

## ANOVA - Tukey's HSD Test

**Application:** One-way ANOVA – pair-wise comparison of means.

**Requirements:** Model is usually balanced, which means that the sample size in each population should be the same. The samples taken in each population are called **replicates**. Each population is called a **treatment**. (Note: There are methods of approximating this model if the design is not balanced, but we will not cover them.)

**Tests:**  $H_o : \mu_i = \mu_j$     $H_a : \mu_i \neq \mu_j$  where the subscripts  $i$  and  $j$  represent two different populations

**Overall significance** level of  $\alpha$ . This means that **all pairwise tests** can be run at the same time with an overall significance level of  $\alpha$ .

**Test Statistic:** 
$$HSD = q \sqrt{\frac{MSE}{n_c}}$$

$q$  = value from studentized range table.

MSE = Mean Square Error from ANOVA table

$n_c$  = number of replicates per treatment

**Decision:** Reject  $H_o$  if  $|\bar{X}_i - \bar{X}_j| > HSD$

Note: Minitab will group differences into families by assigning letters. Pairs that do not share a common letter are significantly different pairs.

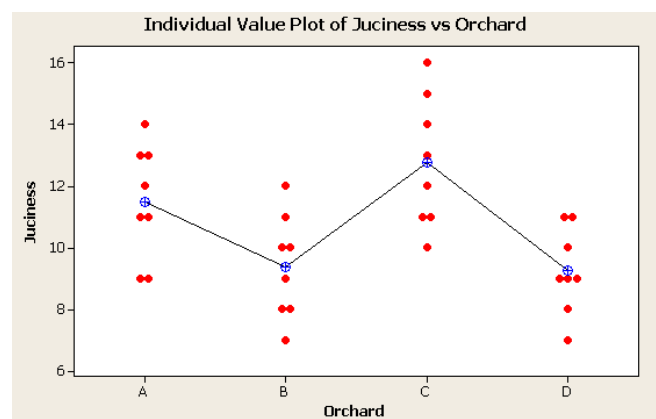
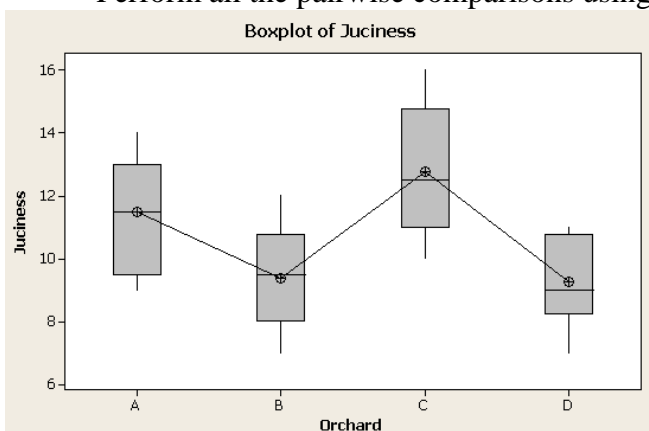
### Example:

Valencia oranges were tested for juiciness at 4 different orchards. Eight oranges were sampled from each orchard, and the total ml of juice per 20 gms of orange was calculated:

<b>Orchard A:</b>	<b>Orchard B:</b>	<b>Orchard C:</b>	<b>Orchard D:</b>
11,13,12,14, 9,13,11,9	10,9,8,10, 11,12,7,8	13,15,14,11, 12,10,16,11	9,7,11,9, 9,11,10,8
SS Total =158.469		SS Between=69.594	

a. Test for a difference in Orchards using alpha = .05

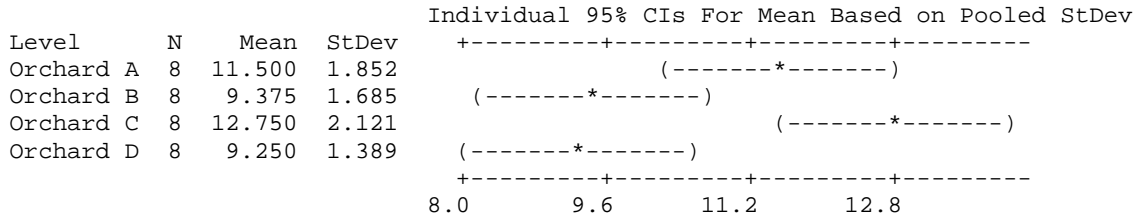
Perform all the pairwise comparisons using Tukey's Test and an overall risk level of 5%.



# One-way ANOVA: Orchard A, Orchard B, Orchard C, Orchard D

Source	DF	SS	MS	F	P
Factor	3	69.59	23.20	7.31	0.001
Error	28	88.88	3.17		
Total	31	158.47			

S = 1.782    R-Sq = 43.92%    R-Sq(adj) = 37.91%



Pooled StDev = 1.782

## Grouping Information Using Tukey Method

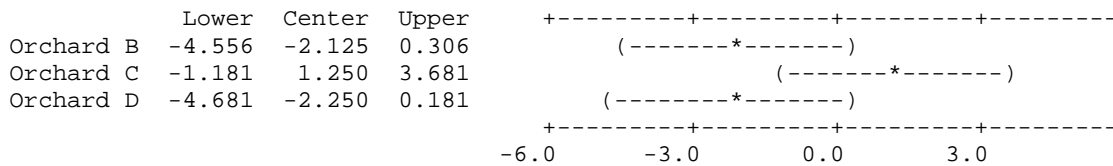
	N	Mean	Grouping
Orchard C	8	12.750	A
Orchard A	8	11.500	A B
Orchard B	8	9.375	B
Orchard D	8	9.250	B

Means that do not share a letter are significantly different.

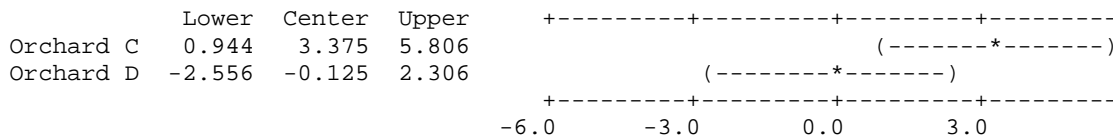
## Tukey 95% Simultaneous Confidence Intervals All Pairwise Comparisons

Individual confidence level = 98.92%

### Orchard A subtracted from:



### Orchard B subtracted from:



### Orchard C subtracted from:

