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Evaluating characteristics related to drought tolerance in tea genetic resources as the basis to select new tea clone with drought resistance

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Vietnam is one of the contries which have been considered to be severely affected by climate change. Tea plant (*Camellia sinensis*) is often grown in hill and mountain lands in Vietnam, where are frequently sustained drought condition, leading to depress productivity of tea. To improve the productivity of tea, one of solutions should be done is that selecting and breeding new tea varieties which have ability to tolerate drought conditions. This research focused on evaluating the characteristics associated with drought resistance of tea plants such as withered of tea leaves, root length and content of polyphenol of the tea leaf. Sixty (60) tea varieties were successively evaluated basing on wilt index in drought conditions, which were scaled from 0 to 46.59%, for 4 weeks. There were 32 out of 60 tea varieties denoting the wilt index of leaves from 0-5%. They are local varieties and some new tea clones such as CNS84, CNS85, and CNS86. Tea cuttings from 60 tea varieties were put into an artificially drought-causing condition in greenhouse for 12 weeks. The results showed the root-growing depth and the polyphenol content of tea leaves influenced drought resistance of the tested tea varieties. The tested tea clones with characteristic of shallow growing of roots were susceptible to drought condition, and conversely, the tested tea clones with characteristic of deep-growing of roots were more resistant to drought. The tested tea clones, which had high polyphenol content, were susceptible to drought and deep rooted clones resistant. The drought-tolerant tea varieties were determined as Trung du, Gay NA, CNS76, CNS84, CNS85 and CNS86. These varieties will be used as the material for breeding drought-resistant tea varieties in future researches and some of them will be further evaluated with the desire for drought tolerance and high yield, good quality for tea production..

Key words: drought tolerance, tea (*Camellia sinensis*), varieties, rooting depth, polyphenol, wilt index

Introduction

Vietnam is one of the top tea producers in the world (worldatlas,april 2015). Tea in Vietnam is mostly grown in mountainous areas, which often are drought regions, leading to reduce yield significantly. In addition, Vietnam has been affecting severely by climate change, resulting in irregulary rain distributions, increase the drought areas, which thread agricultural productions including the tea industry. Therefore new tea varieties that can tolerate to drought conditions are needed.

Evaluation of tolerant characteristics to harsh conditions is the first crucial step to select a tolerant variety. The drought-tolerant ability of a tea variety is related to high water bond in leaf, regulation of stomas, evapotranspiration… *etc* (J. M. Tang, Y. S. Li and Q. Tang, 2011). The speed of evapotranspiration throught leaves partly reflects the tolerant ability of variety to hot, dry conditions. In tolerant varieties, evapotranspiration rate often is lower than that in weak or sensitive varieties (Harikrishnan, B.; Sharma, V. S. 1980). The ability to develop a strong root system is also a typical characteristic of drought-tolerant tea variety (S. Nagarajah and G. B. Ratnasuriya 1981; Bùi Chí Bửu 2009). Moreover, plyphenol content is also and indicators of drought-tolerant tea varieties (Erick K. Cheruiyot 2007).

This paper presents the evaluation of these drought-tolerant indicators in tea samples from the tea collection of NOMAFSI, providing scientific basis for selection drought-tolerant tea varieties for the north mountainous region in Vietnam.

Methodology

Seedlings of sixty different tea samples from the tea collection of NOMAFSI were evaluated for their abilities to tolerate drought.

Assessment the wilt of tea leaves under hot-drought conditions

The ability to tolerate with hot-drought conditions of tea samples were assessed through leaf wilt rate that was calculated as formula below:

Leaf wilt rate (%) = 100*(the number of scorched leaves/ total of valuated leaves)

The tolerant ability of tea samples were then evaluated on the following scale: 1 = good tolerance: 0 – 5% leaves scorched, 2 = rather tolerance: >5 – 10% leaves scorched, 3 = medium tolerance: > 10 – 15% leaves scorched, 4 = weak tolerance: > 15 – 20% leaves scorched, and 5 = very weak: >20% leaves scorched.

Evaluation of tolerant ability of seedlings through development of roots under green house conditions and evapotranspiration of leaves

20-cm-heigh tea cuttings of the testing varieties that planted in plastic pots were artificially dried in the green house. The testing plants were watered only when started wilting. The process was repeated for 7 months. The seedlings then were carefully washed out potting mix, and the length of roots was measured.

Mature leaves of the testing tea varieties were collected in the early morning from 9-month-old plants. Subsequently, the leaves were weighed, and then incubated at 40ºC for 2h. Finally, the leaves were weighed again, and the percentages of weights lost duo to evapotranspiration were calculated.

Evaluation of tolerant ability of tea samples throught chemical components of buds

Buds testing tea samples were collected, and chemical components such as reduced sugar, catechin and polyphenol contents were analyzed. The analyses were carried out at laboratory in Northern Mountainous Agriculture and Forestry Science Institute, Vietnam.

Results and Disscusions

Assessment the wilt of tea leaves under hot-drought conditions

As showing in the Table 1, 32 tea samples belonging to TD, GNA, CN and CSN groups had the leaf wilt rates from 0 – 5%, suggesting good tolerance to hot-drought conditions. Especially, of which, 05 samples consisting of CNS 76, CSN 84, CSN 85, CSN 86 and CSN 352 were absolutely not scotched. These samples are valuable materials for selection and breeding. In addition, of 60 testing samples, there were 14, 4, 2 and 8 tea samples showed rather, medium, weak and very weak tolerance to the hash condition, respectively.

Table 1. Leaf wilt rates of tea samples under hot-drought conditions

Samples	Leaf wilt rate (%)	Samples	Leaf wilt rate (%)	Samples	Leaf wilt rate (%)
CNS 142	2.33	CN4	4.06	CNS 153	4.16
CNS 35	13.7	CN5	4.44	CNS 163	4.40
CNS 54	36.29	CN 6	19.45	CNS 76	0.00
Honam 2	30.16	CN7	8.95	CNS 81	1.13
LV 2000	9.35	CN12	4.00	CNS 82	22.22
PVT	23.33	CN14	3.87	CNS 141	2.28
Shan CT	10.69	CN 91	22.22	CNS 132	2.52
DBT	13.00	CNS 41	4.72	CNS 122	2.69
GNA1	3.76	CNS 42	4.91	CNS 87	2.88
GNA2	4.78	CNS 45	46.59	CNS 25	4.00
GNA3	5.88	CNS 512	5.32	CNS 35	4.03
GNA4	3.18	CNS 61	5.35	CNS 162	20.80
PH11	11.29	CNS 84	0.00	CNS 212	3.50
PH14	7.85	CNS 85	0.00	CNS 233	4.59
PH1	8.68	CNS 86	0.00	CNS 352	0.00
TD-NA1	6.37	Gruzi 2	16.49	CNS 442	4.94
TD-NA2	4.55	LDP1	12.00	CNS 243	6.41
TD-PT	4.66	LDP2	8.32	CNS 661	6.67
TD-YB1	4.58	TD-TN1	7.95	CNS 711	0.83
TD-YB2	6.69	TD-TN2	6.38	CNS 721	1.19
$LSD_{0.05}$	1.65				
CV%	12.39				

[1]Mean of four replicates

Evaluation of tolerant ability of seedlings through development of roots under green house conditions and evapotranspiration of leaves

Table 2. Length of tap-roots of seedlings of tea sample after 7 months under artificial drought conditions in green house

Samples	Length of tap-roots (cm)	Samples	Length of tap-roots (cm)	Samples	Length of tap-roots (cm)
CNS 142	13.06	CN4	14.38	CNS 153	13.87
CNS 35	9.65	CN5	14.03	CNS 163	13.06
CNS 54	4.72	CN 6	9.50	CNS 76	15.61
Honam 2	5.75	CN7	12.91	CNS 81	14.83
LV 2000	11.25	CN12	13.75	CNS 82	6.44
PVT	6.29	CN14	14.32	CNS 141	13.68
Shan CT	10.17	CN 91	7.48	CNS 132	14.13
DBT	11.24	CNS 41	13.96	CNS 122	13.46
GNA1	14.40	CNS 42	13.57	CNS 87	14.27
GNA2	12.33	CNS 45	4.17	CNS 25	13.57
GNA3	11.95	CNS 512	11.94	CNS 35	13.88
GNA4	14.16	CNS 61	12.35	CNS 162	6.72
PH11	10.69	CNS 84	14.86	CNS 212	14.16
PH14	12.29	CNS 85	15.53	CNS 233	13.37
PH1	12.58	CNS 86	15.72	CNS 352	15.69
TD-NA1	12.87	Gruzi 2	7.93	CNS 442	13.41
TD-NA2	13.75	LDP1	10.37	CNS 243	12.55
TD-PT	13.64	LDP2	12.15	CNS 661	12.05
TD-YB1	13.43	TDTN1	12.56	CNS 711	14.40
TD-YB2	13.00	TDTN2	12.59	CNS 721	13.59
$LSD_{0.05}$	1.60				
CV%	8.11				

[1]Mean of four replicates

As shown in the Table 2, the lengths of tap-roots varied among tea samples. The samples that had low scotched leaf rates produced longer tap-roots. For instance, the samples CNS 76, CSN 84, CSN 85, CSN 86 and CSN 352, which had wilt leaf rates of 0%, exhibited tap-root lengths of 14.86 – 15.72 cm. Meanwhile, the samples that showed high rates of wilt such as PVT, CNS 82, CN 91, CNS 45 and CNS 162 had tap-root lengths only from 4.17 – 7.48 cm. These results are in agreements with previous studies. S. Nagarajah and G. B. Ratnasuriya (1981) found that tolerant tea varieties developed longer roots that could reach more deeply in the soil compared to roots of weak tolerant varieties. Bui (2009) also indicated the ability to develop long roots as an important characteristic of tolerant tea varieties.

Table 3. Evapotranspiration rates of 9-month-old leaves from different tea samples

Samples	Weight of fresh leaves (g)	Weight of leaves after drying (g)	Evapotranspiration (%)
TD-PT	8.45	3.00	54.49
TD-TN	8.24	5.40	55.33
GNA1	9.32	5.61	53.20
GNA2	9.40	5.62	54.78
LDP1	7.55	4.90	65.00
LDP2	7.76	2.74	64,69
PH1	10.06	6.85	68.15
PH14	9.22	6.40	69.45
TD-YB	8.35	5.70	68.36
TD-NA	8.62	5.99	69.60
Shan CT	8.84	3.24	63.34
CN14	6.96	3.46	50.28
CN41	7.02	3.66	52.18
CN42	7.59	4.12	54.35
CN92	8.45	4.45	52.74
CNS 84	9.19	3.39	63,11
CNS 85	10.15	4.95	51.22
CNS 86	12.00	4.17	65.25
CNS 76	11.50	4.35	62.17
CNS 352	9.15	5.88	64.35
CNS 711	10.20	6.87	67.42
CNS 91	7.38	6.36	86.25
CNS 54	7.50	5.95	79.46
CNS 162	8.74	4.96	79.46
Honam 2	8.62	4.74	76.25
$LSD_{0.05}$	1.14	0.58	2.72
CV%	7.99	7.36	9.67

The leaf weight lost due to evapotranspiration reflects the responses of testing samples to drought conditions. Base on the evapotranspiration rates (Table 2), the testing samples could be classified into three groups. The first included the samples that had evapotranspiration rates below 60%, suggesting good ability to tolerate with high temperature. These samples belonged to TD, GNA and CN groups. The second included commonly used varieties in Vietnam that showed evapotranspiration rates ranging from 61 – 70%. These were considered to be medium tolerant samples to such condition. The third contained the others, which exhibited evapotranspiration rates more than 70%. This group may be considered as weak tolerant samples.

Evaluation of tolerant ability of tea samples through chemical components of buds

Table 4. Chemical components of buds of tea samples

No.	**Samples**	**Parameters**		
		Reduced sugar content (%)	Catechin content (mg/g)	Polyphenol content (%)
1	CNS 142	3.90	154.70	20.14
2	Honam 2	2.09	112.50	14.84
3	GNA2	3.70	134.60	18.55
4	GNA3	2.31	135.20	18.02
5	CNS 153	2.60	138.90	19.08
6	PH1	3.20	130.80	17.49
7	CNS 84	2.95	163.00	21.20
8	CNS 85	3.25	168.40	21.72
9	TD-NA1	3.55	140.70	18.02
10	PH 11	2.70	121.40	16.43
11	TD-TN1	3.70	135.80	17.23
12	TD-YB1	2.60	138.30	18.55
13	PVT	2.18	112.20	14.84
14	CNS 162	2.13	121.80	15.37
15	GNA1	2.27	138.50	19.61
16	CN14	2.13	142.50	20.14
17	CNS 81	2.80	144.10	20.67
18	CNS 61	3.05	137.10	18.55

19	CNS 163	2.09	139.40	19.08
20	CNS 82	3.51	126.40	15.21
21	LDP1	2.74	126.80	16.37
22	CNS 141	2.31	148.70	20.56
23	CNS 442	2.54	134.60	17.84
24	GNA4	3.40	151.10	19.63
25	CN 6	2.90	142.60	15.46
26	Shan CT	3.21	144.70	16.83
27	CNS 243	2.76	158.40	17.61
28	CNS 86	2.81	118.20	21.53
29	CNS 132	2.63	145.80	20.46
30	CN 91	3.21	136.50	14.68
31	CNS 35	3.42	131.40	19.05
32	CNS 661	2.60	126.70	17.21
33	CN4	3.05	133.80	18.93
34	CNS 87	3.70	142.30	20.56
35	CNS 54	2.80	161.40	14.37
36	CNS 35	2.58	148.50	15.64
37	CNS 41	3.10	126.70	18.39
38	CNS 122	2.70	136.90	20.75
39	CNS 42	2.14	135.80	18.55
40	CNS 711	3.40	141.20	21.64
41	DBT	2.68	136.50	15.71
42	TD-YB2	2.51	132.10	17.84
43	CNS 233	3.17	126.30	20.06
44	CN7	2.65	135.40	15.72
45	CN12	2.28	126.50	19.45
46	TD-NA2	2.74	131.70	18.51
47	TD-TN2	2.26	142.80	17.62
48	CNS 721	3.40	146.40	20.74
49	Gruzi2	3.20	123.80	15.46
50	CNS 45	2.53	167.30	14.28
51	LV 2000	3.08	131.20	16.07

52	PH 14	2.80	112.60	17.23
53	CNS 212	3.50	153.90	19.66
54	CNS 76	2.46	161.50	21.78
55	CN5	2.57	133.40	18.57
56	LDP2	3.15	128.70	17.66
57	CNS 352	2.70	138.60	21.84
58	CNS 25	3.40	133.70	19.53
59	CNS 512	2.80	148.90	18.14
60	TD-PT	3.60	134.50	19.23
	$LSD_{0.05}$	0.24	5.07	1.42
	CV%	5.29	6.27	4.83

[1]Mean of four replicates

Contents of reduced sugar, catechin and polyphenol were analysed and presenting in the table 3. There were the variations in the analysed parameters among testing tea samples. In general, however, the tea samples that showed low wilt rates had significantly higher reduced sugar, polyphenol and cachein contents as compared those showed higher wilt rates. For instance, the samples CNS 76, 84, 85, 86, 352, 711, Trung du and Gay groups, which had wilt leaf rates of 0 – 5%, exhibited polyphenol rates of 18 – 21%. In contrast, the samples such as Honam 2, PVT, CNS 45, 54 and 91 that had high wilt rates showed polyphenol rates only 14 – 15%. The correlations between polyphenol content and tolerances of testing tea samples in this study are correspondent to research of Cheruiyot *et al.* (2007) who concluded that polyphenol content correlates to tolerance of tea plant. The authors demonstrated that while polyphenol content was reducing in weak-tolerant tea varieties under drought conditions, it was stable in the tolerant varieties. Therefore, polyphenol content has been used as indicator in selection of tolerant tea varieties.

In conclusions, through assessment of 60 tea samples, the current stdudy found that 32 samples had good tolerance to drought condition with wilt rates of 0 – 5%. The others were ranging from rather to very weak tolerant to the harsh conditions. This study also demonstrated that the good tolerant samples produced longer tap-roots in artificial drought condition as compared to those produced by the others. Some of these samples also showed lower evapotranspiration rates under high temperature condition. Moreover, polyphenol, reduced sugar and catechin contents of the good tolerant samples were significantly higher than those of weak tolerant samples.

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