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Effect of Water Stress on Morpho-physiological Parameters of Coriander (*Coriandrum sativum* L.)

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Abstract: Twelve coriander accessions having released varieties, advance breeding material, regional and exotic collections were evaluated for effect of water stress on morpho-physiological and seed quality parameters. All accessions showed variability in ratio of fresh weight to dry weight, shoot length to root length, shoot weight to root weight, plant water relation parameters, total oil and essential oil. Water stress applied at flowering stage and terminal growth stage affected these parameters significantly in all accessions. There is high variability among accessions for their response to water stress which can be exploited for development of varieties for limited water conditions.

Key words: *Coriandrum sativum*, coriander, morpho-physiological, total oil, essential oil, water stress.

Limited water supply is a major environmental constraint for higher productivity of crop plants including coriander (*Coriandrum sativum* L.). Moisture deficiency influences various physiological and metabolic processes and the response of plant to water stress depends on duration, magnitude of stress, developmental and differentiation stage of the plant/tissue (Kramer and Boyer, 1995). Genotypic variability has also been reported in various plants in relation to drought responses and this variability can be exploited for development of drought tolerant varieties.

In India, the major coriander growing area lies under semi-arid climate of Rajasthan and Gujarat, where the crop is cultivated on conserved moisture during rabi season requiring two to three irrigations depending upon soil conditions and rainfall. Hence, the available water has to be used very judiciously so that maximum yield can be harvested without affecting the quality of seeds in terms of seed size, test weight and essential oil content (Saxena *et al.*, 2010). The present investigation was undertaken to evaluate the genotypic variation in response to water stress and its effect on morpho-physiological parameters and seed quality parameters of coriander. Results of this investigation will also help growers to decide time of irrigation when water availability is limited.

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Materials and Methods

Twelve coriander accessions comprising of released varieties, advance breeding material, regional and exotic collections were evaluated at National Research Centre on Seed Spices, Ajmer, for effect of water stress on morpho-physiological parameters including ratio of fresh weight to dry weight, shoot weight to root weight and shoot length to root length, plant water potential, osmotic potential, turgor potential, total oil and essential oil. All 12 accessions were sown with three replications in a randomized block design. The data were analyzed for genotypic variation using randomized block design (Panse and Sukhatme, 1967). Three irrigation schedules namely, irrigated, water stress at flowering stage and water stress at terminal growth stage were created. Under irrigated schedule, irrigation was given after establishment of seedlings (30 days after sowing), at pre flowering stage and at ripening stage. In mid-term water stress schedule irrigation at flowering stage was not given. In terminal water stress irrigation at ripening stage was not applied. Except irrigation all other agronomic practices, including pest and disease management, were followed uniformly up to harvest in all three schedules. Plant water potential was determined by soil moisture analysis system (Plant Water Status Console, Soil Moisture Equipment Corporation, USA) as described by Scholander *et al.* (1965). Three samples were taken per treatment.

Table 1. Effect of water stress on growth parameters during water stress at flowering stage

Accessions	Fresh weight/dry weight		Shoot weight/root weight		Shoot length/root length		Seed yield (g plant^{-1})	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
LCC-91	5.033	3.844	9.869	12.78	3.240	4.500	7.675	5.645
LCC-101	4.962	6.038	12.287	13.28	2.699	5.222	5.462	5.963
ACr-91	9.548	4.155	13.058	11.85	2.742	3.321	8.610	7.586
RCr-435	7.148	4.955	11.931	15.17	2.931	4.571	8.202	8.453
RCr-436	7.566	5.406	12.730	13.38	2.091	3.000	7.330	10.421
ACr-1	7.429	7.770	10.847	6.873	2.881	3.011	5.706	7.437
RCr-41	7.32	5.252	11.83	10.36	2.89	2.567	6.998	6.526
Australia	6.487	8.379	16.493	16.11	2.852	2.968	14.927	10.276
Sadhana	8.028	7.044	13.361	9.570	3.084	2.549	2.832	6.484
ND/Cor-60	4.826	7.204	16.219	13.06	4.125	3.224	1.307	5.328
YS/RC-66	4.900	10.834	11.943	14.96	3.653	2.831	3.184	6.399
Sudha	5.341	4.659	12.906	13.74	3.288	2.567	2.004	4.620
Swati	4.356	3.429	8.280	8.69	3.224	2.187	2.808	4.783
Mean	6.302	8.151	12.494	9.35	3.136	3.194	5.927	6.142
CD 0.05	2.196	5.449	4.746	7.96	0.791	0.901	5.778	5.762
CV %	20.580	39.671	22.435	50.54	14.897	16.733	57.850	55.672

Leaves from the same twig were placed in a disposable syringe and put in deep freezer at -4°C. On next day the syringes were put at room temperature for thawing of frozen leaves. After thawing one drop of cell sap was extracted by pressing the piston of syringe and directly placed on chamber of Vapor Pressure Osmometer (Wescor 5500, USA) to measure osmomolality (OSM kg^{-1}). A devisor (400) was used to compute osmotic potential in MPa. Turgor potential was calculated by subtracting osmotic potential from water potential (Lange *et al.*, 1976)

Total oil was extracted using Accelerated Solvent Extraction System (Dionex India Pvt. Ltd.). The Accelerated Solvent Extraction System accelerates the traditional extraction process by using solvent at elevated temperatures and pressures. Pressure is maintained in the sample cell to maintain the heated solvent in a liquid state during the extraction. After heating, the extract is rinsed from the sample cell into a collection vessel. Total oil was obtained after evaporating the solvent in rotary evaporator. Thirty gram seeds of each accession obtained from different irrigation schedules were utilized for the estimation of essential oil using all glass Clevenger apparatus (Clevenger, 1928).

Results and Discussion

All recorded parameters showed significant genotypic variation. Water stress at flowering stage had adverse effect on most of the studied parameters, while terminal water stress exhibited reduction in most of the accessions. The ratio of shoot length to root length was found important as the genotypes showing higher yield maintained more shoot length to root length ratio under both midterm and terminal water stress conditions. Genotypes RCr-436 (10.421 g plant^{-1}) and Australia (10.276 g plant^{-1}) showed significantly higher yield than average (6.142 g plant^{-1}) under midterm water stress. More fresh weight to dry weight ratio resulted in higher yield in most of the accessions except Sadhana, Swati and Sudha, which are genetically short structured genotypes from south India. No clear effect of shoot weight to root weight ratio was observed on seed yield under midterm water stress. Among all accessions Sadhana, ND/Cor-60 Sudha, YS/RC-66 and Swati showed higher yield under terminal water stress (Table 2). Theses accessions were found to maintain fresh weight to dry weight ratio at par with control. Accession Australia gave significantly higher (8.031 g plant^{-1}) than average seed yield (5.289 g plant^{-1}) under terminal stress conditions and also showed more fresh weight to dry weight

Table 2. Effect of water stress on growth parameters during terminal water stress

Accessions	Fresh weight/dry weight		Shoot weight/root weight		Shoot length/root length		Seed yield (g plant^{-1})	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
LCC-91	5.123	4.246	10.464	28.858	3.995	6.167	7.675	3.082
LCC-101	5.228	4.571	12.870	11.213	3.859	5.274	5.462	6.198
ACr-91	4.970	8.382	10.320	18.948	3.663	5.682	8.610	6.336
RCr-435	10.352	7.826	10.320	17.275	3.609	4.999	8.202	5.893
RCr-436	8.215	6.125	15.077	15.781	3.557	4.281	7.330	6.606
ACr-1	8.768	2.772	7.671	11.687	3.371	7.217	5.706	6.163
RCr-41	8.869	3.379	7.096	24.000	3.001	5.917	6.998	6.523
Australia	4.621	5.656	16.207	21.893	5.865	6.813	14.927	8.031
Sadhana	4.439	4.488	10.252	19.516	4.693	7.076	2.832	4.683
ND/Cor-60	4.616	4.271	15.401	12.758	3.780	5.254	1.307	3.664
YS/RC-66	5.339	3.825	8.191	19.324	3.947	7.061	3.184	5.292
Sudha	4.390	5.979	12.686	17.739	3.147	3.649	2.004	4.450
Swati	4.583	3.972	11.981	18.016	2.569	5.162	2.808	3.065
Mean	3.136	6.116	6.116	18.231	3.774	5.735	5.927	5.289
CD 0.05	0.791	4.840	4.840	9.814	1.103	2.631	5.778	2.674
CV %	14.897	46.956	46.956	31.944	17.339	27.227	57.850	29.864

ratio. At the same time these accessions were maintaining higher shoot weight to root weight ratio. This indicated that these accessions were able to extract the moisture from deep soil by increasing the root length thus maintaining good shoot biomass.

Table 3 showed the effect of water stress on plant water potential, osmotic potential and turgor potential at flowering stage. In most of the accessions water potential was more under control except LCC-91 and Sadhana, while osmotic potential was more under stress in ACr-1, ACr-91, RCr-41, RCr-435, Sadhana, ND/Cor-60, Sudha and Swati accessions. All the accessions maintained positive turgor under stress condition. Accessions Australia, RCr-436,

Table 3. Effect of water stress on plant water relation parameter during flowering stage

Accessions	WP (MPa)		OP (MPa)		TP (MPa)	
	Control	Stress	Control	Stress	Control	Stress
LCC-91	0.767	0.667	1.179	1.359	0.413	0.693
LCC-101	0.633	0.633	1.404	1.599	0.771	0.966
ACr-91	0.633	0.667	1.488	1.265	0.854	0.598
RCr-435	0.533	0.633	1.641	1.447	1.108	0.813
RCr-436	0.333	0.433	1.358	1.493	1.025	1.059
ACr-1	0.333	0.467	1.470	1.183	1.137	0.716
RCr-41	0.433	0.667	1.223	1.198	0.790	0.531
Australia	0.567	0.633	1.458	1.689	0.891	1.056
Sadhana	0.567	0.433	1.582	1.376	1.015	0.943
ND/Cor-60	0.533	0.733	1.625	1.063	1.092	0.330
YS/RC-66	0.433	0.533	1.590	1.603	1.157	1.069
Sudha	0.333	0.767	1.780	1.343	1.447	0.577
Swati	0.333	0.667	1.797	1.653	1.463	0.987
Mean	0.495	0.610	1.507	1.405	1.012	0.795
CD 0.05	0.093	0.101	0.156	0.287	0.187	0.316
CV %	11.209	9.818	6.146	12.109	10.986	23.577

LCC-101 and YS/RC-66 were able to maintain more turgor pressure under stress conditions. Water relations changed dramatically when plants were exposed to water or salinity stress. Lower water potential under stress conditions is an established plant response to water stress. (Greenway and Munns, 1980). However increase in water potential on account of stress may be attributed to the response of a tolerant type. The decrease in osmotic potential on account of ware stress is a well documented response of glycophytes and helophytes (Greenway and Munns, 1980; Morgan, 1984; Munns, 1990; Kumar, 1991). This is accepted because plants accumulate ions against concentration gradient and the lowering of osmotic potential than that of water potential under stress situation leads to maintenance of a positive turgor through osmotic adjustment (Levitt, 1980). The situation regarding turgor potential is also in conformity with earlier inferences. The turgor potential was invariably positive. This may be attributed to a favorable water balance (Morgan, 1984).

Effect of water stress at flowering and terminal growth stage on total and essential oil content (%) of 12 coriander accessions have been analyzed by Saxena *et al.* (2010). Under non-stress condition essential oil content ranged from 0.01% (YS/RC-66) to 0.51% (LCC-101) exhibiting high genotypic variation. Total oil content varied from a minimum of 9.25% in YS/RC-66 to a maximum of 16.59% in ACr-91. Some accessions viz. Australia, Sindhu and YS/RC-66, however, showed significant increase over control in essential oil content.

In the situation of terminal water stress essential oil content in some accessions like ACr-1, Australia, ND/COR-60, RCr-41, Sindhu and YS/RC-66 showed significant increase over control, while accessions ACr-91, LCC-101, LCC-91, RCr-435 and RCr-436 exhibited slight decrease in essential oil content. Total oil content from most of the accessions was reduced as compared to non-stress as well as midterm stress condition.

It is very well known that genetic constitution and environmental conditions influence the yield and composition of volatile oil produced by medicinal plants (Ramezani *et al.,* 2009). Drought stress increases the essential oil percentage in medicinal and aromatic plants, because in case of stress, more metabolites are produced in plants. Farahani *et al.* (2008) revealed that drought stress had significant effect on oil yield and oil percentage of calendula. Their results showed that highest oil yield was achieved under non-drought condition and oil percentage was highest under drought condition. Aliabadi *et al.* (2008) reported that water stress had significant effect on flowering shoot yield, essential oil yield of flowering shoot and essential oil percentage of flowering shoot of coriander. Drought stress reduced essential oil content of most medicinal and aromatic plants and increased essential oil percentage under drought conditions (Aliabadi *et al.,* 2008).

In this study we observed significant genotypic variation on morpho-physiological parameters in response to water stress. A significant interaction effect of accessions and different stress conditions revealed that genotypes could be identified for a particular environment. Midterm water stress had no adverse effect on most of the parameters in many accessions, however, terminal water stress reduced the studied parameters in most of the accessions. It may be suggested that in the situation of limited water midterm irrigation can be avoided and water must be applied at terminal growth stage.

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