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BIOCHEMICAL RESPONSE OF POTATO TO VARIOUS LEVELS OF SOIL MOISTURE TENSION

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Abstract

Effects of soil moisture tension on yield and biochemical composition of potato tubers cv. Cardinal were investigated. Under moisture tension of 60 and 80% AWR, normal tuber initiation was affected and yield declined. Individual weight of tubers, increased under stressed conditions. Increase in water stress appeared to promote foliar concentration of chlorophyll-b associated with increase in specific gravity of the tubers. The reducing sugar content, however, behaved irregularly. There was decline in protein content, and rise in Total Glycoalkaloids (TGA) of the tubers. TGA under 80% AWR irrigation was found to cross the permissible limit deteriorating the quality of the tubers.

Introduction

Potato crop faces recurrent threats of moisture deficit in many parts of Pakistan. The usual response of the plant is manifested by the appearance of deformed tubers and reduced yield. Varied biochemical behaviour of different plants under stressed conditions has been reviewed by Hsiao (1973). The biochemical response of potato under moisture stress is described.

Material and Methods

Seed potatoes cv. Cardinal obtained from Ayub Agriculture Research Institute, Faisalabad, were used. Plants were grown in autumn, 1978 at the Experimental Station of Botany Department, University of Karachi. Standard practices were followed for cultivation and duplicate plots of 6 rows each were maintained for various treatments.

(i) *Soil analysis:* Five soil samples collected from each plot at 15 cm rhizosphere depth were oven dried, passed through 2 mm sieve. Soil was subjected to 0.33 and 15 atms pressure using the pressure membrane apparatus and field capacity (FC) and permanent wilting percentage (PWP) was determined as described by Richards (1947). Available water range (AWR) was calculated by subtracting the value of PWP from FC.

(ii) *Moisture control:* Gypsum blocks were installed at three levels at 15 cm interval to monitor soil moisture level of various depths. Prior to installation, they were calibrated by gravimetric determinations of soil moisture contents of the samples in which

the blocks were embedded. The calibration curve was prepared for standardizing the readings of galvanometer with respect of AWR. Blocks of almost equal sensitivity were sorted out and used for field installations.

Following stress treatments were given and irrigation schedule was worked out accordingly:-

Plants 4 week old were subjected to 60 and 80% AWR cycles. The plots were irrigated when the soil moisture content reduced by 60 and 80% of the available water range (AWR). Control was kept in which moisture contents of the plots were kept at 25% AWR.

Irrigation schedule of various treatments is given in Fig. 1.

(iii) *Climatic diversity:* Dew-fall during the growing seasons was recorded using a Hiltner type dew balance, installed at 10 cm above ground. Meteorological data (Table. 1) were obtained through the courtesy of Pak. Met. Dept., Air Port, Karachi.

(iv) *Potato grading and biochemical analysis:* Potato tubers harvested in mid growth period and at maturity were graded in the following manner:

First harvest		Second harvest	
A:	< 10g	A & B:	< 25 g
B:	10.1 – 25 g	C:	25.1 – 50 g
C:	25.1 – 50 g	D:	50.1 – 100g
D:	> 50g	E:	> 100g

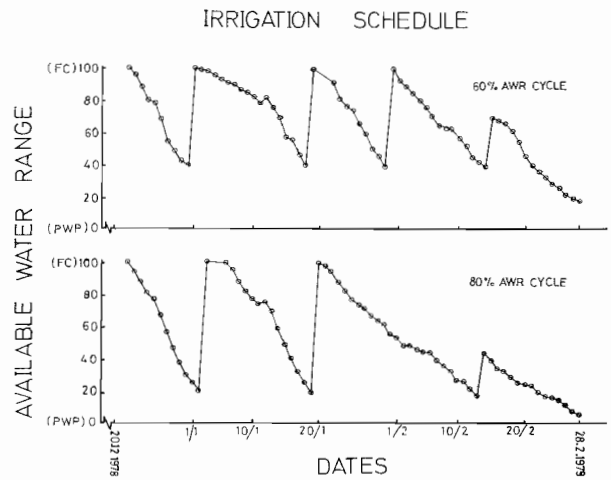

Fig. 1. Schedule adopted to irrigate potato (cv. cardinal) plants subjected to soil moisture tention of 60 and 60% AWR cycle.*, Rainfall (mm).

Table 1. Meterological data or the Experimental fields (Autumn, 78-79). 24° 54'N: 67° 08'E, Altitude 22 meter above sea level.

Months	Temperature C° Min.	Max.	Rainfall mm	Relative Humidity	Dew fall mm	Remarks
Oct. '78	14.1	27.2	—	a 81 b 74 c 41	3.91	sowing 20 Oct. 1978.
Nov. '78	14.2	29.0	5.7	a 69 b 65 c 37	5.33	sprouting & growth.
Dec. '78	16.3	23.0	—	a 62 b 56 c 31	5.21	Commencement of AWR cycle (20.12. 1978).
Jan. '79	16.9	27.0	1.7	a 67 b 66 c 33	6.60	I harvest.
Feb. '79	14.9	26.0	96.0	a 79 b 74 c 42.	11.95	Termination of AWR cycle & II harvest.
Mar. '79	23.0	28.0	—	a 81 b 77 c 50	4.25	

a, 5 a.m.; b, 8 a.m.,; c, 5 p.m.

Foliar chlorophyll content was determined after second earthing using the method of Maclachlam & Zalik (1963). Fresh wt. of tubers and shoot were also recorded along with number of tubers per plant. The final produce was analysed for water content, specific gravity (Manzer *et al,* 1965), reducing sugars (Nelson, 1944), total proteins (Frydman, 1963; Lowry *et al.*, 1951) and total glycoalkaloids (Baker *et al.*, 1955).

Results and Discussion

Soil moisture at a depth of 30 cm with time lapse (Fig. 1) is apparently influenced by variations in environment, therefore, number of days required to complete an irrigation cycle varied. Meterological data (Table 1) was useful in understanding these variations. The greater amount of dew fall during February appears to prolong the third irrigation period of 80% AWR cycle.

Tuber as well as the shoot biomass of early harvest decreased significantly in 80% AWR cycle. The tuber/shoot biomass ratio of 1.99 in control plants reduced down to 1.83 in 60% AWR irrigation cycle whereas this ratio further reduced to 1.63 in 80% AWR irrigation cycle (Table 2). The number of tubers/plant as compared to that in control also declined in stressed plants. It is apparent that increased moisture tension impedes the normal tuber initiation in this cultivar. At harvest, the yield of potato was severely affected by moisture since the plants subjected to 60% AWR irrigation cycle suffered

a 45.64% loss in tuber yield and those under 80% AWR cycle could produce only 33.60% of the control (Table 2). The number of tubers/plant reduced to almost half in stressed plants.

In the early harvest (Table 2) there was a greater proportion of grade A tubers in the control (68.75%) and 60% AWR irrigation cycle (33.33%) whereas in 80% AWR cycle grade B tubers were more (44.44%). Grade D tubers were only present in the produce of 60% AWR cycle. At harvest, tubers of grade A and B predominated the produce in control (47.06%) followed by grade C tubers (35.29%). Among the tubers of 60% AWR cycle major proportion was dominated by grade D tubers (44.44%) followed by tubers of A and B category (33.33%). In 80% AWR cycle half of the total number of tubers was represented by Grade C tubers and the rest was equally apportioned between A, B and D category. Tubers having more than 100g individual weight were only present in control plants, the quantum of which did not exceed the value of 5.88%. It appears that an increase in soil moisture tension after certain level does not facilitate normal tuber initiation and lesser number of developing tuber under stress conditions get more photosynthates per tuber increasing the weight of the individual tuber.

The foliar chlorophyll a/b ratio decreased progressively with the increase in the magnitude of soil moisture tension (Table 3). This is presumably due to increased concentration of chlorophyll-b under stress conditions.

Table 2. Effect of water stress on tuberization in potato cv. Cardinal.

First Harvest

Treatment	Shoot wt. (g)	Tubers wt. (g)	Tuber/ foliage ratio.	No. of tubers per plant	Tuber grading (ratio)			
					A	B	C	D
Control	136.45	271.10	1.99	16	11 (68.75)*	3 (18.75)	2 (12.50)	—
60% AWR	162.00	297.00	1.83	9	3 (33.33)	2 (22.22)	2 (22.22)	2 (22.22)
80% AWR	144.20	185.00	1.62	9	2 (22.22)	4 (44.44)	3 (33.33)	—

Final Harvest

Treatment	Tuber yield per plant (g)	Total No. of tubers/plant	Tuber grading (ratio)			
			A & B	C	D	E
Control	524.37	17	8 (47.06)*	6 (35.29)	2 (11.76)	1 (5.88)
60% AWR	284.97	9	3 (33.33)	2 (22.22)	4 (44.44)	—
80% AWR	176.20	8	2 (25.00)	4 (50.00)	2 (25.00)	—

* percentage of total number of tubers.

Table. 3 Foliar cholorophyll contents of potato cv. Cardinal as affected by soil moisture tension.

Treatment	Chlorophyll a	Chlorophyll b	Chlorophyll a/b ratio
Control	0.515	0.152	3.388
60% AWR	0.536	0.230	2.330
80% AWR	0.535	0.249	2.148

Increase in water stress seemed to promote specific gravity of tuber associated with decreased water content (Table 4). The level of reducing sugars rose to almost double under 60% AWR cycle which is in agreement with Hsiao (1973). A decline in the same parameter was discernible under the influence of 80% AWR cycle. A concomitant decrease in the level of proteins was noticed with increasing soil moisture stress. The total glycoalkaloid (TGA) level increased progressively with moisture tension and reached to 29.00 mg/100g f. wt. of tuber in 80% AWR irrigation cycle. It appears that the splitting of macromolecules under stress conditions (Hsiao, 1973) may provide organic acids which may act as substrate to glycoalkaloid synthesis. Several authors (Khan & Low, 1954; Gull & Isenberg, 1960; Baerug, 1962; Sinden & Webb, 1974) have reported that presence of higher amounts of TGA in potato tubers (>20 mg/100g f. wt.) was responsible for the undesirable taste, colour and degradation of quality. Symptoms of abdominal cramps, diarrhoea, headache, rapid pulse, sudden weakness, vomiting, fever and abortion are developed during potato poisoning (Willimot, 1933). In rare instances, deaths have resulted from ingestion of potatoes having greater TGA contents, particularly in farm animals (Harborne, 1973). Increase in TGA level beyond permissibel limit under high moisture tension, obviously deteriorated the quality of potato tubers.

Comparing these findings with the response of cultivar Calimero to soil moisture stress (Ahmad *et al.*, 1977), it appears that Cv. Cardinal showed a high water requirement. Under 75% AWR cycle, the yield of Cv. Calimero was reduced only by 18.44%

Table 4. Effect of water stess on biochemical composition of tubers of potato cv. Cardinal.

Treatment	Spacific gravity	Water contents %	Reducing sugars % dry wt.	Total protein % dry wt.	(TGA) mg/100g fresh wt.
Control	1.069	79.24	3.95	4.26	13.48
60% AWR	1.079	78.99	6.76	4.11	17.20
80% AWR	1.106	75.73	3.17	3.85	29.00

whereas Cv. Cardinal suffered a reduction of 45.65% under 60% AWR irrigation cycle. Whereas sugars, proteins and TGA did not exhibit any marked changes in response to moisture stress in Cv. Calimero, a strong influence of soil moisture tension on all these parameters was observed in our study with Cv. Cardinal.

References

Ahmad, R., Z. Abdullah, P. Akhtar and A. Azim. 1977. *Glycoalkaloid content of Pakistan Potatoes.* 2nd Ann. Res. Report. Dept. of Botany, University of Karachi, Pakistan.

Baerug, R. 1962. Influence of different rates and intensities of light on solanine content and cooking quality of potato tubers. *European potato Journ.*, 5: 242–251.

Baker, L.C., L.H. Lampitt and O.B. Meredith. 1955. Solanine glycoside of the potato III. An improved method of extraction and determination. *J. Sc. Food and Agric.*, 6: 197–202.

Frydman, R.B. 1963. Starch synthtase of potato and waxy maize. *Arch. Biochem. Biophys.*, **102:** 242–248.

Gull, D.D. and F.M. Isenberg. 1960. Chlorophyll and solanine content and distribution in four varieties of potato tubers. *Amer. Soc. Hort. Sci. Proc.*, 75: 545–556.

Harborne, J.B. 1973. *Phytochemical Methods. A guide to modern techniques of plant analysis. Chapman and Hall, London, pp. 278.*

Hsiao, T.C. 1973. Plant response to water stress. *Ann. Rev. Plant Physiol.*, 24: 519–570.

Kuhn, R. and I. Low. 1954. Die knostitution des solanins. *Agnew. Chem.*, 66: 639–640.

Lowry, O.H., N.J. Rosebrough, Al. Farr and R.J. Randall. 1951. Protein measurement with Folin phenol reagent. *J. Biol. Chem.*, 193: 265–275.

Maclachlam, S. and S. Zelik. 1963. Plastid structure, chlorophyll concentration and free aminoacid composition of chlorophyll mutant of barley. *Can. J. Bot.*, 41: 247–251.

Manzer, F.E., R.C. Cetas, R.E. Partyka, S.S. Leach and D. Merriam. 1965. Influence of late blight and foliar fungicides on yield and specific gravity of potatoes. *Amer. Potato. J.*, 42: 247–251.

Nelson, N. 1944. Photometric adaptation of Somogyi's method of determination of glucose. *J. Biol. Chem.*, 153: 375–380.

Sinden, S.L. and R.E. Webb. 1974. Effect of environment on glycoalkaloid content of six potato varieties at 39 locations. Tech. Bull., 1472, *Agric. Res. Ser. USDA:* 1–28.

Richards, L.A. 1947. Pressure-membrane apparatus, construction and use. *Agr. Engin.*, 28: 451–454.

Willimot, S.G. 1933. An investigation of solanine poisoning. *Analyst.*, 58: 431–438.

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