BRIEF COMMUNICATION

Effect of gibberellic acid on stomatal diffusive resistance and photosynthesis in waterlogged peanut plants

N.R. BISHNOI and H.N. KRISHNAMOORTHY

Department of Botany, Haryana Agricultural University, Hisar 125004, India

Abstract

Plants of peanut (*Arachis hypogaea* L.) were subjected to 7-d and 14-d waterlogging and sprayed with 10 and 100 mg l^{-1} of gibberellic acid (GA_3). Waterlogging decreased the leaf area (A), net photosynthetic rate (P_N), chlorophyll content (Chl) and temporarily the leaf water potential (ψ_w) and increased stomatal diffusive resistance (r_s) of both leaf surfaces. Application of GA_3 increased A and P_N and significantly decreased the r_s of both leaf surfaces but did not affect ψ_w or Chl. Thus GA_3 partially alleviated the effects of waterlogging on A, r_s and P_N.

Waterlogging of soil is reported to cause inhibition of photosynthesis in several species of plants (Regehr *et al.* 1975, Wample and Thornton 1984). Inhibition of net photosynthetic rate (P_N) was ascribed to reduction in the leaf area owing to abscission of leaves and reduction in growth (Kozlowski 1984), decrease in leaf water potential (ψ_w) with a subsequent increase in stomatal diffusive resistance (r_s) (Kramer 1969), stomatal closure due to abscisic acid accumulation and cytokinin depletion (Bradford 1983b), reduction in photosynthetic enzymes, particularly ribulose bisphosphate carboxylase (Bradford 1983a), and inhibition of photosynthate transport from source to sink as a result of reduced strength of carbohydrate sinks (Wample and Thornton 1984).

Waterlogging of soil decreases also gibberellin content in plants (Reid and Crozier 1971). Increased carbon assimilation following gibberellic acid (GA_3). application is probably mediated by an increased rate of cyclic and non-cyclic photophosphorylation (Yakushina and Pushkina 1975), enhanced RuBP carboxylase

---

Received 14 November 1991, *accepted* 17 March 1992.

Abbreviations used: A - leaf area; Chl - chlorophyll ($a + b$) content; GA_3 - gibberellic acid; P_N - net photosynthetic rate; r_s - stomatal diffusive resistance; ψ_w - leaf water potential.

activity and increased chlorophyll content (Chl) in the leaves (Treharne and Stoddart 1968, Briant 1974). In addition, promotion of stomatal opening by GA_3 (Livne and Vaadia 1965, Goswami and Jai Dayal 1987) may increase the P_N. Because of these considerations the present study was conducted to investigate the effect of GA_3 on r_s and P_N of waterlogged peanut plants.

Plants of peanut (*Arachis hypogaea* L. cv. MH-2) were grown in polyethylene bags containing 5 kg acid-washed river sand. Proper drainage was ensured by a small hole at the bottom covered with a wad of glass wool. These were supplied with 100 cm^3 of nitrogen-free nutrient solution (Wilson and Reisenauer 1963) in alternate weeks till the end of the experiment. The plants were divided into three lots. While one lot remained at approximate field capacity, the other two were subjected to 7 and 14 d of waterlogging, respectively. Flooding was imposed to 36-d plants which had just started flowering, by dipping the polyethylene bags in plastic buckets with water so that of constant water level about 2 cm above the sand surface was maintained. After the stress was relieved, the plants were sprayed with water (control) and with 10 and 100 mg l^{-1} of aqueus solution of GA_3. Subsequently all the plants were maintained at approximate field capacity till the end of experiment. Five plants from each treatment were sampled twice, in late-flowering and pod filling stages *i.e.* 50 and 80-d after sowing, respectively. The same plants were used for other determinations. Five such determinations were carried out from each treatment.

The leaf area of each plant was determined by portable leaf area meter (*LI-3050A, Lambda Instrument Corporation*, Lincoln, USA).

P_N of the shoot was measured by enclosing the plant in a perspex chamber of known volume and of suitable size as described by Luthra *et al.* (1983). The depletion of CO_2 from the chamber was monitored with IRGA (*ADC-225-MK$_3$ Analytical Development Co.*, Hoddesdon, England). The experiment was conducted under a photosynthetic photon flux density of 1172 ± 61 and 1027 ± 30 μmol m^{-2} s^{-1}, and 39 ± 2 and 36 ± 2 °C, at the flowering and pod-filling stages, respectively.

All other parameters were measured on the 4th fully expanded leaf from the apex: r_s of the abaxial and adaxial surfaces with a porometer (*Model LI 60, Lambda Instrument Corporation*, Lincoln, USA) between 09.00 and 10.00 (local time), ψ_w with a pressure chamber (*Model 3005, Soil Moisture Equipment Corporation*, Santa Barbara, USA) and Chl content according Arnon (1949).

Waterlogging significantly reduced A, while application of GA_3 increased it (Table 1). Moreover GA_3 partially alleviated the inhibitory effect of flooding increased with the concentration of GA_3. The duration of waterlogging and concentration of GA_3 had a reciprocal effect on A.

P_N also decreased both with the age of the plant and with flooding. On the other hand, application of GA_3 significantly increased the P_N and relieved partially the deleterious effects of waterlogging only at pod filling but not at flowering stage. The total Chl content of the leaf decreased with the age of plants. Flooding also had a similar effect but GA_3 was not effective (Table 1).

Flooding of soil increased r_s of both leaf surfaces indicating stomatal closure. GA_3 significantly decreased r_s (increased stomatal aperture) of both leaf sides on all sampling dates and partially relieved the effect of flooding. In contrast, ψ_w became more negative by waterlogging on all sampling dates. However, the decrease was slower after 14 d of flooding as compared with 7 d. Application of both concentrations of GA_3 did not affect ψ_w (Table 1).

Table 1. Effect of waterlogging (0, 7 and 14 d) and GA_3 application on leaf area, net photosynthetic rate, chlorophyll content, stomatal diffusive resistance and leaf water potential in peanut at flowering and pod filling stage.

GA_3	Flowering			Pod filling		
[mg l^{-1}]	0 d	7 d	14 d	0 d	7 d	14 d
Leaf area [m^2 $plant^{-1}$]						
0	0.023	0.019	0.015	0.046	0.030	0.019
10	0.024	0.020	0.018	0.055	0.033	0.022
100	0.027	0.021	0.020	0.053	0.035	0.027
C.D. at 5%		0.002			0.001	
Net photosynthetic rate [mg (CO_2) m^{-2} s^{-1}]						
0	0.458	0.439	0.361	0.278	0.258	0.256
10	0.467	0.442	0.383	0.314	0.303	0.278
100	0.464	0.439	0.372	0.308	0.272	0.267
C.D. at 5%		0.014			0.011	
Chlorophyll [mg g^{-1}(fresh mass)]						
0	7.25	5.12	3.96	6.19	5.09	3.87
10	7.27	5.15	3.96	6.22	4.92	3.72
100	7.24	5.09	3.91	5.72	4.32	3.34
C.D. at 5%		0.24			0.17	
Adaxial leaf diffusive resistance [s m^{-1}]						
0	0.059	0.071	0.082	0.074	0.082	0.094
10	0.058	0.068	0.073	0.060	0.076	0.087
100	0.046	0.061	0.068	0.045	0.073	0.082
C.D. at 5%		0.003			0.004	
Abaxial leaf diffusive resistance [s m^{-1}]						
0	0.025	0.031	0.039	0.024	0.038	0.059
10	0.018	0.030	0.031	0.022	0.038	0.053
100	0.017	0.025	0.031	0.020	0.031	0.051
C.D. at 5%		0.003			0.002	
Leaf water potential [MPa]						
0	-0.64	-0.88	-0.62	-0.84	-0.92	-0.85
10	-0.68	-0.92	-0.80	-0.88	-1.02	-0.98
100	-0.65	-0.87	-0.76	-0.86	-0.96	-0.95
C.D. at 5%		0.08			0.07	

Waterlogging decreased P_N of peanut plants. Similar effects of flooding have been reported earlier in other plants as well (Regehr *et al.* 1975, Bradford 1983a, Kozlowski 1984). Such a reduction may reflect a decrease in CO_2 uptake as a consequence of stomatal closure (Table 1). Stomatal closure in response to flooding is generally attributed to increased root resistance as a consequence of low soil oxygen levels (Kramer 1969). This resistance reduces replenishment of transpired water, decreases ψ_w and eventually leads to stomatal closure (Elfying *et al.* 1972). It was so with peanut where increased r_s was associated with decreased ψ_w, stomata on the adaxial surface being more sensitive than that on the abaxial surface. Similar differential sensitivity of the stomata on both leaf surfaces to water stress has been reported earlier (Kanemasu and Tanner 1969). However, stomatal closure due to flooding need not always be accompanied by decrease in ψ_w (Sojka and Stolzy 1980, Bradford and Hsiao 1982). In addition, decreased regeneration of RuBP carboxylase (Bradford 1983a) and feedback inhibition as a consequence of poor sink availability (Wample and Thornton 1984) may also account for decreased P_N under flooded conditions.

Both synthesis and upward transport of giberellins from roots are inhibited following flooding of soil (Reid and Crozier 1971) which may be an additional factor contributing to decreased P_N. The spray of GA_3 increased P_N and decreased r_s due to promotion of stomatal opening (Livne and Vaadia 1965, Goswami and Jai Dayal 1987). Additional stimulation of P_N could have resulted from an increase rates of cyclic and noncyclic photophosphorylation, from enhanced RuBP carboxylase activity and from increased Chl content as was mentioned above. Thus, the application of GA_3 partially alleviated the effect of flooding on r_s and P_N. However, the possibility of the hormone acting on the partial processes of photosynthesis cannot be ruled out.

References

Arnon, D.I.: Copper enzymes in isolated chloroplast polyphenoloxidase in *Beta vulgaris*. - Plant Physiol. **24**: 1-5, 1949.

Bradford, K.J.: Effect of soil flooding on leaf gas exchange of tomato plants. - Plant Physiol. **73**: 475-479, 1983a.

Bradford, K.J.: Involvement of plant growth substances in the alteration of leaf gas exchange of flooded tomato plants. - Plant Physiol. **73**: 480-483, 1983b.

Bradford, K.J., Hsiao, T.C.: Stomatal behaviour and water relations of waterlogged tomato plants. - Plant Physiol. **70**: 1508-1513, 1982.

Briant, R.E.: An analysis of the effects of GA on tomato leaf growth. - J. exp. Bot. **25**: 764-769, 1974.

Elfying, D.C., Kaufmann, M.R., Hall, A.E.: Interpreting leaf water potential measurements with a model of the soil-plant-atmosphere continuum. - Physiol. Plant. **27**: 161-168, 1972.

Goswami, C.L., Jai Dayal: Effects of BA and GA_3 on stomatal resistance of maize leaf under waterlogging. - Indian J. Plant Physiol. **30**: 317-319, 1987.

Kanemasu, E.T., Tanner, C.B.: Stomatal diffusion resistance of snap beans. I. Influence of leaf water potential. - Plant Physiol. **44**: 1547-1552, 1969.

Kozlowski, T.T.: Plant response to flooding of soil. - BioScience **34**: 162-167, 1984.

Kramer, P.J.: Plant and Soil Water Relationships. A Modern Synthesis. - McGraw Hill, New York 1969.

Livne, A., Vaadia, Y.: Stimulation of transpiration rate in barley leaves by kinetin and gibberellic acid. - Physiol. Plant. **18**: 658-663, 1965.

Luthra, Y.P., Sheoran, I.S., Singh, R.: Ontogenetic interaction between photosynthesis and symbiotic nitrogen fixation in pigeonpea. - Ann. appl. Biol. **103**: 549-556, 1983.

Regehr, D.L., Bazzaz, F.A., Boggess, W.R.: Photosynthesis, transpiration and leaf conductance of *Populus deltoides* in relation to flooding and drought. - Photosynthetica **9**: 52-61, 1975.
Reid, D.M, Crozier, A.: Effects of waterlogging on the gibberellin content and growth of tomato plants. - J. exp. Bot. **22**: 39-48, 1971.
Sojka, R.E., Stolzy, L.H.: Soil oxygen effects on stomatal response. - Soil Sci. **130**: 350-358, 1980.
Treharne, K.J., Stoddart, J.L.: Effects of gibberellin on photosynthesis in red clover (*Trifolium pratense* L.). - Nature **220**: 457-458, 1968.
Wample, R.L., Thornton, R.K.: Differences in the response of sunflower (*Helianthus annuus*) subjected to flooding and drought stress. - Physiol. Plant. **61**: 611-616, 1984.
Wilson, J.R., Reisenauer, H.M.: Cobalt requirement of symbiotically grown alfalfa. - Plant Soil **18**: 364-373, 1963.
Yakushina, N.L., Pushkina, G.P.: [Changes in the rate of photophosphorylation in corn seedlings under the influence of gibberellin and kinetin.] - Fiziol. Rast. **22**: 994-998, 1975. [In Russ.]

Communicated by J. POSPÍŠILOVÁ