Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 14 Issue 10 Version 1.0 Year 2014
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Tuber Yield, Tuber Quality and Plant Water Status of Potato under Drought and Well Watered Condition

By Abullah-Al-Mahmud, Mohammad Hossain, Md. Mahfuz Bazzaz, Md. Shawquat Ali Khan, Md. Altaf Hossain & M.S. Kadian

International Potato Center, Bangladesh

Abstract- Four CIP potato clones with one check variety Asterix were grown during 2010-11 and 2011-12 at horticulture research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University to observe the effect of water stress on yield and tuber quality of potato. The present study revealed that the tuber yields of all the genotypes were reduced by different degrees of drought. Genotype CIP 393371.58 and CIP 396244.12 performed better in severe drought condition produced higher yield per plant. The highest percent of small sized and deformed tuber was found in the CIP 391004.18 and Asterix under severe drought condition, whereas the normal sized tuber was found in CIP 396244.12 and CIP 393371.58. These two genotypes also maintained more relative water content (RWC) with higher xylem exudation rate under water stress condition than the susceptible genotypes.

Keywords: drought susceptibility index, relative water content, xylem exudation rate and spad value.

GJSFR-D Classification : FOR Code: 829999

TUBERYIELDTUBERQUALITYANDPLANTWATERSTATUSOFPOTATOUNDERDROUGHTANDWELLWATEREDCONDITION

Strictly as per the compliance and regulations of:

Tuber Yield, Tuber Quality and Plant Water Status of Potato under Drought and Well Watered Condition

Abullah-Al-Mahmud[α], Mohammad Hossain [σ], Md. Mahfuz Bazzaz [ρ], Md. Shawquat Ali Khan [Ѡ], Md. Altaf Hossain[¥] & M.S. Kadian [§]

Abstract- Four CIP potato clones with one check variety Asterix were grown during 2010-11 and 2011-12 at horticulture research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University to observe the effect of water stress on yield and tuber quality of potato. The present study revealed that the tuber yields of all the genotypes were reduced by different degrees of drought. Genotype CIP 393371.58 and CIP 396244.12 performed better in severe drought condition produced higher yield per plant. The highest percent of small sized and deformed tuber was found in the CIP 391004.18 and Asterix under severe drought condition, whereas the normal sized tuber was found in CIP 396244.12 and CIP 393371.58. These two genotypes also maintained more relative water content (RWC) with higher xylem exudation rate under water stress condition than the susceptible genotypes. On the basis of tuber yield and plant water status under drought condition, the genotypes CIP 393371.58 and CIP 396244.12 could be drought tolerant.

Keywords: drought susceptibility index, relative water content, xylem exudation rate and spad value.

I. Introduction

Ptato is a cool loving crop, needs regular water supply for its normal growth and development. Potatoes grown all over the world are characterized as drought sensitive (Deblonde & Ladent, 2001; Lahlou et al., 2003; Onder et al., 2005 and Hassanpanah, 2009). RWC is a measure of plant water status, which represents also variation in water potential, turgor potential and osmotic adjustment. RWC is closely related with cell volume; it may more closely reflect the balance between water supply to the leaf and transpiration rate (Schonfeld et al., 1988). This influences the ability of plant to recover from the stress and consequently affects yield and yield stability (Lilley and Ludlow, 1996). Relative water content (RWC) is an integrative indicator (Parsons and Howe, 1984), and was used effectively to detect drought resistance in French bean (Choudhury, 2009), wheat (Sarker et al., 1999), and mustard (Kumar and Singh, 1998). Xylem exudation rate is known as the flow of sap out of the cut end of a stem against the gravitational force. Thus, the exudation rate can be used as an indicator to measure the severity of water deficit. Water stressed plants showed a marked reduction in xylem exudation rate compared to well-watered condition (Aziz, 2003; Chowdhury, 2009). Water deficit is a common phenomenon for potato production, which leads to reduction in tuber quality and yield. Because of the vulnerability of potato to drought (Hassanpanh et al., 2008) arranging adequate water is very important for improving potato quality and increasing quantity. Interrupted water supply leads poor plant growth and reduced tuber number (Hassanpanah et al., 2008) and can decrease tuber yield up to 69% subject to the periods and strength of the stress (Schafleitner et al., 2007).

A well-watered crop is more capable of giving higher yields. Deficit water in irrigation reduces potato yield. The percent of reduction in potato yield may also vary from genotype to genotype. According to some authors, to obtain maximum yields soil moisture should not drop below 50% of crop available water in the soil, although it may vary 25 to 75%. These differences can be explained by climatic, plant and soil characteristics (Van loon, 1981). As water stress in potato is a common phenomenon and its effect has a good impact on growth & development, it is essential to find out how much a tolerant or a susceptible variety can withstand water stress for prolonged period and what is the impact on the water status in plant system. Therefore, the present study was under taken to determine effects of severe and moderate drought on plant water status and tuber yield of potato.

II. Materials and Methods

a) Site and Season of the Experiment

- The experiment was conducted at the Horticultural Research Farm, BSMRAU, Gazipur, Bangladesh

Author α: International Potato Center, Bangladesh.
e-mail: A.Mahmud@cgiar.org, Mahmud.tcrc@gmail.com
Author: σ International Potato Center, Bangladesh.
e-mail: Mohammad.hossain@cgiar.org
Author ρ: Agronomy Division, Bangladesh Agricultural Research Institute, Rajbari, Dinajpur, Bangladesh. e-mail: Mbazzaz72@yahoo.com
Author Ѡ: Agronomy Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.
e-mail: Shawquatshahadat@yahoo.com
Author ¥: Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.
e-mail: Altafmy@yahoo.com
Author §: International Potato Center, New Delhi, India.
e-mail: M.Kadian@cgiar.org

during winter season of 2010-11 and 2011-2012. The experimental site is situated in a sub- tropical climate zone and characterized by no rainfall during December to March and plenty during the rest of the year and this area is moderately drought prone, and face drought both winter and late winter season (Ramamasy and Baas, 2007). Air temperature and humidity, precipitation, evaporation, soil temperature and ground water table were recorded throughout the crop period (Table 1).

Table 1 : Climatological data of 2010-11 and 2011-12 crop season

Month	Air Temperature (°C)			Soil Temperature (°C),Depth			Humidity (%)	Rain Fall (mm)
	Max.	Min.	Ave.	10 cm	20 cm.	30 cm		
2010-11								
November	26.60	22.43	24.52	26.03	26.57	26.93	80.47	8.44
December	19.90	15.45	17.68	20.81	21.26	21.61	89.05	0.00
January	15.20	11.58	13.39	16.90	17.33	17.72	90.80	0.00
February	23.85	19.08	21.47	20.85	21.30	21.66	89.89	8.43
March	31.16	26.09	28.62	22.71	23.22	23.59	76.70	29.84
2011-12								
November	27.76	23.76	25.76	26.55	26.91	27.33	85.66	0.00
December	24.80	16.58	20.69	22.72	23.17	23.56	90.70	5.19
January	22.32	11.53	16.93	18.85	19.34	19.84	89.81	0.00
February	27.31	13.24	20.28	20.03	20.45	20.83	87.66	0.00
March	32.58	20.68	26.63	23.53	23.97	24.42	83.94	3.10

b) Planting materials, date of planting and Crop management

Four CIP clones (CIP 391004.18, CIP 393371.58, CIP 396031.119 and CIP 396244.12) and high yielding variety Asterix were used in this experiment. Apparently diseases free, uniform (28-40 mm) sized well sprouted potato were selected as planting material for the experiment. Seed tubers were planted on 25th November, 2010 and 17th November, 2011. Plant spacing was 60 x 25cm. Fertilizers were applied @ 160-44-132-15 kg ha^{-1} of N, P, K and S, respectively. Full amount of P, K and S and 50% of N were applied as basal and the remaining amount of urea was top dressed at 30 days after planting. Intercultural operations such as weeding, earthing up were done manually. Effective crop protection measures were taken according to Dey *et al.*, (2007).

c) Design and treatments of the experiment

The experiment was laid out in the field following strip plot design with three replications. Three drought treatments were applied (T1= severe drought and T2=moderate drought and T3= well-irrigated control). In severe drought plots, only one irrigation was applied at 30 DAP for good crop stand, but no irrigation was applied thereafter until harvest. In moderate drought plot, irrigation was applied twice at 30 and 45 DAP, but no water was applied thereafter till harvest. The control plot was irrigated four times at 30, 45, 60 and 75 DAP.

d) Harvesting and data collection

Selected plants were harvested at 90 DAP. Data were collected on i) Tuber yield (g/plant), ii) % tuber grades (by number) from randomly selected 10 plants.

e) Measurement of plant water status

Relative water content of leaves for each genotype was measured at 60 DAP at 8:00 am. Fully developed 4th and 5th leaf from the top were used for RWC measurement. Relative water content was calculated according to Kumar and Singh (1998). Xylem exudation rate was measured at 60 DAP stage 8:00 am in the morning 5cm above stem base. At first, dry cotton was weighed. A slanting cut on stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of sap was collected from the stem for 1 h at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was calculated by deducting cotton weight from the sap containing cotton weight and expressed per h basis as follows-

$$\text{Xylem exudation rate} = \frac{(\text{Weight of cotton} + \text{sap}) - (\text{Weight of cotton})}{\text{Time (h.)}}$$

f) Statistical analysis

Data on different attributes recorded for two years were analyzed by 'CROSTAT 7.2' statistical package. Appropriate standard errors (S.E.) of the means were also calculated.

III. Results and Discussions

a) Tuber yield per plant

The main effect of drought, genotype and drought-genotype interaction effect for tuber yield per plant was varied significantly (Table 2). Tuber yield of different potato genotypes under different drought conditions were ranged from 169.13 to 488.60 g plant^{-1} in 2010-11 and 155.50 to 357.88 g plant-1 in 2011-12. In severe drought condition, the highest yield was observed in CIP 396244.12 (219.73 g and 203.50 g with a mean of 211.62 g) which was similar to CIP 393371.58 (215.80 g and 160.38 g with a mean of 188.09 g) and the lowest from CIP 391004.18 (169.13 g and 155.50 with a mean of 162.32 g). In moderate drought condition, no significant difference was observed among the genotypes in 2010-11. It might be due to rainfall at later stage of growth (Table 1). Asterix produced significantly the highest tuber yield (315.88 g) in 2011-12 which was similar to CIP 396244.12 (283.38 g), CIP 393371.58 (274.94 g) and CIP 391004.18 (261.66 g). CIP 396031.119 produced the lowest yield (242.61 g) per plant. Tuber yield significantly increased in all genotypes in well watered control condition and ranged from 386.90 g to 488.60 g in 2010-11 and 327.38 to 357.88 g in 2011-12. Among the genotypes, CIP 396244.12 produced the highest mean tuber yield in the year 2010-11 and Asterix in 2011-12. In severe drought and moderate drought conditions, mean yield reduction were 54.80% and 20.49% in 2010-11 and 50.70% and 19.33% in 2011-12, respectively. Under severe stress conditions CIP 396244.12 and CIP 393371.58 performed better, but in moderate stress condition Asterix gave the highest yield followed by CIP 396244.12 and CIP 393371.58. Therefore, CIP 393371.58 and CIP 396244.12 have good yield potentials under both stress conditions. The present findings are in agreement with the findings of Struik and Voorst, 1986; Deblonde and Ladent, 2001; Heuer and Nadler, 1998 and Hassanpanh, 2010. Deblonde et al., (1999) also reported that severe drought treatment adversely affected tuber yield.

Table 2 : Interaction effects of drought and genotype on tuber yield/plant

• Genotype	• Yield (g plant-1)							
	• 2010-11				• 2011-2012			
	• T1	• T2	• T3	• Mean	• T1	• T2	• T3	• Mean
• CIP 391004.18	• 169.13	• 316.90	• 386.90	• 290.98	• 155.50	• 261.66	• 346.72	• 254.63
• CIP 393371.58	• 215.80	• 363.56	• 419.10	• 332.82	• 160.38	• 274.94	• 327.38	• 254.23
• CIP 396031.119	• 175.33	• 318.40	• 393.00	• 295.58	• 158.94	• 242.61	• 331.33	• 244.29
• CIP 396244.12	• 219.73	• 361.73	• 483.43	• 354.96	• 203.50	• 283.38	• 345.33	• 277.40
• Asterix	• 201.33	• 365.70	• 488.60	• 351.88	• 164.02	• 315.88	• 357.88	• 279.26
• Mean	• 196.26	• 345.26	• 434.21	•	• 168.47	• 275.69	• 341.73	•
• Statistics	• LSD0.05		• S.Em ±		• LSD0.05		• S.Em ±	
• Drought (T)	• 23.17		• 7.73		• 25.45		• 8.49	
• Genotype (G)	• 29.92		• 9.98		• 32.86		• 10.96	
• T x G	• 51.82		• 17.28		• 56.91		• 18.98	

T1= Severe drought, T2=Moderate drought and T3= Well watered control

b) Drought susceptibility index

Drought susceptibility index (DSI) was calculated for all the genotypes and presented in the (Fig. 1). The DSI for tuber yield per plant was the lowest in CIP 396244.12 (0.92) followed by CIP 393371.58 (0.94) in the severe drought condition. The highest DSI for yield per plant was recorded in Asterix (1.07), followed by CIP 391004.18 (1.05).Similarly, under moderate drought condition, the lowest DSI was found in CIP 393371.58 (0.72) followed by Asterix (0.98). The highest DSI was found in CIP 396031.119 (1.13) followed by CIP 396244.12 (1.11) High yielding genotype Asterix showed high DSI under severe drought condition as well as very much sensitive to water stress condition. On the other hand, clone CIP 393371.58 showed minimum DSI for yield both in severe (0.94) and moderate (0.72) drought condition.

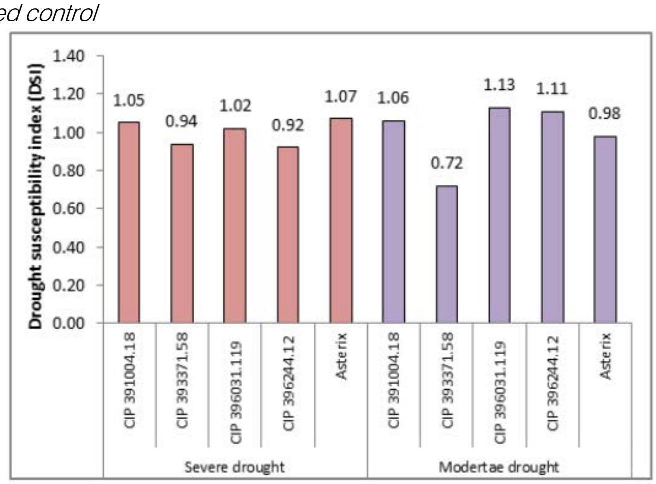

Figure 1 : Drought susceptibility index of potato genotypes under severe and moderate drought condition (Mean of 2010-11 and 2011-12)

c) Tuber grade (% by number)

Tubers of all the treatment combinations were graded into four different groups according to tuber diameter viz. under size (<28mm), Grade- A (28-40mm), Grade-B (40-55mm) and Over size (>55mm). Marked variation on tuber grade (% by no.) was observed among the all treatment combinations (Table-3). In severe drought treatment, CIP 391004.18 produced the highest proportion of under sized tuber (48.48%) followed by CIP 396031.119 (43.69 %) and Asterix (35.66%). The maximum A-grade tuber was produced by CIP 393371.58 (59.35%) followed by CIP 396244.12 (49.68%), Asterix (49.74%) and CIP 391004.18 (48.34%), while CIP 396031.119 produced lowest (39.42%). However, in B-grade tuber, large variation observed which ranged from 2.78 to 33.95 %, CIP 391004.18 produced the lowest, and CIP 396244.12 produced the highest. No oversized (>55mm) tubers were found in severe drought treatment. In moderate drought treatment CIP 396031.119 produced the highest proportion of under sized tuber (28.30%) followed by CIP 391004.18 (27.80 %) and Asterix (27.11%). CIP 396244.12 (12.84%) was the lowest. The highest proportion of A-grade tubers were produced in CIP 391004.18 (61.01%) followed by Asterix (56.78%), and CIP 393371.58 (52.75%) while CIP 396244.12 produced the lowest (45.48%). Larger variation was observed in B-grade tuber which ranged from 11.19 to 38.01% where CIP 391004.18 produced the lowest and CIP 396244.12 produced the highest. CIP 393371.58 and CIP 396244.12 produced 1.97 and 3.67 % over sized tuber, respectively but none were found in CIP 391004.18, CIP 396031.119 and Asterix. In well watered control treatment, % under sized and A-grade tubers decreased, but B-grade and oversized tubers increased. The highest B-grade tubers were found in CIP 396244.12 (44.87%), followed by CIP 393371.58 (38.67%), CIP 396031.119 (33.39%) and Asterix (30.21%), where the lowest was found in CIP 391004.18 (24.50%). The highest oversized tubers were produced by Asterix (10.20%) followed by CIP 396244.12 (6.33%), CIP 396031.119 (5.67%) and CIP 393371.58 (5.33%), and the lowest (2.39 %) was in CIP 391004.18.

Table 3 : Tuber grade (% by number) of five potato genotypes under different drought conditions

Treatment	Genotype	% under size	% seed size		% over size
		<28 mm	A-Grade (28-55 mm)	(B-Grade) 40-55 mm	<55 mm
Severe drought	CIP 391004.18	48.88	48.34	2.78	0.00
	CIP 393371.58	22.12	59.35	18.53	0.00
	CIP 396031.119	43.69	39.42	16.89	0.00
	CIP 396244.12	16.37	49.68	33.95	0.00
	Asterix	35.66	49.74	14.61	0.00
Moderate drought	CIP 391004.18	27.80	61.01	11.19	0.00
	CIP 393371.58	14.33	52.75	30.95	1.97
	CIP 396031.119	28.30	47.17	24.53	0.00
	CIP 396244.12	12.84	45.48	38.01	3.67
	Asterix	27.11	56.78	16.12	0.00
Well watered condition	CIP 391004.18	30.37	42.74	24.59	2.39
	CIP 393371.58	15.74	40.25	38.67	5.33
	CIP 396031.119	24.31	36.64	33.39	5.67
	CIP 396244.12	17.91	30.89	44.87	6.33
	Asterix	22.26	37.33	30.21	10.20

d) Plant water status

i. *Relative water content*

Relative water content (RWC) of leaves of five potato genotypes varied significantly due to treatment effects (Figure 2). The lowest RWC of leaves was observed in severe drought condition (75.08%) followed by moderate drought (85.86%). In severe drought condition, the RWC of leaves among the genotypes varied from 72.09 to 77.06%. The lowest was found in CIP 391004.18 and the highest was in CIP 396244.12 followed by CIP 393371.58 (75.11%). In moderate drought condition, the RWC of leaves varied from 83.58 to 87.16 % where the lowest was found in CIP 391004.18 and the highest was in CIP 396244.12 followed by CIP 393371.58 (86.52%). In well watered condition, the RWC of leaves varied from 89.30 to 91.20

% where the lowest was found in CIP 391004.18 and the highest was in Asterix followed by CIP 396031.119 (90.9%). It was observed that the genotype CIP 396244.12 and CIP 393371.58 maintained more RWC than the rest three in severe and moderate drought conditions. Similar findings were reported by Begum and Paul, 1993, Paul and Aman, 2000 and Omae et al., 2005, Chandrasekar et al., 2000 and Choudhury, 2009.

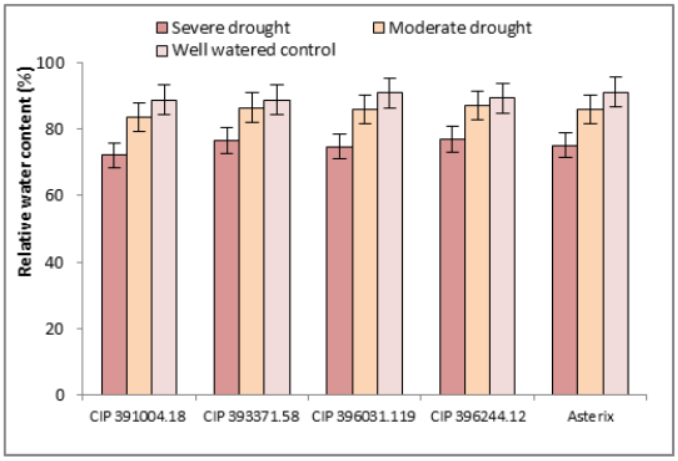

Figure 2 : RWC of five potato genotypes at different drought treatment (Mean of 2010-11and 2011-12).Bar represent mean ± S.E. of 3 replications

ii. *Xylem exudation rate*

Xylem exudation rates of five potato genotypes measured in the morning (9:00am) at 60 DAP stages varied significantly due to treatment effects (Figure 3). The lowest rate was observed in severe drought treatment followed by moderate drought treatment in all genotypes. In severe drought condition, the xylem exudation rate varied from 37 to 117 mg hr^{-1} where, the lowest was found in CIP 391004.18 and the highest was in CIP 396244.12. In moderate drought condition, it varied from 92 to 207 mg hr^{-1} where the lowest was found in CIP 391004.18 and the highest was in CIP 396244.12. Again in well watered condition it varied from 199 to 316 mg hr-1 where the lowest was found in CIP 391004.18 and the highest was in Asterix followed by CIP 396244.12 (298 mg hr-1.). Both in severe and moderate drought conditions, the higher xylem exudation rate was observed in CIP 396244.12 and CIP 393371.58 Similar results in different crops were reported by Islam, 2008 in mungbean and Choudhury, 2009 in French bean.

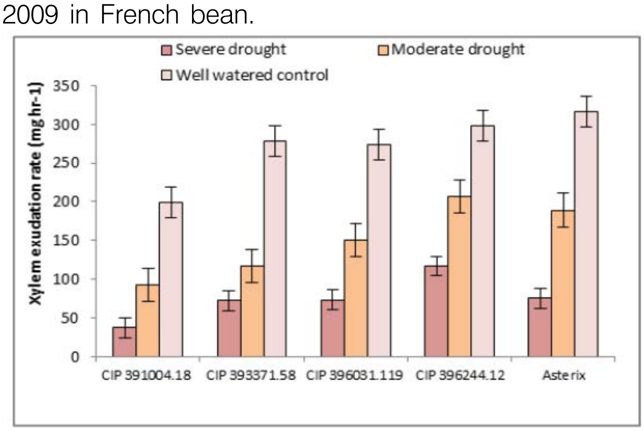

Figure 3 : Xylem exudation rate of five potato genotypes at different drought treatment (Mean of 2010-11and 2011-12). Bar represent mean ± S.E. of 3 replications

iii. *SPAD value*

SPAD (Soil-Plant Analysis Development) value was measured at 60 DAP and found significant variation among the treatments. Mean values of SPAD in severe drought, moderate drought, and well watered conditions were 39.89, 43.58, and 50.98. In severe drought condition, the SPAD values of the genotypes varied from 37.66 to 45.90 where the lowest was in CIP 391004.18 and the highest was in CIP 396244.12. In moderate drought condition, the SPAD values varied from 35.43 to 48.06 where the lowest was in CIP 391004.18 and the highest was in CIP 396244.12. In well watered condition, the values varied from 45.86 to 53.60 where the lowest was in CIP 391004.18 and the highest was in Asterix.

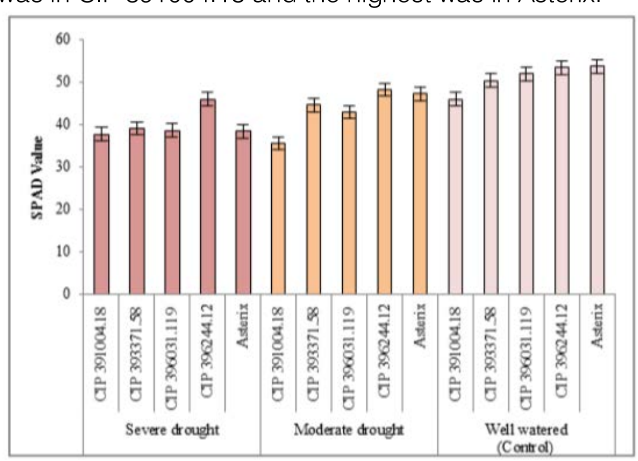

Figure 4 : SPAD value of five potato genotypes at different drought treatment (Mean of 2010-11and 2011-12). Bar represent mean ± S.E. of 3 replications

IV. Discussions

Potato yield greatly depends on its canopy structure as well as on yield contributing attributes like

Global Journal of Science Frontier Research (D) Volume XIV Issue X Version I Year 2014

tuber number per plant, average tuber size and tuber yield per plant. All these attributes affected by deficit irrigation during the production period which ultimately lowered the yield. Growth and yield of potato grown under water stress conditions reduced as a result of stress induced changes of physiological and bio-chemical process (Huffacker et al., 1970). It was clear that drought cause leaf area reduction with leaf fall. Leaf falling and leaf area reduction under drought condition causes reduction of photosynthetic area of the potato plants (Mahmud, 2012) which lowering the rate of photosynthesis. The number of shoots per plant is determined by the size of the tuber (Wurr, 1974), soil condition and soil moisture at planting, although pathogens (black scurf) and pests may have an effect. It may also be influenced by the length and conditions of the pre sprouting period (Allen, 1978). Haverkort et al. (1990) reported that the later dry period does not affect the number of stolons and tubers. Potato plants are especially sensitive to water stress during stolonization and tuberization stages (Steckel and Gray, 1979). The main cause of tuber reduction in water stress condition was the reduction of the number of stolons per plant, and not through a reduction of the number of tubers per stolon (Haverkort et al., 1990). Once stolons are initiated, they yield tubers regardless of a subsequent water stress period. Similar results were reported by Deblonde and Ladent, 2001 and Schafleitner et al., 2007. It was clear from the results that deficit water supply during tuber formation stage reduced the tuber number and size. Irrigated condition favored larger sized tuber formation (Mackerron and Jefferies, 1988; Struik and Voorst, 1986 and Onder et al., 2005).

Genotypes with high DSI were high yielder as well as very much sensitive to water stress. But, oppositely genotypes with low DSI were low yielder and tolerant to water stress. So, potato genotypes with comparatively low DSI and moderate to high yield for better productivity under water stress situation might be selected. Tera´n and Singh (2002) reported that water stress resistant lines had relatively low DSI while the water stress susceptible lines had high DSI values.

RWC in severe and moderate drought conditions which is a good indicator of drought tolerance. Reasons might be the cause of more xylem exudations and production of high amount of osmo-regulatory compounds like proline, sugar etc. Higher exudation rates under drought condition indicated that plants have deep root system and can uptake more water and can tolerate drought condition. It is directly associated with the flow of transpiration stream. Lower SPAD values indicated the reduction of chlorophyll in the leaf due to drought imposition. Leaf chlorophyll content is well correlated with leaf nitrogen status, and photosynthetic capacity. Therefore, the productivity of a crop can be predicted by examining the SPAD values.

V. Conclusion

Tuber yield and grades were seriously affected by drought. The lowest reduction in tuber yield was found in genotypes (CIP 396244.12 and CIP 393371.58). Small sized and deformed tubers were higher under severe drought condition in the genotypes CIP 391004.18 and Asterix, whereas the highest percent of normal sized tubers was found in the genotypes CIP 396244.12 and CIP 393371.58. These two genotypes maintained more RWC with higher xylem exudation rate and higher SPAD values under water stress condition than others which indicated the capacity of the genotypes to thrive well in the water deficit environment.

References Références Referencias

1. Allen, E.J. 1978. Plant density. In: P.M. Harris (Ed.), The Potato Crop, the Scientific Basis for Improvement. Chapman & Hall, London: p. 278-326.
2. Aziz, M.A. 2003. Growth, yield and some physiological mechanisms of salinity tolerance in mungbean. A Ph.D. Dissertation. Dept. of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.
3. Begum, F.A. and Paul, N.K. 1993. Influence of soil moisture on growth, water use and yield of mustard. J. Agron. Crop Sci. 170: 136-141.
4. Chandrasekar, V., Sairam, R.K. and Srivastava, G.C. 2000. Physiological and Biochemical Responses of Hexaploid and Tetraploid Wheat to Drought Stress. J. Agron. Crop Sci. 185: 219-227.
5. Choudhury, A.K. 2009. Water stress tolerance of French bean (Phaseolus vulgaris L.), Ph.D. Dissertation. Department of Agronomy. Bangabandhu Sheikh Mujibur Rahaman Agricultural University, Salna, Gazipur-1703. Bangladesh.
6. Deblonde, P.K.M., Haverkort, A.J. and Ladent, J.F. 1999. Response of early and late potato cultivars to moderate drought conditions: agronomic parameters and carbon isotope discrimination. Europ. J. Agronomy. 11: 91-105.
7. Deblonde, P.M.K. and Ladent, J.F. 2001. Effects of moderate drought conditions on green leaf number, stem height, leaf length and tuber yield of potato cultivars. Europ. Journal of Agronomy. 14: 31-41.
8. Dey, T.K., Prodhan, Z.H. and Hossain, M.S. 2007. Potato Late Blight and its Integrated Management. (Booklet in Bengali). Breeders Seed Production Centre. Bangladesh Agricultural Research Institute, Debiganj, Panchagarh, Bangladesh.
9. 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. AVRDC, Shanhua, Taiwan. pp. 257–270.

10. Hassanpanah, D. 2010. Evaluation of Potato Advanced Cultivars against Water Deficit Stress Under in vitro and in vivo Condition. Biotechnology. 9(2): 164-169.
11. Hassanpanah, D., Gurbanov, E., Gadimov, A. and Shahriari, R. 2008. Determination of yield stability in advanced potato cultivars as affected by water deficit and potassium humate in Ardabil region, Iran. Pak. J. Biol. Sci., 15: 1354-1359.
12. Hassanpanh, D. 2009. Effects of water deficit and potassium humate on tuber yield and yield component of potato cultivars in Ardabil region, Iran. Res. J. Environ. 3(3): 351-379. (http://scialert.net/-abstract/?doi=rjes.2009.351.356)
13. Havaerkort, A.J., Waart, M. van de and Bodlaender, K.B.A. 1990. The effect of early drought stress on numbers of tubers and stolons of potato in controlled and field conditions. Potato Research. 33: 89-96.
14. Heuer, B. and Nadler, A. 1998. Physiological response of potato plants to soil salinity and water deficit. Plant Science. 137: 43-51.
15. Huffaker, R.C., Radin, T., Kleinkopf, G.R. and Cox, E.L. 1970. Effects of mild water stress on enzymes of nitrate assimilation and of the carboxylative phase of photosynthesis in barley. Crop Sci. 10: 471-474.
16. Islam, M.S. 2008. Water stress tolerance of mungbean [Vigna radiata (L.) Wilczek] genotypes as influenced by plant growth regulators. A Ph.D. Dissertation, Dept. of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.
17. Kumar, A. and Singh, D.P. 1998. Use of physiological indices as a screening technique for drought tolerance in oilseed Brassica species. Ann. Bot. 81: 413-420.
18. Lahlou, O., Ouattar, S. and Ledent, J.F. 2003. The effect of drought and cultivar on growth parameters, yield and yield components of potato. Agronomie. 23: 257-268.
19. Lilley, J.M. and Ludlow, M.M. 1996. Expression of osmotic adjustment and dehydration tolerance in diverse rice lines. Field Crops Res. 48: 185-197.
20. Mackerron, D.K.L. and Jefferies, R.A. 1998. The distribution of tuber sizes in droughted and irrigated crops of potato. I. Observation on the effect of water stress on graded yields from differing cultivars. Potato Research. 31: 269-278.
21. Mahmud, A.A. 2012. Improvement of Drought Tolerant Potato Variety. A Ph.D. Dissertation. Dept. of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.
22. Omae, H., Kumar, A., Egawa, Y., Kashiwaba, K. and Shono, M. 2005. Midday drop of leaf water content to drought tolerance in snap bean (Phaseolus vulgaris L). Plant Prod. Sci. 8: 465-467.
23. Onder, S., Caliskan, M.E., Onder, D. and Caliskan, S. 2005. Different irrigation methods and water stress effects on potato yield and yield components. Agricultural water management. 73: 73-86. (Available on www. elsevier.com/locate/agwat)
24. Parsons, L.R., and Howe, T.K. 1984. Effects of water stress on the water relations of Phaseolus vulgaris and the drought resistant Phaseolus acutifolius. Plant Physiol. 60, 197-202.
25. Paul, N.K. and Aman, R. 2000. Genotypic variation in physiological characters and grain yield of wheat under low soil moistures. Ann. Bangladesh Agric. 10: 195-201.
26. Ramamasy, S. and Baas, S. 2007. Climate variability and change: Adaptation to drought in Bangladesh. A resource book and training guide. Asian Disaster Preparedness Center, Food and Agriculture Organization of the United Nations, Rome.
27. Sarker, A.M., Rahman, M.S. and Paul, N.K. 1999. Effect of soil moisture on relative leaf water content, chlorophyll, proline and sugar accumulation in wheat. J. Agron. Crop Sci. 183: 225-229.
28. Schafleitner, R., Guitierrez, R., Espino, R., Guadin, 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.
29. Schonfeld, M.A., Johnson, R.C. Carver, B.F. and Mornhinweg, D.W. 1988. Water Relations in Winter Wheat as Drought Resistance Indicators. Crop Sci. 28: 526-531.
30. Steckel, J.R.A. and Gray, D. 1979. Drought tolerance in potatoes. Journal of Agricultural Science. Cambridge. 92: 375-381.
31. Struik, P. C, and Voorst, G. van. 1986. Effects of drought on the initiation, yield and size distribution of tubers of Solanun tuberosum L. cv. Bintje. Potato Research. 29: 487-500.
32. Tera′n, M. and Singh, S.P. 2002. Comparison of sources and lines selected for drought resistance in common bean. Crop Sci. 42: 64-70.
33. Van Loon, C.D. 1981. The effect of water stress on potato growth, development and yield. Amer. Potato J. 58: 51-69.
34. Wurr, D.C.E. 1974. Some effects of seed size and spacing on the yield and grading of two main potato varieties. I. Final yield and its relation to plant population. Journal of Agricultural Science, Cambridge. 82: 37-45.

Global Journals Inc. (US) Guidelines Handbook 2014

www.GlobalJournals.org