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Principal component analysis for yield attributing traits and disease incidence parameters for rust (*Uromyces phaseoli*) in French bean (*Phaseolus vulgaris* L.)

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Abstract
French bean (*Phaseolus vulgaris* L.) belongs to the family fabaceae grown for its green tender pods as well as dry beans. Cultivation of this crop was hindered due to various biotic stresses. Among them rust caused by *Uromyces phaseoli* leads to the yield loss to the tune of 18 to 78%. Several fungicides like chlorothalonil used for the control of rust disease. However use of resistant varieties is the ideal way for the control of rust disease. Principal component analysis (PCA) was used to reduce the size of the data set containing the disease assessment characteristics. The present study aimed to identify the individual components responsible rust infection in french bean.

Keywords: French bean, rust, PCA

Introduction
French bean *Phaseolus vulgaris* L. (2n=22) is one of the most important leguminous vegetables belongs to the fabaceae family. It is also known as rajmah, kidney bean, snap bean and string bean. It is grown for its green tender pods, which are consumed either fresh or processed as canned, frozen or freeze dried products. It has gained popularity due to its high protein content and nutritional balance, as well as certain medicinal properties that result in increased biological efficiency (Duke, 1981) [4]. It is a New World native crop, originating primarily in Central and South America (Kalpan, 1981) [3], with a small genome of 633 Mbp (Arumuganatham and Earle, 1991) [5]. It is a highly self-pollinated crop; depending on growth habit, plants can be dwarf bush or pole type. The leaves are trifoliate and the flowers are didelphous and can be white, purple or pale yellow in colour. Pods can be round, oval or flat in cross section with or without having fibre.

Legume vegetables are susceptible to a variety of biotic and abiotic stresses. Among the biotic stresses rust (*Uromyces phaseoli* L.) has spread rapidly throughout bean-growing regions, especially where long dew periods, humid to moderately humid conditions and cool temperatures are common during the bean-growing season. Rust can reduce yield by 18 to 78% and it will be more during Rabi season (Grafton *et al*., 1985; Mohan *et al*., 1993) [9, 10]. A 1% increase in bean rust severity, results in a yield loss of about 19 kg/ ha (Lindgren *et al*., 1995) [11]. The pathogen will be more active at moderate temperatures of 17^0C to 27 ^{0}C and relative humidity of more than 95%, (Silbernagel, 1986) [12] and this disease is more severe in the tropics than in temperate regions (Coyne and Schuster, 1975) [13]. Hence the present study aimed to identify the individual components responsible rust infection in french bean.

Material and Methods
The experiment was conducted in ICAR-IIHR, Bengaluru during 2019-2020 in randomizes block design with three replications with a spacing of 30X10 cm. Yield, yield attributing traits and disease assessment parameters were recorded. The data was subjected to principal component analysis by using GRAPES 1.0.0 (General R-shiny based Analysis Platform Empowered by Statistics).

Results and Discussion
Principal component analysis (PCA) was used to reduce the size of the data set containing the studied disease assessment characteristics. PC1 to PC4 explained the most variability, as evidenced by their Eigen values, variability values (%) and Cumulative values (%) (Table 1).

The first principal component (PC1) accounted for 58.30% of total variation, with an eigen value of 13.41.Triats such as number of pustules during end of the season (7.38%), number of pustules during pod maturation (7.33%), area under disease progress curve (7.30%), number of pustules during seed development (7.25%), PDI during seed development (7.25%), PDI during pod maturity (7.24%), PDI during seed development (7.23%) contributed major variance. The second principle component (PC2), with an eigenvalue of 3.81, explained 16.59% of the total variation. If the eigen values are greater than one, it indicates that the evaluated principal component weight values are trustworthy (Mohammadi and Prasanna, 2003) [6]. Traits such as Days to pod formation (20.22%), Days to first flowering (18.73%), pod length 16.445, Pod thickness (12.41%) explained major variance in PC2. Rate of infection during seed development to end of the season (28.02%), Rate of infection during pod development to seed development (11.76%), Days to first disease incidence (11.58%), Rate of infection during pod formation to pod development (11.43%) contributed major variance in PC3 with an eigen value of 3.11. Yield attributing traits such as Pod diameter (43.91%), Pod thickness (14.64%), Days to first flowering (12.31%), Days to pod formation (10.37%) contributed major variance in PC4 with a eigen value of 1.26.

When the biplot is examined, varieties are distributed in the graph based on their association with yield attributing traits and disease assessment parameters. ARka sukomal and IIHR 31 grouped together with respect to number of pods per plant and pod weight. Highly susceptible varieties NZ and US2 grouped together with respect to days taken to appear first disease, pod length, disease assessment parameters such as number of pustule, rate of infection and PDI during flowering. Another highly susceptible varieties Arka komal and Arka suvidha were grouped together with respect to PDI at the end of the season, area under disease progress curve. Susceptible varieties Arka anoop and Arka Sharath were grouped together with respect to rate of infection during seed development to end of the season. Resistant varieties Arka Bold and IIHR 79 were gropued together with respect to pod diameter and pod thickness. Through multivariate analysis 38 diverse pea genotypes showed that three of the slow rusting components, i.e., AUDPC, latent period (LP), and several pustules per leaf (NPL) accounted for 49.77% of the total variance as the first main factor, while the other three traits distributed within the next two factors determined 26.34% (pustule size and a number of aecial sups) and 10.46% (sensitivity of leaf to rust) of the total variance respectively (*Singh et al*., 2015) [7]. Singh *et al*. (2021) [8] reported that five french bean germplasm accessions with negative factor I scores demonstrated slow rusting characteristics, such as longer incubation, latent period and lower disease severity against bean rust. Ali *et al* 2018 reported that 112 lines of wheat were divided in to six PC explained 98% of variance for rust resistance. Liu *et al*., 2020 did PCA in spring wheat against rust identified three subpopulations in which second group has lowest disease scores than the first group.

Table 1: Principal component analysis for yield attributing traits and disease assessment parameters for rust in french bean

Characters	PC1	PC2	PC3	PC4
Days to first flowering	0.12	18.73	0.98	12.31
Days to pod formation	0.04	20.22	2.09	10.37
Number of pustules	2.97	13.35	1.16	0.11
Pod thickness	0.07	12.41	3.22	14.64
Pod weight	4.29	4.32	0.37	7.46
Pod length	0.89	16.44	3.78	7.46
Pod diameter	0.62	1.44	6.2	43.91
Days to first disease incidence	0.70	8.78	11.58	2.74
PDI during flowering	6.22	0.05	4.66	0.51
PDI during pod formation	6.79	0.10	1.09	0.19
PDI during pod maturity	7.24	0.00	0.72	0.13
PDI during seed development	7.25	0.03	0.26	0.05
PDI at the end of the season	7.23	0.09	0.35	0.04
Area under disease progress curve	7.30	0.03	0.211	0.05
Number of pustules during flowering	5.91	0.64	4.79	0.01
Number of pustules during pod formation	6.31	0.89	1.33	0.06
Number of pustules during pod maturation	7.33	0.01	0.17	0.21
Number of pustules during seed development	7.25	0.04	0.63	0.1
Number of pustules during end of the season	7.38	0.01	0.18	0.02
Rate of infection during flowering to pod formation	6.18	0.22	4.95	0.32
Rate of infection during pod formation to pod development	3.86	0.14	11.43	0.08
Rate of infection during pod development to seed development	3.76	1.33	11.76	0.66
Rate of infection during seed development to end of the season	0.24	0.67	28.02	0.65
Eigen value	13.41	3.81	3.11	1.26
% of variance	58.30	16.59	13.53	5.47
Cumulative % of variance	58.34	74.89	88.42	93.9

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