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EFFECT OF WATER STRESS ON LEAF CHLOROPHYLL CONTENT (CHL-A, B & TOTAL CHLOROPHYLL) OF POTATO CULTIVARS

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Abstract

Four potato cultivars namely Kufri Chipsona-1, Kufri Pukhraj, Kufri Lauvkar and Desiree were investigated under water stress conditions with respect to three growth stages viz. tuber initiation (T_2), tuber enlargement (T_3) and tuber maturation stage (T_4). In present study chlorophyll-a, chlorophyll-b and total chlorophyll content per gram fresh weight was found to be higher under water stress in comparison with that of well-waterd control. Chlorophyll-a content increased significantly due to water stress treatments at different growth stages against well watered control (T_1). Maximum chlorophyll 'a', 'b' and total chlorophyll content were recorded under water stress treatment at tuber enlargement stage (T_3) whereas minimum observed when water stress was imposed at tuber maturation stage (T_4). Among four cultivars evaluated Kufri Pukhraj recorded maximum chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents.

Key words: chlorophyll 'a', chlorophyll 'b', total chlorophyll, tuber growth stages, water stress, potato.

Introduction

The global potato production is estimated to be 382 million tons in 2014, ranking first highest produced non-cereal food crop and the fourth highest produced crop worldwide after wheat, corn and rice (FAO, 2018, Keshav Dahal *et al.,* 2019). Potato is a drought sensitive crop and identification of water deficit tolerant potato genotypes is an adaptation strategy to mitigate the climatic changes (Romero *et al.,* 2017). Water-saving irrigation methods such as deficit irrigation (DI) and partial root-zone drying irrigation (PRD) permit a crop to tolerate some water deficit degrees to decrease the irrigation budget and increase potential revenue (Tarek K. Zin El-Abedin *et al.,* 2019). Chlorophyll content is an index of organic matter production and plant growth. To understand the photosynthetic responses to environmental variables, especially water stress, the biochemical factors are of great significance. Photoinhibition is a phenomenon in which excess excitation energy, being dissipated as heat of fluorescence, is transferred from the light harvesting pigments – chlorophyll to the reaction centers of photosynthesis. The ensuing inactivation of such reaction centres reduces quantum yield (Jones and Kok, 1966; Bjorkman, 1968). Photoinhibition may reduce ATP and $NADPH_2$ generation to match the lower availability of CO_2 during drought. Romero *et al.,* 2017 also found influence of drought stress on photosynthetic characteristics and protective enzymes of potato. Mescht *et al.,* (1999) used chlorophyll fluorescence and chlorophyll content as a measure of drought tolerance in potato. Moisture stress influences the synthesis of chlorophyll, possibly through nutrient availability. Status of chlorophyll development in common potato cultivars grown under stress will help in deciphering the strategy adopted by different cultivars for climatic responses.

Materials and Method

The field experiments were conducted at Research Farm of ICAR-CPRI Campus, Modipuram, Meerut (UP) during rabi season. Forty eight plots were used in a split plot design for accommodating 4 treatments. Field trials were conducted in three replicates employing the 4

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varieties viz. Kufri Chipsona-1, Kufri Pukhraj, Kufri lauvkar and Desiree having treatments: T1: Control (well watered plants), T2: Water stress at tuber initiation stage, T3: Water stress at tuber enlargement stage, T4: Water stress at tuber maturation stage. T1 control (well watered) plots were irrigated at 6 DAP (days after planting), 27 DAP, 42 DAP, 63 DAP and 80 DAP during 1st year and at 8 DAP, 25 DAP, 44 DAP, 67 DAP and 83 DAP during 2nd year. The water stress was imposed by withholding water in T2, T3 and T4 treatments at different growth stages. The growth stage was identified and confirmed by uprooting the plants and by examining the stage of tuber development. Experimental plots were dehaulmed at 90 DAP and harvesting was done 10-15 days after of dehaulming so that tuber skin is matured. Chlorophyll content of the leaf was estimated by Arnon (1949) method. Chlorophyll was extracted in 80% acetone and the absorbances were recorded using a UV-VIS spectrophotometer at 663 nm and 645 nm. Using the absorption coefficients, the amount of chlorophyll was calculated as per standard formulae. Data was pooled and analyzed with the help of statistical software IRRISTAT (1999).

Results and Findings

Chlorophyll 'a' Content of leaf

Mean values of treatments in table 1 showed that chlorophyll 'a' content was increased up to tuber enlargement stage and reached maximum at this stage thereafter chlorophyll 'a' content was declined and reached minimum at tuber maturation stage in well watered control (T_1). Chlorophyll 'a' content increased significantly due to water stress treatments at different growth stages against well watered control (T_1). Maximum chlorophyll 'a' content (2.11 and 2.16 mg g^{-1} fw during 1st year and 2nd year, respectively) was recorded due to water stress treatment at tuber enlargement stage (T_3) whereas minimum chlorophyll 'a' content (0.62 and 0.68 mg g^{-1} fw during 1st year and 2nd year, respectively) was observed when water stress was imposed at tuber maturation stage (T_4). Water stress caused maximum percent increase (21% and 18% in respective years) in chlorophyll 'a' content in T_3 while minimum percent increase (4% in both the years) in T_4. Interaction between cultivar and treatment also found significant at all growth stages except tuber initiation stage. Under water stress conditions at tuber initiation stage (T_2) cultivar Kufri Pukhraj recorded the highest chlorophyll 'a' content (1.20 and 1.37 mg g^{-1} fw during 1st year and 2nd year, respectively) whereas cultivar Kufri Chipsona-1 recorded lowest chlorophyll 'a' content (1.11 and 1.19 mg g^{-1} fw during 1st year and 2nd year, respectively). Maximum percent increase in chlorophyll 'a' content due to water stress at this stage was found in cultivar Kufri Lauvkar (12% and 10%) while minimum percent increase in cultivar Kufri Pukhraj (4 and 11%) in comparison with respective well irrigated control. As a result of water stress treatment at tuber enlargement stage (T_3) Kufri Pukhraj recorded the maximum chlorophyll 'a' content (2.34 and 2.40 mg g^{-1} fw during 1st year and 2nd year, respectively) while Desiree recorded the minimum chlorophyll 'a' content (1.95 and 1.99 mg g^{-1} fw during 1st year and 2nd year, respectively). The cultivar Kufri Pukhraj also showed maximum percent increase in chlorophyll 'a' content (27% and 28% in respective years) whereas cultivar Desiree showed minimum percent increase (14% in both the years) in chlorophyll 'a' content. As a result of water stress treatment at tuber maturation stage (T_4), cultivar Kufri Chipsona-1 recorded the maximum chlorophyll 'a' content (0.67 and 0.72 mg g^{-1} fw during 1st year and 2nd year, respectively) whereas Kufri Pukhraj recorded minimum (0.64 and 0.63 mg g^{-1} fw during 1st year and 2nd year, respectively).

Chlorophyll 'b' content of leaf

Mean values of treatments in table 2 showed that chlorophyll 'b' content was increased up to tuber enlargement stage and reached maximum at this stage thereafter chlorophyll 'b' content was declined and reached minimum at tuber maturation stage in well watered control (T_1). Maximum chlorophyll 'b' content (0.96 and 0.98 mg g^{-1} fw during 1st year and 2nd year, respectively) was recorded due to water stress treatment at tuber enlargement stage (T_3) whereas minimum chlorophyll 'b' content (0.29 and 0.32 mg g^{-1} fw during 1st year and 2nd year, respectively) under water stress conditions was recorded when water stress was imposed at tuber maturation stage (T_4). As a result of water stress maximum percent increase in chlorophyll 'b' content (14% in both the years) was found in T_3 whereas minimum percent increase (6% and 12% in respective years) was found in T_4. In T_2 Kufri Pukhraj (0.83 and 0.84 mg g^{-1} fw during 1st year and 2nd year, respectively) recorded highest chlorophyll 'b' content whereas Kufri Lauvkar (0.75 and 0.76 mg g^{-1} fw during 1st year and 2nd year, respectively) recorded lowest chlorophyll 'b' content. In T_3 the cultivar Kufri Lauvkar (0.94 and 1.02 mg g^{-1} FW during 1st year and 2nd year, respectively) recorded the maximum chlorophyll 'b' content whereas cultivar Desiree recorded the minimum chlorophyll content (0.92 and 0.95 mg g^{-1} fw during 1st year and 2nd year, respectively).

Table 1: Effect of water stress on chlorophyll 'a' content (mg/g fw) of leaves at various growth stages of potato cultivars.

Treat-ments*	1st year			2nd year		
	Growth stage**			Growth stage		
	TI	TE	TM	TI	TE	TM
Kufri Chipsona-1						
T_1	1.01	1.76	0.55	1.05	1.89	0.68
T_2	1.11 (+10%)***	1.92	0.58	1.19 (+13%)	1.99	0.68
T_3	1.01	2.15 (+22%)	0.60	1.04	2.22 (+18%)	0.70
T_4	1.02	1.77	0.67 (+4%)	1.05	1.81	0.72 (+6%)
Mean	1.04	1.90	0.60	1.08	1.98	0.69
Kufri Pukhraj						
T_1	1.15	1.84	0.61	1.24	1.87	0.63
T_2	1.20 (+4%)	2.02	0.62	1.37 (+11%)	2.05	0.61
T_3	1.14	2.34 (+27%)	0.64	1.60	2.40 (+28%)	0.59
T_4	1.15	1.85	0.64 (+5%)	1.14	1.82	0.63
Mean	1.16	2.01	0.63	1.33	2.03	0.62
Kufri Lauvkar						
T_1	1.05	1.68	0.59	1.09	1.85	0.61
T_2	1.18 (+12%)	1.84	0.61	1.20 (+10%)	1.90	0.61
T_3	1.04	2.02 (+20%)	0.62	1.07	2.04 (+10%)	0.61
T_4	1.05	1.70	0.62 (+5%)	1.07	1.81	0.65 (+7%)
Mean	1.08	1.81	0.61	1.11	1.90	0.62
Desiree						
T_1	1.11	1.71	0.62	1.14	1.74	0.73
T_2	1.21 (+9%)	1.87	0.63	1.29 (+13%)	1.89	0.76
T_3	1.12	1.95 (+14%)	0.65	1.17	1.99 (+14%)	0.69
T_4	1.12	1.69	0.63 (+2%)	1.14	1.75	0.70 (+4%)
Mean	1.14	1.80	0.63	1.18	1.84	0.72
Mean values of treatments						
T_1	1.08	1.75	0.59	1.13	1.84	0.66
T_2	1.18 (+9%)	1.91	0.61	1.26 (+12%)	1.96	0.66
T_3	1.08	2.11 (+21%)	0.63	1.22	2.16 (+18%)	0.65
T_4	1.09	1.75	0.62 (+4%)	1.10	1.80	0.68 (+4%)
CD at 5%						
Cultivar (C)	0.041	0.068	0.022	0.041	0.081	0.024
Treatment (T)	0.030	0.050	0.017	0.030	0.060	0.018
C × T	NS	0.100	NS	0.061	0.123	0.036

* Treatments: T_1 = -Control (well watered), T_2 = water stress at tuber initiation, T_3 = water stress at tuber enlargement and T_4 = water stress at tuber maturation stage.

** Growth stages: TI = Tuber initiation, TE =Tuber enlargement and TM = Tuber maturation.

*** Figures in parenthesis are percent (%) change in leaf chlorophyll 'a' content due to water stress treatment T_2, T_3 and T_4 as compared with respective control.

Total chlorophyll content of leaf

Mean values of treatments in table 3 showed that total chlorophyll content was increased up to tuber enlargement stage and reached maximum at this stage thereafter total chlorophyll content was declined and reached minimum at tuber maturation stage. Total chlorophyll content increased significantly due to water stress treatments at different growth stages as compared with well watered control (T_1). Maximum total chlorophyll content (3.20 and 3.14 mg g^{-1} fw during 1st year and 2nd year, respectively) was observed when water stress was imposed at tuber enlargement stage (T_3) whereas minimum total chlorophyll content (1.01 and 1.00 mg g^{-1} FW during 1st year and 2nd year, respectively) was observed when water stress was imposed at tuber maturation stage (T_4). Similarly, maximum percent increase (18% and 16% in respective years) and minimum percent increase (4% and 5%) was also observed in T_3

Table 2: Effect of water stress on chlorophyll 'b' content (mg/g fw) of leaves at various growth stages of potato cultivars.

Treat-ments*	1st year			2nd year		
	Growth stage**			Growth stage		
	TI	TE	TM	TI	TE	TM
Kufri Chipsona-1						
T_1	0.61	0.85	0.22	0.71	0.82	0.30
T_2	0.72 (+18%)***	0.93	0.22	0.76 (+7%)	0.94	0.33
T_3	0.63	0.98 (+15%)	0.23	0.70	0.99 (+21%)	0.33
T_4	0.62	0.83	0.23 (+5%)	0.70	0.83	0.35 (+17%)
Mean	0.64	0.90	0.22	0.72	0.89	0.33
Kufri Pukhraj						
T_1	0.71	0.86	0.28	0.73	0.84	0.31
T_2	0.83 (+17%)	0.95	0.28	0.84 (+15%)	0.93	0.32
T_3	0.71	0.98 (+14%)	0.29	0.72	0.96 (+14%)	0.33
T_4	0.73	0.86	0.28	0.72	0.84	0.31
Mean	0.74	0.91	0.28	0.75	0.89	0.32
Kufri Lauvkar						
T_1	0.69	0.82	0.30	0.72	0.93	0.27
T_2	0.75 (+9%)	0.91	0.31	0.76 (+6%)	0.99	0.28
T_3	0.69	0.94 (+15%)	0.32	0.70	1.02 (+10%)	0.28
T_4	0.70	0.83	0.32 (+7%)	0.70	0.92	0.29 (+7%)
Mean	0.71	0.88	0.31	0.72	0.96	0.28
Desiree						
T_1	0.71	0.83	0.29	0.72	0.85	0.28
T_2	0.81 (+14%)	0.90	0.31	0.83 (+15%)	0.91	0.21
T_3	0.71	0.92 (+11%)	0.31	0.72	0.95 (+12%)	0.34
T_4	0.70	0.84	0.33 (+14%)	0.72	0.84	0.35 (+25%)
Mean	0.73	0.87	0.31	0.75	0.89	0.29
Mean values of treatments						
T_1	0.68	0.84	0.27	0.72	0.86	0.29
T_2	0.78 (+14%)	0.92	0.28	0.80 (+11%)	0.94	0.29
T_3	0.69	0.96 (+14%)	0.29	0.71	0.98 (+14%)	0.32
T_4	0.69	0.84	0.29 (+6%)	0.71	0.86	0.32 (+12%)
CD at 5%						
Cultivar (C)	0.023	0.031	0.010	NS	0.032	0.012
Treatment (T)	0.018	NS	0.008	0.018	0.025	0.008
C × T	NS	NS	NS	NS	NS	0.016

*Treatments: T_1 = -Control (well watered), T_2 = water stress at tuber initiation, T_3 = water stress at tuber enlargement and T_4 = water stress at tuber maturation stage

**Growth stages: TI = Tuber initiation, TE =Tuber enlargement and TM = Tuber maturation

***Figures in parenthesis are percent (%) change in leaf chlorophyll 'b' content due to water stress treatment T_2, T_3 and T_4 as compared with respective control

and T_4, respectively. In T_2 Kufri Pukhraj (2.16 and 2.20 mg g^{-1} FW during 1st year and 2nd year, respectively) recorded highest total chlorophyll content whereas Kufri Chipsona-1 (2.01 and 1.95 mg g^{-1} fw during 1st year and 2nd year, respectively) recorded lowest total chlorophyll content. In T_3 Kufri Pukhraj (3.45 and 3.36 mg g^{-1} fw during 1st year and 2nd year, respectively) recorded the maximum total chlorophyll content whereas the cultivar Desiree (3.00 and 2.93 mg g^{-1} fw during 1st year and 2nd year, respectively) recorded the minimum total chlorophyll content. When water stress was imposed at tuber maturation stage (T_4), the cultivar Desiree was found superior in total chlorophyll content (1.08 and 1.05 mg g^{-1} fw during 1st year and 2nd year, respectively) whereas Kufri Pukhraj was found inferior (1.02 and 0.95 mg g^{-1} fw during 1st year and 2nd year, respectively) in total chlorophyll content.

Table 3: Effect of water stress on total chlorophyll content (mg/g fw) of leaves at various growth stages of potato cultivars.

Treat-ments*	1st year			2nd year		
	Growth stage**			Growth stage		
	TI	TE	TM	TI	TE	TM
Kufri Chipsona-1						
T_1	1.79	2.74	0.88	1.76	2.71	0.98
T_2	2.01 (+12%)***	2.97	0.91	1.95 (+11%)	2.93	1.01
T_3	1.80	3.26 (+19%)	0.94	1.73	3.21 (+19%)	1.02
T_4	1.81	2.73	0.91 (+3%)	1.75	2.64	1.06 (+8%)
Mean	1.85	2.93	0.91	1.80	2.87	1.02
Kufri Pukhraj						
T_1	2.01	2.83	1.00	1.96	2.71	0.94
T_2	2.16 (+8%)	3.10	1.02	2.20 (+12%)	2.98	0.93
T_3	2.00	3.45 (+22%)	1.04	2.32	3.36 (+24%)	0.92
T_4	2.02	2.83	1.02 (+2%)	1.86	2.66	0.95(+11%)
Mean	2.05	3.05	1.02	2.08	2.93	0.93
Kufri Lauvkar						
T_1	1.90	2.63	0.99	1.81	2.78	0.89
T_2	2.10 (+11%)	2.88	1.03	1.97 (+9%)	2.88	0.89
T_3	1.90	3.08 (+17%)	1.05	1.77	3.06 (+10%)	0.89
T_4	1.92	2.66	1.04 (+5%)	1.78	2.73	0.94 (+6%)
Mean	1.95	2.81	1.03	1.83	2.86	0.90
Desiree						
T_1	1.97	2.66	1.02	1.86	2.59	1.01
T_2	2.16 (+10%)	2.89	1.06	2.11 (+13%)	2.80	0.97
T_3	1.98	3.00(+13%)	1.08	1.89	2.93(+13%)	1.03
T_4	1.99	2.65	1.08 (+6%)	1.86	2.59	1.05 (+4%)
Mean	2.02	2.80	1.06	1.93	2.73	1.02
Mean values of treatments						
T_1	1.92	2.72	0.97	1.85	2.70	0.95
T_2	2.11 (+10%)	2.96	1.01	2.06 (+11%)	2.90	0.95
T_3	1.92	3.20 (+18%)	1.03	1.93	3.14 (+16%)	0.97
T_4	1.93	2.72	1.01 (+4%)	1.81	2.66	1.00 (+5%)
CD at 5%						
Cultivar (C)	0.070	0.102	0.037	0.057	0.093	0.035
Treatment (T)	0.051	0.077	0.027	0.044	0.073	0.025
C × T	NS	NS	NS	0.088	0.146	NS

*Treatments: T_1 = -Control (well watered), T_2 = water stress at tuber initiation, T_3 = water stress at tuber enlargement and T_4 = water stress at tuber maturation stage

**Growth stages: TI = Tuber initiation, TE =Tuber enlargement and TM = Tuber maturation

***Figures in parenthesis are percent (%) change in total chlorophyll content of leaf due to water stress treatment T_2, T_3 and T_4 as compared with respective control

Discussion

Chlorophyll concentration in leaves is an indicator of potato tuber yield in water-shortage conditions (Jianhui Li *et al.,* 2017). This is because increased photosynthesis has been linked to increased chlorophyll content in plants (Chowdhury and Kohri, 2003). As a result, chlorophyll content is a measurement of physiological activities in plants. Water stress influences the synthesis of chlorophyll and can cause structural change in chlorophyll (Poljakoff Mayber, 1981). Several workers found reduction in chlorophyll-a, chlorophyll-b and total chlorophyll contents under water stress conditions (Lingling *et al.*, 2004), but in present study chlorophyll-a, chlorophyll-b and total chlorophyll content was found to be higher in comparison with per gram fresh weight of control. Rolando *et al.*, (2015) also found increase in chlorophyll a and b concentration (greenness) following water stress. Higher chlorophyll content in stressed samples is not due to

synthesis of more chlorophyll *per se*, it may be either due to inclusion of more leaf area of water stressed potato leaves per gram fresh weight than control plants or due to tolerance of water stress by keeping higher chlorophyll concentration owing to dehydration. It is considered as main component of 'stay green' trait particularly during post stress period. Maximum chlorophyll content (Chlorophyll 'a', chlorophyll 'b' and total chlorophyll) was found in cultivar Kufri Pukhraj table 1, 2, 3. Increase in chlorophyll content helps the plants to cope with changes in water status of plants for some extent. In and independent study, Kumar and Minhas (2013) evaluated about forty potato varieties /genotypes under drought and reported that water stress induced enhancement in foliage damage was moderate in Kufri Pukhraj (10%) and highest in Kufri Chipsona-1 (25%). It indicates that retention of higher level of chlorophyll pigments in Kufri Pukhraj is associated with overall better tolerance to abiotic stresses in this variety. Michelozzi *et al.,* (1995) also found increase in chlorophyll content in eucalyptus under water stress conditions. Mescht *et al.,* (1999) reported that chlorophyll content of drought tolerant potato cultivars was greater than non-tolerant cultivars. Varietal variations in photosynthetic pigments under stress may be exploited for achieving higher yield thresholds in potato improvement programmes.

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