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Impact of moisture stress and ameliorants on growth and yield of sunflower

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Abstract: The response of sunflower to the induction of soil moisture stress at different phenlogical stages and the application of amelorants to overcome the stress were evaluated using the variety Co. 4. The results showed that moisture stress at vegetative and flowering stages has more adverse effects. The effects of soil moisture stress can be corrected by the foliar application of potassium dihydrogen phosphate, mepiquat chloride and succinic acid. The occurrence of stress at flowering stage caused an yield reduction of 29% over unstressed control. Foliar application of potassium dihydrogen phosphate could improve the yield marginally by 4.1% over unsprayed control. (*Key words*: *Moisture stress, Ameliorants, Sunflower*).

The occurrence of soil water deficit during the crop growth period depletes the crop yielding potential considerably. Hsiao and Acevedo (1974) reported that the effects of water stress on growth and yield depend both on the degree of stress and on the stage of growth at which stress occurs. The water status of a plant is dynamic, continually changing both with the soil water status and the aerial environment. Even though sunflower crop is by and large adopted to soil moisture stress conditions the depletion of soil moisture below the critical level as well as at critical stages of crop growth adversely affect the growth, biophysical characteristics and finally the yield. The occurrences of soil moisture stress especially during flowering/peak flowering period drastically affect the crop performance and the yield. The sunflower crop plays a significant role since a sizable percent of our oil required is met by the crop due to its lesser cholesterol content. On the other hand the yield potential of crops are very much depleted due to moisture stress. The timing of water stress in relation to crop development has a significant impact on grain maturation and yield (Sadras *et al.* 1993). The occurrence of stress in sunflower for a period of 15 days before and after flowering has been found to be very critical and affect the seed yield considerably by reducing the size and weight of inflorescence. In most of the determinate crops like sunflower, water deficits during or shortly after anthesis are considered important as it affects the seed yield (Begg and Turner, 1976).

The present investigations were carried out to find out the effect of stress coupled with chemical application such as potassium dihydrogen phosphate, mepiquat chloride and succinic acid on the growth and yield of sunflower.

Materials and Methods

The investigations were carried out at Tamil Nadu Agricultural University, Coimbatore during Summer and *kharif*, 2000. The experiment was laid out in a factorial randomized block design with three replications. The experimental plots were formed into ridges and furrows. The normal recommended fertilizer schedule of 40 kg N, 20 kg P_2O_5 and 20 kg K_2O were given as basal and the seeds of Co4 sunflower were sown at 30 cm x 30 cm spacing. Pre-emergence herbicide *viz.* fluchloralin was applied at the rate of 1.0 kg ai ha^{-1} on third day after sowing, and subsequently necessary plant protection measures were followed. The following stress and ameliorant treatments were followed.

Stress Treatment(S)
S_0 - Control (No stress) Irrigation at 40% Available Soil Moisture
S_1 - Stress at vegetative stage
S_2 - Stress at flowering stage
S_3 - Stress at post – flowering stage

The soil moisture stress was created by with holding one irrigation at the respective stages of growth, while for the control, irrigations were given based on the 40% available soil moisture. The duration of stress; otherwise the period between two irrigations varied from one week to 10 days depends upon the evapotranspiration.

Amerliorant Treatment (A)
A_1 - No srpray
A_2 - Potassium dihydrogen phosphate (0.5%)
A_3 - Mepiquat chloride (125ppm)
A_4 - Succinic Acid (1000 ppm)

The growth parameters such as leaf area, total dry matter production, Relative Water Content (Barrs and Weatherley, 1962), transpiration rate and Stomal Diffusive Resistance were, estimated at vegetative, flowering and post flowering stages. The yield parameters such as total number of seeds $head^{-1}$, number of filled seeds $head^{-1}$, 100 – seed weight, seed set percent, grain yield and

Table 1. Effect of chemicals and bioregulators on leaf area and total dry matter production of Co1 sunflower under different water stress conditions.

Parameters	Leaf Area (cm² plant⁻¹)					TDMP (g plant⁻¹)				
Chemicals/ Stress stage	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean
No stress	1216	1247	1182	1238	1220	71.1	71.8	69.7	71.1	70.9
Stress at vegetative	1111	1163	1060	1160	1123	68.6	69.2	68.6	69.1	68.8
Stress at flowering	1104	1129	978	1116	1081	68.0	68.1	67.5	68.1	67.9
Stress at post "	1154	1194	1026	1187	1140	68.2	68.5	67.3	68.4	68.1
Mean	1146	1183	1061	1175	-	68.9	69.4	68.2	69.1	-

CD 5%, Stress : 98,
Ameliorants : 73, Stress X Ameliorants : NS

CD 5%, Stress :2.1
Ameliorants : NS, S X A : NS

Table 2. Effect of chemicals and bioregulators on the Relative Water Content and Transpiration rate of Co 1 sunflower at different moisture stress conditions

Parameters	RWC (%)					Transpiration Rate (ug H^2O cm²S⁻¹)				
Chemicals/ Stress stage	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean
No stress	80.94	83.10	81.65	81.44	81.78	20.5	19.6	19.7	19.8	19.9
Stress at vegetative	71.96	74.82	73.78	73.55	73.52	18.6	18.9	18.1	18.1	18.1
Stress at flowering	74.14	76.55	74.90	75.22	75.20	19.5	18.8	18.8	18.8	18.9
Stress at post "	73.83	75.76	74.77	74.41	74.69	19.5	18.8	19.1	19.1	19.1
Mean	75.21	77.55	76.27	76.15	-	19.7	19.0	19.1	19.2	-

CD 5%, Stress : 3.62
Ameliorants : 0.84, S X A : NS

CD 5%, Stress : 0.64
Ameliorants : NS, S X A : NS

Table 3. Effect of chemicals and bioregulators on stomalal diffusive resistance of sunflower (var Co 1) under different water stress conditions

Parameters	SDR (Scm⁻¹)				
Chemicals/ Stress stage	No spray	KH_2Po_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean
No stress	0.68	0.92	0.85	0.91	0.84
Stress at vegetative	0.92	1.41	1.24	1.27	1.21
Stress at vegetative	1.01	1.31	1.31	1.21	1.21
Stress at post-flowering	1.21	1.36	1.32	1.29	1.29
Mean	0.95	1.25	1.18	1.17	-

CD 5%, Stress : 0.052, Ameliorants : 0.21, S X A : NS

Table 4. Effect of chemicals and bioregulators on total number of filled seeds head[-1] (var Co 1) under different water stress conditions

Parameters	Total no. of seeds/head					Number of filled seeds/head				
Chemicals/ Stress stage	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean
No stress	590	617	611	603	605	504	542	530	525	525
Stress at vegetative	512	534	521	518	521	377	441	403	441	415
Stress atflowering	445	467	452	450	453	277	322	296	292	297
Stress at post "	461	475	461	463	465	290	321	305	295	302
Mean	502	523	511	508	-	362	406	383	388	-

CD 5%, Stress : 15.6
Ameliorants : 18.3, S X A : NS

CD 5%, Stress : 45.8
Ameliorants : 28.4, S X A : NS

Table 5. Effect of chemicals and bioregulators on 100 seed weight and seed set percent (var Co 1) of sunflower under different water stress conditions

Parameters	100 - Seed weight (g)					Seed set percentage				
Chemicals/ Stress stage	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean
No stress	4.41	4.52	4.48	4.49	4.47	85.4	87.7	86.7	87.0	86.7
Stress at vegetative	4.12	4.28	4.26	4.30	4.24	73.6	82.5	77.3	83.1	79.1
Stress at flowering	3.96	4.14	4.06	4.12	4.07	62.3	69.0	65.5	65.1	65.4
Stress at post "	3.92	4.18	4.12	4.14	4.09	63.0	67.6	66.6	64.7	65.3
Mean	4.10	4.28	4.23	4.26	-	71.0	76.7	73.8	74.9	-

CD 5%, Stress : NS
Ameliorants : NS, S X A : NS

CD 5%, Stress : 14.6
Ameliorants : NS, S X A : NS

Table 6. Effect of chemicals and bioregulators on grain yield and WUE of sunflower under different water stress conditions

Parameters	Grain yield (kg ha^{-1})					WUE (kg ha^{-1} cm^{-1})				
Chemicals/ Stress stage	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean	No spray	KH_2PO_4 (0.5%)	Mepiquat chloride (125 ppm)	Succinic acid (1000 ppm)	Mean
No stress	747	768	763	761	760	2.11	2.19	2.18	2.17	2.16
Stress at vegetative	611	651	634	634	632	2.03	2.17	2.17	2.11	2.10
Stress at flowering	527	544	534	533	535	1.75	1.81	1.81	1.77	1.77
Stress at post "	539	561	550	547	549	1.79	1.87	1.87	1.82	1.82
Mean	606	631	620	618	-	1.92	2.01	2.10	1.96	-

CD 5%, Stress : 64.8
Ameliorants : 16.4, S X A : NS

CD 5%, Stress : 0.12
Ameliorants : 0.064

water use efficiency of crop were calculated at the harvest stage for both seasons. The data were pooled and analysed statistically by the method of Panse and Sukhatme (1985).

Results and Discussion

Leaf Area:

A decline in leaf area was noticed with the induction of stress irrespective of growth stages. Imposition of water stress of vegetative and flowering stages recorded lower leaf area of 1123 and 1081 cm^2 $plant^{-1}$ compared to the maximum of 1220 recorded in unstressed control. The reduction in the development of leaf area due to mositure stress might be due to the poor maintenance of cell turgor which is absolutely essential for cell division and cell enlargement. Though the application of ameliorants could increase the leaf of crop, the potassium dihydrogen phosphate at 0.5% level recorded a maximum of 1183 cm^2 $plant^{-1}$, and this amount to a marginal increase of 3.2% over unsprayed control. This increase was caused due to the expansion of surface areas of the epidermal cells of the leaves. (Table 1). The results of Constable and Hearn (1978) reported in soybean strongly support the findings of the present investigation.

Total Dry Matter Production

Induction of soil moisture stress of flowering stage caused a marginal reduction of 3.0g plant (67.9g) as against the control value of 70.9g, however the stress imposed at various stages, could significantly deplete the biomass accumulation. Moreover the reduction in biomass accumulation might have been due to limitation of water which s obligatory to carryout some basic metabolic activities of plants. The application of ameliorative chemicals though could not make significant variation, the foliar spraying of potassium dihydrogen phosphate could enhance the biomass accumulation (69.4g) slightly over unsprayed control (68.9g) (Table 1). This is in conformity with earlier findings of Muchow et al (1986) in soybean.

Relative Water Content

The data (Table 2) indicated that, the occurrence of soil moisture stress at vegetative stage had the lowest value of RWC (73.52%) which has comparable to stress occurred at other stages as well as the control value of 81.78 percent, and the stress could significantly influence the relative water content of leaves. On the contrary, the application of ameliorants increased the RWC of leaves, and among the chemicals, the potassium dihydrogen phosphate could record a maximum of 77.55% compared to the lowest value 75.21% in the unsprayed control. The potassium ion could act as an osmolyte and inducted the plants to retain more water even under stress conditions, and this is strongly supported with the earlier findings of Teare and Kanemasu (1972) in sorghum leaves.

Transpiration rate

The data indicated that the creation of soil moisture stress at the vegetative stage had the lowest rate of 18.1 mg H_2O cm-2 S^{-1} as against the unstressed control value of 19.9 mg H_2O cm^2 S^{-1}. Regarding the effect of ameliorants, no significant difference was observed, however, potassium dihydrogen phosphate could minimize the loss of water to the maximum (19.0) compared to 19.7 mg H_2O cm^2 S^{-1} recorded in the unsprayed control (Table 2), Rawson et al (1978) reported similar trend of results in soybean which strongly support the findings of this experiment.

Stomatal Diffusive Resistance

The imposition of water stress normally lead to the partial closure of stomata as an adaptive mechanism to maintain the tissue water content by maximizing the water loss through transpiration. An increase in the rate of stomatal resistance has a greater effect on transpiration than on photosynthesis, because it constitutes a relatively larger proportion of the total resistance to water diffusion than to CO_2 diffusion. The data (Table 3) indicated that the imposition of water stress increased the stomatal resistance and the values ranged from 1.21 to 1.29 as against 0.84 Scm^{-1} recorded in the unstressed control. The increased stomatal resistance preferably for water vapor might have been caused due to the partial closure of stomata, and it is considered as an advantageous to tide over the water scarcity conditions. Though all the chemicals could increase the resistance of stomata to water stress the potassium application regulates the movement of stomata, in order to maintain higher tissue water potential. Similar pattern of results have been reported by Sionit and Kramer (1976) in sunflower and soybean.

Total number of seeds/head

The size of the sink potential determines the crop yield, and in this context, the total number of seeds/head was reduced by the depletion of soil moisture at all stages of growth, and the reduction was maximum when the moisture stress occurred at flowering stage compared to other stage *viz.* post flowering and vegetative which could record relatively lower number of seeds/head, which was comparable to unstressed control. But the foliar spraying of potassium dihydrogen phosphate could improve the seeds production plant^{-1} compared to unsprayed control and the other two chemicals such as mepiquat chloride and succinic acid recorded more seeds/head (Table 1). This is in support of results reported by Gunton and Evenson (1980) in Navy beans.

Number of filled seeds/head

The number of filled seeds as the sink strength more the number, the yield would be better. The occurrence of soil moisture stress at flowering stage of crop caused a maximum reduction in the filled seeds/plant followed by post flowering and vegetative stages which were comparable to unstressed control. Probably the moisture stress at flowering could have suppressed the fertilization, and the movement of metabolites to the developing seeds at post flowering stage reduced the filling of seeds and hence the poor filling. However, here again supplementing with potassium nutrient through KH_2PO_4 could substantially improve the seed filling (12% more) over unsprayed control. Since potassium ion enhances the translocation of photosynthates besides maintaining the tissue water potential (Table 1). The result is strongly supported by the earlier findings of Mahalakshmi et . al. (1988) in Pearlmillet.

Hundred seed weight

The weight of seeds did not attain significant variation both for stress and ameliorative treatments, though both of these treatments could reduce the seed weight, and reduction in seed weight might have been due to poor seed filling under depleted soil moisture condition. The range of seed weight was between 4.07 and 4.47g for stress treatments and between 4.10 and 4.28 g for the ameliorative treatments respectively (Table 2).

Seed set percentage

As a percent ratio of filled seeds to the total number of seeds, the movement of photosynthates from the nearest source to the developing sink determines this factor. More the number of filled seeds, the values will be higher, but in general under depleted plant water potential, most of the metabolic activities will be hampered, and hence the filling of seeds also considerably reduced. The data (Table 2) indicated that the occurrence of moisture stress of flowering and post-flowering recorded a maximum value of 65.4 and 65.3% and the reduction was nearly 21.3% compared to unstressed control. However, the spraying of potassium dihydrogen phosphate improved the seed set percent by 5.6 over unsprayed control, and a similar trend of results have been reported by Dubetz and Mahalle (1969) in bush beans.

Grain yield

The yield is the net result contributed by the integration of quantity of filled seeds and seed weight, almost the above two parameters determined the yield potential. The reduction in soil moisture inturn affect the tissue water potential and in this regard, the depletion of soil moisture at flowering and post-flowering or the early seed filling stage recorded a minimum of 535 and 549 kg ha^{-1} respectively, followed by a slight improvement recorded at the vegetative stage (632 kg ha^{-1}) as against the control yield of 760 kg ha^{-1}. The stress occurred at flowering stage caused an yield reduction of 29.6% compared to control. However, supplementing with foliar application of chemicals such as potassium dihydrogen phosphate (631 kg), mepiquat chloride (620 kg) and succinic acid (618 kg) recorded an yield increase of 2.0 to 4.1 over than 606 kg ha^{-1} recorded in unsprayed control.. The results of this experiment has strongly been supported by the earlier findings of Choudhary and Kumar (1980) in dwarf wheat.

Water use Efficiency (WUE)

As an index of crop potential for the effective utilization of water absorbed/applied ie, the economic yield per unit of water consumed, the water stress occurred at flowering stage recorded a lowest value followed by post flowering and vegetative stages compared to control. The WUE of the crop could be improved by the foliar application of potassium dihydrogen phosphate followed by, mepiqut chloride and succinic acid as against the lowest efficiency recorded in the unsprayed control. (Table 3). The reduction in the efficiency of water use both under stress as well as unsprayed situations was mainly due to poor economic yield recorded in both conditions due to reduced filling of seeds coupled with lower seed weight and poor seed setting percentage. The earlier findings of Stanhill (1986) strongly supports the results obtained in this experiment. Nevertheless, both yield and efficiency of water use by the crop can be improved considerably by the application of chemical containing potassium nutrient, which helps the plant not only to maintain the tissue water potential, apart the photosynthates get translocated to the developing sink from the nearest source even under water stress conditions the crop performance in terms of yield can be juxtapositioned comfortably.

The results of the present investigations emphasized the need for the application of potassium dihydrogen phosphate for maintaining high tissue water content, by partial closure of stomata under soil moisture stress condition and for better growth and yield.

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