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# Survey About Climatic Type of Years and European Black Pine Eustress

KEYWORDS: *Pinus nigra* Arn., climatic type, SPI, eustress, SPPAM application

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**ABSTRACT** *The present study deals with the relationships of climatic type of years and the periods with low radial stem growth of black pine in 29 locations in Europe.*

*The identification of climatic types (CT) and eustress caused CT, their relative participation in the period of 1901-2009 by locations, the manifestation of main adverse type, led periodically to reduction of tree ring width, as well as the comparison of obtained types by precipitations and the SPI classes were the subjects of investigation.*

*The analyses demonstrated that despite the local differences, the stress impact of dry and wet years, especially if they are accompanied by the cold or hot regimes, is well expressed. The successive changes of climatic types at least two years before the eustress year are also relevant. The application of climatic types to study the relationship with trees eustress is more applicable than SPI, when there are no large deviations in temperatures or precipitations by years and locations.*

**Introduction**

The distribution and ecology of black pine, the importance and state of its communities, the eustress existence and its features in different European locations have been already discussed [1].

According to some authors [2], the group of predisposing tree growth factors refers to climate, soil type, age, air pollutants, etc. These factors operate throughout the whole ontogenesis of the forest and usually create the background where the impact of other factors (initializing and accompanying) is manifested. Climate is one of the most powerful predisposing factors that influence the growth. In the initial studies [3] in order to reflect the impact of climate on the growth authors used the average temperature index (Itm) and precipitation index (Ip). The hot or cold years are identified when Itm>1 or Itm<1 and the wet or dry – when Ip>1 or Ip<1. But due to the inability to obtain the sufficient appropriate approximate models for precipitation and temperature changes, frequent inconsistency between periods of low growth and type of adverse climatic year has existed. So, as a climatic type of year (CTY) we consider a calendar year with the corresponding values of average annual temperatures and annual precipitation compared to the corresponding climatic norms, which are the mean values of average annual temperature and average annual precipitation for every 30 years and their confidence intervals ($\mu_{ti}$, $\mu_{pi}$). The published investigations with oaks, beech and white pine [4, 5, 6] illustrated that most of discovered eustress related with the obtained five climatic types of years, manifested in current year and the two previous ones. The climatic years that correspond to the identified stress years are adverse or stress years for the growth. Determination of the most common types of adverse years corresponds to the most of the reported eustress years for different locations and trees is very important issue to forecast the forest state and also allows to identify reactive functional types of trees [7]. The aims of the study are: to identify the climatic type of years for black pine growth period; to compare the obtained types according to the precipitation norms with the SPI classes; to find the main adverse years comparing them with the results for eustress. The demonstrated analyses of obtained eustress in black pine and CTYs, leading to the radial growth reduction, are necessary for the black pine forests monitoring and management.

**Object and Methods**

Analyses were conducted for 29 locations in Europe (from 36.55º lat. and 22.21º long. to 48.07ºlat. and 16.15º long) . on the altitude ranged from 350 to 1800 m, taken from on-line data base [8]. The average annual temperature ($T_{avg.}$) of selected locations varied from 8.6 to 14.4$^0$ C and average annual sums of precipitation ($P_{avg.}$) were from 371 to 1456 mm. The average climatic parameters were calculated from 1901 to the latest year of studied series. The data analysis was conducted by applying SPPAM version 1.2 application [5]. The climatic database CRU – TS [8] was used as a source of temperature and precipitation for 1901-2009. The average annual temperatures ($T_{avg}$.) and precipitations ($P_{avg.}$) and their confidence intervals ($\mu_{ti}$ and $\mu_{pi}$ at the level of significance - $\alpha$ = 0.05) for every 30 years were calculated, starting from 1901 [5]. Values inside the intervals: $T_{avg.} \pm \mu_{ti}$ and $P_{avg.} \pm \mu_{pi}$ respectively are considered as climatic norms for temperature and precipitation. The designated climatic types of years (CTYs) are: hot (H) – $dT>\mu_{ti}$, cold (C) – $dT<-\mu_{ti}$, wet (W) – $dP>\mu_{pi}$, and dry (D) – $dP<-\mu_{pi}$. An year is with normal (N) average temperature when $-\mu_{ti} \leq dT \leq \mu_{ti}$ and with normal sum of precipitation when $-\mu_{pi} \leq dP \leq \mu_{pi}$ [5].

The cited CTY are compared with the scale of precipitation based on the standardised precipitation index (SPI) [9, 10, 11]. The length of interval of SPI values for near normal class looks too large in comparison with other intervals – 4 times (Table 1). In this relation the interval was divided into three intervals and two more classes were included - mildly wet and mildly dry as it is presented in Table 1.This way a better granularity of SPI classes is achieved.

**Table 1. SPI classes**

| SPI[10] | Class [10] | SPI | Class [Lyubenova] |
|---|---|---|---|
| 2.0+ | extremely wet | 2.0+ | extremely wet |
| 1.5 to 1.99 | very wet | 1.5 to 1.99 | very wet |
| 1.0 to 1.49 | moderately wet | 1.0 to 1.49 | moderately wet |
| -0.99 to 0.99 | near normal | 0.5 to 0.99 | mildly wet |
| | | -0.49 to 0.49 | normal |
| | | -0.50 to -0.49 | mildly dry |
| -1.0 to -1.49 | moderately dry | -1.0 to -1.49 | moderately dry |
| -1.5 to -1.99 | severely dry | -1.5 to -1.99 | severely dry |
| -2 and less | extremely dry | -2 and less | extremely dry |

**Results**

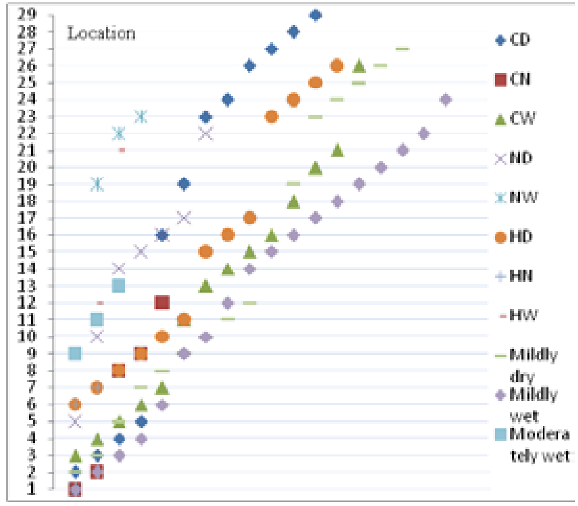
After the statistic calculations it was found that over 30% of obtained eustress (adverse) years occurred in more than 50% of the locations; 46% of years - in more than 40% of the locations; 20-40% of years - in more than 31% of the locations and only for under 20% of the locations studied common eustress years were 24% - Table 3. Presented common eustress years for a high percentage of the black pine locations were obtained as eustress years for other tree species in Europe for 1901 – 2009 (Lyubenova et al. 2014).

**Table 3. Common stress years for studied locations of *P. nigra* Arn.**

| Year | N of years | % of locations |
|---|---|---|
| 1917 1924 1946 1947 1949 1963 1968 1969 | 8 | 90-72 |
| 1909 1918 1928 1934 1935 1943 1945 1950 1965 1971 1972 | 11 | 66-62 |
| 1906 1907 1910 1921 1922 1925 1929 1931 1964 1970 1974 | 11 | 59-52 |
| 1908 1915 1916 1927 1942 1944 1948 1954 1956 1957 1962 1966 1967 1975 1981 1986 | 16 | 48-41 |
| 1904 1905 1911 1913 1919 1923 1930 1932 1933 1936 1937 1938 1939 1941 1951 1952 1953 1955 1958 1973 1976 1978 1979 1980 1982 1983 1984 1985 1987 1988 1993 | 31 | 38-21 |
| 1912 1920 1959 1960 1961 1977 1989 1992 1994 1995 1996 1998 2000 2006 | 14 | 17-10 |
| 1914 1926 1940 1990 1991 1999 2003 2004 2005 2008 | 10 | 7-3 |

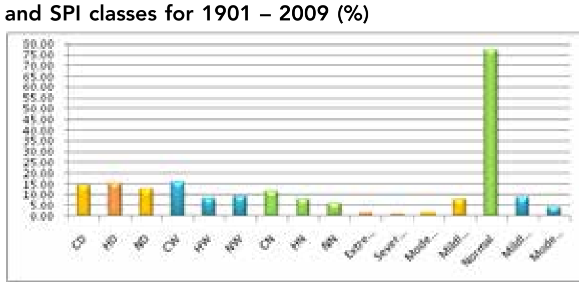
The established stress years in tested locations of black pine respond to nine climatic types and seven SPI classes. Percent participations of different CTYs and SPI classes in the obtained set of adverse years for black pine (1901 – 2009) varies by studied locations in relation to their geographical coordinates and existing differences and specificity of corresponding habitats – Table 2. But CW and HD were the main types causing to eustress for almost all of the locations. This applied also to the influence of mildly wet and mildly dry years while ND type was the main eustress causing type only at the smaller examined latitudes. Some of the climatic types as HN, HW, NW and moderately wet class prevailed for a few of the locations investigated at smaller or larger examined latitude – Fig. 1.

**Fig. 1. Distribution of prevaling CTYs and SPI classes among eustress years for *P. nigra* Arnold. by locations**




The mean values of CTYs and SPI classes percent participation are representative at the level of significance - $\alpha = 0.05$ and $n = 29$ (Table 2). The mean distribution of eustress years to different climatic types also illustrated that the adverse influence of cold - wet and warm - dry type is best expressed; the effect of dry and cold types for the onset of eustress is also significant. Generally adverse climatic influence on the black pine growth in the period can be characterized by a slight predominance of cold (cold : hot = 1.3) and dry (dry : wet = 1.3) climatic types. Years with average annual temperatures and average precipitations at the climatic norms that correspond to the presence of eustres are 5.14% of all adverse years – Fig. 2.

**Fig. 2. Average distribution of eustress years by climatic and SPI classes for 1901 – 2009 (%)**



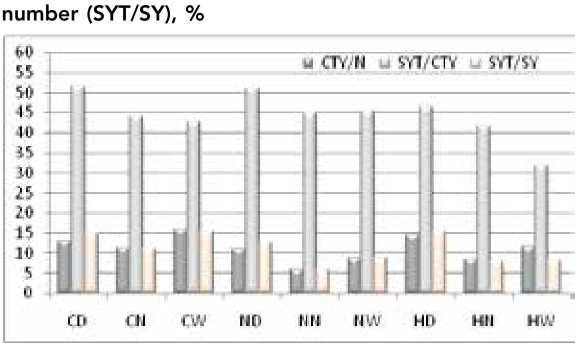
The average participation of the obtained types and classes is presented on Fig. 2. According to SPI the majority of adverse years has normal climatic mode (77.25%) and only mildly dry and mildly wet types have noticeable participation. The comparative analysis showed that dry climatic types and classes were matched in both classifications; 12.91% of normal years also were matched in both classifications; but mildly dry and mildly wet SPI classes fell within the normal climatic type; 53.23% and 33.86% of normal SPI classes met the wet and dry climatic types.

**Discussion**

The climatic year can be identified applying statistical methods as hot or cold, dry or wet. However only by studying the bio system reaction (in our case the radial stem growth) against climatic impact, the adverse climatic types of years can be obtained. So the forest reaction depends on factors connected with ecological features of tree species and their habitats. It also depends on the strength of climatic impact and duration of the exposure. In other words, the concrete habitat environment has a complex impact on the trees: the inhabitants in forest community and other non-climatic factors can change the climatic background and the corresponding reaction. Nevertheless climate is the main ecological background for the operation of all other influences. The obtained large percentage of locations with common eustress years, despite different geographical features and local environmental differences, confirm the strength of the climatic background. For example, the growth of black pine in the studied locations was limited from the average ratios, shown in Fig. 3 (CTY/N) and determining the climate in the period - with a predominance of CW, HD and CD. The same climatic types predominate among the eustress years (Fig. 3, SYT/SY). Over 45% of the dry climatic years (CD, ND and HD) and 40-45% of wet, cold and warm climatic types (CW, CN, NW and HN) are stressful for the black pine (Fig. 3, SYT/CTY). This ratio is perfectly acceptable in the presence of a powerful environment-forming and buffer effect of forest ecosystem as complex functional system. However, the examination of climatic types influence is promising approach for monitoring and management of forest areas.

It is interesting to discuss the result that the part of normal climatic years have appeared as stressful years in the studied locations. Possibly some other negative factor influenced the growth or there was a negative climatic influence in previous years that occurred later. In all cases, analyzing the climatic types for at least two years previous before the normal year will help to clarify this issue. The analysis showed that in only 12.86% of the cases, the climate in the previous two years has been normal, ie the registered stress is likely not due to the climate. In the rest 87.14% of the cases - for the previous two years was seen respectively: adverse climatic type or adverse mode (temperature or precipitation) and their maintenance, changing in climatic type or in one of modes in the opposite type or mode, transition from normal to adverse mode and vice versa.

**Fig. 3. Percent participation of: climatic types in studied period of years (CTY/N); stress year types in climatic types (SYT/CTY) and stress year types in stress years number (SYT/SY), %**




Considering the local features of habitats, the prevailing adverse climatic types and SPI classes in different locations of black pine were sought. Generally the adverse CW and HD were the main types that led to eustress for almost all of the studied locations. The influence of mildly wet and mildly dry classes is also widespread, but extremely low participation. The adverse influence of other types and classes is highly dependent on local habitat features.

Considering the common climatic influence and the ecological features of black pine as a species, match between the average distribution (for all studied locations) of adverse climatic types and classes was discussed. This mean distribution allows determining the main climatic types, leading to the reduction of growth and therefore the black pine behavior under the climatic impact. The mean distribution of eustress years to different climatic types confirmed that cold - wet and warm - dry types have the predominant negative influence on the growth of black pine.

The comparative analyses between two classifications, of climatic types and SPI classes according to the precipitations, demonstrated that in the overwhelming cases the normal SPI class was obtained in the eustress recorded CTYs. In the studied locations, except two in Greece, extreme or very dry years were occurring very rarely. So we cannot expect high variation in the precipitations in the region of study. In this case applying the classification of climatic types and corresponding adverse years to discuss the stem growth seems to be more proper for estimation of relation between climate and eustress years. than SPI classes.

**Conclusion**

Despite the local differences, the stress impact of dry and wet years, especially if they are accompanied by the cold or hot temperature regimes, is well expressed in the studied 29 locations of black pine in Europe. For the power and manifestation of eustress, the status and the buffer capacity of forest ecosystem are also important factors. The successive changes of climate types at least two years prior to the year of registration of eustress is also relevant. The analyzes illustrated that not all registered eustresses were limited by climate, but it created the ecological background for the operation of other environmental factors and for the biological response (in this case the reduction of the stem radial growth).

The joined application of CTYs and SPI classes allows us to conclude that when there are no large deviations in temperatures or precipitations, the use of climatic types to study the relationship with trees eustress is more applicable. than SPI classes.

The applied holistic approach for the analyzing of relationships between the climatic types and the forest ecosystem functioning is suitable for the monitoring and management of forest areas.

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**Table 2.Percent participation of CTY and SPI classes in the total number of stress years by locations**

| N | Location | CD | CN | CW | ND | NN | NW | HD | HN | HW | Extremely dry | Severely dry | Moderately dry | Mildly dry | normal | Mildly wet | Moderately wet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | | | | | | | | | | | |
| 1 | *Taygetos Forest* | 12.82 | 17.95 | 2.56 | 7.69 | 15.38 | 15.38 | 7.69 | 5.13 | 15.38 | 2.56 | 2.56 | 5.13 | 5.13 | 71.79 | 7.69 | 5.13 |

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| N | Location | CD | CN | CW | ND | NN | NW | HD | HN | HW | Extremely dry | Severely dry | Moderately dry | Mildly dry | normal | Mildly wet | Moderately wet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | | | | | | | | | | | |
| 2 | *Langada (Sparta)* | 17.86 | 17.86 | 10.71 | 14.29 | 3.57 | 10.71 | 3.57 | 10.71 | 10.71 | 0.00 | 0.00 | 0.00 | 7.14 | 82.14 | 7.14 | 3.57 |
| 3 | *Puertollano* | 16.28 | 6.98 | 23.26 | 13.95 | 11.63 | 9.30 | 6.98 | 4.65 | 6.98 | 0.00 | 0.00 | 0.00 | 9.30 | 76.74 | 9.30 | 4.65 |
| 4 | *Canada de la Fuente* | 22.50 | 5.00 | 30.00 | 7.50 | 10.00 | 5.00 | 10.00 | 2.50 | 7.50 | 0.00 | 0.00 | 2.50 | 7.50 | 75.00 | 12.50 | 2.50 |
| 5 | *LasBanas* | 16.67 | 11.90 | 19.05 | 14.29 | 9.52 | 9.52 | 9.52 | 4.76 | 4.76 | 0.00 | 0.00 | 0.00 | 9.52 | 80.95 | 7.14 | 2.38 |
| 6 | *Cuenca - buenavhe* | 6.90 | 10.34 | 20.69 | 13.79 | 0.00 | 3.45 | 20.69 | 20.69 | 3.45 | 0.00 | 0.00 | 3.45 | 3.45 | 82.76 | 6.90 | 3.45 |
| 7 | *Torreton* | 12.24 | 12.24 | 18.37 | 10.20 | 4.08 | 2.04 | 16.33 | 14.29 | 10.20 | 0.00 | 0.00 | 2.04 | 8.16 | 81.63 | 6.12 | 2.04 |
| 8 | *Cuenca - una (Site 1)* | 12.50 | 21.88 | 15.62 | 6.25 | 6.25 | 3.13 | 21.88 | 6.25 | 6.25 | 0.00 | 0.00 | 3.13 | 12.50 | 71.88 | 9.38 | 3.13 |
| 9 | *Cuenca - una (Site 2)* | 11.11 | 19.44 | 16.67 | 11.11 | 5.56 | 0.00 | 19.44 | 8.33 | 8.33 | 0.00 | 0.00 | 2.78 | 5.56 | 80.56 | 5.56 | 5.56 |
| 10 | *Gudar los Roquetas* | 10.00 | 5.00 | 10.00 | 17.50 | 2.50 | 10.00 | 25.00 | 10.00 | 10.00 | 0.00 | 0.00 | 2.50 | 5.00 | 85.00 | 5.00 | 2.50 |
| 11 | *TierraMuerta* | 13.79 | 13.79 | 24.14 | 13.79 | 0.00 | 0.00 | 20.69 | 6.90 | 6.90 | 0.00 | 0.00 | 3.45 | 6.90 | 79.31 | 3.45 | 6.90 |
| 12 | *Scotida Forest, Kastoria* | 14.29 | 17.14 | 8.57 | 5.71 | 8.57 | 5.71 | 11.43 | 5.71 | 22.86 | 2.86 | 0.00 | 2.86 | 8.57 | 74.29 | 8.57 | 2.86 |
| 13 | *Cercelas* | 6.45 | 12.90 | 29.03 | 12.90 | 0.00 | 16.13 | 12.90 | 3.23 | 6.45 | 0.00 | 0.00 | 3.23 | 3.23 | 83.87 | 3.23 | 6.45 |
| 14 | *Penahorcada* | 9.52 | 14.29 | 21.43 | 19.05 | 0.00 | 9.52 | 16.67 | 4.76 | 4.76 | 0.00 | 0.00 | 2.38 | 4.76 | 80.95 | 7.14 | 4.76 |
| 15 | *Gudar villarluengo* | 12.20 | 7.32 | 21.95 | 19.51 | 2.44 | 7.32 | 19.51 | 7.32 | 2.44 | 0.00 | 0.00 | 2.44 | 9.76 | 75.61 | 9.76 | 2.44 |
| 16 | *Gaudarrama* | 16.98 | 11.32 | 16.98 | 16.98 | 3.77 | 5.66 | 16.98 | 5.66 | 5.66 | 0.00 | 1.89 | 1.89 | 7.55 | 75.47 | 9.43 | 3.77 |
| 17 | *Riskopol* | 7.50 | 7.50 | 17.50 | 20.00 | 0.00 | 17.50 | 22.50 | 5.00 | 2.50 | 0.00 | 0.00 | 0.00 | 7.50 | 75.00 | 10.00 | 7.50 |
| 18 | *Tajo* | 13.95 | 11.63 | 23.26 | 11.63 | 4.65 | 4.65 | 13.95 | 4.65 | 11.63 | 0.00 | 0.00 | 0.00 | 6.98 | 79.07 | 9.30 | 4.65 |
| 19 | *Zagradeniye Forest* | 18.75 | 12.50 | 6.25 | 12.50 | 3.13 | 18.75 | 12.50 | 9.38 | 6.25 | 0.00 | 0.00 | 0.00 | 6.25 | 84.38 | 6.25 | 3.13 |
| 20 | *CamosciaraeM. Teamaro* | 10.00 | 5.00 | 27.50 | 2.50 | 7.50 | 2.50 | 17.50 | 15.00 | 12.50 | 0.00 | 0.00 | 2.50 | 5.00 | 80.00 | 12.50 | 0.00 |
| 21 | *Monte Mattone* | 9.68 | 9.68 | 19.35 | 16.13 | 3.23 | 6.45 | 9.68 | 6.45 | 19.35 | 0.00 | 0.00 | 0.00 | 0.00 | 83.87 | 9.68 | 6.45 |
| 22 | *Col de SorbaMt. Renoso* | 12.50 | 6.25 | 9.38 | 21.88 | 3.13 | 18.75 | 9.38 | 6.25 | 12.50 | 0.00 | 0.00 | 0.00 | 6.25 | 78.12 | 12.50 | 3.13 |
| 23 | *Gabra Reserve, VlachinaMount.* | 17.14 | 8.57 | 8.57 | 8.57 | 11.43 | 17.14 | 17.14 | 5.71 | 5.71 | 0.00 | 0.00 | 0.00 | 14.29 | 71.43 | 8.57 | 5.71 |
| 24 | *Vitosha Mount.* | 16.13 | 12.90 | 9.68 | 12.90 | 9.68 | 12.90 | 16.13 | 6.45 | 3.23 | 0.00 | 0.00 | 0.00 | 12.90 | 67.74 | 12.90 | 6.45 |
| 25 | *Berkovitza t., W. Balkans Mount.* | 12.90 | 12.90 | 16.13 | 9.68 | 9.68 | 6.45 | 22.58 | 3.23 | 6.45 | 3.23 | 0.00 | 0.00 | 12.90 | 70.97 | 6.45 | 6.45 |
| 26 | *Ennenda GL Sitenwald* | 20.45 | 6.82 | 18.18 | 4.55 | 4.55 | 15.91 | 18.18 | 9.09 | 2.27 | 0.00 | 0.00 | 0.00 | 11.36 | 77.27 | 9.09 | 2.27 |
| 27 | *Bierhaeuslberg* | 22.45 | 10.20 | 2.04 | 10.20 | 8.16 | 10.20 | 16.33 | 12.24 | 8.16 | 0.00 | 2.04 | 4.08 | 10.20 | 71.43 | 8.16 | 4.08 |
| 28 | *Kammerstain huette* | 23.40 | 8.51 | 2.13 | 10.64 | 8.51 | 8.51 | 14.89 | 12.77 | 10.64 | 0.00 | 0.00 | 4.26 | 8.51 | 70.21 | 12.77 | 4.26 |
| 29 | *Parapluiberg* | 20.83 | 12.50 | 2.08 | 10.42 | 10.42 | 8.33 | 14.58 | 12.50 | 8.33 | 0.00 | 0.00 | 4.17 | 8.33 | 72.92 | 10.42 | 4.17 |
| Mean value | | 14.41 | 11.39 | 15.55 | 12.28 | 5.77 | 9.00 | 15.33 | 7.92 | 8.35 | 0.30 | 0.22 | 1.82 | 7.74 | 77.25 | 8.51 | 4.15 |
| St. Dev. | | 4.75 | 4.47 | 8.24 | 4.80 | 4.19 | 5.61 | 5.29 | 4.18 | 4.86 | 0.90 | 0.68 | 1.69 | 3.22 | 4.91 | 2.64 | 1.78 |
| Error | | 0.88 | 0.83 | 1.53 | 0.89 | 0.78 | 1.04 | 0.98 | 0.78 | 0.90 | 0.17 | 0.13 | 0.31 | 0.60 | 0.91 | 0.49 | 0.33 |
| Student's t | | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| Represent. of mean value | | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |

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