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Drought response of biotic-stress tolerant accessions of black pepper (*Piper nigrum* L.)

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Abstract

Tandem selected 20 superior accessions of black pepper having better yield and biotic stress tolerance were evaluated for drought response along with drought tolerant black pepper variety, Panniyur-5 under controlled condition. Physiological responses of accessions were evaluated under 5 and 10 days of drought induction. Accessions did not differ for physiological parameters under field capacity without stress. All the physiological parameters except leaf temperature got reduced continuously at fifth and tenth days of drought induction. More than 50 per cent reduction was observed for mean value for photosynthesis, stomatal conductance, chlorophyll content and chlorophyll stability index after 10 days of drought induction. The accessions IC 598869 and IC 598890 ranked better than the drought tolerant variety P5, can be tested further for yield and other attributes to release as a variety.

Keywords: Abiotic stress, Black pepper, Drought stress, Stress physiology, Stress tolerance

Introduction

Black pepper (*Piper nigrum* L), often hailed as the 'King of Spices' or 'Black Gold', is unequivocally the most important spice crop in the world (Purseglove et al., 1981). It is also an important medicinal plant having widespread applications in the traditional Indian medicine system. As a species of evergreen forests it is susceptible to moisture deficit, throughout its growth period (Athar and Ashraf, 2005). Black pepper is highly sensitive to drought resulting in significant loss in yield (Alagupalamuthirsolai et al 2023)

The Indian Institute of Spices Research (ICAR - IISR), Calicut, Kerala, is devoted to research on spices. They maintain a germplasm conservatory of 1075 wild, 1282 accessions and 9 exotic species and 1375 hybrids of black pepper. (www.spices.res.in). This can be a rich source of many novel traits including biotic and abiotic stress. However, there has been limited success with drought tolerant genotypes of black pepper. George et al. (2017), observed success rate of 2 per cent when they screened 1000 germplasm accessions. This study aimed to find variation in drought response among the high yielding and biotic stress tolerant black pepper accessions of Kerala.

Materials and methods

Fifty accessions of black pepper maintained at IISR Calicut were morphologically evaluated for yield, field tolerance to foot rot and pollu beetle (Prakash et al., 2019, 2020). Twenty tandem selected accessions having field tolerance score of 1 for foot rot, >= 3 for pollu beetle and dry yield of more than 400g /vine were used for the study (Prakash et al, 2019, 2020) (Table1). The standard drought tolerant black pepper variety, Panniyur-5 (P5) (Thankamani

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Table 1. Yield and score for foot rot infection and pollu beetle Infestation in the tested black pepper accessions

Sl. No.	IC. No.	Score for foot rot nfection	Score for pollu beetle infestation	Dry berry yield (g)
1	598866	1	3	2740
2	598869	1	1	2500
3	598872	1	1	3320
4	598874	1	3	8200
5	598875	1	1	8200
6	598880	1	1	2650
7	598883	1	1	14000
8	598890	1	1	3900
9	598891	1	1	820
10	598893	1	3	8600
11	598899	1	1	1000
12	598902	1	3	4150
13	598903	1	1	2190
14	598904	1	3	5000
15	598906	1	1	3720
16	598920	1	1	450
17	598929	1	1	2350
18	598930	1	3	2500
19	598933	1	3	700
20	598936	1	1	1350

and Ashokan 2004) was used as the check variety.

Six-month-old rooted cuttings of the accessions were raised in cement pots of 0.3 m diameter with a volume of 12.69 M^3containing 10 kg potting mixture with soil, FYM and sand in 3:1:1 ratio. Each pot was planted with three rooted cuttings and three such pots constituted a replication. All the plants were maintained under field capacity (37.5% moisture content) in a nethouse. The study was conducted from September to December 2018 at Vellanikkara (AUZ Malayoram) and stress induction and observations were taken in November and plants were maintained until December. For the induction of stress, irrigation was withheld continuously for three weeks after reaching field capacity. The physiological changes in response to moisture stress were studied at field capacity, five days and 10 days after withdrawing irrigation. There was 37.5, 8.69 and 2.71 per cent soil moisture at field capacity, five and 10 days after withholding irrigation, respectively.

All physiological observations were taken on a clear day between 9 am and 10 am IST. Photosynthesis, leaf temperature, transpiration, and stomatal conductance were recorded using LI-6400 Infra-Red Gas Analyser (LICOR Inc, Nebraska) from the third fully matured leaf from the top of each plant. Relative water content (RWC), chlorophyll content, chlorophyll stability index (CSI) and membrane stability index (MSI) were estimated by standard procedures (Krishnamurthy et al., 2000). Accessions were ranked based on physiological response under moisture stress as a modified method of Arunachalam and Bhandhopadhyay (1984) and accessions that were on par for the values were given the same rank.

Results and discussion

Physiological parameters except chlorophyll stability index did not show significant difference among black pepper accessions at field capacity prior to induction of stress treatment (Table 2a and 2b)

Main cause for decreased photosynthesis under mild to moderate water stress is reported to be due to decreased CO_2 diffusion from the atmosphere to the site of carboxylation. (Pinheiro and Chaves 2011). At field capacity mean value of the photosynthesis of the accessions was 3.79 $\mu molCO_2m^{-2}s^{-1}$ which got reduced in all the accessions under stress. Higher rate and less reduction in photosynthesis under stress was showed by accessions IC 598869 and IC 598890 at five and ten days after stress induction followed by the check variety P5. Accessions, IC 598891 and IC 598920, were on par with P5 at five days after stress induction. The rate of reduction in photosynthesis at10 days in stressed condition ranged from 63 per cent (IC 598869) to 86 per cent (IC 598902).

Stomatal closure was mostly controlled by chemical signals such as Abscisic acid (ABA) produced in dehydrating roots and is closely related to soil moisture than leaf water status (Brodribb and Adam,

Table 2a. Physiological observations on black pepper accessions at field capacity and under moisture stress

Accession	Photosynthesis (μmol CO_2 m^{-2} s^{-1})			Stomatal conductance (mmol$m^{-2}s^{-1}$)			Transpiration (mmol H_2O^{-1} $m^{-2}s^{-1}$)			Leaf temperature (°C)		
	FC	5-day stress	10-day stress	FC	5day stress	10-day stress	FC	5-day stress	10-day stress	FC	5day stress	10-day stress
IC 598866	3.82	1.43^{ijk}	0.60^{qr}	0.278	0.038^{mn}	0.026	1.83	1.09^{no}	1.00^{pq}	32.98	34.88	34.58^{b}
IC 598869	3.80	3.00^{a}	1.40^{a}	0.286	0.100^{a}	0.096	1.90	1.78^{a}	1.22^{a}	32.52	33.10	33.24^{d}
IC 598872	3.80	1.57^{hijk}	0.64^{pq}	0.275	0.042^{lm}	0.031	1.84	1.15^{mn}	1.02^{op}	33.35	34.67	34.51^{b}
IC 598874	3.76	2.26^{bcdf}	1.01^{ij}	0.270	0.069^{fg}	0.068	1.89	1.40^{ghij}	1.10^{hi}	32.93	33.79	34.10^{bcd}
IC 598875	3.77	1.97^{defgh}	0.90^{lm}	0.271	0.054^{i}	0.059	1.88	1.33^{jk}	1.07^{jk}	32.96	34.00	34.21^{bcd}
IC 598880	3.75	2.04^{cdefgh}	0.94^{kl}	0.268	0.066^{hi}	0.061	1.88	1.35^{ijk}	1.08^{jk}	32.84	33.94	34.17^{bcd}
IC 598883	3.74	1.27^{jk}	0.55^{rs}	0.281	0.035^{n}	0.025	1.86	1.07^{no}	0.99^{qr}	33.16	34.97	34.65^{b}
IC 598890	3.75	2.98^{a}	1.36^{ab}	0.259	0.099^{ab}	0.092	1.89	1.72^{ab}	1.21^{ab}	32.56	33.20	33.26^{cd}
IC 598891	3.82	2.92^{a}	1.29^{cd}	0.278	0.093^{bc}	0.088	1.87	1.61^{bcd}	1.19^{cd}	32.88	33.31	33.75^{bcd}
IC 598893	3.83	1.88^{efghi}	0.86^{mn}	0.276	0.052^{ij}	0.046	1.87	1.30^{jkl}	1.06^{kl}	33.28	34.13	34.25^{bcd}
IC 598899	3.80	1.67^{hij}	0.67^{p}	0.277	0.044^{kl}	0.032	1.86	1.16^{mn}	1.03^{no}	33.34	34.57	36.10^{a}
IC 598902	3.79	1.16^{k}	0.52^{s}	0.265	0.029^{o}	0.029	1.86	1.00^{o}	0.98^{r}	33.22	34.75	35.07^{b}
IC 598903	3.76	2.21^{bcdefg}	0.96^{jk}	0.269	0.067^{gh}	0.065	1.88	1.38^{hij}	1.09^{ij}	32.82	33.86	34.14^{bcd}
IC 598904	3.81	1.83^{fghi}	0.83^{n}	0.274	0.050^{jk}	0.043	1.87	1.27^{kl}	1.05^{lm}	33.09	34.21	34.29^{bcd}
IC 598906	3.81	2.67^{ab}	1.25^{de}	0.274	0.084^{cd}	0.083	1.88	1.58^{cde}	1.17^{de}	33.08	33.22	33.84^{bcd}
IC 598920	3.81	1.76^{ghi}	0.76^{o}	0.272	0.047^{jkl}	0.036	1.87	1.20^{lm}	1.04^{mn}	32.86	34.32	34.38^{bc}
IC 598929	3.81	2.53^{ab}	1.21^{ef}	0.193	0.028^{de}	0.082	1.85	1.54^{def}	1.16^{ef}	33.39	33.46	33.92^{bcd}
IC 598930	3.80	2.45^{bc}	1.16^{fg}	0.271	0.080^{e}	0.079	1.84	1.50^{efg}	1.15^{f}	32.75	33.59	33.98^{bcd}
IC 598933	3.82	2.40^{bcd}	1.11^{gh}	0.272	0.076^{f}	0.074	1.83	1.47^{fgh}	1.13^{g}	32.89	33.65	34.02^{bcd}
IC 598936	3.77	2.33^{bcde}	1.05^{hi}	0.271	0.073^{f}	0.071	1.89	1.44^{fghi}	1.11^{gh}	33.36	33.72	34.05^{bcd}
P5	3.77	2.94^{a}	1.32^{bc}	0.276	0.094^{b}	0.091	1.88	1.68^{abc}	1.20^{bc}	32.90	33.25	33.29^{cd}
Mean	3.79	2.16	0.97	0.269	0.063	0.054	1.87	1.38	1.10	33.01	33.90	34.16
% change from FC		43.00	74.41		76.58	79.92		26.20	41.18		2.70	3.48
SE	0.03	0.24	0.03	0.04	0.09	0.06	0.02	0.05	0.01	0.42	0.53	0.53
CV%	1.16	1.36	3.61	16.7	6.35	7.63	1.81	4.72	0.91	1.57	1.91	1.91

- FC field capacity

2011). The mean value of stomatal conductance among the accessions at field capacity was 0.269 mmolm^{-2} s^{-1}, while the value under stress was 0.054 mmol $m^{-2}s^{-1}$. There was 76.57 and 79.92 per cent reduction in stomatal conductance at 5th and 10th day of stress, respectively.

Water stress causes a decline in the transpiration rate in many crops. In cashew seedlings, transpiration rate declined from 4.75 ìmol$H_2O^{-1}m^{-2}s^{-1}$ to 2.1175 ìmol$H_2O^{-1}m^{-2}s^{-1}$ when stress was given for five days (Latha, 1998). Drought tolerance in cocoa was mainly attributable to stomatal regulation resulting in reduction in transpiration (Balasimha et al., 1988). The rate of transpiration of the accessions under normal conditions had a mean value of 1.87 mmol$H_2O^{-1}m^{-2}s^{-1}$. It got reduced to 1.38 and 1.10 mmol$H_2O^{-1}m^{-2}s^{-1}$, respectively, at 5 and 10 days after stress induction. Accessions IC 598869, IC 598890 and P5 were having a high transpiration rate and a lower reduction in transpiration under drought stress. Accessions IC 598883, IC 598866 and IC 598872 had higher reduction % in transpiration (47 and 45) and lower rate of transpiration.

A higher canopy air temperature difference indicates the loss of energy by sensible heat than latent heat, indicating increased stress levels of the plant. Leaf temperature is thus a very useful and quick tool for evaluation of assessing stress due to drought and heat in plants and has been exploited for scheduling irrigation (Pramanik et al., 2017). The mean leaf temperature of the accessions was 33.01^{0}C. Under drought stress, the mean leaf temperature increased by 2.7 and 3 per cent at 5 and 10 days of stress

Table 2b. Physiological observations on black pepper accessions at field capacity and under moisture stress

Accession	Chlorophyll Content (μgg^{-1})			Chlorophyll stability (%)			Relative water content(%)			Membrane stability index (%)		
	FC	5-day stress	10-day stress	FC	5day stress	10-day stress	FC	5-day stress	10-day stress	FC	5day stress	10-day stress
IIC 598866	2.80	1.18^{pq}	1.03^{pq}	70.21^{bcd}	44.58^{m}	33.70^{hij}	91.72	81.16^{h}	66.18^{pq}	89.38	84.87^{ij}	76.67^{p}
IC 598869	2.84	1.95^{a}	1.38^{a}	70.59^{abcd}	48.01^{a}	35.66^{a}	91.73	85.33^{a}	78.08^{a}	89.54	85.98^{a}	78.27^{a}
IC 598872	2.82	1.24^{qp}	1.04^{op}	70.47^{abcd}	44.88^{l}	33.94^{ghij}	92.33	81.35^{gh}	66.90^{op}	89.58	84.96^{hij}	76.83^{o}
IC 598874	2.86	1.58^{hi}	1.17^{h}	69.61^{de}	46.33^{gh}	34.94^{abcdef}	90.59	82.99^{bcd}	71.83^{i}	89.47	85.27^{efghi}	77.69^{h}
IC 598875	2.79	1.45^{jk}	1.12^{jk}	71.04^{ab}	45.77^{j}	33.36^{ij}	91.86	82.30^{cdef}	69.30^{k}	89.63	85.05^{ghij}	77.49^{jk}
IC 598880	2.78	1.51^{ij}	1.13^{ij}	71.23^{ab}	45.94^{ij}	34.80^{bcdef}	90.54	82.57^{bcde}	70.63^{j}	87.48	85.14^{fghi}	77.56^{ij}
IC 598883	2.80	1.14^{q}	1.01^{q}	69.82^{d}	44.35^{mn}	33.41^{ij}	91.12	80.01^{i}	65.51^{qr}	89.92	84.43^{kl}	76.46^{q}
IC 598890	2.81	1.91^{ab}	1.35^{b}	70.38^{bcd}	47.88^{ab}	35.49^{ab}	91.71	85.24^{a}	76.90^{b}	89.61	85.86^{ab}	78.26^{a}
IC 598891	2.83	1.82^{cd}	1.31^{c}	69.82^{d}	47.49^{cd}	35.31^{abc}	90.65	84.97^{a}	75.09^{d}	89.00	85.72^{abcd}	78.12^{bc}
IC 598893	2.79	1.42^{kl}	1.11^{kl}	70.19^{bcd}	45.46^{k}	34.60^{cdefg}	90.75	82.14^{defg}	68.82^{kl}	89.70	85.00^{ghij}	77.40^{kl}
IC 598899	2.78	1.28^{no}	1.06^{no}	71.13^{ab}	45.02^{l}	34.13^{fghi}	91.45	81.52^{fgh}	67.30^{no}	90.08	84.78^{jk}	76.96^{n}
IC 598902	2.81	1.06^{r}	1.02^{pq}	69.85^{d}	44.18^{n}	33.10^{j}	89.76	79.75^{i}	65.27^{r}	87.99	84.33^{l}	76.32^{r}
IC 598903	2.8	1.54^{hi}	1.15^{i}	70.32^{bcd}	46.12^{hi}	34.89^{abcdef}	89.34	82.75^{bcd}	70.97^{j}	89.56	85.21^{fghi}	77.63^{hi}
IC 598904	2.80	1.36^{lm}	1.09^{lm}	69.93^{cd}	45.32^{k}	34.42^{defgh}	89.60	81.80^{efgh}	68.22^{lm}	88.36	84.96^{hij}	77.28^{l}
IC 598906	2.82	1.77^{de}	1.29^{d}	68.60^{e}	47.24^{d}	35.26^{abcd}	90.52	84.78^{a}	74.36^{de}	89.26	85.65^{abcde}	78.05^{cd}
IC 598920	2.76	1.33^{mn}	1.07^{mn}	71.53^{a}	45.17^{kl}	34.28^{efgh}	89.98	81.68^{efgh}	67.90^{mn}	89.70	84.86^{ij}	77.15^{m}
IC 598929	2.83	1.73^{ef}	1.27^{e}	70.18^{bcd}	47.24^{d}	35.20^{abcd}	90.63	84.55^{a}	74.03^{ef}	88.4	85.53^{bcdef}	77.98^{de}
IC 598930	2.82	1.69^{fg}	1.24^{f}	71.00^{ab}	46.95^{e}	35.13^{abcd}	91.61	83.44^{b}	73.58^{fg}	88.73	85.47^{bcdef}	77.92^{ef}
IC 598933	2.82	1.66^{fg}	1.21^{g}	71.14^{ab}	46.77^{ef}	35.06^{abcde}	91.52	83.18^{bc}	72.96^{gh}	89.83	85.40^{cdefg}	77.82^{fg}
IC 598936	2.83	1.62^{gh}	1.19^{gh}	70.47^{abcd}	46.50^{fg}	34.98^{abcde}	91.19	83.01^{bcd}	72.53^{hi}	90.03	85.33^{defgh}	77.75^{gh}
P5	2.82	1.86^{bc}	1.33^{bc}	70.93^{abc}	47.66^{bc}	35.39^{abc}	91.14	85.09^{a}	75.90^{c}	89.1	85.79^{abc}	78.20^{ab}
Mean	2.81	1.53	1.17	70.4	46.14	34.62	90.94	82.84	71.06	89.25	85.22	77.51
% change from FC		45.55	58.36		34.46	50.82		8.90	21.86		4.51	13.15
SE	0.03	0.04	0.01	0.52	0.15	0.42	1.26	0.46	0.373	1.033	0.21	0.06
CV%	1.32	3.16	1.19	0.91	0.39	1.49	1.71	0.68	0.64	1.42	0.30	0.10

respectively. Accessions IC 598869, IC 598890 and P5 were having low leaf temperature under stress. The check variety P5 had the lowest increase (1%) in leaf temperature. The highest leaf temperature of 36.10^{0}C was observed in accession IC 598899 under 10th day of drought stress with 8 per cent increase. Canopy *temperature* can used as screening tool for identifying *drought-tolerant genotypes* (Rashid et al. 1999)

According to Ormaetxe et al., 1998, drought stress cause reduction in chlorophyll content and damage the photosynthetic apparatus inhibiting the photosynthesis of plants. Reactive Oxygen Species causes damage to chloroplasts and this result in decrease in chlorophyll under drought stress (Smirnoff 1995). Herbinger et al., 2002, reported that plants degrade the absorbing pigments to avoid the production of reactive oxygen species which is mainly driven by excess energy absorption in the photosynthetic apparatus. Degrading the pigments lowers the light harvesting capacity of plants and consequently photosynthesis getting lowered.

In the current study, the mean content of chlorophyll in stressed leaves was reduced by 58.36 per cent compared to field capacity at 10 days after stress. Accessions IC 598869, IC 598890 and P5 had high chlorophyll content with less reduction under stress. Low chlorophyll content was observed in accessions IC 598883, IC 598866, IC 598872 and IC 598902. There was 64 per cent reduction in chlorophyll content in accessions IC 598883 and IC 598902 when exposed to stress for 10 days. A significant correlation (r = 0.52) in chlorophyll content was observed between the stressed and non-stressed plants indicating a uniform degradation of chlorophyll across all the accessions. .

One of the indications of stress tolerance capacity of plants is the Chlorophyll stability Index (CSI) Reduction in values of CSI can be attributed to reduced synthesis and increased breakdown of chlorophyll due to stress. When plants have higher CSI, it can help the plants to combat stress through better availability of chlorophyll. Which will lead to increased rate of photosynthetic rate, dry matter production and higher productivity (Mohamadkhani and Heidari, 2008).

CSI at the stress stage was only half of the non-stressed stage. Under field capacity, the highest value of CSI was observed in accession IC 598920 (71.53%) and lowest in IC 598906 (68.60%). There was 34.5 and 51 per cent reduction in the mean value of CSI under 5 and 10 days of stress induction. Under stress condition, the accession IC 598869 had the maximum CSI value of 35.66 per cent. Accessions IC 598869, IC 598891, and IC 598906 had a lower reduction in CSI under stress. Lowest CSI and highest reduction under stress were observed for the accession IC 598902. The reduction in CSI was not uniform across accessions. This indicate the inherent differences between the constitution of these pigments leading to the difference in their behaviour under stress situations, that could be exploited in breeding programs.

Maintenance of membrane integrity as measured by Membrane stability index (MSI), is essential for maintaining cellular homeostasis in plants. Along with CSI, MSI has been employed as a handy tool for drought tolerance screening in many crops (Sairam et al., 1998). Compared to CSI, the reduction in MSI was moderate with a value of 4.5 and 13 per cent reduction on the 5th day and 10th day of stress induction. The mean value for MSI under normal condition was 89.25. Accessions IC 598869, IC 598890 and P5 were having high values of MSI under stress. Low values of MSI were observed in accessions IC 598883 and IC 598866. Accession IC 598880 had the lowest reduction of MSI under stress, while a larger reduction was observed in accessions IC 598883 and IC 598899. Further, the fall in MSI values was not uniform among accessions pointing to differences in the membrane constitution of various accessions leading to their difference in performance under stress.

Cell hydration is necessary for optimum physiological and biochemical functioning and growth processes in plants. This can be clearly indicated by the RWC of the cells (Silva et al. 2007). Preservation of a high RWC during drought is indicative of drought resistance and this has been reported by several researches (Pour-Aboughadareh et al, 2017). The mean value RWC of the black pepper accessions under field capacity was 90.94 per cent. There was 8.9 and 21.86 per cent reduction in mean RWC at the 5th and 10th day of stress induction. Accession IC 598869 retained high RWC followed by IC 598890 and P5 (78.08 %, 76.90 % and 75.90 %) under stress. The lowest value for RWC was observed in the accession IC 598902. In black pepper accessions, which maintain relative water content greater than 70 per cent and membrane stability above 80 per cent after 12 days of drought stress that is complete withholding of water are considered to be relatively tolerant to drought stress (Krishnamurthy et al., 2006). Though based on these criteria, none of the accessions in this experiment can be considered tolerant to drought stress, there was significant difference among the accessions for drought stress and two accessions were better than the check variety P5.

Ranking of accessions based on physiological parameters

Selection of accessions considering many traits simultaneously will be more effective to identify a superior line. Ranking of accessions based on superiority for the physiological basis of drought tolerance identified two accessions IC 598869 and IC 598890 better than the established drought tolerant variety P5.Out of eight characters

Table 3. Ranking of black pepper accessions based on physiological traits

Accession	PS	SC	TS	CC	CS	RWC	MSI	LT	TS	R	Days to PW
IC 598866	21	2	2	13	2	16	12	4	72	19	16
IC 598869	1	9	10	1	1	1	1	1	25	1	20
IC 598872	14	2	2	13	2	15	11	4	63	17	16
IC 598874	9	7	6	8	1	9	5	2	47	9	17
IC 598875	11	5	4	10	4	12	6	2	54	12	16
IC 598880	10	6	5	9	2	11	6	2	51	11	17
IC 598883	15	1	1	14	4	16	13	4	68	20	16
IC 598890	1	8	9	2	1	2	1	1	25	1	20
IC 598891	3	8	8	3	1	4	2	2	31	3	19
IC 598893	11	5	4	11	2	12	7	2	54	13	16
IC 598899	14	3	3	12	2	14	10	5	63	16	16
IC 598902	15	1	1	14	4	16	14	4	69	18	16
IC 598903	10	6	5	9	1	10	5	2	48	10	17
IC 598904	12	4	3	12	2	13	8	2	56	14	16
IC 598906	4	8	8	4	1	4	2	2	33	4	19
IC 598920	13	3	3	12	3	14	9	3	60	15	16
IC 598929	5	8	7	5	1	5	3	2	36	5	19
IC 598930	6	8	7	6	1	6	4	2	40	6	18
IC 598933	7	8	6	7	1	7	4	2	42	7	18
IC 598936	8	7	6	7	1	8	4	2	43	8	18
P5	2	8	9	2	1	3	1	1	27	2	19

PS- photosynthesis SC - stomatal conductance TS- transpiration CC- chlorophyll content CS - chlorophyll stability RWC-relative water content MSI-membrane stability index LT- leaf temperature TS-total score R-rank Days to PW- no. of days taken for permanent wilting

considered accessions IC 598869and IC 598890 were ranked low for most of the characters and were having the least total score of 25 . Both these accessions took 20 days to wilt indicating the effectiveness of using physiological characters in identifying drought tolerance (Table 3). These accessions were better than P5 which is reported as a drought tolerant pepper variety which was ranked two with a total score of 27 based on physiological traits and it took 19 days to wilt. Accessions IC 598891, IC 598906, IC 598929 which took 19 days to wilt were ranked 3, 4 and 5 respectively. Among these accession IC 598906 was found to be moderately resistant to foot rot (Prakash et.al 2019) under artificial screening for footrot. Accessions which ranked high can be considered for further evaluation to release as a variety with drought tolerance, high yield and resistance to biotic stresses

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