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Different climatic data observation and its effect on tea crop

Abdul Waheed [1], F. S. Hamid [1], Habib Ahmad [2], Sohail Aslam [1], Naseer Ahmad [3], Ahmad Akbar [4]

[1] *National Tea Research Institute (PARC) Shinkiari Mansehra, Pakistan.*
[2] *Genetics Department Hazara University KPK Pakistan.*
[3] *Ccrop sciences Division (PARC) Islamabad.*
[4] *Botany Department Hazara University KPK Pakistan.*
National Tea Research Institute PARC (Shinkiari) Pakistan.

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* Corresponding author. E mail: abdulw900@gmail.com ; Tel + 92 997 531125

Abstract
Rainfall particularly, is an agro-met factor that generally playing a significant role on all agric crops including tea. There is considerable spatial and temporal variability in rainfall & others data characteristic, which affect tea crop production and soil erosion problem. For the adoption of soil & water conservation technique, the information of rain fall with the other agro-met factors in general is very important. This paper describes all the agro-met characteristic in relation with the tea crop production nearby suburb of National Tea Research Institute Shinkiari, located at 25km north of Mansehra city on the Karakoram Highway way to China silk route , it is located at 34°28'0N, 73°16'60E at an altitude of 1019 meters (3346 feet). A detail production of tea crop during all the eleven years were also discussed for the efficient utilization of available water for the sustained productivity. It was observed that winter season comprising on 7 month while summer period shorten on 5 months only. However days length and time was countable. In all the 11 years average maximum rain fall was received 209 mm during summer (July) followed by 108mm during February in winter seasons. Minimum average rainfall of 30 & 31 mm was received in Oct & Nov respectively. Maximum average rain fall events (139 mm) were recorded during 2010 followed by 125 mm in 2005. Maximum temperature 37^{0}C shoot up in June 2003, while minimum-1 observed in January 2011. Evapotranspiration of 0.96 mm at minimum level during December 2008 and 0.670 mm in July 2004 was recorded. 3.327 mm evapotranspiration was observed during all the eleven years of study it includes 4 years of wettest & 2001 without any data. Humidity difference during all 11 years was in minimum and maximum range of 43 – 78 % respectively. This attributes shows the climatic effect on tea crop during fermentation of black and deoxidizing of green tea. Maximum made tea in total was 12221 kg/annum during 2008 with rainfall 1092 mm, although it was less as compare to 2010, 2007, 2005, 2002 and 2001 respectively while other climatic factors were also responsible for the maximum production.

Keywords: Tea crop. Weather. Soil. Water. Yield. KPK.

Introduction
Tea *Camellia sinensis L* has wide adaptability and grows in a range of different climates / soils in various parts of the world. **Watson [1]** reported that commercial plantations are found as far as Georgia (42^0 N) in USSR and south as Argentina (27 ^{0}S) at altitudes ranging from 200 to 2200 m sea level. Agro met observations in general and rain fall specially is the most important climatic factor for any crop. Annual rain fall of 2500-3000 mm is considered optimal, with a minimum requirement of 1200 mm for tea. Evenness distribution is more important than the total rainfall annually received in Kenya, Sri Lanka and India. A well even distributed rainfall is essential for its cultivation viz., the rainfall varies from 125 mm to 750 mm like in the tea growing regions of India **[2]**. Secondly important factor was the ideal temperature required for tea crop considered to be 18-25 ^{0}C. Seasonal temperature should not be < 13 ^{0} C (average for the coldest months) or higher > 30^0 C (average for the warmest month). Tea is grown on commercial scale in many areas of the world in warm and moist climatic conditions **[2]**.

In Pakistan the annual rain fall varies from nearly 1500 mm at the south east corner and drops to 375 mm or less in the south east west. **[3]**. Agricultural production is mainly dependent on the amount of rain fall received and its distribution. Rain fall is, of course, the critical factor for the production of crops even in a high rainfall zone. There is substantial yearly variation in certain areas, total rain fall may be exceeding the crop requirements do not synchronize with crop water requirements but the crop suffer due to drought / stress condition. For designing & development of different soil and water conservation techniques i.e., water harvesting water conservation and disposal of excess water etc. the information of various rain fall parameters are prerequisite. The yearly variability in rainfall is important in interpreting response to improve management practices in rain fed areas **[4]** to increased water use efficiencies in Pakistan and are primarily considered in terms of irrigated agriculture. The analysis of long term rain fall & other agro- met data provides an insight into the behavior of rainfall and helps to develop technologies for efficient utilization of available moisture. Opportunities /potential to increase the productivity of tea crop through improved water management depends on specific site knowledge of available moisture and how this can be manipulated to sustain productivity. The amount of water which is lost to the air from an evapotranspiration tank is varying nearly equal to the amount lost from the field (evapotranspiration) **[5]**. A change in the level of water tank represents the combined effect of rain fall & evapotranspiration. In all districts of east Africa tea yields are limited at some seasons of the year by a lack of soil moisture. This loss of potential crop is not restricted up to any periods if it continues for several weeks, until roots die during the drought they can re-grow and enable the plants to make use of the water which is by then present in the soil. **[5].**

Mansehra district is located at the eastern border of the Khyber Pukhtuan Khawa (KPK). The said district is located at 34º - 12' and 35º - 50' and 47º - 07' longitude. While NTRI , Shinkiari is located 25 km north of Mansehra city on the Karakoram Highway silk route to China , it is located at 34°28'0N, 73°16'60E at an altitude of 1019 meters (3346 feet). Climate of Shinkiari is very suitable for tea crop. Research about tea production in Pakistan was first initiated by a local farmer of Union council of Baffa 10 km away from Shinkiari. There were privately owned tea farms in Baffa even in late 70s. Owner of the world leading tea company “Brook Bond” Mr. David Brooks visited Baffa in early 80s and admire the research work of the local farmer on tea production. The Government of Pakistan established Pakistan’s first tea research center namely “National Tea Research Institute (NTRI)” Shinkiari. Keeping in view of climatic condition /many factors and its importance role for tea production. This paper would provide information about effect of weather on tea crop and appropriate management practices for efficient utilization of water.

2. Materials and methods

2.1. Observance location and parameter recorded

Eleven years (2001- 2011) data on rain fall, air temperature, evapotranspiration, and humidity were recorded at National Tea Research Institute’s Agro-met weather Station. The topographic location is given below.

2.2. Location detail of metrological Observation

Latitude	34.4667	Longitude	73.2833	Altitude (feet)	3346
Lat (DMS)	34° 28' 0N	Long (DMS)	73° 16' 60E	Altitude (meters)	1019
Approximate population for 1 km radius from this point: 40710					

2.3. Rain gauge

The data was recorded on rain fall through rain gauge. The collected water was poured into a rain measure which was graduated in10th millimeters or in 10th of 100 of an inch. The bottom of the measure was tapered to measure that small quantity accurately.

2.4. Evapotranspiration tank

The data was recorded on evapotranspiration and observed through Evapotranspiration Tank, the specification were 183 cm in circumference by 61 cm deep, constructed of 30 mm iron sheets. 1.9 cm rim round the top edge to keep the side, there is two cross struts, perpendicular to each other, with in the tank 30 cm depth. Painted inner & outer side and marked with scale in inches as well as in centimeters. Used a still well & permanently fixed hook gauge & bolted to the inside of the tank & allow the water level to be read to the nearest 1 mm /cm. on each day.

2.5. Hygro meter

Humidity was recorded through dry & wet bulb in Celsius by following formula:
WB ^{0}C reading -DB ^{0}C reading = difference Humidity. Outcome of reading difference of humidity were checked in % from the table available with the HM kit.

2.6. Thermometer

Maximum / minimum temperature was recorded accordingly by using thermometer fixed in the wooden box having size of 70 cmx70 cm. The direction of box was placed towards north in scale of the Agro-met weather station. All the equipments were installed properly at weather station. The data were recorded daily basis at 0900 hours accordingly **[5]**. The data maintained were compiled and analyzed statistically using LSD **[5]**.

3. Results and discussion

3.1. Rain events

Table 1 presents rain fall events received at Shinkiari, where the Institute is located. Winter season comprising 7 months. Rainfall received during all the 7 months were, January 66, February 108, March 102, April 70, October 30, November 31& December 33 mm), respectively. Whereas summer season: (May 50, June 94, July 209, August 171 & September 96mm) rain fall were recorded. It was noticed that maximum 209 mm followed by 171 mm & minimum 30, 31, 33 mm of rain fall were received during July, August, October, November and December. It showed that out of all the 12 months only 5 months were either of its peak or lowest level of rain. It was observed that low erratic rainfall affected less comparatively tea bushes during winter seasons because tea plants remains dormant from October to mid April at this local climatic condition. It was also observed that low rain fall badly affected the injury recovery after pruning/skiffing during Oct/Nov/Dec. However growth was started very late in case of deep pruning only. **Willson and Clifford [6]** summarized that tea is grown in areas where the annual rainfall may be less than 700 mm as at Chipinga (Zimbabwe), but where irrigation is essential to ensure economic yields or up to > 5000 mm in parts of Sri Lanka. The distribution of rain over the year depends upon latitude, was modified by altitude and topographic factors associated with the proximity to escarpments, mountains or inland water. **Figure 1** was the research able area which highlighted yellow mark, showed the topographic sketch of district Mansehra with its surrounding.

Table 1: Seasonal rain fall (mm) received at NTRI, Shinkiari Mansehra

Year	**Winter seasons**							**Summer seasons**				
	Months							**Months**				
	Jan.	Feb.	March	April	Oct.	Nov.	Dec.	May	June	July	Aug.	Sep.
2001	28	22	118	112	38	25	5	90	166	17	275	144
2002	55	199	130	139	19	5	0	37	54	243	128	97
2003	105	56	131	17	2	86	0	11	12	253	152	84
2004	75	35	40	7	30	0	40	57	137	299	18	152
2005	0	15	69	87	3	44	3	64	150	229	101	132
2006	48	77	66	31	0	0	24	16	124	52	243	44
2007	26	284	183	125	19	34	78	83	89	233	169	125
2008	96	39	10	84	127	22	60	56	94	213	177	116
2009	120	265	121	52	25	33	0	39	25	143	111	36
2010	174	80	99	74	65	74	135	16	75	471	359	44
2011	1	116	156	39	0	20	22	83	103	145	152	78
Total	728	1188	1123	767	328	343	367	552	1029	2297	1885	1052
Avg.	66	108	102	70	30	31	33	50	94	209	171	96

* Source Agro-Met Weather Station NTRI Shinkiari "KPK" Pakistan.

3.2. Monthly and yearly rainfall

Rain fall data was an interesting one both in a specific locality and over considerable area. Since rain gauge gives the perception at the given point. It is easier to make a point to point rain fall analysis. Results are more or less similar to the Schwab **[7].** Table 2 presents the maximum & minimum rain fall of all the 11 years. It was observed that there was a less variability (CV 83% to 93%) in all the years during winter seasons with coefficient of variation above 80 %. Further the variability during the months of May & January i.e., was (CV 87% & 93%) respectively. It was noticed that low rain fall of 724 mm 911 mm & 970 mm were recorded during the last 4-5 years respectively. It directly reflects on yield of tea during the year because of minimum rain fall received **[8]**.

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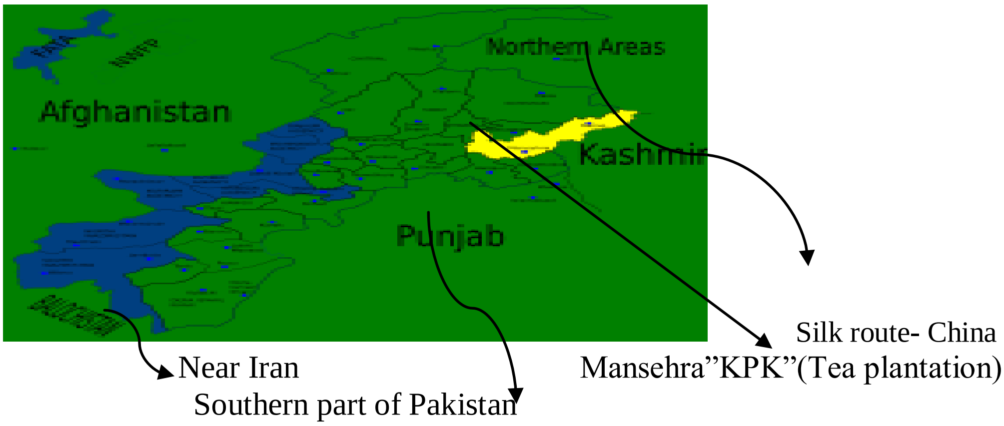


Figure 1: Researchable area & Location (highlighted in yellow) within the (KPK Province, Pakistan)

It was noted that maximum rain was received 1667 mm in July 2010 (CV 87%) followed by 299 mm during 2004 (CV 92%). However, minimum rain fall of 1 mm was received during January followed by October (+ 0 mm). Total annual rain fall at the maximum was received (1667 mm year 2010) followed by (1499 mm year 2005). This proportion showed a high variation in rain fall received during all the eleven years. Lowest rainfall was received (724 mm) during 2006 and (724 mm) in 2006. Yearly, variability in average shown quite differently among each other in all the years. The difference leads for rain fall that received 104 mm in2001, whereas only 92 mm received during 2002. It showed that only 6 years i.e., 2001, 2002, 2005, 2007 2008 and 2010 where the rainfall received more than 1000 mm up above the required level. Continuously for two years, drought may prevail followed by one or two years with sufficient rain fall. There is quite special & temporal variability in rainfall characteristic. The amounts, duration, intensity and aerial distribution are important parameters of rain fall, which affect surface runoff and soil loss [7]. Further-more tea crop suffers moisture stress at different growth stages. The geographical distribution of rainfall is largely determined by the location of large water bodies, by the movement of major air masses and by the changes in the elevation. The highest rain fall occurs when the air is pushed up by the mountains, with lesser rises as the dryer air is pushed to higher elevation. As the air move down the mountains slops/foot hills, low annual fall is generally observed **[7]**. As the NTRI is located in medium elevation and small pockets in its surrounding so the rain fall is vary from another years as presented in the table 2 and Fig. 1 & 2.

3.3. Monthly and yearly temperature

Table 3 indicates the correlation between hottest & coldest months in all the eleven years of the data recorded. Month of January showed the temperature range of -9 to 04 ^{0}C (CV 32% and CV 30%, respectively). The highest CV values (33%) were observed in the years 2002, 2009 and 2010. Maximum temperature of 37^{0}C (CV 33%) recorded in June 2003, followed by 36^{0}C (CV 30%) during the months of May, June and July respectively. This temperature showed direct relation to evapotranspiration because when the temperature shoots up the rate of evapotranspiration automatically increased which ultimately the indication of loss of water from the soil. Yield will suffer due to insufficient quantity of water when the temperature shoot up to 30^{0}C, the growth of tea plant is stopped. Hence the basal portion of the plant become wilted, by virtue of this attribute there is no fresh production by plant in such a high temperature **[9]**. It is also noted that during coldest month the soil temperature ranged below 13^{0}C resultant no growth, while tea plant become in dormancy & remain dormant during all the winter season. When temperatures shoot up from 13^{0}C the breaking of dormancy is gradually affected & plant starts to flush, perhaps the photosynthesis process become an active at that low temperature. The ideal ambient temperature required for the tea is considered to be 18- 25^{0}C. Seasonal temperature should not be lower than 13 ^{0}C (average for the coldest month) or higher than 30 ^{0}C (average for the warmest months). In Assam and Bangladesh maximum daily air temperature in the summer can often exceed 30^{0}C. This high temperature combined with high levels of irradiance during the middle of day may lead tea leaves to air saturation deficits with resultant reduction in the rates of shoots extension and (probability of reduction) net photosynthesis **[9]**.

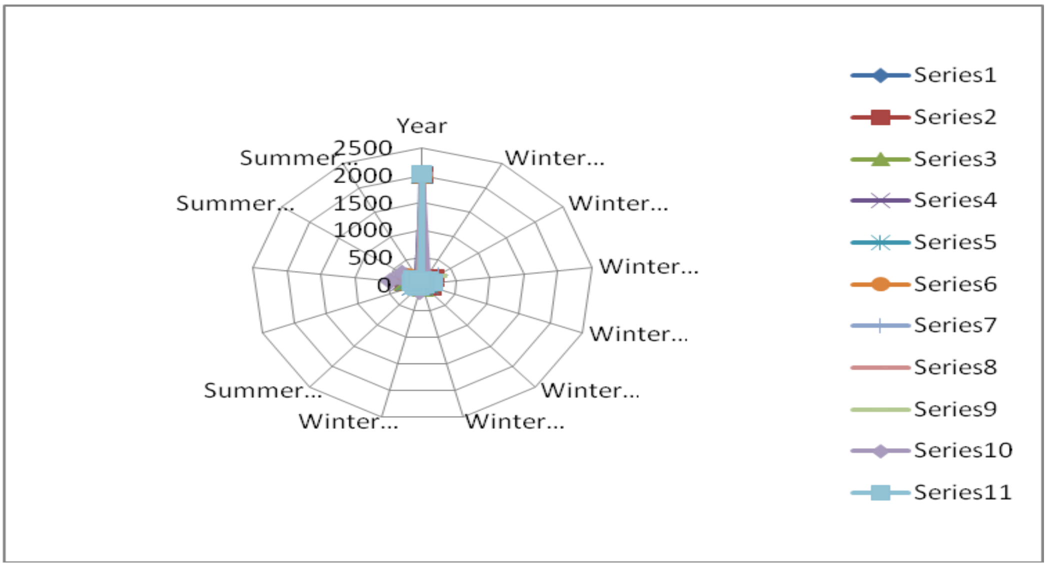


Figure 2: Graphic presentation of Seasonal rain fall (mm) received at NTRI, Shinkiari Mansehra

Table 2: Year wise rain fall events received (2001-2011) at NTRI Shinkiari

Year	Minimum(mm)		Maximum(mm)		Rain-fall^{-annum}	Average	SD	CV %
	mm	Month	mm	Month				
2001	5	Dec	275	Aug	1251	104	46	85
2002	5	Nov	243	July	1107	92	55	92
2003	2	Oct	253	July	911	76	29	91
2004	7	Aug	299	July	992	83	45	88
2005	3	Nov	229	July	1499	125	47	92
2006	16	Mar	243	Aug	724	60	27	89
2007	19	Oct	284	Feb	1448	121	44	92
2008	10	Mar	213	July	1092	91	52	95
2009	23	June	265	Feb	970	81	42	83
2010	16	May	471	July	1667	139	39	87
2011	1	Jan	156	Mar	916	76	54	93

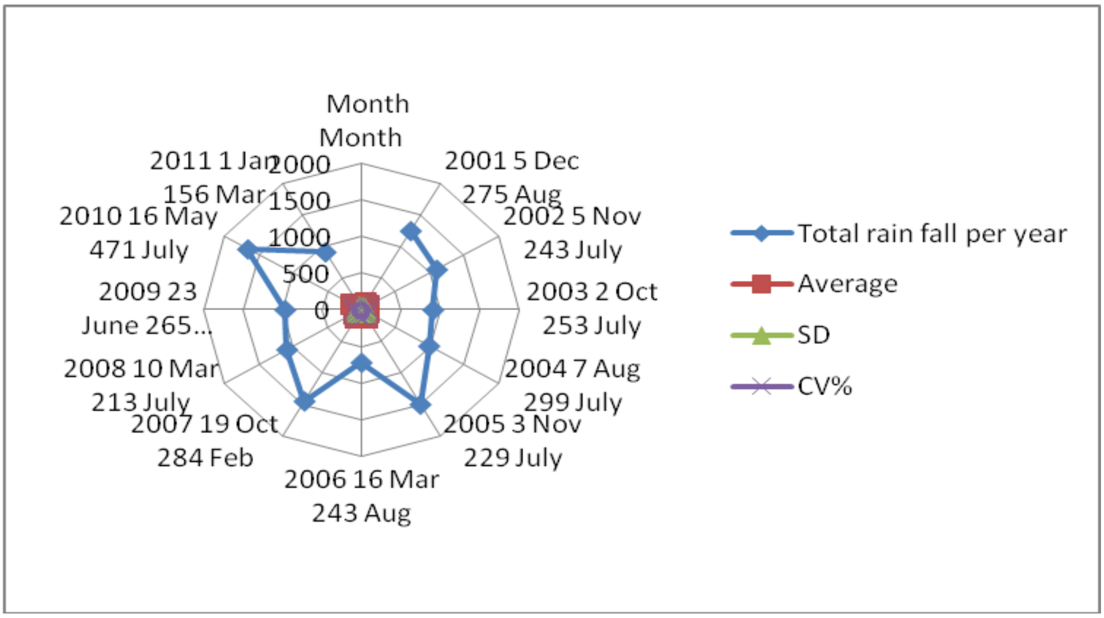


Figure 3: Graphic presentation of Year wise rain fall events received (2001-2011) at NTRI Shinkiari

Table 3: Monthly minimum & maximum temperature 2001-2011 at NTRI

Year	Minimum (^{0}C)		Maximum (^{0}C)		Average	SD	CV%
		Month		Month			
2001	-1	Jan	33	June/Aug	3	4	29
2002	1	Jan	35	June	3	3	31
2003	2	Dec	37	June	3	3	33
2004	2	Jan	36	June/July	3	4	32
2005	2	Jan	36	May	3	4	32
2006	2	Jan	36	June/July	3	3	28
2007	2	Jan	36	June	3	4	30
2008	4	Jan	33	May/June	3	3	30
2009	1	Jan	36	June	3	3	33
2010	1	Jan	36	May	3	4	33
2011	-9	Jan	34	June	3	3	32
Total	7	-	38.8	-	33	-	-
Avg.	0.63		35	-	3	-	-
Month wise total:		Jan(10) & (01) Dec		June (09) & 02 July& (03 may) 01 August	-	-	-

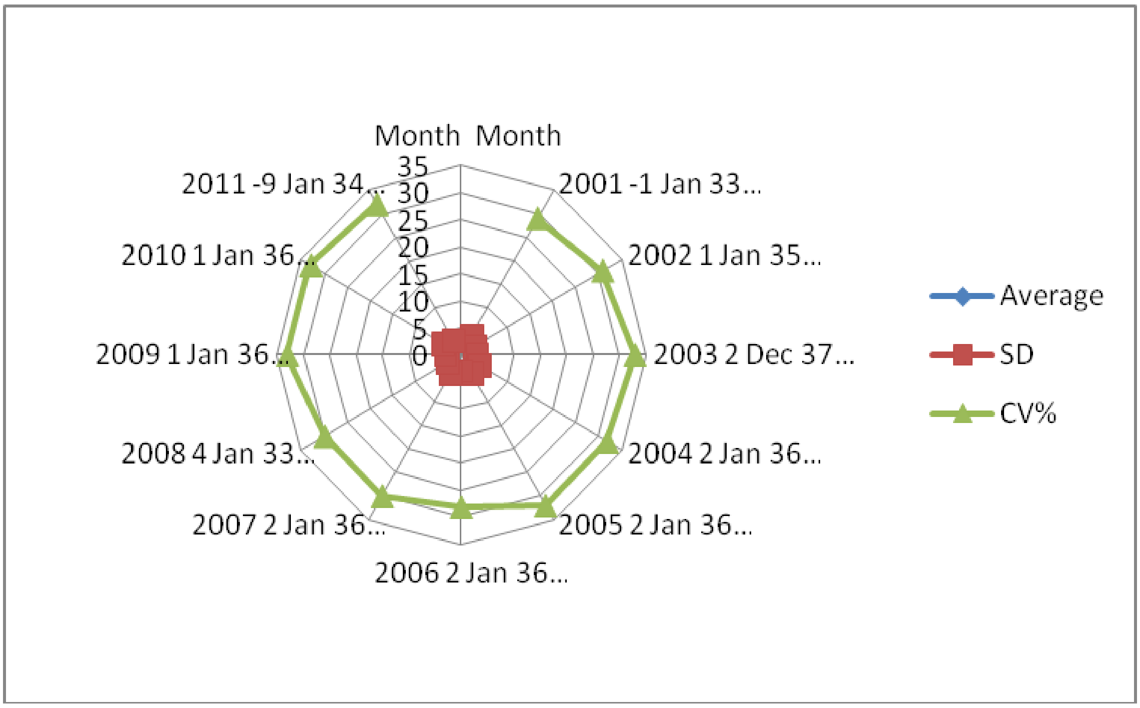


Figure 4: Graphic presentation of Monthly minimum & maximum temperature 2001-2011 at NTRI

*3.4. Monthly , yearly **e**vapotranspiration and humidity*

The data in **table 4** shows recorded data. The minimum of evapotranspiration was (0.96 cm during December 2008 & maximum was 0.670 cm in July 2004. However the minimum water for the tea crop is at least 1000 mm requirements with in the vicinity of NTRI, Shinkiari. Table-4 revealed that the minimum 08 mm of rain fall was required by the year 2004, and the maximum requirements of rainfall were 276 mm during 2006 at the highest ratio. The excess water 448 mm was received during 2007. (2001 data was not available)

Table 2 represents that during 2007 the rainfall received was 1448 mm which, reflected /affected tea yield, the total black tea was made (12221 kg) with ratio of 5.8 % between fresh and made tea in 177 days$^{\text{annum-1}}$.

Table 6 also represents 609 kg /acre/annum of made with an average of – 448 mm of rain , where as it was below the required table. Weather or rain fall in any area is adequate to ensure high yields or continuous production when temperature allow depends largely on the prevailing potential evaporation rate **[6]**.

Table 4: Year wise total evapotranspiration (2001-2011) & co relation of rain fall requirements for tea crop

Year	Minimum (mm)		Maximum (mm)		Evapotranspiration Total/ year	Average	Minimum average water requirements(mm)/ year by tea crop*
		Month		Month			
2001	-	-	-	-	-	-	Data not available
2002	0.146	Feb	0.536	June	4.234	0.352	-107 excess wettest year
2003	0.116	Mar	0.542	June	3.916	0.326	90
2004	0.138	Jan	0.670	July	4.272	0.356	8
2005	0.123	Dec	0.475	June	4.423	0.368	100
2006	0.145	Jan	0.561	May	3.770	0.314	276
2007	0.127	Dec	0.518	June	3.570	0.297	- 448 excess wettest year
2008	0.96	Dec	0.580	May	4.566	0.380	- 92 excess wettest year
2009	0.116	Jan	0.640	June	3.739	0.311	30
2010	0.113	Dec	0.541	May	3.748	0.312	- 667 wettest year
2011	0.98	Dec	0.540	May	3.738	0.311	84
Total	2.964		5.603		39.97	3.327	

* (Ref. Report "Economic feasibility of tea cultivation in Pakistan by Chinese Experts Team 1990.)

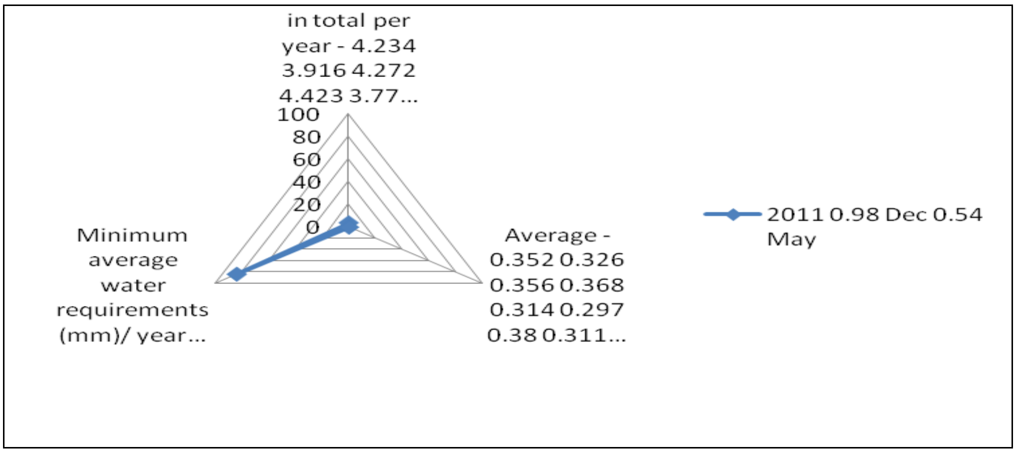


Figure 5: Graphic presentation of year wise total **e**vapotranspiration (2001-2011) & co relation of rain fall requirements for tea crop.

3.5. Humidity

Table 5 indicates that maximum humidity was recorded CV 92 in December 2002, June 2004, and December 2008 respectively . Minimum humidity of 16 % was recorded during winter seasons (February 2004), whereas during summer seasons 36% (March) during year 2003. Maximum average humidity of 104 % was recorded in 2001 as the 57+ 88 % of humidity was noted, the same trend in rainfall on average basis (104 mm) has also been observed during the same year. This attribute perhaps may be due to evapotranspiration & rainfall received.

3.6. Effect of weather on the tea crop

It may be inferred that in summer, when more water is available for crop like tea it may utilize moisture and provide cover to reduce soil erosion. During summer heavy showers (especially in wet years) are received. The plants failed to utilize the rainfall fully, because the rain water is lost through evaporation & surface runoff. **Fayaz & Sair [10]** reported that most suitable vegetables may be utilized through intercropping in tea is the best source to cover surface runoff. Tea crop yielding 3000 kg ha^{-1} of made tea in an area where the annual evapotranspiration is 1250 mm, of which transpiration makes up 1050 mm the water- used efficiency is the 2.4 kg ha^{-1} mm^{-1}, and the transpiration efficiency is 2.9 kg ha^{-1} mm^{-1}. If the total annual rain fall at the same place is 1700 mm, the water- use efficiency (for rain) is 1.8 mm. Water use efficiencies values like these, carefully defined, provides a good way of evaluating the effectiveness of various agronomic or drought mitigation practices, and of assenting, in crop yield and financial terms, the worth wiliness of irrigation **[6]**.

Table 5 Year wise percent humidity form 2001-2011 at tea garden Shinkiari location

Year	Minimum (%)		Maximum (%)		Average	SD	CV%
		Month		Month			
2001	57	Feb	88	Sept	104	46	85
2002	46	Jun	78	Dec	92	55	92
2003	36	Mar	89	Dec	76	29	91
2004	16	Feb	36	June	27	28	92
2005	45	May	80	Nov	63	24	88
2006	40	Mar	89	Aug	59	21	81
2007	47	May	77	July	62	23	84
2008	45	May	83	Dec	65	29	92
2009	54	June	76	Feb	62	25	76
2010	44	April	84	Aug	64	46	67
2011	47	May	79	Oct	62	45	88
Total	477	-	859	-	736	-	-
Avg.	43	-	78	-	-	-	-

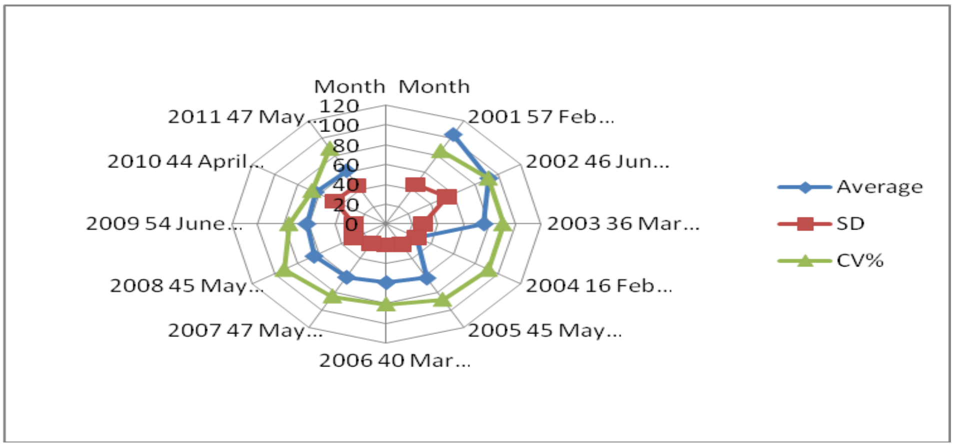


Figure 6: Graphic presentation of year wise percent humidity from 2001-2011 at tea garden Shinkiari

Table 6: Effect of weather on fresh harvest /plucking and made tea per year from 2001-2011 at NTRI, Shinkiari Pakistan***

Year	Fresh leaves obtained(kg^{-yr})		Total Fresh Harvest	Made Tea (kg)		Made tea(kg)	Percent ent ratio between fresh/made tea	Plucking Days	Yield /kg^{-} acre/yr
	NTRI	Farmers Tea Gardens		NTRI	Farmers Tea Gardens				
2001	2224	-	2224	494*	-	494	4.5	38	99
2002	17794	800	18594	3954*	177	4132	4.5	58	439
2003	11524	1275	12799	2560*	233	2843	4.5	88	284
2004	12082	1065	13147	2083*	184	2267	5.8	65	231
2005	9491	-	9491	2109*	-	2109	-	76	234
2006	30745	2442	33193	6769**	485	7254	4.6	66	356
2007	56483	3715	60199	10553**	701	11254	5.3	145	555
2008	67804	4150	71954	11565**	656	12221	5.8	177	609
2009	13893	-	13893	2395*	-	2395	5.8	77	299
2010	48127	4227	52353	8855**	714	5969	5.47	145	466
2011	32847	3475	36323	6060**	606	6666	5.44	89	318

Source: NTR I /TRDP completion report & tea processing plant data
*Green tea made
**Black tea made
-Data not available
*** Data were research based , may be differ from Institute's figures.

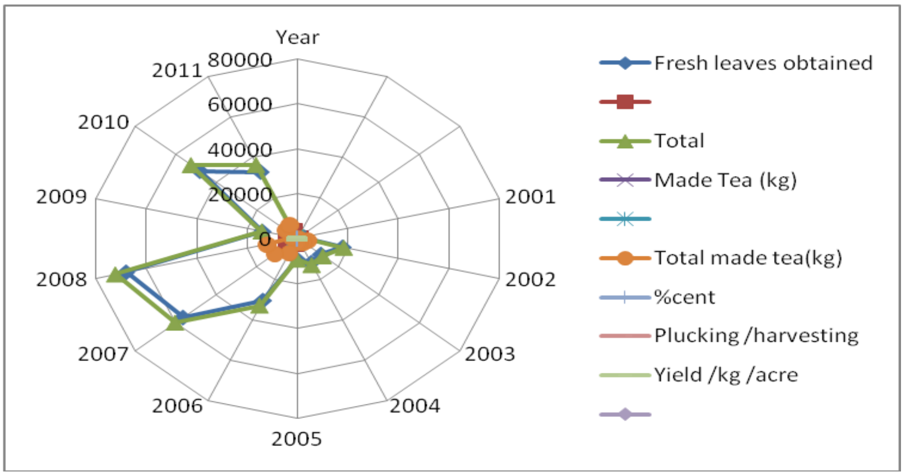
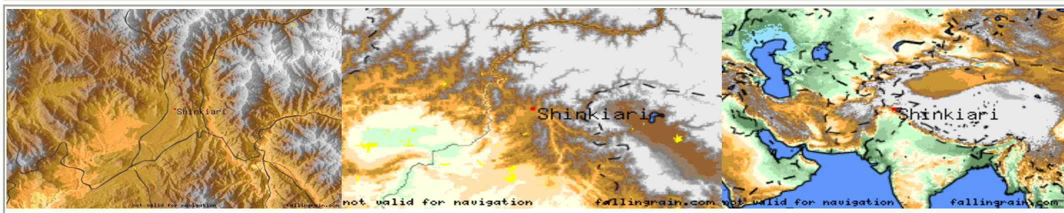


Figure 7: Graphic presentation of effect of weather on fresh harvest /plucking and made tea per year from 2001-2011 at NTRI, Shinkiari Pakistan

Table 6 represents that maximum fresh harvest was obtained 67804 kg for black & 4150 kg for green tea during 2008. Total black tea were processed & made of 11565 kg. Yield/kg/ year was 609 followed by the year 2008 where fresh tea leaves were obtained 71954 kg while processed black tea was made 11565 kg with 609 kg/acre /annum. Tea crop is critically dependent on the amount of rainfall and its distribution- pattern during the growth/ harvesting period. Frequent fluctuations in rainfall and its distribution results are unstable cop production and subsequently affect the tea growers (**table 6)**. During 2010 & 2011the yield were obtained 52353 & 36323 kg. Made tea yield per kg was low as 466 & 318 kg /acre/ annum perhaps due to the effect of weather & none application of inorganic fertilizers.

Latitude	34.4667	**Longitude**	73.2833	**Altitude (feet)**	3346
Lat (DMS)	34° 28' 0N	**Long (DMS)**	73° 16' 60E	**Altitude (meters)**	1019
Approximate population for 7 km radius from this point: 40710					



Nearby Cities and Towns

West	**North**	**East**	**South**
Kandar (0.4 nm)	Khanpu (1.6 nm) Tambah (1.9 nm) Chandwal (2.1 nm)	Kalas (1.3 nm) Ukhrila Gail (1.7 nm) Ukhrila (1.7 nm)	Bedadi (1.3 nm)

Figure 8: Latitude, longitude, altitude (feet) and nearby cities / towns

During year 2001 only green tea were made because of non availability of black tea processing plant. The Black tea processing plant was installed by the year 2001 tea processing were started from year 2002. Lowest yield for green tea was obtained during the year, 2001 & produced 494 kg made tea with 99 kg /acre in 38 plucking days. Year, 2004 produce the total yield 231 kg/ acre /annum with 65 days. In the quoted year deep pruning were practiced by virtue of deep pruning yield were affected badly. Due to this resultant in the loss of crop as the plants could not produced the required quantity of fresh harvest. **Willson and Clifford [6]** concluded that there are seasonal differences in temperature, with cool-dry & warm - dry periods. In some tea areas snow fall (e.g. , Georgia , USSAR protecting the canopy from frost , whilst another e.g., Kericho , Kenya) , hail is a serious hazard causing average annual yield losses of about 10 % , but reaching 30 % in some years. **Waheed *et al* [11]** reported that in climatic condition of Mansehra/Shinkiari where the uneven rainfall received and temperature changes due to drought 140-180 days hardly be possible for the total plucking of tea crop**.** Criteria used for the selection of best tea bushes among the different type of varieties of both *Camellia sinensis L. and C. assamica L* grown at NTRI in the climatic condition of both district Mansehra and AJK for further screening and multiplication for their adaptation **[12]** . The results presents in table 6 "Col 2" are similar with **Waheed *et al* [13]** they reported that tipping practice plus application of N improve the tea yield in the farmers field even at high altitude above 3500 ft .

Recommendations

Water harvesting. As there is great temporal variability and rainfalls do not synchronize with crop water requirements, the crop/ plants suffer moisture stress. To avoid these stresses, rain water technique may be adopted. The excessive rain fall received during the monsoon may be stored by appropriate places and applied through supplemental irrigation. The harvested water may also be utilized ground water recharge at feasible places. Ground water is the best source which may be utilized as and when needed.

Selection of cropping system: Since greater proportion of the crop received during summer seasons, the emphasis should be on growing of summer crops. This will not only utilize rainwater more efficiently but also save the land from soil erosion.

Adaptation of technique for water conservation/ utilization. Appropriate water conservation/ utilization techniques (improvements of bunds, terracing, deep plough, counter plough) should be adopted. Considering site specific conditions. To improve efficiency of conserved moisture, selection of crops & use of soil test base fertilizer should be adopted.

System of shade tea plants should be practiced: Mostly forest tree silver oak *Grevillea robusta, Albizia coriaria* species with 600 m x 600 cm are to be used in tea gardens as shade tree plant to conserve the moisture retention during hot & humid condition. These plants have tap root system therefore no competition between tea plant & shade tree are to be seen.

SALT: Sloppy Agric. Land Technology should also be adopted in tea gardens, planting of vegetables or other suitable crops in terracing to conserve the rainfall for proper utilization & soil erosion there in if any.

Promulgation of policies: Which enhance water harvesting and conservation utilization practices .Subsidies should be provided for different practices. Establishment of an adequate hydro-metrological net work for carrying out water balance studies to access water requirements. The development of data base and their publicizing for efficient rain water management urgently required.

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