Short Communication

Influence of Antitranspirants on Rapeseed (Brassica campestris) Plants under Water-stressed and Nonstressed Conditions

Received for publication September 5, 1974 and in revised form January 6, 1976

B. B. Patil2 and Rajat De
Division of Agronomy, Indian Agricultural Research Institute, New Delhi-110012, India

ABSTRACT

Daily transpiration rate was decreased by low soil moisture, phenylmercuric acetate (PMA) in combination with kaolinite, Mobileaf (a film-forming wax emulsion manufactured by the Mobil Oil Co.), PMA alone, and kaolinite alone in this order. At high soil moisture, dry matter was decreased by PMA but was increased by Mobileaf and by PMA + kaolinite combination. At low soil moisture, dry matter was increased by Mobileaf.

Water use efficiency was increased at low soil moisture and by antitranspirants. The relative water content of leaves was reduced by low soil moisture but was increased by the antitranspirants which relieved plant water stress.

Transpiration is generally reduced by applying very dilute solutions of chemicals that close stomates or by emulsions of wax or latex to form a thin film cover over the stomates or by reflective materials which when applied to upper surface of leaves reflect back a portion of the incident radiation. Since stomates are common portals of entry of CO₂ and exit of water vapor, it is likely that stomata-closing chemicals may affect photosynthesis adversely while reducing transpiration. It has however been shown that a stomata-closing-type antitranspirant, PMA, reduced transpiration more than photosynthesis under laboratory (22) and greenhouse conditions (17) and in whole plants growing out doors (15). Increase in dry weight with little or no reduction in photosynthesis is possible with film-forming antitranspirants under specific environmental conditions (6, 9).

A reflectant coating of kaolinite was found to decrease leaf temperature by reducing the energy input on leaves and to reduce transpiration more than photosynthesis at high radiation levels in species which are light-saturated at low light intensities (1).

It has been noted that while reducing transpiration, the stomata-closing antitranspirants cause increase in leaf temperature from 1 to 4 C in grass (3), cotton (16), and soybeans (14).

Shimshi (16) reported that PMA reduced transpiration more than photosynthesis in potted maize plants at both low and high soil moisture conditions. Transpiration was reduced by 26% and 11% at high and low soil moisture, respectively; while photosynthesis was reduced by 11% at high moisture but was increased by 3% at a low soil moisture regime. The influence of stomata-closing and film-forming antitranspirants in increasing sorghum grain yield under field conditions was more pronounced with limited irrigation than with full irrigation (8). A film-forming antitranspirant was found to be more effective in increasing the photosynthesis under adverse environmental conditions than under favorable conditions (10). The relative influence of a reflective antitranspirant at high and low soil moisture is not yet clearly known.

A pot-culture experiment was conducted to study the effect of different types of antitranspirants on the transpiration rate, dry matter production, WUE, and RWC of rapeseed (Brassica campestris) plants grown at low and high moisture conditions in the greenhouse. The experiment was terminated before the seed maturity stage.

MATERIALS AND METHODS

Plastic pots were filled with 1.5 kg of air-dry silt loam soil sieved to 2 mm. Seed of ‘Pusa Kalyani’ variety of rapeseed (Brassica campestris var. brown sarson) was planted at 1 cm depth on January 10, 1974. Two plants/pot were maintained.

For the nonstressed treatment, moisture level was maintained from field capacity to 25% of available soil moisture depletion, and for stressed plants moisture level was kept from field capacity to 75% available moisture depletion. Plants were grown at high moisture level until antitranspirant treatments were applied on March 1, 1974, after which high and low moisture levels were maintained by weighing the pot-soil-plant system at least twice a day and by adding water. A split-plot design with soil moisture levels as main-plot treatments and antitranspirants as subplot treatments with five replications was used.

To reduce loss of water by evaporation from soil, a uniform volume of liquid paraffin was added on the soil surface, protecting the stem from contact with hot liquid. A hole was provided in the paraffin layer to allow addition of water.

On March 1, 1974, antitranspirant treatments were applied as follows: (a) no antitranspirant (control); (b) PMA (0.3 mm); (c) PMA (0.3 mm) plus 6% kaolinite suspension; (d) 6% kaolinite (60 g/l); (e) Mobileaf4 to water 1:8 (v/v).

A 0.2% emulsion of Teepol B-300 (a surfactant) was used with each antitranspirant spray. PMA and Mobileaf were applied on both sides of the leaves. The number of stomates on the upper surface was relatively lower than that on the lower surface of leaf. Kaolinite was applied only on the upper surface of leaves.

Transpiration was measured daily by pot weighings over a 21-

1 This paper is a part of a Ph.D. thesis submitted by B.B.P. to the Indian Agricultural Research Institute, New Delhi, in 1974.
2 Present address: Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra State, 413722, India.
3 Abbreviations: PMA: phenylmercuric acetate; WUE: water use efficiency; RWC: relative water content.
4 A film-forming wax emulsion manufactured by the Mobil Oil Co. and supplied by Mobil Research and Development Corp., Research Department, Paulsboro Laboratory, Paulsboro, N. J. 08066 (U.S.A.).
day period. RWC of leaves was measured by the method suggested by Weatherly (20) and modified by Barrs and Weatherly (2) using 1.5 cm diameter leaf discs excluding midribs. The RWC was determined on March 10, 1974 at 900 and 1500 hr.

At the end of the 21-day period, plants were harvested and oven-dried at 70 C in a vacuum oven for 48 hr to determine dry matter production. WUE was estimated by the ratio of dry matter produced to total water transpired during this 21-day period.

RESULTS AND DISCUSSION

Transpiration. Soil moisture levels and antitranspirants significantly influenced the daily transpiration rate (Fig. 1). Daily transpiration rate of rapeseed plants was decreased by nearly 25% at low soil moisture than at high soil moisture.

PMA-kaolinite combination showed maximum reduction in the mean daily transpiration. PMA alone and Mobileaf treatments decreased transpiration rate over no antitranspirant check, but the differences in the transpiration rates between these two antitranspirant treatments were not significant. Kaolinite alone was less effective in decreasing transpiration, but when used in combination with PMA its effectiveness was increased. Reduction in transpiration by PMA is caused by narrowing stomatal aperture and thereby increasing stomatal resistance to water vapor diffusion (22), whereas reduction in transpiration by kaolinite is reported to be due to increase in the reflectivity of incident radiation especially in the visible region (1). Both these processes decrease the steepness of vapor pressure gradient between the inside and outside of the leaf. Since the number of stomates on the lower surface of leaves is more in rapeseed plants, kaolinite alone did not reduce the transpiration as much as when used with PMA. Kaolinite reduced the heat load on the foliage, while PMA increased the stomatal resistance. Kaolinite and PMA when used in combination thus showed maximum reduction in transpiration.

Dry Matter Production. The difference between dry matter production at high and low soil moisture was not statistically significant (Table 1). Antitranspirant treatments affected the dry matter production significantly. Plants treated with Mobileaf and PMA + kaolinite produced more dry matter than the untreated check. Dry matter production was decreased by PMA under high soil moisture but not under low soil moisture conditions.

Partial covering of leaf with Mobileaf presumably resulted in a favorable plant water balance (6) and increase in the rate of photosynthesis due to reduced mesophyll resistance (19). PMA decreased dry matter production due to phytotoxicity, but PMA in combination with kaolinite increased dry matter production possibly due to counteractive effects on leaf temperature and to improved water balance in the plant.

Increased dry matter production by antitranspirant application might also be attributed to the increased water potential in pods which developed during the period of measurement. Pods of rapeseed plants have been recognized to significantly contribute to growth by their photosynthetic activity (12).

Water Use Efficiency. WUE was higher at low soil moisture than at high soil moisture (18). The highest WUE resulted when PMA was used in combination with kaolinite at both levels of soil moisture. Increased WUE by Mobileaf and PMA in combination with kaolinite, compared to untreated plants, is attributed to both increase in dry matter production and decrease in water use. The increased WUE by PMA alone and by kaolinite alone was due only to reduction in transpiration. Increased WUE by stomata closing PMA (3, 17, 22), by film-forming materials (10, 11) and by reflective kaolinite (1) has been reported by several investigators.

Relative Leaf Water Content. The RWC values for leaves (Table 1) were lower at 1500 hr than at 0900 hr, indicating high evaporative demand of the atmosphere and relatively low root ability to absorb water from the soil. The lag in the rate of absorption of water by roots compared to the rate of transpiration might be attributed to restricted root growth in small sized pots.

The RWC at low soil moisture was lower by about 5 units than at high soil moisture at 0900 hr indicating greater resistance to water flow at soil-root interface or decreased hydraulic conductivity of soil at low soil moisture content.

The RWC was highest for Mobileaf at both times of the day. PMA in combination with kaolinite was better than PMA alone in improving plant water status under hot dry conditions at 1500 hr specially under low soil moisture level. PMA alone could have retarded stomatal closure naturally induced by low soil moisture (5). The effective reduction in transpiration by Mobileaf and PMA + kaolinite resulted in improved water status of plant and in increased RWC of rapeseed leaves by nearly 6 to 8%. The RWC values for Mobileaf might have been underestimated (4), particularly for low soil moisture level and at 1500 hr.

According to the criterion of Hsiao (13) leaves of untreated plants in our experiment showed moderate water stress, RWC less than 90, even at 0900 hr; while leaves of antitranspirant treated plants did not develop water stress by this time of the day. Plants at high soil moisture exhibited moderate water stress at 1500 hr, while Mobileaf-treated leaves did not develop water stress condition at this time. Leaves of untreated plants at low soil moisture experienced severe water stress at 1500 hr, RWC less than 80, while the leaves of treated plants developed only moderate water stress. Thus, antitranspirants, in general, were effective in improving plant water status and releasing water stress under unfavorable soil moisture and atmospheric conditions.

Results of this experiment indicate that the transpiration rate of potted plants of rapeseed is reduced by stomata-closing antitranspirant PMA, film-forming Mobileaf, and reflective kaolinite at low soil moisture as well as at high soil moisture conditions. The dry matter production of plants was adversely affected at low soil moisture, was unaffected by PMA alone or kaolinite alone, but was improved by Mobileaf and PMA in combination with kaolinite. The increase in dry matter production has been ascribed to improved water potential of antitranspirant-treated plants as indicated by increased RWC of leaves both at low and high soil moistures.
ANTITRANSPIRANTS AND WATER STRESS

Table 1. Effect of Soil Moisture Regimes and Antitranspirants on Dry Matter Production, Water Use Efficiency, and Relative Leaf Water Content of Rapeseed Plants

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean Transpiration</th>
<th>Dry Matter Production</th>
<th>Water Use Efficiency</th>
<th>Relative Leaf Water Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( g/pot )</td>
<td>( g/pot )</td>
<td>( g/g \times 10^4 )</td>
<td>900 hr</td>
</tr>
<tr>
<td>Soil moisture regimes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>2084</td>
<td>8.5</td>
<td>40.8</td>
<td>87.8</td>
</tr>
<tr>
<td>High</td>
<td>2760</td>
<td>9.4</td>
<td>34.0</td>
<td>93.2</td>
</tr>
<tr>
<td></td>
<td>30.2(^1)</td>
<td>0.07(^1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antitranspirants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>3234</td>
<td>8.7</td>
<td>26.9</td>
<td>84.8</td>
</tr>
<tr>
<td>PMA</td>
<td>2192</td>
<td>8.1</td>
<td>36.9</td>
<td>91.3</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>2598</td>
<td>8.8</td>
<td>33.9</td>
<td>89.4</td>
</tr>
<tr>
<td>PMA + Kaolinite</td>
<td>1818</td>
<td>9.2</td>
<td>51.2</td>
<td>91.3</td>
</tr>
<tr>
<td>Mobileaf</td>
<td>2272</td>
<td>10.0</td>
<td>32.0</td>
<td>93.2</td>
</tr>
<tr>
<td></td>
<td>38.2(^1)</td>
<td>0.14(^1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) S.E. ±.

The antitranspirants were more effective in reducing transpiration during the period of about 2 weeks and this effect was almost negligible at the end of 3 weeks. The effectiveness of Mobileaf lasted longer than PMA, while kaolinite was effective for only 2 weeks. The use of PMA as antitranspirant was only for experimental purposes and it cannot be suggested for field application because of its mercury content. More work needs to be done on the use of kaolinite before it is considered as an antitranspirant under field conditions. Mobileaf has been shown to be an effective antitranspirant for horticultural and transplanted plants under field condition (7).

Acknowledgments. The authors acknowledge gratefully the supply of antitranspirant chemicals by R. H. Cole, Pennsylvania State University. We are also indebted to A. B. Joshi, Director, I.A.R.I., New Delhi for his keen interest and encouragement in this study. The help of S. Ray in setting up the experimental technique is acknowledged.

LITERATURE CITED