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PHYSIOLOGICAL RESPONSE OF COTTON TO METHANOL FOLIAR APPLICATION

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Abstract: A study was conducted at Central Cotton Research Institute, Multan during crop season 1995 to determine the effects of foliar applications of methanol on physiological processes, water relations, growth and yield on cotton cultivar CIM-240. The treatments consisted of untreated check, 30% methanol, 30% methanol plus 2% urea and 30% methanol + 2% urea + 2.5 litre per hectare foliar fertilizer (Omex Foliar 3x Emulsion). Four foliar applications of solutions were made during bloom stage. The results showed that foliar application of methanol, and/or of urea/foliar fertilizer had positive effect on physiological processes, water relations, plant structure and seed cotton yield. The foliar application of 30% methanol caused significant increase in seed cotton yield by about 9% over untreated check. These data suggest that methanol has potential to improve productivity of cotton crop under our arid and semi-arid environment.

Keywords: Arid and semi-arid environments, bloom stage, cotton, methanol foliar, physiological response.

INTRODUCTION

Environment has a pronounced effect upon growth and development of plants. Important among the environmental factors are light and temperature. Heat stress has been recognized as the main environmental limitation to cotton production in Pakistan. Excessive temperatures (42-44^{o}C day temperatures and 28-31^{o}C night temperatures) cause heavy shedding of young flower buds and bolls. It is only after mid-August that effective period of boll setting starts in cotton. Irrespective of planting dates and cotton cultivars, about two-third of total boll load is set during the month of September [Taha *et al.* 1981, Malik 1991, Malik *et al.* 1999]. Increase in cotton productivity potential is possible by lengthening effective boll period or adoption of management practices to offset the harsh temperatures prevailing during early reproductive development stage to retain fruit for sustained cotton production.

Foliar applications of methanol have been reported to increase the yields of a variety of irrigated crops under arid conditions [Nonomura *et al.* 1992]. Cotton (*Gossypium hirsutm* L.) dry matter production was reportedly increased by 50% as a result of methanol applications, while treated leaves had increased surface area, thickness and turgidity. Foliar methanol applications also resulted in 2-week earlier maturity and increased water use efficiency. Foliar application of methanol is recommended to farmers for crop production in USA [Arizona Department of Agriculture 1993]. It has been reported that foliar application of methanol caused increase in seed cotton yield in the U.S. Cotton Belt [Mauney and Gerik 1994]. The effect of methanol and other long-chain alcohol have been reported on other crop plants [Rowe *et al.* 1994]. A small increase in leaf and stem mass of tomato as a result of methanol foliar application has been reported [Rowe *et al.* 1994]. However, in other study no positive effect on dry matter and water use of tomato and melon was observed [Hartz *et al.* 1994]. Foliar applications did not result in faster development of the cotton crop in the southeastern USA [Van Iersel *et al.* 1995]. Although alcohols can influence the physiology of plants, there have no research work done on the effect of alcohol on the physiology of field crops under arid and semi-arid conditions of Pakistan. Therefore, the objectives of the present study were to evaluate the physiological response of cotton to methanol foliar application under field conditions.

MATERIALS AND METHODS

A field experiment was conducted on cotton cultivar CIM-240 (*Gossypium hirsutum* L.) during (crop seasons) 1995-96 at Central Cotton Research Institute, Multan. Cotton planting was carried out in early June on silt loam soil Miani soil series and the planting density was approximately 35000 ha^{-1} in rows 75 cm apart. The crop was irrigated and received 150 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. Standard production practices were followed throughout the growing season. Treatments were replicated four times in a randomized complete block design. The treatments were: (a) unsprayed, (b) methanol 30% (v/v), (c) methanol 30% (v/v) plus urea 2% (w/v) and (d) methanol 30% (v/v) plus urea 2% (w/v) plus foliar fertilizer. The foliar fertilizer contained a solution of 12.7% NO_3, 24% P, 18% K, 1.50% MgO, 0.16% Fe (EDTA), 0.08% Mn (EDTA), 0.08% Cu (EDTA), 0.08% Zn (EDTA), and 0.03% B and other minor nutrients (this solution is sold under the trade name ("Omex Foliar 3x Emulsion"). Both the foliar and methanol treatments were applied in a total of 150 litres spray solution per hectare. These treatments were applied on July 18th, August 2nd, August 17th and August 31st between 10:00 am to 12:00 noons during bright sunny days with hot temperature. The treatments were planned to coincide with First Square, and fortnightly after First Square for a total of 4 applications. All solutions contained surfactant "Tween 80" at 1% (v/v) to improve adhesion. Data on air temperatures, relative humidity, solar radiation and cumulative heat units are shown in Table 1. Crop was sprayed with knapsack sprayer using two nozzles per row and operated at 4 km per hour using 275 KPa pressure to deliver 150-litre ha^{-1}. Plot size in each replication was 8 m wide and 15 m long.

Photosynthesis/transpiration rates/leaf temperatures, stomatal conductance, leaf water potential, osmotic potential and leaf area measurements were made with ADC-LCA4 photosynthesis system (Analytical Development Company, England), Automatic Porometer-MK3 (Delta-T Devices, England), Pressure Chamber Technique, 5500 Vapor Pressure Osmometer (Wescor Inc; USA) and Automatic Area Meter System respectively. Transpiration rates were determined three times, 2 hours after the third methanol application. The other measurements were taken 1 day after each application around mid-day.

Dry matter yield and plant structure measurements were made by harvesting five random plants from each treatment. Plant were brought to laboratory and partitioned into leaves, stalks and fruit. The biological material was dried in a forced air oven to a constant weight at approximately 70 ^{o}C. Seed cotton was hand picked two times in each plot and total yield calculated for each of factors measured on area basis. Data on number of bolls per plant, boll weight, and lint percentage were recorded on 15 random plants at maturity. Data were analyzed according to the prescribed methods [Gomez and Gomez 1984].

RESULTS AND DISCUSSION

Seed cotton yield, number of bolls per plant and boll weight differed significantly due to foliar application of methanol (Table 1). Seed cotton yield of 2187 kg ha^{-1} was obtained in crop sprayed with methanol only showing an increase of about 9 percent over unsprayed plot. However, lint percentage was little affected. The most likely beneficial effect of the methanol spray on seed cotton yield and its components is on the nutritional status of the crop. This could come about through enhanced foliar uptake of mineral nutrients from the solution and thereby changes in nutritional status of leaves or by enhanced root activity engendered by the methanol spray. Methanol could serve as an efficient carrier of the nutrients into the leaves [Mauney and Gerik 1994]. Furthermore, it has been reported that effects of the methanol spray was an enhancement of the turgor potential due to increase in sugar contents in the leaves and utilization of the methanol as a carbon source (much as carbon dioxide is used) and suppression of photorespiration [Benson and Nonomura 1992]. Thus increase in turgor potential enhances water use efficiency and enables longer times between irrigation for irrigated crops. These results are in agreement with the other scientists [Nonomura and Benson 1992]. Beneficial effects of methanol spray on cotton yield have been reported [Arizona Deprtament of Agriculture 1993, Mauney and gerik 1994]. These results differ from early studies, which reported little effect of foliar applications of methanol on cotton in the southeastern USA [Malik *et al.* 1999]. The present studies were conducted under arid environment (temperatures of upto 41.5 ^{o}C combined with low humidity). Drought can induce ethylene synthesis in cotton and cause fruit and leaf abscission [Jordan *et al.* 1972, Guinn 1976]. Methanol has been shown to inhibit ethylene-induced ripening of tomato disks [Saltveit 1989]. Methanol and other longer-chain alcohols promote senescence in the light [Thimann *et al.* 1977].

The dry matter yield and plant structure are useful tools in understanding crop production potential in a given environment and to evaluate treatment effects. These are approximate expression of net photosynthesis over a season. Data presented in Table 2 indicate that dry matter yield per unit land area and plant height increased due to methanol foliar application. Increase in main stem node numbers was mainly responsible for plant height. These data suggest that foliar application of methanol and/or with urea/micronutrients resulted in stimulation of growth processes and this ended up in large plant structure and more dry matter yield. Increase in plant height with the application of methanol has been reported [Barnes and Houghton 1994].

Table 1: Seed cotton yield and its components as influenced by foliar application of methanol

Treatments	Seed cotton yield (kgha $^{-1}$)	Number of bolls per plant	Boll weight (g)	Lint (%)
Unsprayed	2016 a	18 a	3.11 a	36.7 a
Methanol	2187 b	20 b	3.44 b	36.7 a
Methanol + Urea	2192 b	20 b	3.44 b	36.7 a
Methanol + Urea + Foliar Fertilizer	2198 b	20 b	3.45 b	36.7 a

Means followed by the same letter do not differ significantly at 5 % probability level.

Table 2: Dry matter yield and plant structure as influenced by foliar application of methanol

Treatments	Dry matter yield (g m^{-2})	Main stem height (cm)	Main stem node number	Internodal length (cm)
Unsprayed	610 a	102.8 a	30 a	3.43 a
Methanol	644 b	118.3 b	33 b	3.58 b
Methanol + Urea	644 b	119.1 b	33 b	3.61 b
Methanol + Urea + Foliar Fertilizer	648 b	120.8 b	33 b	3.66 b

Means followed by the same letter do not differ significantly at 5 % probability level.

The foliar application of methanol alone and/or urea plus foliar fertilizer did not produce any significant effect on quality of fibre (Table 3). The reason being that genetic and environmental factors apparently exert so much influence on quality of fibre that little effect from methanol spray could be elucidated. These results agree with other researchers who observed non-significant differences in fibre characteristics due to foliar application of methanol [Barnes and Houghton 1994, Mauney and Gerik 1994].

Table 3: Fibre characteristics as influenced by foliar application of methanol

Treatments	Fibre length (mm)	Fineness (ug g^{-1})	Uniformity ratio (%)	Fibre strength (000 lbs inch^{-2})
Unsprayed	26.1	4.8	46.4	95.9
Methanol	26.2	4.8	46.4	95.9
Methanol + Urea	26.2	4.8	46.4	95.9
Methanol + Urea + Foliar Fertilizer	26.2	4.8	46.5	96.1

Means followed by the same letter do not differ significantly at 5 % probability level.

Stomatal conductance, net photosynthesis, transpiration rates and leaf temperature differed statistically significant due to foliar application of methanol (Table 4). Stomatal conductance and net photosynthesis increased with foliar application of methanol compared to untreated check. However transpiration rate and leaf temperature decreased in plots treated with methanol. The higher stomatal conductance resulted in reduced leaf temperature and transpiration rate in methanol treated crop compared to unsprayed one. Furthermore, there is possibility that methanol can simulate growth significantly through its effect as a carbon source [Nonomura and Benson 1992]. These results are in agreement with the previous researchers who observed significant increase in various physiological processes [Benson and Nonomura 1992, Gerik and Faver 1994].

Table 4: Net photosynthesis, stomatal conductance, transpiration rate and leaf temperature as influenced by foliar application of methanol

Treatments	Net Photosynthesis (μmol CO_2 m^{-2} s^{-1})	Stomatal conductance (m mol m^{-2} s^{-1})	Transpiration rate (mmol H_2O m^{-2} s^{-1})	Leaf Temperature (^oC)
Unsprayed	24.3 a	310 a	9.12 b	31.3 b
Methanol	27.6 b	344 b	8.77 a	29.6 a
Methanol + Urea	27.8 b	347 b	8.77 a	29.7 a
Methanol + Urea + Foliar Fertilizer	28.1 b	349 b	8.80 a	29.7 a

Means followed by the same letter do not differ significantly at 5 % probability level.

The leaf water potential and its two components (osmotic potential and turgor pressure) were also found to be affected by methanol application (Table 5). Methanol applications resulted in higher leaf turgidity and leaf area index. Plants that received urea and foliar fertilizer applications maintained almost similar water, osmotic and pressure potentials than the plants that received only methanol foliar spray. The enhancement in the physiological processes resulted in improvement of water use efficiency. Positive response to methanol application in improvement of water use efficiency and water relations has been reported by the previous researchers [Nonomura and Benson 1992, Gerik and Faver 1994]. However, other scientists did not indicate any positive effect of methanol on any growth and development measurements [Husman *et al.* 1994, Mauney and Gerik 1994, Nelson *et al.* 1994, Van Iersel *et al.* 1995].

Table 5: Water potential, osmotic potential and turgor pressure of cotton plants as influenced by foliar application of methanol

Treatments	Leaf water potential (MPa)	Leaf osmotic potential (MPa)	Leaf turgor potential (MPa)	Leaf Area Index
Unsprayed	-1.72 b	-2.13 b	0.41 a	3.11 a
Methanol	-1.51 a	-2.07 a	0.56 b	3.59 b
Methanol + Urea	-1.51 a	-2.08 a	0.57 b	3.60 b
Methanol + Urea + Foliar Fertilizer	-1.53 a	-2.10 a	0.57 b	3.63 b

Means followed by the same letter donot differ significantly at 5 % probability level.

In summary, our findings indicate that foliar applications of methanol in combinations with urea and foliar fertilizer have an important influence on the physiology of cotton. Water relations, physiological processes and leaf area index were affected by methanol. The foliar applications increased seed cotton yields, dry matter yield and plant structure. The lint quality was little affected by the foliar applications.

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