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Response of different tea (*Camellia sinensis* L.) clones against drought stress

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Abstract
Eight clones of three cultivars i.e Rupi (Aa/NTRI-101, Aa/NTRI-108, Aa/NTRI-561), Chuye (Aa/NTRI -117, Aa/NTRI -122) Qi-men (Bb/NTRI -470, Bd/NTRI -180, Ab/NTRI -219) of *Camellia sinensis* were studied for drought tolerance at National Tea Research Institute (NTRI) Shinkiari Mansehra (KPK) during 2010-11. Four treatments (Control, Nursery, Room temperature and open Sun light) were applied. Data recorded on morphological characters, soil and leaves moisture contents. Significant variations were observed in all the studied parameters among cultivars. In control conditions all clones showed best results in all parameters. In nursery conditions there was no growth in any clone but maximum number of leaves, branches, buds, flowers, soil moisture contents and relative water contents of leaves were observed in clone Aa/NTRI 117, Aa /NTRI 101, Aa /NTRI 122, Bb/NTRI-470 as compare to the others. On the other hand at room temperature, there was no growth in any clone however maximum number leaves, branches, buds, flowers, soil moisture content and relative water content of leaves were observed in Bb /NTRI 470, Bd/NTRI 180, Aa/NTRI 101, Aa /NTRI 219. Sunlight conditions exerted severe drought stress but clones Aa /NTRI 101, Aa /NTRI 117, Bb /NTRI 470, Bd/NTRI 180 could survive and showed maximum response to conditions applied, reveling that these clone i.e, Aa /NTRI 101 of Rupi, Aa /NTRI 117 of Chuye and Bb /NTRI 470, Bd/NTRI 180 of Qi-men are prove to drought significantly.

Key words: Tea, Clone, Water Stress, Drought, Shinkiari

Introduction
In the broadest sense, tea is a water extract of leaves, blossoms, roots, bark, or other parts of plants. The most common tea is from the leaves of the plant known as *Camellia sinensis* [1].
There are many environmental factors that adversely affect and reduce the yield of *Camellia sinensis,* these environmental factors are called stresses. Stresses may be (a) biotic stresses, which are pathogenic in nature, such as disease, insect/pest and weeds etc. (b) abiotic stresses (physical environment) such as salinity, heat cold and drought etc [5]. Loss by biotic stresses typically decrease crop yield less than 10%, but abiotic

stresses, are responsible up to 65% reduction in yield. Among the abiotic stresses drought is one of the major and ever present threat that adversely affect the plant growth and yield all over the world [14] .Being sessile plants are incapable of escape from environmental insults, therefore for survival plants develop resistance mechanisms to the environmental stresses they live in. Mature tea bushes with well developed, deep root systems can withstand drought to a greater extent than shallow rooted young tea. Under prolonged dry weather conditions, growth of tea is adversely affected by plant water deficits created by lack of soil moisture and associated high saturation vapor pressure deficit of the air [9].

As reported by [17] that the drought tolerance of tea clones in Kenya can be improved by grafting on appropriate rootstocks, with more susceptible clones showing greater improvement. It appears that drought may have distinct effects on rootstock with rootstock performance correlated with xylem water potential, while scion performance was correlated with stomata conductance. Drought tolerance is not only requirement for a rootstock under Kenyan conditions; while most tolerant rootstocks do not necessarily give the high yield when non-drought occurs. It has been evaluated by [2] two-year-old potted plants of six*(Camellia sinensis L)* cultivars (TV-18, TV-26, UPASI-3, UPASI-26, T-78 and HV-39) were subjected to water stress for 4, 8 and 12 days, relative water content (RWC) of leaves of all cultivars declined with water stress, but in two drought tolerant cultivars (UPASI-3 and UPASI-26), higher RWC were maintained in comparison to the others.

Tea *camellia sinensis* primarily grown in a rain fed tropical areas. Although monsoonal rain bring sufficient amount of rain fall to both west and intermediate zones. Erratic distributions with in a year can results in moisture stress on tea plants during the month of February, March, May, June, October and November. Tea land of Pakhall valley is 3500 from sea, susceptible to moisture stress together with temperature and high saturation vapor pressure deficit during the dry month [18].

Temperature is the major environmental variable affecting the yield of tea, but within the framework of a temperature model shoot extension is severely depressed when daily maximum vapor pressure deficits rise above 2.3 kPa. Day length does not affect shoot extension when the nights are cool (10°C), but growth rate is depressed by short days (11 h) when nights are warm (20°C). Soil temperatures between 18–25°C do not affect shoot extension [16].Plant survival and growth significantly higher under the wettest compared with the driest regime [7]. There is a diurnal change in the sap tension of shoots taken from both irrigated and un-irrigated tea plants. The stomata of two genetically distinct populations of tea differ in their sensitivity to increasing sap tension. Sap tension measurements confirm that sheltered tea can deplete soil water faster than tea more exposed to the wind [3]. Water stress affects biochemical constituents that determine the tea quality. Soil moisture stress causes a reduction in PAL (Phenylalanine ammonia lyase) activity. Lower PAL activity correlated with lower synthesis of flavones such as epigallocatechin gallate (EGCG) and epicatechin gallate (ECG), (which are important precursors of theaflavin-3, 3′-digallate**)** that determines final tea quality [9].

Under prolong dry weather conditions the growth of tea is adversely affected by water deficits in soil moisture and saturation vapor pressure deficit in the air [12]. Reported by [19] that most of tea clones planted by National Tea Research Institute (NTRI), Shinkiari have been ranked according to their capacity for drought tolerance on the basis of their field performance. But in depth no study has been conducted on these adoptive /planted clones. This is the context in which this study was under taken with the rationale to enhance our efficiency to target the drought tolerant cultivars/clones.

Materials and Method

Experiment was laid out in Split Plot Design with 4 treatments comprising control having 2 replications i.e season I & II. Comprising total 940 plants i.e. 5 plants/treatments. One and half year old clonal tea plants of three cultivars i.e Rupi (Aa/NTRI-101. Aa/NTRI-108. Aa/ NTRI-561, Aa/NTRI-122), Chuye (Aa/ NTRI-117, Aa/NTRI-122, Aa/NTRI-219) and Qi-men (Bb/NTRI-470. Bd/NTRI-180) used in after study to select drought tolerant at National Tea Research Institute Mansehra. All the young clonal plants were re-transplanted in pots filled with soil of sandy loam texture having of pH 5.5. All plants were subjected to

different stress conditions after irrigating for 24 hours such as in nursery (T2), room temperature (T3) and to sunlight (T4) except the control (T1) which was watered as per requirements.

The parameters were studied are Relative growth rate (RGR).,Average numbers of leaves /clone, average number of branches, average numbers of buds sprouted/clone, average numbers of flowers /clone, Soil moisture content (SMC), relative water content of leaves (RWC), relative water content was calculated by following formula:

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

Where,

W – Sample fresh weight
TW – sample turgid weight
DW – sample dry weigh

Data were recorded on all the five parameters through out the study period and were analyzed statistically to determine the significant level. The data were presented in the table 1-4 accordingly. Whereas, analysis of variance tables are also annexed on all the five parameters for both the seasons i.e I & II.

Results and Discussion

Without water, life on earth could not exist. Every living organism from the smallest microorganism to the largest mammal on the earth relies on water for survival. In animals, water aids in respiration. In plants, water aids in photosynthesis, the process by which plants convert sunlight into food. Being sessile plants are incapable of escape from environmental insults, therefore for survival plants develop resistance mechanisms to the environmental stresses they live in. Among the abiotic stresses drought and salinity are the major one that affects plants more than commonly thought [13].

Table 1: Control

Clone	Season	Plant height	Leaves number	Branches number	Buds number	Flowers number	MCS at the of replication	RWC of leaves at the of replication
Bd 180	1	0.2500	1.25	0.2500	1.125	0.8750	4.222	98.26
	2	0.4375	2.375	0.37500	1.00	1.215	49.41	93.01
Aa 561	1	0.1875	1.25	1.3750	1.875	1.875	4.653	99.29
	2	0.3125	2.750	0.37500	1.25	0.7500	49.63	97.65
Aa 122	1	0.1875	1.25	0.5000	1.500	0.2500	4.850	99.40
	2	0.1875	3.125	0.7500	1.25	1.125	49.56	97.93
Aa 101	1	0.1875	2.000	0.0000	2.125	1.000	4.595	97.72
	2	0.1875	2.750	0.6250	1.000	0.7500	49.48	96.83
Aa 117	1	0.1250	1.625	0.8750	1.500	0.5000	4.568	98.36
	2	0.3750	2.000	0.3750	0.2155	1.125	48.83	95.16
Ab 219	1	0.09537	0.6083	0.2139	0.4475	0.3051	3.620	98.84
	2	0.8452	0.4598	0.2134	0.2155	1.1919	48.83	96.85
Aa 108	1	0.2000	1.200	0.6000	1.400	0.6000	4.537	98.14
	2	0.4000	2.400	0.6000	1.000	1.00	49.59	96.54
Bb 470	1	0.2000	2.400	0.6000	1.000	1.000	0.07723	0.4994
	2	0.3000	1.800	0.6000	1.000	1.200	0.3505	1.593

`The term "drought" denotes a period without precipitation, during which the water content of the soil reduce to such an extent that plants can no longer extract sufficient water for normal life processes . Plant water stress, caused by drought has major impact on plant growth and development. As the plant undergoes water stress, the water pressure inside the leaves decreases and the plant wilts. Like all other plants, growth of tea is also adversely affected by plant water deficits created by lack of soil moisture and associated high saturation vapor pressure deficit of the air [15].

Present research study an attempted way made to observe the effect of drought on different clones of tea during different seasons. Among all morphological characteristics that have been studied first was height, all tea clones do not show increase in plant growth under stress condition in all environmental condition except tea clones under control condition. Control conditions where the tea clones were irrigated continuously and maximum plant height was observed in Bd/NTRI-180. These results agreed with [10] and [15]., that growth of tea is adversely affected by plant water deficits created by lack of soil moisture and associated high saturation vapor pressure deficit of the air. Under drought stress maximum no of leaves were observed in clones at room temperature and some clones show maximum number of leaves in sun light during both the seasons. Results indicated that temperature and drought have positive effect on leaves emergence, but for maintenance of high number of leaves water is utmost necessary. Because temperature and drought cause premature senescence and shedding of leaves. That is why final number of leaves is lower as compared to initial number of leaves. This is consistent with the report of [4] in Yellow poplar (Liriodendron) for shedding of leaves during drought stress. As there is no increase in growth rate similarly no formation of new branches was observed in all of the tea clones in drought condition except the clones which were irrigated continuously. Effect drought on emergence of buds (flowers or leaves) was different in different tea clones in different environmental conditions.

Table 2: Nursery

Clone	season	Plant height	Leaves number	Branches number	Buds number	Flowers number	MCS at the of replication	RWC of leaves at the of replication
Bd 180	1	0	2.000	0	0.5000	1.375	4.192	98.68
	2	0	2.500	0	1.000	0.1250	6.716	88.09
Aa 561	1	0	2.250	0	0.5000	0.8750	4.653	94.49
	2	0	3.125	0	0.7500	0.5000	6.809	83.54
Aa 122	1	0	2.125	0	0.3750	1.125	4.850	98.88
	2	0	3.625	0	1.000	0.6250	6.884	85.14
Aa 101	1	0	2.000	0	0.5000	0.7500	4.537	96.29
	2	0	3.625	0	1.250	0.6250	6.855	86.78
Aa 117	1	0	2.750	0	0.5000	1.125	4.580	96.67
	2	0	3.75	0	0.3750	0.7500	6.770	84.52
Ab 219	1	0	0.6985	0	0.1878	0.2747	3.620	91.18
	2	0	0.5370	0	0.2123	0.1954	5.292	86.47
Aa 108	1	0	1.800	0	0.4000	1.200	4.580	93.75
	2	0	4.0000	0	1.000	0.4000	6.796	87.46
Bb 470	1	0	1.800	0	0.6000	1.000	0.07723	0.4994
	2	0	2.800	0	1.200	0.2000	0.03438	1.660

Table 3: Room Temperature

Clones	season	Plant height	Leaves number	Branches number	Buds number	Flowers number	MCS at the of replication	RWC of leaves at the of replication
Bd 180	1	0	3.625	0	1.000	0.7500	4.382	83.49
	2	0	2.3750	0	0.8750	0.7500	8.318	88.84
Aa 561	1	0	2.875	0	0.8000	0.7500	2.607	86.93
	2	0	4.000	0	0.3750	0.6250	5.491	87.59
Aa 122	1	0	2.625	0	1.000	0.5000	2.807	87.84
	2	0	3.000	0	0.6250	0.7500	5.586	76.74
Aa 101	1	0	2.000	0	1.125	0.7500	2.783	85.81
	2	0	2.875	0	0.8750	0.7500	5.510	87.06
Aa 117	1	0	3.375	0	1.875	0.7500	2.658	90.92
	2	0	1.625	0	0.6250	0.6250	8.318	78.23
Ab 219	1	0	0.5197	0	0.2839	0.5181	2.510	92.17
	2	0	0.855	0	0.3148	0.2097	4.394	88.13
Aa 108	1	0	2.600	0	1.200	1.000	2.648	90.34
	2	0	0.8000	0	1.000	0.6000	5.507	86.19
Bb 470	1	0	2.800	0	0.2839	0.8000	0.05986	2.104
	2	0	4.200	0	1.000	0.4000	0.3130	1.563

Table 4: Sun Light

Clones	season	Plant height	Leaves number	Branches number	Buds number	Flowers number	MCS at the of replication	RWC of leaves at the of replication
Bd 180	1	0.000	3.000	0.000	0.7500	0.6250	0.1120	87.19
	2	0.000	1.375	0.000	0.7500	0.3750	0.1280	70.58
Aa 561	1	0.000	2.875	0.000	0.6250	0.8750	0.06500	68.50
	2	0.000	3.875	0.000	0.6250	0.3750	0.07375	70.18
Aa 122	1	0.000	2.500	0.000	0.7500	0.3750	0.09250	68.85
	2	0.000	4.250	0.000	0.6250	0.6250	0.08500	71.51
Aa 101	1	0.000	3.125	0.000	0.5000	0.5000	0.08825	69.57
	2	0.000	4.625	0.000	1.000	1.000	0.0765	72.04
Aa 117	1	0.000	2.750	0.000	0.8750	1.625	0.0925	1.899
	2	0.000	6.625	0.000	2.250	0.5000	0.0500	72.94
Ab 219	1	0.000	2.800	0.000	0.2583	0.2544	0.08600	71.81
	2	0.000	0.3590	0.000	0.2807	0.1919	0.00200	78.84
Aa 108	1	0.000	2.400	0.000	0.6000	0.4000	0.07125	67.11
	2	0.000	5.200	0.000	1.200	0.4000	0.07000	71.86
Bb 470	1	0.000	0.6041	0.000	0.6000	0.6000	0.01156	75.33
	2	0.000	3.600	0.000	1.000	0.6000	0.004317	1.90

Maximum numbers of buds were found in clones watered continuously than clones kept in room temperature. Minimum number of buds was observed in sun light and nursery condition. In nursery condition water evaporation is low and plant do not absorbs water. As water logging also has an adverse effect on during the period under observation. Seeds are formed from true flowering during the month of March/April, November, December and January i.e where as false flowers and flowers shed after some days.

It was observed that by drought stress in season one of the clones in control and nursery condition show maximum no of flowers as compare to room temperature and sun light. Clone Ab 219 show maximum number of flowers at room temperature during both the seasons. In season two maximum flowering was observed in clones under control environmental condition. But as a whole adverse effect of drought was observed on different tea clones in drought stress and there is no significant increase in flowers. Our results agree with [11] who reported that the effects of drought on the levels of GA are enhanced by severe water stress, higher in the branches that produced fewer flowers during drought stress. Maximum soil moisture was observed in control and nursery conditions as clones under control condition are watered regularly as & when water required while water evaporation is low in nursery condition. At room temperature maximum soil moisture content was observed in Aa 101 while in sun light condition maximum soil moisture was observed in clones Aa 117 in season one and in both season while at sun light condition maximum soil moisture was observed in clone Aa 122. But temperature in October and November was higher then December and January. So the clone with high soil water content was more drought tolerant then the others and clones in sun light condition are more drought tolerant than the clones under rest of environmental conditions. Because the soil moisture stress induce anatomical changes in plant leaves, and these changes enhance the ability of the plant to restrain water loss [8]. Relative water content of leaves decrease in drought conditions, maximum relative water content were observed in clones under control and nursery condition at room temperature clone Aa-117 showed maximum relative water content and in Bd-180 sun light showed maximum relative water content as compared to others clones . Relative water content (RWC) of leaves of all cultivar decline with water stress, but drought tolerant clones retain higher relative water content indicating that these are more drought tolerant as compare to others [2].

CONTROL

Relative Growth Rate (RGR)

Data in table-1 shows relative growth rates of eight different tea clones for two seasons at control condition. During the first season maximum relative growth rate was observed in Bd 180 followed by Aa108, Bb 470, Aa 561 and Aa 122, Aa 101, Aa 117 and minimum in Ab 219, while in second season maximum growth rate was shown by Ab 219 followed by Bd 180, Aa 108, Aa 117, Aa 561, Bb 470 and Aa 122 and Aa 101 respectively. The analysis of variance shows no significant effect of environmental conditions on relative growth rate.

The data regarding the effect drought on different tea clones in nursery is given in table-2. There is no growth in any tea clone in nursery during both seasons. Analysis of variance show significant effect of nursery conditions on growth rate of different clones.

The table -3 shows that there is no growth in any clone at room temperature during Sun-light treatment. Analysis of variance shows significant effect on height or growth of different clones in both seasons of light 1 & 2.

Number of leaves

Maximum number of leaves in control condition during season one were observed in Bb 470, followed by Aa 101, Aa 117, Bd 180, Aa 561, Aa 122, Aa 108 and minimum number of leaves were observed in Ab 219, while during second season maximum number of leaves were shown by Aa 122 followed by Aa 561, Aa 101, Aa 108, Bd 180, Aa 117, Bb 470 and minimum number of leaves were observed in Ab 219.The analysis of variance shows no significant effect of environmental conditions on number of leaves during both seasons.

In nursery condition maximum number of leaves during season one were found in Aa 117 followed by Aa 561, Aa 122, Bd 180, Aa 101, Aa 108, Bb 470 and minimum in Ab 219. In second season maximum number of leaves were observed in Aa 108, followed by Aa 117, Aa 122, Aa 101, Bd 180 and minimum in AB 219. Analysis of variance showed no significant effect of nursery conditions on number of leaves of different clones.

Number of branches

Date given in the table- 1 shows that among the different tea clones maximum number of branches were shown by Aa 117 in season one in control conditions, followed by Aa 108, Bb 470, Aa 122, Aa 561, Bd 18, Ab 21 and minimum number of branches were observed in Aa 101. While in second season maximum no of branches were observed in Aa 122, followed by Aa 101, Aa 108 and Bb 470, Bd 180 and Aa 561, Ab 219. Analysis of variance showed no significant effect of the control conditions on number of branches during both seasons. While nursery conditions drought caused inhibition of growth of branches. Analysis of variance show significant effect of nursery conditions on number of branches of different clones in both seasons.

Number of buds

Table-1 illustrated that maximum number of buds were observed in Aa 101 followed by Aa 561, Bd 470, Aa 117 and Aa 122, Aa 108, Bd 180 while minimum number of buds were observed in Ab 219. However in second season maximum number of buds were observed in Aa 117, Aa 122, and in Aa 561, Bd 180, Aa 101, Aa 108 and in Bb 470 and minimum were observed in Ab 219. Analysis of variance shows no significant effect of the control condition on number of buds during both the seasons.

Table -2 illustrate that during season one under drought stress among eight tea clones maximum number of buds were found in Bb- 470, followed by Aa-101 and Aa-117, Bd-180, Aa-561, Aa-108, and minimum number of buds were observed in Ab-219. In case of season two maximum numbers of buds were found in Aa 101, Bb 470, Bd 180, Aa 122, Aa 101, and Aa 117 and in Ab 219. Analysis of variance shows no significant effect of nursery conditions on number of buds of different clones in both seasons.

Number of flowers

Data presented in table-1 shows that maximum number of flowers were observed in Aa 561 followed by Bd 180, Aa 101, Bb 470, Aa 108, Aa 117, Ab 219 and minimum in Aa 122, while in second season maximum number of flowers were observed in Aa 122, Bd 180, Bb 470, Aa 117, Aa 108, Aa 561 and Aa 101 but minimum were observed in Ab 219. Analysis of variance shows no significant effect of the control conditions on number of flowers during both seasons.

Data given in table- 2 show that maximum number of flower were found in Bd 180 followed by Aa 108, Aa 117, Aa 122, Bb 470, Aa 561, Aa 101 and Ab 219 during season one. In second season maximum number of flowers Aa 117 followed by Aa 122, Aa 101, Aa 561, Aa 108, Bb 470, Ab 219 and minimum number of flowers were observed in Bd 180. Analysis of variance shows no significant effect of nursery conditions on number of flowers of different clones in both seasons.

Soil Moisture Content (SMC)

Relative soil moisture contents of different clones in two seasons are given in the table -1 show that maximum soil moisture contents were retained by clone Aa 117 followed by Aa 108, Aa 561, Ab 219, Aa 122, Aa 117 and Bb 470, while during second season maximum soil moisture contents were observed in Aa 108 followed by Aa 561, Ab 219, Aa 122, Aa 101, Bd 180, Aa 117 and Bb 470. Analysis of variance shows no significant effect of the control conditions on soil moisture contents of different clones during both seasons.

Data given in table -2 shows the effect of drought on different tea clones during seasons. In season one maximum soil moisture was found in Aa 122, followed by Aa 561, Aa 117, Aa 101, Aa 108, Bd 180, Ab 219 and minimum in Bb 470. In season two maximum soil moisture contents were observed in Aa 122, Aa101, Aa 561, Aa 108, Aa 117, followed by Bd 180, Ab 219, Ab 219,and Bb 470. Analysis of variance shows no significant effect of nursery conditions on soil moisture contents of different clones in both seasons.

Relative Water Content (RWC) of leaves

Table -1 showed that maximum relative water contents of leaves were observed in Aa 122, Aa 561, Ab 219, and Aa 117 followed by Bd 180, Aa 108, and Aa 101 and in Bb 470. However in second season maximum water content of leaves shown by Bb 470 followed by Aa 122, Aa 561, Ab 219, Aa 101, Aa 117, Aa 108, Aa 117, Bd 180 respectively. Analysis of variance show significant effect of control conditions on relative water contents of leaves.

Data regarding the effect of drought stress in two seasons is given in table- 2. It shows that during season one maximum relative water contents were observed in Bd 108 followed by Aa122, Aa 117, Aa101, Aa 561, Aa 108, Ab 219, and minimum relative water contents of leaves were observed in Bb 470. While in second season maximum water contents of leave were found in Bb 470, Bd 180, Aa 108, Aa 101, Aa 117, Aa 122, Aa 117 and minimum in Aa 561. Analysis of variance shows no significant effect of nursery condition on relative water contents of leaves of different clones in both seasons.

ROOM TEMPERATURE

Relative Growth Rate (RGR)

Number of leaves

Maximum numbers of leaves were observed in Bd 180, and in Aa 117 followed by Aa 561, Bb 470, Aa 122, Aa 108, Aa 101, and Ab 219. Similarly in season two under drought conditions maximum number of leaves were observed in Bb 470, followed by Aa 561, Aa 122, Aa 101, Aa 117, and Ab 219, and Aa 108. Analysis of variance show no significant effect on number of leaves of different tea clones in both seasons.

Number of branches

Table -3 shows that there is no increase in number of branches in any clone during both seasons. Analysis of variance shows significant effect on number of branches of different tea clones in both seasons.

Number of buds

Data in table -3 represent the number of buds in each of eight tea clone during two seasons at room temperature. Maximum number of buds in seasons one were observed in Aa 117 followed by Aa 101, Aa 108, Bd 180 and in Aa 122, Aa 561 and minimum number of buds were observed in Ab 219 and Bb 470. In case of season two maximum number of buds were found in Aa 108, Bb 470 followed by were Aa 101, Bd 180,Aa 122, Aa 561, and Ab 219. Analysis of variance shows no significant effect on number of buds of different tea clones in both seasons.

Number of flowers

Data about number of flowers of different tea clones at room temperature is given in table- 3. Maximum number of flowers were observed in Aa 108, Bb 470 followed by Aa 101, Aa 117, Bd 180, Aa 561, Ab 219, Aa 122 during season one. In season two maximum number of flowers were observed in three clones i.e Bd 180, Aa 122 and Aa 101 followed by Aa 561, Aa 117, Aa 108 and minimum in Ab 219. Analysis of variance shows no significant effect on number of flowers of different tea clones in both seasons.

Soil Moisture Content (SMC)

Soil moisture of each clone at room temperature is given in table- 3. During season one maximum soil moisture contents were found in Bd 180, followed by Aa 122, Aa 101, Aa 561, Aa 117, Aa 108, Ab 219 while minimum soil moisture contents were observed in Bb 470. In season two maximum soil moisture content were observed in Bd 180 followed by Aa 122, Aa 101, Aa 101, Aa 108, Aa 561, Aa 117, Ab 219 and Bb 470. Analysis of variance shows no significant effect on soil moisture content of different tea clones in both seasons.

Relative Water Content (RWC) of leaves

Data given in table -3 show relative water contents of leaves of different clones. Table- 3 representing that maximum relative contents moisture of leaves were observed in Bd 180, Ab 219, Aa 117, Aa 108, Aa 122, Aa 561, Aa 101 and Bd 470. Similarly in season two maximum relative water contents were observed in Bd 470, followed by Bd 180, Aa 219, Aa 561, Aa 101, Aa 108, Aa 117 and Aa 122. Analysis of variance shows significant effect on relative water of leaves of different tea clones in both seasons.

SUN LIGHT

Relative Growth Rate (RGR)

Table -4 illustrate the growth rate of eight different tea clones under sun light during two seasons. The table shows that there is no growth rate of eight tea clones in any clone during both seasons in sun light conditions. Analysis of variance shows significant effect on growth rate of different tea clones in both seasons.

Number of leaves

Analysis of data shows that in season one maximum number of leaves was observed in Aa 101, followed by Bd 180, Aa 561, Ab 219, Aa 117, Aa 122, Aa 108 and Bb 470. While in season two maximum numbers of leaves were observed in Aa 117 followed by Aa 108, Aa 101, Aa 122, Bb 470, Bd 180 and AB 219. Analysis of variance shows no significant effect on number of leaves of different tea clones in both seasons.

Analysis of variance of both the seasons

Season 1

Fig-I: Control

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	0.016	0.035	0.073		
Leaves no	1.275	3.086	2.961		0.425
Branches no	0.837	0.286	0.366	0.0849	
Buds no	1.188	1.682	1.602		0.4201
Flower no	3.088	1.200	0.745	0.0092	0.1732
Mc of soil	0.116	0.269	0.149		0.1234
Rwc of leaves	80.907	566.945	28.853	0.0448	0.0000

Nursery

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	-	-	-	-	-
Leaves no	0.775	2.654	3.904		
Branches no	-	-	-	-	-
Buds no	0.025	0.282	0.282		0.454
Flower no	0.475	0.443	0.604		
Mc of soil	0.137	8.943	0.047	0.0392	0.0000
Rwc of leaves	32.357	38.359	9.740	0.024	0.0041

Room Temperature

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	-	-	-	-	-
Leaves no	0.463	2.214	2.920		
Branches no	-	-	-	-	-
Buds no	0.088	0.368	0.645		
Flower no	0.025	0.511	0.225	0.0588	
Mc of soil	0.046	19.734	0.029	0.2033	0.0000
Rwc of leaves	0.046	19.734	0.029	0.2033	0.0000

Sunlight

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	-	-	-	-	-
Leaves no	0.463	2.214	2.920		
Branches no	-	-	-	-	-
Buds no	0.162	0.114	0.534		
Flower no	1.975	0.875	0.518	0.0135	0.1612
Mc of soil	0.002	0.008	0.001	0.0969	0.0001
RWC of leaves	80.907	566.945	28.853	0.0448	0.0000

Season 2

Fig-II: Control

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	0.100	0.057	0.057	0.1671	0.4520
Leaves no	1.463	1.468	1.691		
Branches no	0.250	0.114	0.364		
Buds no	0.100	0.157	0.371	0.3557	
Flower no	0.338	0.196	0.295		
Mc of soil	0.928	0.280	0.983		
RWCof leaves	9.480	17.812	20.297		

Nursery

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	-	-	-	--	-
Leaves no	1.750	3.700	2.307	0.1755	
Branches no	-	-	-	-	-
Buds no	0.875	0.628	0.361		0.1090
Flower no	0.462	0.225	0.305	0.2249	
Mc of soil	0.017	10.935	0.009	0.15598	
RWC of leaves	20.805	80.327	22.045		0.0064

Room Temperature

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	-	-	-	-	-
Leaves no	6.088	0.368	5.859		
Branches no	-	-	-	-	-
Buds no	0.4047	0.2336	0.2336		0.1617
Flower no	0.350	1.311	0.793		
Mc of soil	0.015	43.653	0.008	0.1264	
RWC of leaves	219.217	402.449	166.591	0.2882	0.0455

Sunlight

Traits	Mean Square			Probability	
	Replication	Factor	Error	replication	Factor
Height	-	-	-	-	-
Leaves no	28.275	6.386	5.904	0.0045	0.4010
Branches no	-	-	-	-	-
Buds no	3.788	0.157	0.630	0.0013	
Flower no	0.538	0.196	0.295	0.1522	
Mc of soil	0.000	0.037	0.000	0.1893	
RWCof leaves	8.075	136.993	29.494		0.0015

Table-5: Morphological traits tables of different parameters recorded during the experiment.

a. Height

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	0.2500A	0	0	0
Aa-561	0.1875A	0	0	0
Aa-122	0.1875A	0	0	0
Aa-101	0.185A	0	0	0
Aa-117	0.1250A	0	0	0
Ab-219	0.09537A	0	0	0
Aa-108	0.2000A	0	0	0
Bb-470	0.2000A	0	0	0

Values followed by the same letters do not differ significantly at 1% level of significance.

b. Leaves

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	1.25CD	2.000A	3.625A	3.000A
Aa-561	1.25CD	2.250A	2.875A	2.875A
Aa-122	1.25C	2.125A	2.625A	2.500AB
Aa-101	2.000AB	2.000A	2.000AB	3.125A
Aa-117	1.625BC	2.750A	3.375A	2.750AB
Ab-219	0.6083D	0.6985A	0.5197B	2.800AB
Aa-108	1.200CD	1.800A	2.600A	2.400AB
Bb-470	2.400A	1.800A	2.800A	0.6041B

Values followed by the same letters do not differ significantly at 1% level of significance.

c. Branches

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	0.2500AD	0	0	0
Aa-561	0.3750AB	0	0	0
Aa-122	0.5000AB	0	0	0
Aa-101	0.0000AB	0	0	0
Aa-117	0.8750A	0	0	0
Ab-219	0.2139AB	0	0	0
Aa-108	0.6000AB	0	0	0
Bb-470	0.6000AB	0	0	0

Values followed by the same letters do not differ significantly at 1% level of significance.

d.

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	1.125BC	0.5000A	1.000A	0.7500A
Aa-561	1.875AB	0.5000A	0.8000A	0.6250A
Aa-122	1.500AB	0.3750A	1.000A	0.7500A
Aa-101	2.125A	0.5000A	1.125A	0.5000A
Aa-117	1.500AB	0.5000A	1.875A	0.8750A
Ab-219	0.4475C	0.1878A	0.2839A	0.2583A
Aa-108	1.400AB	0.4000A	1.200A	0.6000A
Bb-470	1.600AB	0.6000A	0.2839A	0.6000A

Buds

Values followed by the same letters do not differ significantly at 1% level of significance.

e. Flower

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	0.8750AB	1.375A	0.7500A	0.6250
Aa-561	1.875A	0.8750AB	0.7500A	0.8750AB
Aa-122	0.2500B	1.125AB	0.5000AB	0.3750B
Aa-101	1.000AB	0.7500AB	0.7500A	0.5000B
Aa-117	0.5000B	1.125AB	0.7500A	1.625AB
Ab-219	0.3051B	0.2747B	0.5181B	0.2544B
Aa-108	0.6000B	1.200AB	1.000A	0.4000B
Bb-470	1.000AB	1.000AB	0.8000A	0.6000B

Values followed by the same letters do not differ significantly at 1% level of significance.

f. Moisture (30)

Clone	Control	Nursery	Room Temp	Sun light
Aa-122	4.850A	4.850A	2.807B	0.09250B
Aa-101	4.595AB	4.537B	2.783B	0.08825B
Aa-561	4.653AB	4.653AB	2.670BC	0.06500C
Aa-108	4.537B	4.537B	2.648BC	0.07125C
Aa-117	4.568AB	4.580AB	2.658BC	0.0925D
Bb-470	0.07723E	0.07669E	0.05986D	0.01156E
Ab-219	3.620D	3.620D	2.510C	0.08600B
Bd-108	4.222C	4.192C	4.382A	0.1120A

Values followed by the same letters do not differ significantly at 1% level of significance.

g. RMC of leaves

Clone	Control	Nursery	Room Temp	Sun light
Aa-122	99.40A	98.88A	87.84AB	68.85BC
Aa-101	97.72A	96.29AB	85.81AB	69.57BC
Aa-561	99.29A	94.49BC	86.93AB	68.50BC
Aa-108	98.14A	93.75BC	90.34AB	67.11C
Aa-117	98.36A	96.67AB	90.92AB	1.899D
Bb-470	0.4994B	1.103D	2.104C	75.33B
Ab-219	98.84A	91.18C	92.17A	71.81BC
Bd-108	98.26A	98.68A	83.49B	87.19A

Values followed by the same letters do not differ significantly at 1% level of significance.

h. Height

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	0.4375A	0	0	0
Aa-561	0.3125AB	0	0	0
Aa-122	0.1875AB	0	0	0
Aa-101	0.1875AB	0	0	0
Aa-117	0.3750AB	0	0	0
Ab-219	0.8452B	0	0	0
Aa-108	0.4000A	0	0	0
Bb-470	0.3000AB	0	0	0

Values followed by the same letters do not differ significantly at 1% level of significance.

i. Number of Leaves

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	2.375A	2.500AB	2.375B	1.375BC
Aa-561	2.750A	3.125A	4.000A	3.875ABC
Aa-122	3.125A	3.625A	3.000B	4.250A
Aa-101	2.750A	3.625A	2.875B	4.625A
Aa-117	2.000AB	3.75A	1.625C	6.625A
Ab-219	0.4598B	0.5370B	0.855D	0.3590C
Aa-108	2.400A	4.0000A	0.8000D	5.200A
Bb-470	1.800AB	2.800A	4.200A	3.600ABC

Values followed by the same letters do not differ significantly at 1% level of significance.

j. Number of Branches

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	0.37500A	0	0	0
Aa-561	0.37500A	0	0	0
Aa-122	0.7500A	0	0	0
Aa-101	0.6250A	0	0	0
Aa-117	0.3750A	0	0	0
Ab-219	0.2134A	0	0	0
Aa-108	0.6000A	0	0	0
Bb-470	0.6000A	0	0	0

Values followed by the same letters do not differ significantly at 1% level of significance.

k. Number of buds

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	1.000AB	1.000AB	0.8750A	.7500B
Aa-561	1.25A	0.7500ABC	0.3750A	0.6250B
Aa-122	1.25A	1.000AB	0.6250A	0.6250B
Aa-101	1.000AB	1.250A	0.8750A	1.000B
Aa-117	1.25A	0.3750BC	0.6250A	2.250A
Ab-219	0.215B5	0.2123C	0.3148A	0.2807B
Aa-108	1.000AB	1.000AB	1.000A	1.200B
Bb-470	1.000AB	1.200A	1.000A	1.00B

Values followed by the same letters do not differ significantly at 1% level of significance.

l. Number of Flowers

Clone	Control	Nursery	Room Temp	Sun light
Bd-108	1.215A	0.1250A	0.7500A	0.3750AB
Aa-561	0.7500AB	0.5000A	0.6250A	0.3750AB
Aa-122	1.125A	0.6250A	0.7500A	0.6250AB
Aa-101	0.7500AB	0.6250A	0.7500A	1.000A
Aa-117	1.125A	0.7500A	0.6250A	0.5000AB
Ab-219	0.1919AB	0.1954A	0.2097A	0.1919B
Aa-108	1.00A	0.4000A	0.6000A	0.4000AB
Bb-470	1.200A	0.2000A	0.4000A	0.6000AB

Values followed by the same letters do not differ significantly at 1% level of significance.

m. Soil moisture content

Clone	Control	Nursery	Room Temp	Sun light
Aa-122	49.56A	6.884A	5.586B	0.08500B
Aa-101	49.48A	6.855A	5.510BC	0.0765C
Aa-561	49.63A	6.809AB	5.491BC	0.07375E
Aa-108	49.64A	6.796AB	5.507BC	0.07000F
Aa-117	48.83A	6.770AB	5.470C	0.0500D
Bb-470	0.3505B	0.03438D	0.3130E	0.004317G
Ab-219	49.59A	5.292C	4.394D	0.002000H
Bd-108	49.41A	6.716B	8.318A	0.1280A

Values followed by the same letters do not differ significantly at 1% level of significance.

n. RMC of Leaves

Clone	Control	Nursery	Room Temp	Sun light
Aa-122	97.93A	85.14B	76.74C	71.51C
Aa-101	96.83B	86.78D	87.06E	72.04B
Aa-561	97.65C	83.54B	87.59D	70.18D
Aa-108	96.54E	87.46E	86.19F	71.86C
Aa-117	95.16D	84.52F	78.23E	72.94B
Bb-470	1.593H	1.660G	4.563G	1.920E
Ab-219	96.85G	86.47C	88.13B	78.84A
Bd-108	93.01F	88.09A	88.84A	70.58D

Values followed by the same letters do not differ significantly at 1% level of significance.

Number of branches

Data in Table- 4 shows that there is no increase or decrease in number of branches under sun light condition during season one and two in any of the eight tae clone. Analysis of variance shows significant effect on number of branches of different tea clones in both seasons.

Number of buds

Data regarding the number of buds in different tea clones in sun light during both seasons is given in Table- 4. Maximum numbers of buds were observed in Aa 117 followed by Bd 180, Aa 122, Aa 561, Aa 108, Bb 470, Ab 219 and minimum in Aa 101. During seasons two maximum number of buds were observed in Aa 117 followed by Aa 108, Bb 470, Aa 101, Bd 180, Aa 561, Aa 122 and Ab 219. Analysis of variance shows no significant effect on number of buds of different tea clones in both seasons.

Number of flowers

Table- 4 represents the number of flowers in eight different clones of tea during two seasons in sun light conditions. Maximum numbers of flowers were observed in Aa 117 followed by Aa 561, Bd 180, Bb 470, Aa 101, Aa 108, Aa 122, and Ab 219. While in season two maximum numbers of flowers were observed in Aa 101 followed by Aa 122, Bb 470, Aa 117, Aa 108, Bd 108, Aa 561 and Ab 219. Analysis of variance shows no significant effect on number of flowers of different tea clones in both seasons.

Soil Moisture Content (SMC)

Soil moisture content of different tea clones in sun light condition during two seasons is given in table -4. Maximum soil moisture contents were observed in Bd 180 followed by Aa 117, Aa 122, Aa 101, Ab 219, Aa 108, Aa 561 and Bb 470. In second season maximum soil moisture contents were observed in Bd 180 followed by Aa 122, Aa 101, Aa 561, Aa 108, Aa 117, Bb 470 and Ab 219. Analysis of variance shows no significant effect on soil moisture contents of different tea clones in both seasons.

Relative Water Content (RWC) of leaves

Table-4 represents the data about relative water contents of leaves of every clone in sun light conditions during two seasons. Maximum relative moisture contents of leaves were observed in Ab 219 followed by Aa 117 Bd 180, Bb 470, Aa 101, Aa 122, Aa 108 and minimum leaves moisture content was observed in Aa 561. While during second season maximum moisture contents of leaves were observed in Bb 470 followed by Ab 219, Aa 117, Aa 101, Aa 108, Aa 122, Bd 180 and Aa 561. Analysis of variance shows significant effect on relative water contents of leaves of different tea clones in both seasons.

Recommendation

During the study it has been investigated the most drought tolerant clones, of tea under different environmental conditions. Clone Aa/NTRI-101 of cultivar Rupi, Aa/NTRI-117 of Chuye and Bd/NTRI- 180 of Qi-men are recommended for the water stress conditions in Agro-climatic conditions of Mansehra KPK for most suitable adoption.

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