf, high yielding, medium to long stem	30-45	Collected from International Potato Center (CIP), Lima, Peru. Preliminary yield trials (PYT) was conducted for abiotic/ biotic stress resistance under GTZ project in Bangladesh
Group-4 (Locally collected and multiplied clean seed at TCRSC, Bogra	Indurkani, Lalpakri, Shilbilati, Sadaguti	Stem type, small leafiness, narrow stem	10-18	Indigenous potato variety, before 1950 it was widely cultivated throughout the country, introduced in the country more than 200 years ago, well adapted to cultivate in stress environment

1.65, 1.10, 1.25, 0.60 and 0.60 g urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and magnesium sulfate corresponding to 325-220-250-120-120 kg urea, triple super phosphate, muriate of potash, gypsum and magnesium sulfate per ha, respectively. Half of urea and remaining fertilizer was applied as basal dose and rest was applied at 30 days after planting (DAP). Well-sprouted uniform (28-40 mm) sized tubers were selected as planting material of each genotypes and single tuber was planted in each pot on 18th November 2009. Plants were emerged within 12 days. The plants were watered regularly to maintain optimum soil-moisture condition until the water-stress treatment was imposed. Water stress (WS) was induced by withholding water supply completely after 30 days of planting. The treatment was continued until the symptom of wilting appeared visually after that they were re-watered to 50% field capacity (FC) and continued up to 80 DAP. In non-stress (NS) treatment, water was maintained 80% of field capacity. The pots were weighed at one day intervals to compensate water loss by evapotranspiration. During the growing period maximum and minimum temperature was recorded and presented in the Table 2.

2.1 Data collection and data analysis

Data on yield and yield related components were taken from five plants in each replication. Plant height and number of leaves per plant were measured at 75 days after planting (DAP). Height of the plant was considered from ground level to the top of the longest leaf of the plant. The number of above ground shoots per plant was recorded at 60 DAP. Plant vigor was taken following 1-9 scale "1 to 9 Scale; where 1 is very poor and 9 is highly vigorous" at 45 DAP. Tuber number per plant, yield per plant and individual tuber weight were measured during at 80 DAP (harvesting time). Relative performances (RP) of tuber number per plant, average of tuber size and yield per plant were calculated by using the following formula:

$$RP = \frac{Vws}{Vns} \quad (1)$$

where Vws is the value of a plant character under water stress condition and Vns is the value of that plant character under non stress condition. Tolerance (TOL) was calculated according to Gupta *et al.* (2001).

$$TOL = (Yns\text{-}Yws) \quad (2)$$

where Yws is the mean yields of a given genotype in WS conditions and Yns is the mean yields of a given genotype in NS conditions. Stress susceptibility index (SSI) and drought tolerance index (DTI) for yield per plant of each genotype was calculated as follows (Fernandez, 1993):

$$SSI = \frac{\left(1 - \frac{Yws}{Yns}\right)}{DII} \quad (3)$$

Table 2. Monthly minimum and maximum temperature inside the vinyl house during crop growing period.

Month	Temperature (°C)		
	Min	Max	Mean
November, 2009	22.43	26.60	24.52
December, 2009	15.45	19.90	17.68
January, 2010	11.58	15.50	13.54
February, 2010	19.08	23.85	21.47

where *Yws* is the mean yields of a given genotype in WS condition, *Yns* is the mean yields of a given genotype in NS condition and DII is the water stress intensity index.

$$DTI = \frac{(Yns)(Yws)}{(Xns)^2} \quad (4)$$

where Yws is the mean yields of a given genotype in WS conditions, Yns is the mean yields of a given genotype in NS conditions and Xns is the mean of all genotypes under non-stress (NS) condition.

Range and standard deviation value were calculated for plant height, number of leaves per plant, plant vigor and number of above ground shoots per plant. Tuber number per plant, average of tuber size and yield per plant were analyzed statistically using the software MSTATC (Developed by the Department of Crop and Soil Sciences, Michigan State University, East Lansing, MI 48824 USA). Significance between treatments were tested by using Duncan Multiple Range Test (DMRT) at $p<0.05$ level. Linear relations among the yield and stress attributes were calculated by using MS Excel program.

3. Results and Discussion

3.1 Variability in plant characters

Comparatively small heights were noted in water-stressed plants compared to non-stressed plants. Relative plant height, calculated as the ratio of the height of stressed plants and that of non-stressed plants, ranged from 0.49 to 0.89 (Table 3). Reduced plant height in potato due to drought was reported by Nagaranjan and Bansal (1991), Deblonde and Ladent (2001) and Alsharari *et al.* (2007). The depression in plant height could be resulted from a reduction in plant photosynthetic efficiency as reported by Singer *et al.* (1995).

Less number of leaves per plant was found in water-stressed plants than non-stressed plants (Table 3). Relative number of leaves, calculated as the ratio of number of leaves of stressed plants to that of non-stressed plants, ranged from 0.46 and 0.89 (Table 3). Similar results were reported by Mahmud *et al.* (2015) in potato and Khan *et al.* (2014) in Soybean. Deblonde and Ladent (2001) reported that potato leaf number and leaf length are very sensitive to moderate water stress conditions. Less number of leaves in water stressed plants was due to self-falling and premature falling of leaves (Mahmud *et al.,* 2015) which reduced plant growth and the plant assimilation area (Mahmud *et al*., 2014; Schittenhelm et al., 2006)

More vigorous plant was found in non-stressed condition than that of water-stressed condition (Table 3). Relative plant vigor ranged from 0.50 to 0.74 with a mean of 0.64 and more than 0.70 was found in four varieties (Table 3). Plants lost vigor under water stress condition because of low water uptake. Plant cells loss turgidity which affects physiological processes like transpiration, respiration and photosynthetic efficiency. Low photosynthetic efficiency could be resulted from the depression in leaf number per plant which ultimately affects plant growth and development.

The variation in stem number per plant among genotypes were noted from 3.50 to 7.75 in non-stressed plants, and 3.50 to 6.75 in stressed plants with corresponding means of 5.59 and 4.84, respectively. The relative stem number per plant ranged from 0.57 to 1.00 with an average of 0.84 and more than 0.75 was found in nineteen genotypes. Drought resulted in lower number of stems per plant. The present findings were in agreement with those of Barakat *et al.* (1994) and Alsharari *et al.* (2007).

3.2 Tuber number per plant and average of tuber size

Tuber numbers per plant varied significantly from cultivar to cultivar both under water stress (WS) and non-stress (NS) conditions (Table 4). Water stress reduced mean tuber number per plant which varied from 5.13 to 53.33%. Local cultivar Lalpakri produced the highest tuber number per plant both in water stress and non-stress conditions followed by Sadaguti and Indurkani while Saline was the least. It was clear that, decrease tuber number per plant was recorded in water stress condition. So, tuber number per plant is a sensitive trait to water stress. Deblonde and Ladent (2001) reported that moderate water stress reduced the ultimate productivity. Nadler and Heuer (1995) indicated significant decrease in tuber number due to water stress or salinity. Variation in number of tubers per plant affects tuber fresh yield per plant and are positively related (Alsharari *et al.,* 2007; Mahmud *et al.,* 2015; Schittenhelm *et al.,* 2006).

Average tuber size of the genotypes varied significantly both in stress (WS) and non-stress (NS) conditions (Table 4). Water stress reduced mean individual tuber weight. Under non-stress condition, mean individual tuber weight ranged from 3.56 to 41.23 g. The tuber size of Elgar was the highest and that of Sadaguti was the lowest. In water stress condition, mean individual tuber weight ranged from 2.94 to 19.05 g, and genotype Saline was the highest and Indurkani was the lowest. The lowest reduction % was observed in local cultivar Sadaguti (11.24%) and the highest was in CIP 391004.18 (75.47%).

3.3 Tuber yield per plant and tuber dry matter

Reduced tuber yield per plant in water-stressed plant were noted compared to its non-stressed plant (Table 5). Genotype CIP 396244.12 exhibited the highest yield per plant in water stress environment which was similar to CIP 393371.58 and showed 49.39% and 49.49% yield reductions, respectively. The local cultivar Indurkani yielded the lowest which was similar to other two local cultivars Shilbilati and Sadaguti. But their yield reductions over control were minimum, 40.01%, 40.10% and 41.09%, respectively. Under non-stress condition, genotype Asterix exhibited with highest yield per plant which was similar to Courage and Diamant. These three genotypes showed greater yield reduction (>65%) under stress condition. The maximum yield reduction per plant was recorded in the genotype CIP 391004.18. Yield reduction was ranged from 40.01-76.65 % due to water stress the mean reduction was 57.30%. The highest reduction was observed in CIP 391004.18 followed by Elgar and Courage. Less than 50% yield reduction with greater relative performance (RP) for tuber yield per plant was observed in six potato genotypes viz. Indurkani, Shilbilati, Sadaguti, CIP 393371.58, CIP 396031.119 and CIP 396244.12. The RP for tuber yield per plant ranged from 0.23 to 0.60 with an average of 0.43 (Table 5). The decrease in tuber yield under stress condition was large due to the reduction of plant height, number of leaves per plant, tuber number per plant and individual tuber weight. Similar findings were stated by Alsharari *et al*. (2007), Schafleitner *et al.* (2007), Hassanpanah (2010) and Mahmud *et al.* (2015).

Table 3. Range and mean for quantitative characters in 20 potato genotypes under non-stressed and water-stressed conditions.

Plant Characters	Water stress		Non stress		Relative performance	
	Range	Mean±SD	Range	Mean±SD	Range	Mean ±SD
Plant height (cm)	19.50-38.25	29.49±4.93	31.00-65.25	42.00±7.39	0.49-0.89	0.71±0.12
Number of leaves/plant	32.00-69.50	49.04±9.92	50.50-112.25	80.81±17.27	0.46-0.89	0.62±0.11
Plant vigor	2.25-5.50	4.18±0.90	4.50-8.25	6.54±1.10	0.50-0.74	0.64±0.07
Above ground shoots/plant	3.50-6.75	4.84±0.97	3.50-7.75	5.59±1.31	0.57-1.00	0.84±0.13

Table 4. Mean tuber number per plant and average of tuber size of 20 potato genotypes under water stress and non-stress environments.

Genotype	Tuber number/plant			Average of tuber size (g)		
	WS	NS	RP	WS	NS	RP
Diamant	15.25 de	19.50 c	0.80	8.00 ef	21.47 ef	0.38
Granola	15.00 de	16.75 c-f	0.90	7.99 ef	19.16 fg	0.42
Asterix	15.75 d	17.25 c-e	0.92	9.80 de	26.57 cd	0.37
Courage	10.25 g-i	13.25 f-h	0.78	10.61 d	31.24 b	0.34
Sagita	8.00 j-l	10.75 h	0.75	18.28 a	28.26 bc	0.65
Saline	6.00 l	12.00 gh	0.45	19.05 a	24.67 de	0.77
Smart	15.00 de	16.50 cdef	0.91	10.43 d	22.33 ef	0.48
Burren	7.00 kl	10.75 h	0.61	10.73 d	14.55 h	0.74
Banba	9.75 h-j	10.75 h	0.91	10.99 cd	20.81 f	0.53
Elgar	8.25 i-k	10.75 h	0.77	12.92 bc	41.23 a	0.32
CIP 391004.18	18.50 c	19.50 c	0.95	5.09 gh	20.75 f	0.25
CIP 391046.14	8.75 i-k	18.75 cd	0.47	13.73 b	15.87 gh	0.87
CIP 391058.175	12.25 fg	17.50 c-e	0.74	10.40 d	18.55 fg	0.57
CIP 393371.58	13.50 ef	16.50 c-f	0.82	12.92 bc	20.85 f	0.62
CIP 396031.119	14.50 de	15.50 d-g	0.94	11.69 b-d	21.32 ef	0.55
CIP 396244.12	9.75 h-j	13.75 e-h	0.65	18.46 a	24.47 de	0.77
Indurkani	25.25 b	32.50 b	0.79	2.94 i	3.84 j	0.78
Lalpakri	31.50 a	40.25 a	0.79	3.88 hi	6.98 ij	0.56
Shilbilati	11.50 f-h	12.50 gh	0.92	6.63 fg	10.13 i	0.65
Sadaguti	25.25 b	37.50 a	0.64	3.16 hi	3.56 j	0.88
Mean	14.05	18.13	-	10.38	19.91	-
CV (%)	8.84	9.13		8.07	9.65	

Note: NS = Non-stress, WS = Water stress and RP = Relative performance; Means bearing same letter in a column do not differ significantly at 1% level of probability.

3.4 Tuber dry matter

Tuber dry weight per plant of the genotypes was varied significantly both in stress (WS) and non-stress (NS) conditions (Table 5). Under water stress condition, tuber dry weight ranged from 11.20 to 40.39 g where, genotype CIP 396244.12 being the highest followed by CIP 393371.58. But, in non-water stress condition, tuber dry weight per plant ranged from 16.84 to 83.75 g and genotype Elgar produced the highest per plant tuber dry weight followed by Asterix, Courage and Diamant. In both condition Shilbilati produced the lowest per plant tuber dry weight. The lowest reduction in per plant tuber dry weight was observed in local cultivar Sadaguti followed by Shilbilati and the highest was in Courage followed by Diamant and Asterix.

3.5 Total biomass production and harvest index

Total biomass dry weight per plant of the genotypes was varied significantly both in stress (WS) and non-stress (NS) conditions (Table 6). The lowest reduction in total biomass dry weight per plant was observed in Indurkani followed by CIP 393371.58 and CIP 396244.12. But the highest reduction in total biomass dry weight per plant was observed in Diamant followed by. Reduced harvest index was observed in 12 genotypes under water stress condition compared to non-stress condition. But, increased harvest index was observed in 6 genotypes. Among these genotypes only 2 CIP genotypes CIP 393371.58 and CIP 396244.12 exhibited with higher yield with higher tuber dry matter production under water stress condition.

3.6 Selection of genotypes based on stress tolerance attributes

Stress susceptibility index (SSI) was calculated for all the genotypes and presented in the (Figure 1). The SSI for tuber yield per plant was the lowest in Indurkani, followed by Shilbilati, Sadaguti and Burren. The highest SSI for yield per plant was shown in Elgar, followed by Courage and CIP 391004.18. Genotypes with high SSI were high yield as well as very sensitive to water stress condition. Oppositely other varieties with low SSI were low yield and tolerant to water stress. Teran and Singh (2002) reported that water stress resistant lines had relatively low SSI while the water stress susceptible lines had high SSI values. So, potato genotypes

Table 5. Mean tuber yield per plant of 20 potato genotypes under water stress and non-stress environments.

Genotype	Yield/plant (g)				Tuber dry weight (g)		
	Yws	Yns	RP	% reduction	WS	NS	% reduction
Diamant	121.75 ef	410.78 bc	0.30	70.36	21.50 fg	74.28 b-d	71.06
Asterix	152.90 cd	456.30 a	0.34	66.49	24.14 c-e	82.35 ab	70.69
Granola	119.48 ef	318.78 f-h	0.37	62.52	19.84 g-i	70.39 de	71.81
Courage	108.85 g	412.15 bc	0.26	73.59	20.67 g-i	79.64 a-c	74.05
Sagita	145.18 d	302.80 g-i	0.48	52.05	23.19 ef	44.58 j	47.98
Saline	111.85 fg	294.64 hi	0.38	62.04	18.27 ij	50.39 h-j	63.74
Smart	155.85 c	364.05 d	0.43	57.19	25.85 cd	45.79 j	43.55
Burren	74.43 i	155.36 k	0.48	52.09	13.91 k	20.40 kl	31.81
Banba	105.68 g	222.35 j	0.48	52.47	18.55 hi	28.97 k	35.97
Elgar	106.25 g	441.08 ab	0.24	75.91	23.58 e-f	83.75 a	71.84
CIP 391004.18	94.15 h	403.25 c	0.23	76.65	16.01 jk	70.74 de	77.37
CIP 391046.14	119.10 ef	297.30 hi	0.40	59.94	20.75 gh	48.79 ij	57.47
CIP 391058.175	125.50 e	307.25 g-i	0.41	59.15	26.36 c	55.27 g-i	52.31
CIP 393371.58	173.15 ab	343.50 d-f	0.50	49.59	39.63 a	66.14 d-f	40.08
CIP 396031.119	169.33 b	330.36 e-g	0.51	48.74	36.21 b	63.79 e-g	43.24
CIP 396244.12	179.55 a	354.80 de	0.51	49.39	40.39 a	70.33 c-e	42.57
Indurkani	74.03 i	123.40 k	0.60	40.01	14.19 k	22.26 kl	36.25
Lalpakri	121.73 ef	280.29 i	0.43	56.57	23.21 ef	58.03 f-h	60.00
Shilbilati	75.73 i	126.43 k	0.60	40.10	11.20 l	16.84 l	33.49
Sadaguti	77.85 i	132.15 k	0.59	41.09	15.99 jk	23.51 kl	31.99
Mean	120.62	303.85	-		22.67	53.81	52.86
CV (%)	5.49	6.88			4.57	7.01	

Note: NS = Non-stress, WS = Water stress and RP = Relative performance; Means bearing same letter in a column do not differ significantly at 1% level of probability.

CIP 396031.119, CIP 393371.58 and CIP 396244.12may be selected with comparatively low SSI and moderate to high yield for better productivity under water stress condition.

By conducting trials in non- stress and water stress environments, Munoz-Perea *et al.* (2006) proposed that using mean yield, SSI and per cent reduction might be used as selection criteria for separating drought/water stress resistant from susceptible genotypes. Clarke and Mc Craig (1982) suggested that genotypes with low values might not be desirable, given that such genotypes were often unresponsive to favorable moisture conditions.

The stress tolerance index (STI) for yield per plant was recorded in CIP 393371.58 followed by Asterix and CIP 396244.12. However, Asterix showed more sensitivity in water stress situation with greater yield reduction. CIP 393371.58 and CIP 396244.12 showed less sensitivity to water stress situation with comparatively lower yield reduction. A similar finding in yield drop in high yielding potato genotypes was noted by Schafleitner *et al.* (2007). According to theory, our findings revealed that CIP 393371.58 and CIP 396244.12 may be selected as water stress tolerant genotypes.

Considering the TOL (tolerance) for yield per plant of twenty potato genotypes were also assessed (Figure 2). TOL for tuber yield per plant was the lowest in Shilbilati, followed by Indurkani and Sadaguti. The highest TOL was found in Elgar followed by CIP 391004.18, Courage and Asterix. Higher the tolerance values the higher the productivity with susceptible to water stress, and lower tolerance value indicates tolerance to water stress. From present findings, it was clear that lower tolerance values were also low productive. So, preference should be done in selecting the genotypes with medium tolerance value with high productivity in water stress situation as well as in control environments. Based on the results, CIP 396031.119 and CIP 396244.12 could be selected for future use.

Correlations between Ys and MP, SSI, TOL and STI are illustrated by scatter plots (Figure 3). Linear correlations were found in Ys with MP (r^2= 0.60), Ys with SSI (r^2= 0. 03), Ys with TOL (r^2= 0.17) and Ys with STI (r^2= 0.79). But higher positive association was found in Ys with MP, and Ys with STI than Ys and SSI and Ys with TOL. Correlations between Yp and MP, SSI, TOL and STI are illustrated by scatter plots (Figure 1.2). Highly positive linear correlations were found in Yp with MP (r^2= 0.96), Yp with SSI (r^2= 0.72), Yp with TOL (r^2= 0.92) and Yp with STI (r^2= 0.82). The scatter plot indicated that MP and STI were better predictors for selecting genotypes under drought condition.

Table 6. Mean above ground biomass dry weight and harvest index of 20 potato genotypes under water stress and non-stress environments.

Genotype	Total biomass dry weight (g)			Harvest index	
	WS	NS	% reduction	WS	NS
Diamant	29.02 e-g	94.31 ab	69.23	0.74 f-i	0.79 de
Granola	25.57 h-j	82.57 cd	69.03	0.78 c-g	0.86 ab
Asterix	32.02 cd	101.33 a	68.40	0.82 a-c	0.85 a-c
Courage	26.15 g-i	93.77 ab	72.11	0.79 a-e	0.88 a
Sagita	28.49 f-h	58.63 h	51.41	0.83 ab	0.76 e
Saline	22.92 j-l	61.59 gh	62.79	0.80 a-d	0.82 b-d
Smart	33.98 c	58.94 h	42.35	0.76 d-h	0.79 de
Burren	21.19 kl	35.78 j	40.78	0.66 k	0.55 gh
Banba	26.93 f-i	48.17 i	44.09	0.71 ij	0.58 g
Elgar	29.46 d-f	98.8 a	70.18	0.80 a-d	0.85 a-c
CIP 391004.18	21.41 kl	87.34 bc	75.49	0.75 e-i	0.81 c-e
CIP 391046.14	28.35 f-h	62.02 gh	54.29	0.78 b-f	0.79 de
CIP 391058.175	34.01 c	69.15 fg	50.82	0.78 c-g	0.83 b-d
CIP 393371.58	47.41 a	79.02 de	40.00	0.84 a	0.81 c-e
CIP 396031.119	44.98 b	78.77 c-e	42.90	0.81 a-d	0.82 b-d
CIP 396244.12	48.72 a	84.88 cd	42.60	0.83 a-c	0.81 c-e
Indurkani	20.541	33.14 jk	38.02	0.71 ij	0.52 h
Lalpakri	31.74 c-e	73.95 ef	57.08	0.73 g-i	0.78 de
Shilbilati	15.5 m	27.22 k	43.06	0.72 hi	0.67 f
Sadaguti	24.02 i-k	43.89 i	45.27	0.67 jk	0.50 h
Mean	29.62	68.66	53.99	-	-
CV (%)	4.22	5.01		4.44	4.76

Note: NS = Non-stress condition and WS = Water stress condition; Means bearing same letter in a column do not differ significantly at 1% level of probability.

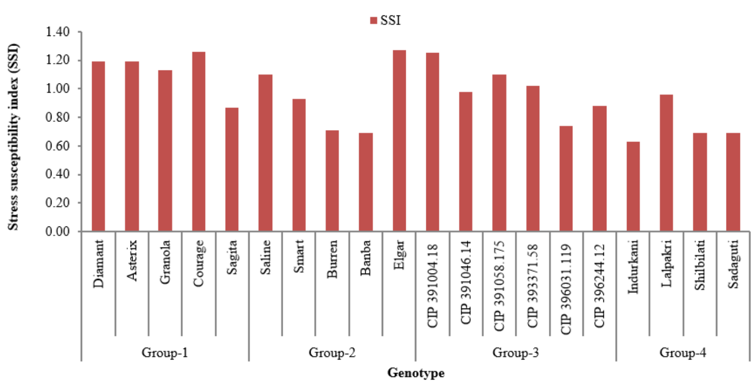

Figure 1. Mean productivity and stress susceptibility index of 20 potato genotypes under water stress condition. The smaller value of SSI, the greater the stress tolerance. Selection based on SSI favors genotypes with low yield potential and high yield under stress conditions.

3.7 Selection and grouping of genotypes based on yield reduction

Tested potato genotypes were categorized on the basis of their yield reduction (Table 7). A scale was made to categorize the genotypes. Genotypes were classified into four groups as tolerant (less than 45 % yield reduction), relatively tolerant (45.01-50.00 % yield reduction), moderately susceptible (51.01-60.00 % yield reduction) and Susceptible (above 60.01 % yield reduction). Genotypes of tolerant groups were less productive (Table 7) than other groups and characterized by stem type potato cultivars with small leafiness. Genotypes from the second group (relatively tolerant) were moderate yielder under non stress condition, but were high yielder

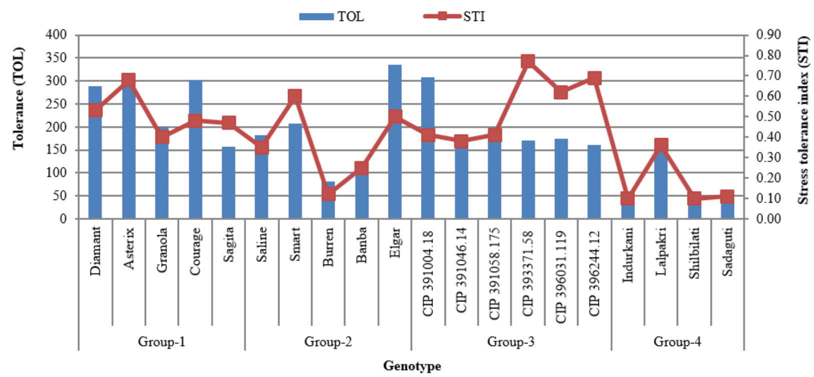

Figure 2. Tolerance and stress tolerance index of 20 potato genotypes under water stress condition. The higher value of STI for a genotype, the higher its tolerance and yield potential.

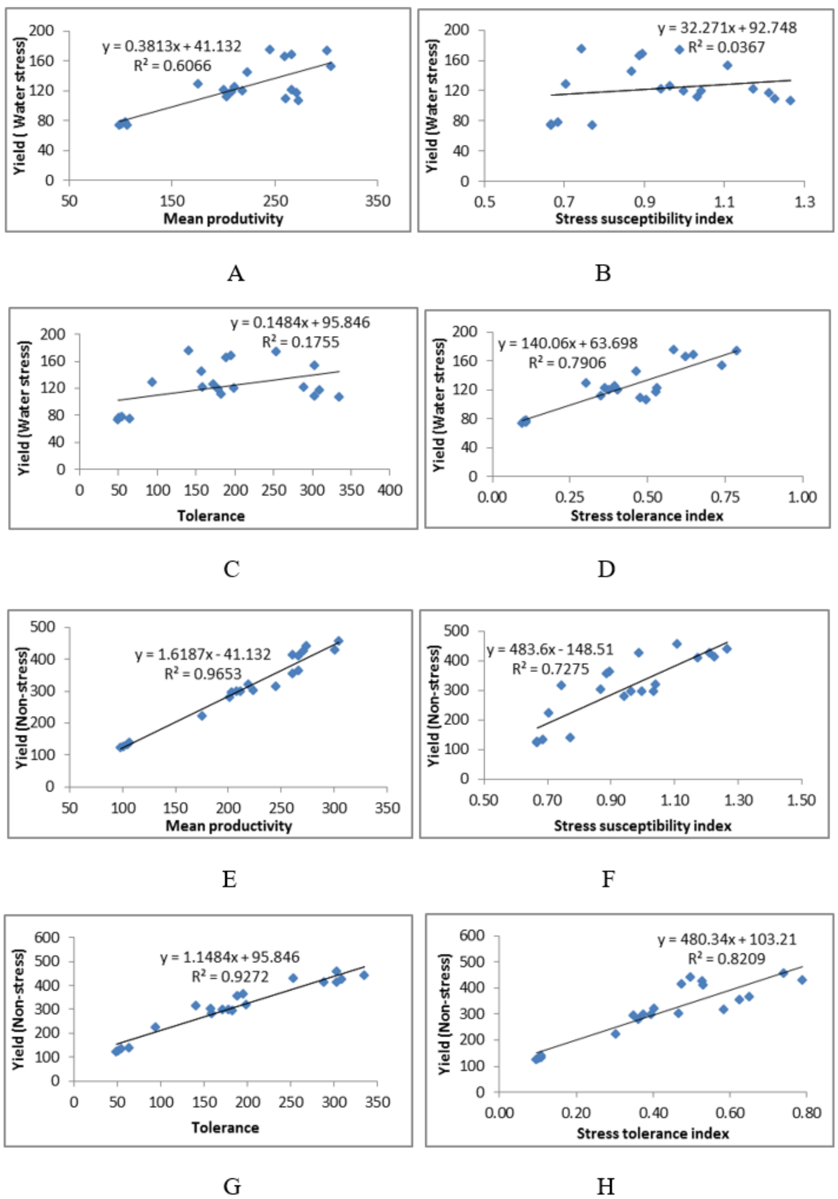

Figure 3. Linear relations between yield (water stress) and stress tolerance attributes (A, B, C and D). Linear relations between yield Non-stress) and stress tolerance attributes (E, F, G and H).

Table 7. Grouping of 20 potato genotypes on the basis of yield reduction

Class/level	Yield reduction % over control	Range yield/plant(g) (under ns condition)	Genotypes
Tolerant	Less than 45.00	123.40-132.15	Indurkani, Shilbilati and Sadaguti
Relatively tolerant	45.01-50.00	330.36-354.80	CIP 396031.119, CIP 396244.12 and CIP 393371.58
Moderately susceptible	51.01-60.00	155.36-364.05	Sagita, Burren, Banba, Smart, Lalpakri, CIP 391058.175 and CIP 391046.14
Susceptible	Above 60.01	294.64-456.30	Saline, Granola, Asterix, Diamant, Courage, Elgar and CIP 391004.18

than tolerant genotypes and can thrive well in water stress condition with a good tuber yield. Susceptible genotypes have the potentiality to give higher tuber yield in non-stress condition.
Insert Table 7 above here.

4. Conclusions

Reduced tuber yield and yield components were established in water stress condition than non-stress condition. Two CIP genotypes CIP 393371.58, CIP 396244.12 were found promising regarding less reduction in tuber yield, dry weight per plant, total biomass dry weight and increased harvest index. Regarding choosing the potato genotypes for water stress environment, CIP 393371.58, CIP 396244.12 were considered for moderate RP for yield, SSI value, greater tolerance and higher STI value. These genotypes also had the high productivity in water stress situation as well as in control environments. Considering all associations, the scatter plot designated that MP and STI were better predictors for choosing genotypes under water stress environment whereas for choosing the genotypes under non-stress condition all the predictors may be considered. As yield concern and using of stress tolerance attributes for choosing the potato genotypes for the water stress situation, CIP 396244.12 and CIP 393371.58 may be considered.

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References

Alsharari, S. F., Alsadon, A. A., & Alharbi, A. R. (2007). Evaluation of water stress tolerance of potato cultivars under greenhouse conditions. *Proceedings of the VIIIth IS on Protected Cultivation in Mild Winter Climates*. *Acta Horticulture*, *747*, 67-74.

Barakat, M. A. S., El-Araby, S. M., & Adgham, F. I. (1994). Varietal response of potato to graded dose of nitrogen and potassium. *Alexandria Journal of Agricultural Research*, *39*(2), 399-414.

Bazzaz, M. M., Khaliq, Q. A., Karim, M. A., Mahmud, A. A., & Khan, M. S. A. (2015). Canopy temperature and yield based selection of wheat genotypes for water deficit environment. *Open Access Library Journal*, 2(10), 1-11. doi:10.4236/oalib.1101917

Clarke, J. M., & Mc Craig, T. M. (1982). Excised leaf water retention capability as an indicator of drought resistance of *Triticum* genotypes. *Canadian Journal of Plant Science*, *62,* 571-578.

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

Ekanayake, I. J., & De Jong. (1992). Stomatal response of some cultivated and wild tuber-bearing potatoes in warm tropics as influenced by water deficits. *Annals of Botany*, *70,* 53-60.

Fernandez, G. C. J. (1993). Effective selection criteria for assessing plant stress tolerance. In C. G. Kuo, (Ed.). *Adaptation of Food Crops to Temperature and Water Stress* (pp. 257–270). Shanhua, Taiwan: Asian Vegetable Research and Development Center.

French, J. (1997). Primary response of root and leaf elongation to water deficits in the atmosphere and soil solution. *Journal of Experimental Botany*, *48*(310), 985-999.

Gupta, N. K., Gupta, S., & Kumar, A. (2001). Effect of water stress on physiological attributes and their relationship with growth and yield in wheat cultivars at different growth stages. *Journal of Agronomy and Crop Science, 86,* 1437-1439.

Hall, A. E. (1993). Is dehydration tolerance relevant to genotypic differences in leaf senescence and crop adaptation to dry environments? In T. J. Close & E. A. Bray (Eds.). *Plant responses to cellular dehydration during environmental stress* (pp. 1-10). Rockville, MD: The American Phytopathological Society.

Hassanpanah, D. (2010). Evaluation of potato advanced cultivars against water deficit stress under in vitro and in vivo Condition. *Biotechnology*, *9*(2), 164-69.

Karafyllids, D. I., Stavropoulos, N., & Georgakis, D. (1996). The effect of water stress on the yielding capacity of potato crops and subsequent performance of seed tubers. *Potato Research*, *39*, 153-163.

Khan, M. S. A., Mamun, M. A. A., Mahmud, A. A., Bazzaz, M. M., Hossain, M. A., Alam, M. S., Shamimuzzaman, M., & Karim, M. A. (2014). Effects of salt and water stress on leaf production, sodium and potassium ion accumulation in soybean. *Journal of Plant Sciences, 2*(5), 209-214.

Lynch, D. R., & Tai, G. C. C. (1989). Yield and yield component response of eight potato genotypes to water stress. *Crop Science*, *29*, 1207-1211.

Mahmud, A. A., Hossain, M. A., Mamun, M. A. A., Shamimuzzaman, M., Rahaman, E. H. M. S., Khan, M. S. A., & Bazzaz, M. M. (2014). Plant canopy, tuber yield and growth analysis of potato under moderate and severe drought condition. *Journal of Plant Sciences*, *2*(5), 201-208.

Mahmud, A. A., Hossain, M. M., Zakaria, M., Mian, M. A. K., & Karim, M. A. (2015). Effects of water stress on plant canopy, yield attributes and yield of potato. *Kasetsart Journal* (*Natural Science*), *49*, 491 – 505.

Maldonado, L. A., Wright, J. E., & Scott, G. J. (1998). Constraints to production and use of potato in Asia. *American Potato Journal*, *75*(2), 71-79.

Munoz-Perea, C. G., Teran, H., Allen, R. G., Wright, J. M., Westermann, D. T., & Singh, S. P. (2006). Selection for drought resistance in dry bean landraces and cultivars. *Crop Science*, *46,* 2111-2120.

Nadler, A., & Heuer, B. (1995). Effect of saline irrigation and water deficit on tuber quality. *Potato Research*, *38*, 119-123.

Nagaranjan, S., & Bansal, K. C. (1991). Growth and distribution of dry matter in a drought tolerant and a susceptible potato cultivar under normal and water deficit condition. *Journal of Agronomy and Crop Science*, *167,* 112-118.

Rana, R. K., Sharma, N., Arya, S., Singh, B. P., Kadian, M. S., Chaturvedi, R., & Pandey, S. K. (2013). Tackling moisture stress with water stress-tolerant potato (*Solanum tuberosum*) varieties: perception of Karnataka farmers. *Indian Journal of Agricultural Sciences*, *83*(2), 216-22.

Rana, R. K., Sharma, N., Kadian, M. S., Girish, B. H., Arya, S., Campilan, D., Pandey, S. K., Carli, C., Patel, N. H., & Singh, B. P. (2011). Perception of Gujarat farmers on heat-tolerant potato varieties. *Potato Journal*, *38*(2), 121-29.

Rashid, M. H., & Islam, M. S. (2007*). Adaptation to climate change for sustainable development of Bangladesh agriculture, Bangladesh country paper*. Paper presented at the 3rd session of Technical Committee of Asian and Pacific Centre for Agricultural Engineering and Machinery, Beijing, China, November 20-21, 2007. Retrieved from http://un-csam.org/Activities%20Files/A0711/01bd.pdf

Schafleitner, R., Guitierrez, R., Espino, R., Guadin, A., Perez, J., Martinez, M., Dominguez, A., Tincopa, L., Alvarado, C., Numberto, G., & Bonierbale, M. (2007). Field screening for variation of water stress tolerance in *Solanum tuberosum* L. by agronomical, physiological and genetic analysis. *Potato Research*, *50,* 71-85.

Schittenhelm, S., Sourell, H., & LÖpmeier, F.J. (2006). Water stress resistance of potato cultivars with contrasting canopy architecture. *European Journal of Agronomy*, *24,* 193-202.

Sharma, N., Kumar, P., Kadian, M. S., Pandey, S. K., Singh, S. V., & Luthra, S. K. (2011). Performance of potato (*Solanum tuberosum*) clones under water stress. *Indian Journal Agricultural Sciences, 81*(9), 825-829.

Singer, S. M., Helmy, Y. I., Karas, A. N., & Abou-Hadid, A. F. (1995). Growth and development of bean plants (*Phaseolus vulgaris* L.) grown under water-stress. *Ciheam Options Mediterraneennes, 31*, 241-250.

Tuber Crops Research Centre. (2009). *Annual Report-2009*. Gazipur, Bangladesh: Tuber Crops Research Centre, Bangladesh Agricultural Research Institute.

Tera2n, M., & Singh, S. P. (2002). Comparison of sources and lines selected for water stress resistance in common bean. *Crop Science*, *42*, 64-70.

Weitz, R., Kaminski, J., & Smilowitz, Z. (1994). Water deficit effects on potato leaf growth and transpiration: utilizing fraction extractable soil water for comparison with other crops. *American Potato Journal*, *71*, 829-840.