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Application of Manova on Some Yield Attributing Characters of Groundnut

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A B S T R A C T

In most of the agricultural experiments, data on multiple characters is frequently used. Analysis of variance (ANOVA) technique is employed for assessment of each single character and the best treatment can be identified on the basis of the performance. But more than one or at least two characters cannot be taken into account simultaneously. If it is seen the system as a whole, more than one characters are important to the researcher. In these situations, Multivariate Analysis of Variance (MANOVA) can be helpful. At first, an experiment on groundnut was conducted involving 11 treatment and 3 replication in Randomized Block Design (RBD) setup at District seed farm, Kalyani, BCKV, West Bengal (22.9878^o N, 88.4249^o E). Three characters namely number of pod per plant, dry pod weight per plant, dry pod yield are taken in consideration for analysis. Three separate ANOVAs and a single MANOVA are performed based on three character separately and simultaneously. At 5% level of significance, based on single character number of pod per plant, there have no significant difference within treatments. In case of dry pod weight per plant T5, T6, T3 are statistical at par. Based on single character dry pod yield T4, T3, T5 and T2 are statistical at par. But based on the three character simultaneously, according to the Wilk's Lambda criterion T3 is statistical at par with T2, T4 and T5. For treatment comparison, MANOVA can give better result than ANOVA in presence of multiple characters.

Introduction

In most of the agricultural experiments, data on multiple characters is frequently used. The characters on which the data generally collected for any experiment are the plant height, number of green leaves, germination count, yield values, etc. of the crop under experiment. Analysis of variance (ANOVA) technique is employed for assessment of each single character and the best treatment can be identified on the basis of the performance. More than one ANOVA techniques are used for each of the characters under study and the best treatment is identified for each individual character. But more than one or at least two characters cannot be taken into account simultaneously. There may be one treatment ranking first in case of first character and may not account rank first for another character. If it is seen the system as a whole, both the characters are important to the researcher. Therefore, while analysing the data say for two characters, both of the two characters should also be taken into consideration at a time or in a single method. In these situations, Multivariate Analysis of Variance (MANOVA) can be helpful as it includes more than one character in a single method. Actually, MANOVA is an extension of common analysis of variance (ANOVA). Games (1990) worked on ANOVA and MANOVA as an alternative analysis method for repeater measured designs. Grice (2007) worked on difference in between MANOVA and ANOVA and comprehensible set of methods for explore the multivariate properties of a data set. Schott (2007) also worked on high dimensional tests for one-way MANOVA.

Groundnut is one of the most important oilseed crop in India. It has different yield attributing characters, among them number of pod per plant, dry pod weight per plant, dry pod yield, etc. are important yield attributing characters. Taylor and Whelan (2011) worked on sweet corn for selection of additional data to develop production management units.

Keeping in mind the importance of MANOVA model for analysis of experimental observations in field experiments, an attempt has made in the present piece of study on Groundnut (*Arachis hypogaea*) to apply MANOVA model on three yielding attributing characters of the crop.

Materials and Methods

An experiment was conducted involving 11 treatment and 3 replication in Randomized Block Design (RBD) setup at District seed farm, Kalyani, BCKV, West Bengal (22.9878^o N, 88.4249^o E) under the project AICRP on groundnut (2015-16). Data are collected from Prof. S. Gunri, In-charge, AICRP on groundnut. Three characters namely number of pod per plant, dry pod weight per plant, dry pod yield are considered for analysis. Table-1 represents 11 treatments as the irrigation schedule with different depth of irrigation water. Irrigation given at 15, 30, 40, 50, 65, 80 days after emergence with 20 mm; 30 mm; 40 mm and 50mm depth of irrigation water. In table-1 bold marked depth of irrigations were skipped during different crop growth stages.

ANOVA

The observations can be represented in RBD (Randomised Block Design) by,

$$y_{ij} = \mu + t_i + b_j + e_{ij}; i = 1, 2, ..., v; j = 1, 2, ..., r;$$

where, y_{ij} is the observation due to ith treatment and jth replication; μ is the general mean; t_i is the effect of ith treatment; b_j is the effect of jth replication; e_{ij} is the error component associated with y_{ij} and e_{ij} assumed to be distributed as iid $N_1(0, \sigma_e^2)$.

MANOVA

MANOVA (Multivariate Analysis of Variance) is a generalized form of ANOVA (Univariate Analysis of Variance). It is used to analyse data that involves more than one dependent variable at a time. MANOVA allows us to test hypotheses regarding the effect of one or more independent variables on two or more dependent variables.

Assumption of MANOVA

1. The dependent variable (e.g. grain yield, straw yield) should be normally distributed within each groups.

2. There have linear relationships among all pairs of dependent variables, all pairs of covariates (e.g. between grain and straw yield).
3. Error component should be follows $iidN_p(\underset{\sim}{0}, \underset{\sim}{\Sigma})$.

The observations can be represented in MANOVA with RBD (Randomised Block Design) set up with three characters (p = 3) is,
$\underset{\sim}{y}_{ij} = \underset{\sim}{\mu} + \underset{\sim}{t}_i + \underset{\sim}{b}_j + \underset{\sim}{e}_{ij}; i = 1, 2, ..., v; j = 1, 2, ..., r; p = 1, 2, 3;$

where, $\underset{\sim}{y}_{ij} = (y_{ij1}, y_{ij2}, y_{ij3})'$ is a 3-variate vector of observations due to ith treatment and jth replication; $\underset{\sim}{\mu} = (\mu_1, \mu_2, \mu_3)'$ is a 3x1 vector of general means; $\underset{\sim}{t}_i = (t_{i1}, t_{i2}, t_{i3})'$ are the effect of ith treatment on p-character; $\underset{\sim}{b}_j = (b_{j1}, b_{j2}, b_{j3})'$ are the effect of jth replication on p-characters; $\underset{\sim}{e}_{ij} = (e_{ij1}, e_{ij2}, e_{ij3})'$ is a 3-variate error component associated with $\underset{\sim}{y}_{ij}$ and it assumed to be distributed independently as iid $N_3(\underset{\sim}{0}_3, \underset{\sim}{\Sigma}_{3x3})$ and y_{ijp} is the observation due to ith treatment and jth replication corresponding to pth character.

The null hypothesis is, H_0 : all $\underset{\sim}{t}_i$'s are equal ; i = 1,2,…,v and H_0: all $\underset{\sim}{b}_j$'s are equal ; j = 1,2,…,r ; Against the alternate hypothesis is, H_1: at least one $\underset{\sim}{t}_i$ not equal to 0 ; i = 1,2,…,v and H_1: at least one $\underset{\sim}{b}_j$ not equal to 0; j = 1,2,…,r

Let, $\bar{y}_{i.1} = \frac{1}{r}\sum_{j=1}^{r} y_{ij1}$; $\bar{y}_{i.2} = \frac{1}{r}\sum_{j=1}^{r} y_{ij2}$; $\bar{y}_{i.3} = \frac{1}{r}\sum_{j=1}^{r} y_{ij3}$ $\bar{y}_{.j1} = \frac{1}{v}\sum_{i=1}^{v} y_{ij1}$; $\bar{y}_{.j2} = \frac{1}{v}\sum_{i=1}^{v} y_{ij2}$; $\bar{y}_{.j3} = \frac{1}{v}\sum_{i=1}^{v} y_{ij3}$; $\bar{y}_{..1} = \frac{1}{vr}\sum_{i=1}^{v}\sum_{j=1}^{r} y_{ij1}$; $\bar{y}_{..2} = \frac{1}{vr}\sum_{i=1}^{v}\sum_{j=1}^{r} y_{ij2}$; $\bar{y}_{..3} = \frac{1}{vr}\sum_{i=1}^{v}\sum_{j=1}^{r} y_{ij3}$

Table-2 represents MANOVA's source of variation, corresponding degree of freedom (d.f.) and SSCPM (Sum of Squares and Cross Product Matrix). Here, $\underset{\sim}{H}, \underset{\sim}{B}, \underset{\sim}{R}, \underset{\sim}{T}$ are 3x3 matrixes $(\because p = 3)$ (. MANOVA can be used when the rank of $\underset{\sim}{R}$ matrix should not be smaller than character-p or in the other words error degrees of freedom e should be greater than or equal to p $(e \geq p)$.

Multivariate treatment contrast analysis

If treatments are found to be significantly differ in MANOVA, then multivariate treatment contrast analysis can be carried out to identify which treatments are significantly differ. Let the null hypothesis is, $H_0 : \underset{\sim}{t}_i = \underset{\sim}{t}_{i'}$ against the alternate hypothesis is, $H_1 : \underset{\sim}{t}_i \neq \underset{\sim}{t}_{i'}; i \neq i' = 1, ..., v$. Here, Pillai's Trace $(V^{(s)})$, Wilk's Lambda statistics (Λ), Lawley-Hotelling Trace (T_g^2) and Roy's Largest Root $(\phi_{\max})$ are used to test the null hypothesis.

Pillai's Trace $(V^{(s)})$

Let, θ_i is the eigenvalue of $\underset{\sim}{H}(\underset{\sim}{R} + \underset{\sim}{H})^{-1}$ matrix. The Pillai's trace statistics $(V^{(s)})$ defined by,

$$(V^{(s)}) = \sum_{i=1}^{s} \theta_i$$

Here,

$$\frac{(2n+s+1)V^{(s)}}{(2m+s+1)(s-V^{(s)})} \sim F_{(s(2m+s+1),s(2n+s+1));};$$

where,

$$s=\min(p,h); m=\frac{|p-h|-1}{2}; n=\frac{e-p-1}{2}.$$

If calculated value of $\frac{(2n+s+1)V^{(s)}}{(2m+s+1)(s-V^{(s)})} > F_{\alpha,(s(2m+s+1),s(2n+s+1));}$ then H_0 is rejected at α % level of significance, Otherwise it is accepted.

Wilk's Lambda statistics (Λ)

The Wilk's Lambda statistics (Λ) is defined by,

$$\Lambda = \frac{|\underset{\sim}{R}|}{|\underset{\sim}{H}+\underset{\sim}{R}|};$$

For any p and h, $\frac{(1-\Lambda^{1/b})(ab-c)}{ph\Lambda^{1/b}} \sim F_{(ph,ab-c)};$

where, $|\underset{\sim}{R}|$ and $|\underset{\sim}{R}+\underset{\sim}{H}|$ represent the determinant value of matrix $\underset{\sim}{R}$ and $(\underset{\sim}{R}+\underset{\sim}{H})$ respectively;

$$a=e-\frac{p-h+1}{2}; b=\sqrt{\frac{p^2h^2-4}{p^2+h^2-5}}; c=\frac{ph-2}{2};$$

If calculated value of $\frac{(1-\Lambda^{1/b})(ab-c)}{ph\Lambda^{1/b}} > F_{\alpha,(ph,ab-c)};$ then H_0 is rejected at α% level of significance, Otherwise it is accepted.

Lawley-Hotelling Trace (T_g^2)

Let, ϕ_i is the eigenvalue of $\underset{\sim}{H}\underset{\sim}{R}^{-1}$ matrix. The Lawley-Hotelling trace statistics (T_g^2) is defined by, $T_g^2 = e\sum_{i=1}^{s}\phi_i$; Here, $\frac{T_g^2}{ce} \sim F_{(a,b)}$; where,

$$s=\min(p,h); a=ph; b=4+\frac{a+2}{B-1}; c=\frac{a(b-2)}{b(e-p-1)}; B=\frac{(e+h-p-1)(e-1)}{(e-p-3)(e-p)};$$

If calculated value of $\frac{T_g^2}{ce} > F_{\alpha,(a,b)}$ then H_0 is rejected at α % level of significance, Otherwise it is accepted.

Roy's Largest Root $(\phi_{\max})$

Let, ϕ_i is the eigenvalue of $\underset{\sim}{H}\underset{\sim}{R}^{-1}$ matrix and Roy's largest root $(\phi_{\max})$ is defined by the largest value in the ϕ_i's. Here,

$$\frac{2v_2+2}{2v_1+2}\phi_{\max} \sim F_{(2v_1+2,2v_2+2)};$$

where,

$$s=\min(p,h); v_1=\frac{|p-h|-1}{2}; v_2=\frac{e-p-1}{2};$$

If calculated value of $\frac{2v_2+2}{2v_1+2}\phi_{\max} > F_{\alpha,(2v_1+2,2v_2+2)}$ then H_0 is rejected at α % level of significance, Otherwise it is accepted.

Wilk's Lambda Criterion (Λ^*)

Suppose the null hypothesis is, $H_0 : \underset{\sim}{t_i} = \underset{\sim}{t_{i'}}$, against the alternate hypothesis is, $H_1 : \underset{\sim}{t_i} \neq \underset{\sim}{t_{i'}}; i \neq i' = 1, 2, ..., v$. For testing the null hypothesis for each pair of treatment, we have to calculate another SSCPM. Let, this SSCPM is denoted by $\underset{\sim}{G}_{pxp}$. The diagonal elements of the matrix is obtained by, $g_{kk} = \left(\frac{r}{2}\right)(\bar{y}_{ik} - \bar{y}_{i'k})^2$ and off diagonal elements are obtained by,

$$g_{kk'} = \left(\frac{r}{2}\right)(\bar{y}_{ik} - \bar{y}_{i'k})(\bar{y}_{ik'} - \bar{y}_{i'k'}); k = 1, 2, 3; i \neq i' = 1, 2, ..., v$$

Then the Wilk's Lambda (Λ^*) is defined by,

$\Lambda^* = \frac{|\underset{\sim}{R}|}{|\underset{\sim}{G} + \underset{\sim}{R}|}$. Where, $|\underset{\sim}{R}|$ and $|\underset{\sim}{G} + \underset{\sim}{R}|$ represent the determinant value of matrix $\underset{\sim}{R}$ and $(\underset{\sim}{G} + \underset{\sim}{R})$ respectively. Here, $\frac{(1-\Lambda^*)(e-p+1)}{p\Lambda^*} \sim F_{(p,e-p+1)}$. If calculated value of $\frac{(1-\Lambda^*)(e-p+1)}{p\Lambda^*} > F_{\alpha,(p,e-p+1)}$, then H_0 is rejected at α % level of significance, Otherwise it is accepted. If this is not significant then two treatments for which Λ^* is calculated, are statistical at par. For Compare in between each pair of treatments [(1,2), (1,3),…,(1,v),(2,3),…,(2,v),… (v-1,v)], each time we have to calculate new $\underset{\sim}{G}_{3x3}$ matrix. In case of v number of treatments, we have to calculate $\frac{v(v-1)}{2}$ numbers of $\underset{\sim}{G}_{3x3}$ matrixes and Λ^*.

Results and Discussion

Here, table-3 represents ANOVA table for the character number of pod per plant. For the replication effect there have significant difference at 5% level of significance but for the treatment effect there have no significant difference at 5% level of significance. Table-4 represents treatment means for the character number of pod per plant. Due to non-significance of treatment effect, there have no grouping for the character number of pod per plant.

Here, table-5 represents ANOVA table for the character dry pod weight per plant. Replication effect and treatment effect both are significant 5% level of significance and null hypothesis is rejected. Table-6 represents treatment means and grouping for the character dry pod weight per plant. For the character dry pod weight per plant 4 number of groups are identified. T5 is the best treatment and it statistical at per with T6 and T3. T10 is the worse treatment.

Here, table-7 represents ANOVA table for the character dry pod yield. For the replication effect there have non-significant difference at 5% level of significance but for the treatment effect there have significant difference at 5% level of significance. Table-8 represents treatment means and grouping for the character dry pod yield. For the character dry pod yield, 5 number of groups are identified. Based on this character T4 is the best treatment and it statistical at par with T3, T5 and T2. T9 is the worse treatment.

Table-9 represents MANOVA. $\underset{\sim}{H}, \underset{\sim}{B}, \underset{\sim}{R}, \underset{\sim}{T}$ all are 3x3 matrices denoted by bold characters. Table-10 represents MANOVA test criteria and F approximations for the hypothesis of no overall treatment effect.

Table.1 Treatments representing the irrigation schedule and different depth of irrigation water

Treatment	Irrigation days after emergence					
	15 DAE	30 DAE	40 DAE	50 DAE	65 DAE	80 DAE
T1	20	20	20	20	20	20
T2	30	30	30	30	30	30
T3	40	40	40	40	40	40
T4	50	50	50	50	50	50
T5	20	20	30	30	40	40
T6	**20**	20	30	30	40	40
T7	20	**20**	30	30	40	40
T8	20	20	**30**	30	40	40
T9	20	20	30	**30**	40	40
T10	20	20	30	30	**40**	40
T11	20	20	30	30	40	**40**

Table.2 MANOVA

Source of variation	d.f.	SSCPM (Sum of Squares and Cross Product Matrix)
Treatment	v-1 = h	$\underset{\sim}{H} = r\sum_{i=1}^{v}\begin{pmatrix}\bar{y}_{i.1}-\bar{y}_{..1}\\ \bar{y}_{i.2}-\bar{y}_{..2}\\ \bar{y}_{i.3}-\bar{y}_{..3}\end{pmatrix}\begin{pmatrix}\bar{y}_{i.1}-\bar{y}_{..1} & \bar{y}_{i.2}-\bar{y}_{..2} & \bar{y}_{i.3}-\bar{y}_{..3}\end{pmatrix}$
Replication	r-1 = t	$\underset{\sim}{B} = v\sum_{j=1}^{r}\begin{pmatrix}\bar{y}_{.j1}-\bar{y}_{..1}\\ \bar{y}_{.j2}-\bar{y}_{..2}\\ \bar{y}_{.j3}-\bar{y}_{..3}\end{pmatrix}\begin{pmatrix}\bar{y}_{.j1}-\bar{y}_{..1} & \bar{y}_{.j2}-\bar{y}_{..2} & \bar{y}_{.j3}-\bar{y}_{..3}\end{pmatrix}$
Error	(v-1) (r-1) = e	$\underset{\sim}{R} = \sum_{i=1}^{v}\sum_{j=1}^{r}\begin{pmatrix}y_{ij1}-\bar{y}_{i.1}-\bar{y}_{.j1}+\bar{y}_{..1}\\ y_{ij2}-\bar{y}_{i.2}-\bar{y}_{.j2}+\bar{y}_{..2}\\ y_{ij3}-\bar{y}_{i.3}-\bar{y}_{.j3}+\bar{y}_{..3}\end{pmatrix}x$ $\begin{pmatrix}y_{ij1}-\bar{y}_{i.1}-\bar{y}_{.j1}+\bar{y}_{..1} & y_{ij2}-\bar{y}_{i.2}-\bar{y}_{.j2}+\bar{y}_{..2} & y_{ij3}-\bar{y}_{i.3}-\bar{y}_{.j3}+\bar{y}_{..3}\end{pmatrix}$
Total	vr-1	$\underset{\sim}{T} = \sum_{i=1}^{v}\sum_{j=1}^{r}\begin{pmatrix}y_{ij1}-\bar{y}_{..1}\\ y_{ij2}-\bar{y}_{..2}\\ y_{ij3}-\bar{y}_{..3}\end{pmatrix}\begin{pmatrix}y_{ij1}-\bar{y}_{..1} & y_{ij2}-\bar{y}_{..2} & y_{ij3}-\bar{y}_{..3}\end{pmatrix} = \underset{\sim}{H}+\underset{\sim}{B}+\underset{\sim}{R}$

Table.3 ANOVA for the character number of pod per plant

Source of variation	d.f.	Sum of Squares	Mean Square	Calculated F value	Sig. (Pr.>F)
Replication	2	75.975	37.988	7.19	0.004
Treatment	10	104.783	10.478	1.983	0.092
Error	20	105.672	5.284		
Total	32	286.43			

Table.4 Treatment means for the character number of pod per plant

Treatment	Mean
T5	40.700
T6	36.100
T3	36.067
T1	34.067
T4	33.267
T2	32.900
T7	32.300
T8	29.867
T11	29.700
T9	29.367
T10	27.467

Table.5 ANOVA for the character dry pod weight per plant

Source of variation	d.f.	Sum of Squares	Mean Square	Calculated F value	Sig. (Pr.>F)
Replication	2	12661.31	6330.655	591.459	0.000
Treatment	10	433.227	43.323	4.048	0.004
Error	20	214.069	10.703		
Total	32	13308.61			

Table.6 Treatment means and grouping for the character dry pod weight per plant

Treatment	Mean	Grouping		
T5	40.700	A		
T6	36.100	A	B	
T3	36.067	A	B	
T1	34.067	B	C	
T4	33.267	B	C	D
T2	32.900	B	C	D
T7	32.300	B	C	D
T8	29.867	B	C	D
T11	29.700	C	D	
T9	29.367	C	D	
T10	27.467	D		

Table.7 ANOVA for the character dry pod yield

Source of variation	d.f.	Sum of Squares	Mean Square	Calculated F value	Sig. (Pr.>F)
Replication	2	126678.727	63339.364	2.567	0.102
Treatment	10	4690474.909	469047.491	19.013	0.000
Error	20	493403.273	24670.164		
Total	32	5310556.909			

Table.8 Treatment means and grouping for the character dry pod yield

Treatment	Mean	Grouping		
T4	4205	A		
T3	4189	A		
T5	4133	A	B	
T2	3937	A	B	C
T11	3896	B	C	D
T6	3789	C	D	
T7	3678	C	D	
T1	3611	D		
T10	3302	E		
T8	3189	E		
T9	3099	E		

Table.9 MANOVA

Source	d.f.	SSCPM (Sum of Squares and Cross Product Matrix)
Treatment	10	$H = \begin{pmatrix} 104.783 & 198.711 & 16076.418 \\ 198.711 & 433.227 & 31551.145 \\ 16076.418 & 31551.145 & 4690474.909 \end{pmatrix}$
Replication	2	$\mathbf{B} = \begin{pmatrix} 75.975 & 906.577 & 1267.800 \\ 906.577 & 12661.311 & 29075.664 \\ 1267.800 & 29075.664 & 126678.727 \end{pmatrix}$
Error	20	$\mathbf{R} = \begin{pmatrix} 105.672 & 79.173 & 146.500 \\ 79.173 & 214.069 & -2583.364 \\ 146.500 & -2583.364 & 493403.273 \end{pmatrix}$
Total	32	$\mathbf{T} = \begin{pmatrix} 286.430 & 1184.461 & 17490.718 \\ 1184.461 & 13308.607 & 58043.445 \\ 17490.718 & 58043.445 & 5310556.909 \end{pmatrix}$

Table.10 MANOVA test criteria and F approximations for the hypothesis of no overall treatment effect

Effect	Test criteria	Statistic value	F-table value	Sig. (Pr.>F)
Treatment	Pillai's Trace	1.519	2.051	0.009
	Wilks' Lambda	0.033	3.909	0.000
	Lawley-Hotelling's Trace	14.297	7.943	0.000
	Roy's Largest Root	13.325	26.651	0.000

Table.11 Wilk's Lambda criterion statistics (Λ^*) for all possible treatment pair comparison

Treatment	1	2	3	4	5	6	7	8	9	10	11
1											
2	0.754										
3	0.454	0.744									
4	0.472	0.797	0.940								
5	0.400	0.580	0.857	0.719							
6	0.850	0.882	0.652	0.653	0.600						
7	0.971	0.808	0.475	0.513	0.399	0.842					
8	0.533	0.325	0.198	0.210	0.177	0.353	0.511				
9	0.436	0.272	0.171	0.180	0.153	0.292	0.417	0.954			
10	0.556	0.356	0.212	0.232	0.185	0.376	0.563	0.901	0.800		
11	0.758	0.900	0.575	0.670	0.436	0.775	0.858	0.372	0.308	0.437	

Table.12 Probability of significance (Pr. > F) of all possible treatment pair comparison using Wilk's Lambda criterion statistics (Λ^*)

Treatment	1	2	3	4	5	6	7	8	9	10	11
1											
2	**0.157**										
3	0.002	**0.141**									
4	0.003	**0.240**	**0.767**								
5	0.001	0.018	**0.414**	**0.108**							
6	**0.392**	**0.510**	0.048	0.049	0.024						
7	**0.909**	**0.269**	0.003	0.006	0.001	**0.364**					
8	0.009	0.000	0.000	0.000	0.000	0.000	0.006				
9	0.002	0.000	0.000	0.000	0.000	0.000	0.001	**0.831**			
10	0.013	0.000	0.000	0.000	0.000	0.000	0.014	**0.588**	**0.248**		
11	**0.163**	**0.584**	0.017	**0.061**	0.002	**0.195**	**0.419**	0.000	0.000	0.002	

Table-11 represents Wilk's Lambda criterion statistics (Λ^*) for for all possible treatment pair comparison (55 treatment pairs) and table-12 represents probability of significance (Pr. > F) of all possible paired treatment comparison using Wilk's Lambda criterion statistics (Λ^*) Here, bold numbers are represents the treatment pairs those are not significantly differ at 5% level of significance.

Based on single character number of pod per plant, there have no significant difference within treatments at 5% level of significance. But comparison using single character dry pod weight per plant, treatments T5, T6, T3 are statistical at par and all of those are best treatment. Based on single character dry pod yield, treatments T4, T3, T5 and T2 are statistical at par. But based on the three character simultaneously, according to the Wilk's Lambda criterion T3 is statistical at par with T2, T4 and T5. So, it can be concluded that, for treatment comparison, MANOVA can give better result than ANOVA in presence of multiple characters.

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