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Study on Character Association and Deciphering the Direct and Indirect Effects thorough Path Coefficient Analysis in Cucumber

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Authors' contributions

This work was carried out in collaboration among all authors. Author IHR did the preparation of the manuscript and field experiment. Author RM did the guidance to conduct the research work. Author SSC did the data analysis. Author SE did the helped in the conduct of experiment. Author RKM did the overall execution of the experiment in field. Author RH did the helped in the conduct of experiment. Author YKKH did the assisted in the preparation of manuscript. Author CK did the assisted in the field experiment All authors read and approved the final manuscript.

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ABSTRACT

Important information on the mutual association between the traits is of para amount importance for the successful plant-breeding program. Fifty-five cucumber genotypes were evaluated during 2022 at College of Horticulture, Bagalkot, Karnataka in RCBD to evaluate the association between traits further to determine the direct and indirect effects. The results of correlation estimation implied that yield/plot observed significant desiarble correlation with No. of branches/plant, last harvest duration, fruit length, No. of fruits/plant and fruit yield/plant at genotypic level. No. of branches/plant, inter-nodal length, No. of nodes/plant, days taken to first harvest, fruit length, No. of fruits/vine and fruit yield/vine showed desirable direct effect on yield/plot at genotypic level. The present study suggested that selection ideology based on these parameters will be effective for improving yield/plot trait in cucumber.

Keywords: Cucumber; correlation; genotypic; path coefficient.

1. INTRODUCTION

Cucumis sativus L. is one of the major cucurbitaceous vegetable crops from nutritional and economic view point. It is mainly grown for its fresh market (slicing) and pickling types. Immature fruits of cucumber used as pickles, salad, brined and even dessert fruit on commercial scale round the world [1]. Currently, in India it is taken up in a vast area of 1,19,000 hectares with a production of 1,694 thousand tonnes and productivity of 14.23 tonnes/hectare [2].

Variability studies throw light on the areas of different traits improvement, On the other hand, it doesn't offer details about the kind and degree of relationships that exist between different factors. Therefore, selection for yield is necessary for a logical method to increasing yield, as genes may only exist for different yield components rather than for yield mean performance. Genetic correlations between two parameters result from linkage, which is a functional relationship generated by development (Harland, 1939). Thus, correlation study has major importance and could be effectively utilized in formulating an effective selection procedure.

Till date, research on correlation of traits in cucumber have been studied majorly in Northern India; but there is a lacuna in suggesting scientific information on character association in cucumber spatially and temporally. Keeping these problems, this research project was initiated using fifty-five genotypes of cucumber collected from various geographical regions of India to assess the relationship between yield and yield components and to determine the direct and indirect effects of different yield-related parameters on yield per plot of cucumber.

2. MATERIALS AND METHODS

Research was experimented at the experimental block of Vegetable Science department, College of Horticulture, Bagalkot, Karnataka, India. This investigation comprised of fifty-five cucumber genotypes which were collected from different regions of India. The details of material used in the experiment is presented in Supplementary Table 1. The experiment was laid out during the summer season (March) of 2022 at Vegetable Science experimental block, College of Horticulture, Bagalkot. During February, 2022. n square of 12 charact.

Totally eighteen traits were evaluated *viz*., vine length at final harvest (cm), No. of branches /plant, inter-nodal length (cm), No. of nodes/plant, nodes up to first female flower appearance, days taken to first female and male flower, days to first picking, days to last picking, sex ratio (M/F), fruit length and diameter (cm), flesh thickness (mm), total soluble solids (˚B), No. of fruits /plant, fruit weight (g), yield/vine (kg) and yield per plot (kg).

According to the procedure formulated by Al-Jibouri et al*.* [3], correlation coefficients among all the possible parameter combination were estimated at rg (genotypic level). Dewey and Lu [4] general formula was followed for working out the path coefficient analysis. The above mentioned statistical analysis was performed by R software version R.4.2.2 using corr and corrplot packages [5].

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance (ANOVA)

The statistical analysis showed the significant differences at $p \leq 0.01$ among the germplasm for all the traits studied in the experiment, thereby implying the presence of sufficient variability which provides ample opportunity for future cucumber crop improvement programs. The similar works were conducted by Kumar et al. [6], Shet et al. [7], Sharma et al . [8] and Deepa et al. [9] in their work on cucumber.

3.2 Correlation between Yield and Yield-related Traits

The outcome of correlation estimates implied that the yield per plot had desirable *i.e.,* significantly positive correlation with No. of branches/vine, days to final harvest, fruit length, No. of fruits/vine and fruit yield/vine at genotypic (Fig. 1 and Supplementary Table 2). This showed that yield/plot increases with No. of branches/plant, as the harvest duration increases yield per plot increases and it is positively linked with yield associated traits like No. of fruits/plant, fruit length and yield/vine. Kumar et al. [6] concluded that at genotypic level yield/plot had positive correlation with days to final harvest, fruit length, No. of fruits/plant and fruit yield/plant and current experiment revealed the negative significant association with length of vine, inter-nodal length, No. of nodes/plant, TSS and average fruit weight and yield per plot revealed negative significant correlation with No. of nodes /plant, nodes to first female flower appearance, days to first male flower and female flower, days to first picking, sex ratio, fruit diameter and flesh thickness. Similar trend of negative significant correlation of fruit yield with days to first female flower appearance as concluded by Hossain et al. [10], earliness parameters negative correlation *i.e.,* days to first pistillate flower appearance with reduction yield as study conducted by Ananthan and Pappiah [11].

Fruit yield/vine was found significant positive correlation with No. of branches /vine, days to last harvest, TSS, fruit length and No. of fruits/vine at genotypic level. Shet et al. [7] revealed that fruit length and No. of fruits/vine had positive highly significant correlation with fruit yield /vine.

Number of nodes/vine was negatively correlated with appearance of first male and female flower and days taken to first fruit picking, which clearly shows that the former trait was would delay earliness parameters. Padmaja [12], Kumar et al. [13]; Hanchinamani and Patil [14] concluded similar suggestions regarding the above mentioned parameters in cucumber. Current study concluded that the selection based on No. of branches /plant, days to last harvest, fruit length, No. of fruits/plant and fruit yield/plant could be more efficient to maximize yield per plot of cucumber.

3.3 Path Coefficient Analysis

Genotypic level path coefficient analysis of the present study is given in Table 1. The following are the 11 parameters which exhibited positive direct effect on yield per plot *viz.,* No. of nodes /plant, days to first harvest, No. of branches /plant, fruit length, internodal length, No. of fruits /plant, days to first male flower, fruit diameter, average fruit weight, nodes to first female flower and fruit yield/ plant. Sharma et al. [8] concluded positive direct effect of fruit length, average fruit weight, days to marketable maturity, No. of marketable fruits/plant and fruit breadth on fruit yield per plot. Although, days to last harvest exhibited significant positive correlation on yield per plot, it showed negative direct effect on yield per plot, which indicates the indirect effects to be the cause of correlation at both genotypic level.

Maximum positive indirect effects on yield/plant were seen in days to first appearance of female flower and male flower followed by nodes to which first female flower appeared through days to first harvest at genotypic level which indicated the parameter consideration of these parameters during selection. Besides other characters which exhibited positive direct effect on yield per plot may be more effective for further yield related improvement of cucumber. Residual effects of 0.0374 at genotypic level implied that characters considered in the path analysis explained 92.1% of the variability in yield per plot at genetic level which shows the minimum error in choosing the traits.

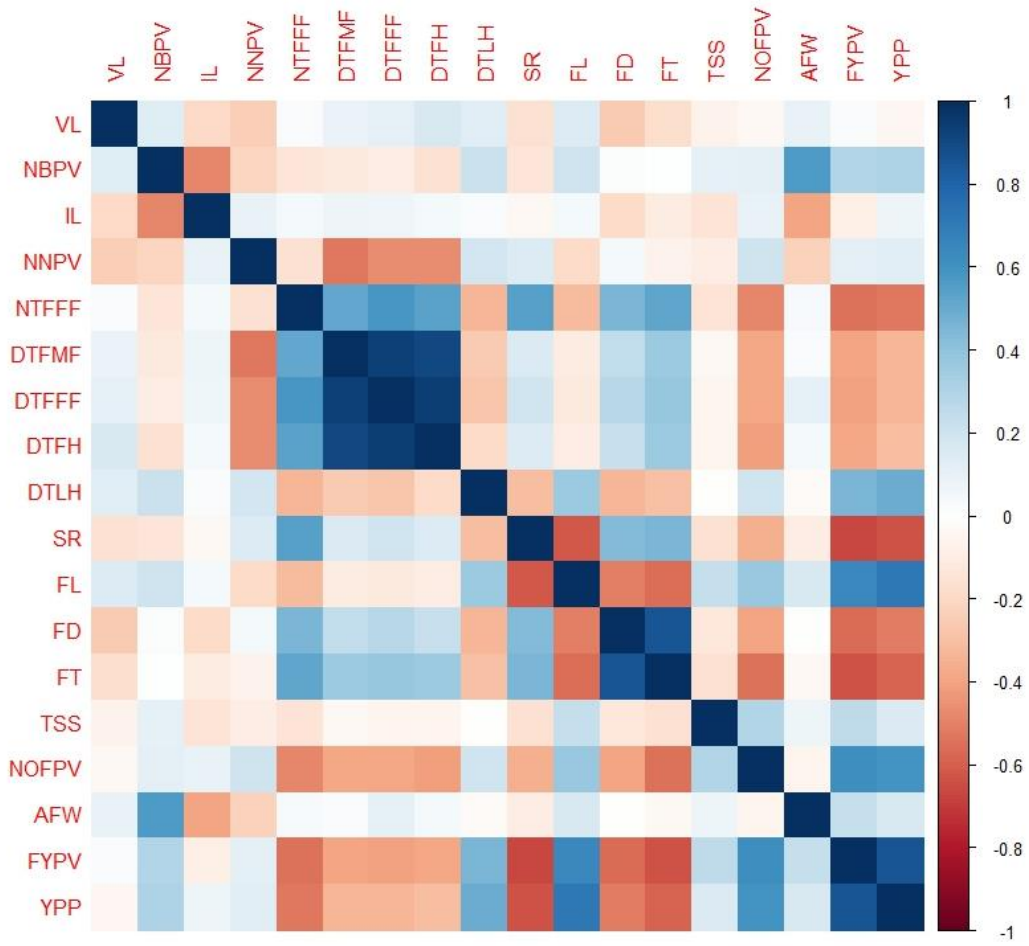

Fig. 1. Heat map of the genotypic correlation coefficients for 18 parameters in cucumber

VL= Vine Length at last harvest (cm), NBPV= No. of Branches /plant, IL = Internodal Length, NNPV= No. of Nodes /plant, NTFFF= Nodes to First Female Flower, DTFMF = Days to First Male Flower, DTFFF = Days to First Female Flower, DTFH = Days to First Harvest, DTLH = Days to Last Harvest, SR = Sex Ratio, FL = Fruit Length, FD = Fruit Diameter, FT = Flesh Thickness, NOFPV = No. of Fruits /plant, AFW = Average Fruit Weight, FYPV = Fruit Yield/plant and YPP = Yield Per Plot.

Table 1. Estimate of direct (bold face) and indirect effects at genotypic level for cucumber

	VL	NBPV	IL	NNPV	NTFFF	DTFMF	DTFFF	DTFH	DTLH	SR	FL	FD	FT	TSS	NOFPV	AFW	FYPV	Residual
VL	**-0.1063**	0.0265	-0.0253	-0.0258	-0.0027	-0.0067	-0.0112	0.0477	0.0039	0.0062	0.0446	0.0037	-0.0024	0.0052	-0.0046	-0.0010	0.0122	0.1351
NBPV	-0.0143	**0.1968**	-0.0642	-0.0232	0.0132	0.0093	0.0107	-0.0441	0.0063	0.0058	0.0573	-0.0002	0.0000	-0.0094	0.0137	-0.0064	0.1546	
IL	0.0205	-0.0964	**0.1310**	0.0101	-0.0034	-0.0059	-0.0062	0.0112	0.0005	0.0016	0.0122	0.0028	-0.0015	0.0132	0.0122	0.0044	-0.0407	
NNPV	0.0258	-0.0429	0.0125	**0.1065**	0.0150	0.0412	0.0503	-0.1314	0.0053	-0.0059	-0.0551	-0.0007	-0.0008	0.0082	0.0257	0.0025	0.0620	
NTFFF	-0.0031	-0.0281	0.0049	-0.0173	**-0.0923**	-0.0404	-0.0617	0.1466	-0.0101	-0.0229	-0.0946	-0.0068	0.0072	0.0127	-0.0586	-0.0004	-0.2805	
DTFMF	-0.0091	-0.0235	0.0099	-0.0561	-0.0476	**-0.0782**	-0.0992	0.2529	-0.0076	-0.0065	-0.0306	-0.0035	0.0050	0.0033	-0.0470	-0.0004	-0.2028	
DTFFF	-0.0112	-0.0198	0.0077	-0.0505	-0.0537	-0.0731	**-0.1061**	0.2619	-0.0082	-0.0083	-0.0349	-0.0041	0.0052	0.0048	-0.0460	-0.0012	-0.2066	
DTFH	-0.0182	-0.0312	0.0053	-0.0504	-0.0487	-0.0711	-0.1000	**0.2779**	-0.0057	-0.0058	-0.0305	-0.0033	0.0051	0.0047	-0.0501	-0.0006	-0.1961	
DTLH	-0.0141	0.0423	0.0023	0.0195	0.0318	0.0202	0.0296	-0.0542	**0.0293**	0.0132	0.1019	0.0052	-0.0040	0.0007	0.0236	0.0002	0.2391	
SR	0.0156	-0.0269	-0.0048	0.0147	-0.0498	-0.0119	-0.0207	0.0383	-0.0091	**-0.0424**	-0.1788	-0.0064	0.0062	0.0141	-0.0426	0.0011	-0.3452	
FL	-0.0166	0.0394	0.0056	-0.0205	0.0305	0.0084	0.0129	-0.0297	0.0104	0.0265	**0.2860**	0.0077	-0.0075	-0.0199	0.0462	-0.0019	0.3390	
FD	0.0265	0.0032	-0.0247	0.0047	-0.0420	-0.0186	-0.0290	0.0619	-0.0102	-0.0181	-0.1480	**-0.0148**	0.0116	0.0110	-0.0473	0.0000	-0.2926	
FT	0.0189	0.0006	-0.0142	-0.0066	-0.0490	-0.0290	-0.0408	0.1041	-0.0086	-0.0194	-0.1581	-0.0127	**0.0135**	0.0138	-0.0660	0.0004	-0.3283	
TSS	0.0064	0.0211	-0.0198	-0.0100	0.0134	0.0030	0.0058	-0.0149	-0.0003	0.0068	0.0654	0.0019	-0.0021	**-0.0872**	0.0354	-0.0008	0.1331	
NOFPV	0.0041	0.0222	0.0132	0.0226	0.0446	0.0304	0.0403	-0.1151	0.0057	0.0149	0.1092	0.0058	-0.0074	-0.0255	**0.1210**	0.0006	0.3186	
AFW	-0.0098	0.1125	-0.0513	-0.0233	-0.0035	-0.0025	-0.0117	0.0142	-0.0005	0.0041	0.0490	0.0000	-0.0005	-0.0064	-0.0067	**-0.0112**	0.1183	
FYPV	-0.0025	0.0589	-0.0103	0.0128	0.0501	0.0307	0.0424	-0.1055	0.0135	0.0283	0.1877	0.0084	-0.0086	-0.0225	0.0747	-0.0026	**0.5171**	

VL= Vine Length at last harvest (cm), NBPV= No. of Branches /plant, IL = Internodal Length, NNPV= No. of Nodes /plant, NTFFF= Nodes to First Female Flower, DTFMF = Days to First Male Flower, DTFFF = Days to First Female Flower, DTFH = Days to First Harvest, DTLH = Days to Last Harvest, SR = Sex Ratio, FL = Fruit Length, FD = Fruit Diameter, FT = Flesh Thickness, NOFPV = No. of Fruits /plant, AFW = Average Fruit Weight, FYPV = Fruit Yield/plant and YPP = Yield Per Plot

4. CONCLUSION

Scientific knowhow about the inter-connection of growth, earliness and yield related parameters are of prime importance for successful crop breeding programme. Correlation estimates exhibited that yield per plot showed positive significant correlation with no. of branches/plant, days to last harvest, fruit length, No. of fruits/plant and fruit yield/plant at genotypic level. Further, these traits should be noted as important selection criteria in cucumber crop improvement programme for better yield. No. of branches /plant, internodal length, No. of nodes /plant, days to first harvest, fruit length, No. of fruits/plant and fruit yield/plant showed positive direct effect on yield per plot at genotypic level. Whereas, traits like No. of branches /plant, days to first male flower, days to first harvest, fruit length and fruit yield/plant contributed maximum on yield per plot at genotypic level. Present study suggested that selection criteria based on these parameters may be effective to improve the yield in cucumber.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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SUPPLEMENTARY MATERIALS

Supplementary 1. Genetic stock of cucumber used for variability and divergence studies

SL. NO.	Genotypes	Source of collection	SL. NO.	Genotypes	Source of collection
1	V-8	KRCCH, Arabhavi	29	Punjab Naveen	PAU, Ludhiana
2	V-12	KRCCH, Arabhavi	30	K-75	Dr Y S Parmar UHF, Solan, HP
3	V-5	KRCCH, Arabhavi	31	Sarpan Hybrid-30	Sarpan Seeds Pvt. Ltd.
4	V-1	KRCCH, Arabhavi	32	Anusha	Chiguru Seeds Pvt. Ltd.
5	V-10	KRCCH, Arabhavi	33	NBPGR-14	NBPGR, New Delhi
6	V-2	KRCCH, Arabhavi	34	Poinsette	NBPGR, New Delhi
7	V-6	KRCCH, Arabhavi	35	IC-430062	NBPGR, New Delhi
8	V-7	KRCCH, Arabhavi	36	IC-469811	NBPGR, New Delhi
9	V-9	KRCCH, Arabhavi	37	IC-469840	NBPGR, New Delhi
10	V-4	KRCCH, Arabhavi	38	IC-430050	NBPGR, New Delhi
11	V-6-12	KRCCH, Arabhavi	39	IC-469812	NBPGR, New Delhi
12	V-3	KRCCH, Arabhavi	40	IC-469530	NBPGR, New Delhi
13	V-17(14)-B-16	KRCCH, Arabhavi	41	IC-469994	NBPGR, New Delhi
14	V-17(11)	KRCCH, Arabhavi	42	IC-355960	NBPGR, New Delhi
15	Mahaveer selection	KRCCH, Arabhavi	43	IC-436971	NBPGR, New Delhi
16	Gokak Local	KRCCH, Arabhavi	44	IC-430069	NBPGR, New Delhi
17	VA-CU-02	KRCCH, Arabhavi	45	IC-613481	NBPGR, New Delhi
18	V-15	KRCCH, Arabhavi	46	IC-613472	NBPGR, New Delhi
19	Heera	KAU, Vellanikkara	47	IC-595504	NBPGR, New Delhi
20	Shubra	KAU, Vellanikkara	48	IC-613471	NBPGR, New Delhi
21	Kerala Selection	KAU, Vellanikkara	49	IC-595517	NBPGR, New Delhi
22	Dev Kamal	IIVR, Varanasi	50	IC-248202	NBPGR, New Delhi
23	Himangi	IIVR, Varanasi	51	IC-613476	NBPGR, New Delhi
24	Swarna Ageti	IIVR, Varanasi	52	IC-595515	NBPGR, New Delhi
25	Bagalkot Local	Bagalkot	53	IC-539818	NBPGR, New Delhi
26	Phule Shubangi	MPKV, Rahuri	54	IC-539809	NBPGR, New Delhi
27	Pant Kheera	GBPUA&T, Pantnagar	55	PI-19677	NBPGR, New Delhi
28	Aurangabad Local	Maharastra			

Supplementary 2. Genotypic correlation coefficients for 18 parameters in cucumber

	VL	NBPV	IL	NNPV	NTFFF	DTFMF	DTFFF	DTFH	DTLH	SR	FL	FD	FT	TSS	NOFPV	AFW	FYPV	YPP
VL	1 **	0.1453 NS	-0.1925 NS	-0.2453 NS	0.0353 NS	0.0895 NS	0.103 NS	0.1816 NS	0.1412 NS	-0.1604 NS	0.1587 NS	-0.2554 NS	-0.1926 NS	-0.069 NS	-0.0367 NS	0.0953 NS	0.0303 NS	-0.0403 NS
NBPV	0.1453 NS	1 **	-0.5501 **	-0.2404 NS	-0.1509 NS	-0.1318 NS	-0.1078 NS	-0.1622 NS	0.235 NS	-0.1753 NS	0.2257 NS	0.0177 NS	-0.0445 NS	0.1015 NS	0.1318 NS	0.633 **	0.3374 *	0.3344 *
IL	-0.1925 NS	-0.5501 **	1 **	0.1057 NS	0.0312 NS	0.0799 NS	0.0666 NS	0.0391 NS	0.0195 NS	-0.0374 NS	0.0378 NS	-0.2016 NS	-0.1146 NS	-0.16 NS	0.1095 NS	-0.4013 **	-0.0821 NS	0.0608 NS
NNPV	-0.2453 NS	-0.2404 NS	0.1057 NS	1 **	-0.1639 NS	-0.5542 **	-0.4974 **	-0.4882 **	0.1865 NS	0.1475 NS	-0.199 NS	0.0469 NS	-0.0594 NS	-0.0992 NS	0.2213 NS	-0.2236 NS	0.1307 NS	0.1234 NS
NTFFF	0.0353 NS	-0.1509 NS	0.0312 NS	-0.1639 NS	1 **	0.5506 **	0.6266 **	0.5619 **	-0.3697 **	0.5819 **	-0.3555 **	0.4896 **	0.5858 **	-0.1472 NS	-0.5213 **	0.0391 NS	-0.6052 **	-0.583
DTFMF	0.0895 NS	-0.1318 NS	0.0799 NS	-0.5542 **	0.5506 **	1 **	0.9772 **	0.9442 **	-0.2699 *	0.172 NS	-0.1052 NS	0.2508 NS	0.4034 **	-0.0383 NS	-0.4214 **	0.0305 NS	-0.4127 **	-0.3592 **
DTFFF	0.103 NS	-0.1078 NS	0.0666 NS	-0.4974 **	0.6266 **	0.9772 **	1 **	0.9656 **	-0.2865 *	0.1992 NS	-0.1232 NS	0.2812 *	0.4064 **	-0.0468 NS	-0.3872 **	0.1107 NS	-0.426 **	-0.3614 **
DTFH	0.1816 NS	-0.1622 NS	0.0391 NS	-0.4882 **	0.5619 **	0.9442 **	0.9656 **	1 **	-0.1935 NS	0.148 NS	-0.1117 NS	0.224 NS	0.3887 **	-0.0517 NS	-0.4246 **	0.0498 NS	-0.3978 **	-0.3252 *
DTLH	0.1412 NS	0.235 NS	0.0195 NS	0.1865 NS	-0.3697 **	-0.2699 *	-0.2865 *	-0.1935 NS	1 **	-0.3193 *	0.3631 **	-0.3508 **	-0.307 *	-0.0115 NS	0.1962 NS	-0.0187 NS	0.4764 **	0.4969 **
SR	-0.1604 NS	-0.1753 NS	-0.0374 NS	0.1475 NS	0.5819 **	0.172 NS	0.1992 NS	0.148 NS	-0.3193 *	1 **	-0.6542 **	0.444 **	0.4796 **	-0.1707 NS	-0.3614 **	-0.0961 NS	-0.7128 **	-0.6868 **
FL	0.1587 NS	0.2257 NS	0.0378 NS	-0.199 NS	-0.3555 **	-0.1052 NS	-0.1232 NS	-0.1117 NS	0.3631 **	-0.6542 **	1 **	-0.5289 **	-0.5802 **	0.2337 NS	0.4045 **	0.1744 NS	0.6715 **	0.7433 **
FD	-0.2554 NS	0.0177 NS	-0.2016 NS	0.0469 NS	0.4896 **	0.2508 NS	0.2812 *	0.224 NS	-0.3508 **	0.444 **	-0.5289 **	1 **	0.9098 **	-0.1262 NS	-0.3967 **	3e-04 NS	-0.5898 **	-0.5457 **
FT	-0.1926 NS	-0.0445 NS	-0.1146 NS	-0.0594 NS	0.5858 **	0.4034 **	0.4064 **	0.3887 **	-0.307 *	0.4796 **	-0.5802 **	0.9098 **	1 **	-0.1739 NS	-0.5695 **	-0.0382 NS	-0.6994 **	-0.6306 **
TSS	-0.069 NS	0.1015 NS	-0.16 NS	-0.0992 NS	-0.1472 NS	-0.0383 NS	-0.0468 NS	-0.0517 NS	-0.0115 NS	-0.1707 NS	0.2337 NS	-0.1262 NS	-0.1739 NS	1 **	0.2992 *	0.0796 NS	0.2778 *	0.1532 NS
NOFPV	-0.0367 NS	0.1318 NS	0.1095 NS	0.2213 NS	-0.5213 **	-0.4214 **	-0.3872 **	-0.4246 **	0.1962 NS	-0.3614 **	0.4045 **	-0.3967 **	-0.5695 **	0.2992 *	1 **	-0.0555 NS	0.6662 **	0.6431 **
AFW	0.0953 NS	0.633 **	-0.4013 **	-0.2236 NS	0.0391 NS	0.0305 NS	0.1107 NS	0.0498 NS	-0.0187 NS	-0.0961 NS	0.1744 NS	3e-04 NS	-0.0382 NS	0.0796 NS	-0.0555 NS	1 **	0.242 NS	0.1772 NS
FYPV	0.0303 NS	0.3374 *	-0.0821 NS	0.1307 NS	-0.6052 **	-0.4127 **	-0.426 **	-0.3978 **	0.4764 **	-0.7128 **	0.6715 **	-0.5898 **	-0.6994 **	0.2778 *	0.6662 **	0.242 NS	1 **	0.925 **
YPP	-0.0403 NS	0.3344 *	0.0608 NS	0.1234 NS	-0.583 **	-0.3592 **	-0.3614 **	-0.3252 *	0.4969 **	-0.6868 **	0.7433 **	-0.5457 **	-0.6306 **	0.1532 NS	0.6431 **	0.1772 NS	0.925 **	1 **

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