

RESEARCH ARTICLE

EVALUATE THE GENETIC VARIABILITY OF SOME SYRIAN LENTIL VARIETIES WHILE USING VERICOMPOST FERTILIZATION

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ABSTRACT

A study was conducted to assess the efficacy of vermicompost fertiliser in enhancing lentil crop productivity. The research, which also involved estimating genetic parameters, correlation, and conducting principal component analysis to identify key traits directly associated with seed yield improvement, was carried out at Abu Garash Farm, Faculty of Agricultural Engineering, Damascus University, during the agricultural season of 2023-2024. Six lentil varieties (Idlib 1, Idlib 2, Idlib 3, Idlib 4, Idlib 5, and Ebla 1) and two types of fertiliser (mineral and vermicompost) were compared using a randomised complete block design (RCBD) with four replicates. Statistical analysis revealed significant differences between the use of mineral fertiliser and vermicompost, with vermicompost application leading to notable increases in plant height, number of pods per plant, number of seeds per plant, seed yield per plant, and harvest index. Furthermore, the results of the phenotypic and genetic variance coefficients, heritability, expected genetic advance through selection, genotypic correlation, and principal component analysis suggested that the traits of the number of pods per plant and the number of seeds per plant could be reliable selection indicators for improving lentil seed yield. This is due to their high heritability, substantial genetic advance values, and genetic correlation with seed yield per plant, besides their inclusion in the first principal component, which explains the variation among lentil varieties.

KEYWORDS

Genetic advance; Genetic improvement; Heritability; Organic fertiliser; Principal component

1. INTRODUCTION

Lentil (*Lens culinaris* Medik.) is considered one of the most important leguminous crops and ranks as the fourth largest leguminous crop cultivated globally, following common beans (*Phaseolus vulgaris* L.), chickpeas (*Cicer arietinum* L.), peas (*Pisum sativum* L.), and faba beans (*Vicia faba* L.) (Kaale et al., 2022; FAO, 2024). The global cultivated area for lentils is approximately 5,503,604 ha, with a total production of 66,558,278 tonnes and a yield of 12,094 kg.ha⁻¹ (FAO, 2024). Lentils are cultivated in tropical, subtropical, and temperate regions (Nath et al., 2014). Lentils are among the earliest leguminous crops that originated in the Near East and later spread to Central Asia and the Mediterranean Basin (Zohary, 1999; Lev-Yadun et al., 2000). Today, lentils are considered an important winter leguminous crop in the Middle East, the Indian subcontinent, North America, North Africa, and West Asia (Stefaniak and McPhee, 2015). In the Syrian Arab Republic, the cultivated area for lentils is approximately 81,363 ha, with a production of 26,614 tonnes and a yield of 327 kg.ha⁻¹ (SASG, 2022).

Excessive use of chemical fertilisers, pesticides and herbicides and minimal organic fertiliser use characterise traditional agriculture (Gill and Garg, 2014). To address such issues, the trend towards fertilising crops with organic fertilisers made from organic materials, which have immense potential to improve soil biodiversity and structure, represents an alternative strategy for sustainable and commercially viable agricultural production while reducing environmental pollution. Vermicompost is an alternative and frequently used technique in sustainable agriculture. Plants easily absorb rich in both macro- and micro-nutrients,

vermicompost (Dominguez, 2004). The incorporation of vermicompost in agricultural practices offers various advantages, such as reducing the need for irrigation, bolstering resistance against pests, diminishing weed growth, promoting rapid seed germination, enhancing seedling growth and development, and ultimately increasing grain crop yield (Olle, 2019). Despite these benefits, the widespread adoption of vermicompost remains limited (Anonymous, 2009).

Parameters such as means, phenotypic and genotypic variances, heritability, genotypic correlation, and principal component analysis play pivotal roles in determining the effectiveness of breeding programmes (Sharma et al., 2020). The estimation of the genetic correlation coefficient indicates the extent of an association between two or more traits, whereas a significant correlation suggests the potential for the simultaneous improvement of traits that are meaningfully related. This improvement relies on genotypic correlation, additive genetic variance, and the heritability of these traits (Hayes et al., 1955).

Principal Component Analysis (PCA) is a technique employed to summarise and reduce data dimensions. The method transforms several interrelated variables into a substantially smaller set of independent variables known as principal components. These components are derived from the original variables, with their proportions and magnitudes varying according to the role and influence of each variable, aiming to describe as much of the information present in the original dataset as possible. PCA segregates total variance into components. Furthermore, PCA reflects the significance of the principal contributor to the total variance for each differentiation axis (Greenacre et al., 2022).

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In Syria, crop production faces challenges from climate change and a notable increase in the costs of agricultural production inputs (such as water, seeds, mineral fertilisers, fuel, and pesticides), which has subsequently raised production costs for Syrian farmers. This situation has led to a reluctance among farmers to cultivate all arable land, in addition to facing marketing challenges for the crops generated (AL-Boush and Al-Ouda, 2021). The study of quantitative traits associated with seed yield and phenotypic expression under varying production conditions is critically important for scientifically guiding breeding programmes, ensuring genetic advancement in breeding and genetic improvement initiatives, and determining the optimal combination of varieties and agricultural inputs.

While research has explored vermicompost's benefits and genetic variations in lentils separately, the combined impact of both remains understudied (Patidar et al., 2024; Singh and Lakhan, 2022; Ilyas et al., 2024; Pavithra et al., 2023; Akter et al., 2020; Chowdhury et al., 2019). This study aimed to assess the effectiveness of vermicompost in enhancing lentil productivity and analyse genetic variations, and to perform principal component analysis to identify key selection traits.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted at Abu Garash Farm, Faculty of Agricultural Engineering, Damascus University, during the winter of 2023-2024. At an elevation of approximately 743 m above sea level, the farm coordinates are approximately 33.537° north and 36.319° east. The area is situated in the fifth agricultural stabilisation zone, characterised by a precipitation rate of less than 200 mm, and it received an average annual rainfall of 187 mm during the study period (Table 1). The experimental

field consisted of loamy clay soil with an even pH of 7.3 and a low content of 0.75% organic matter; therefore, it was necessary to add vermicompost fertiliser to improve the soil properties due to its high content of total nitrogen (Table, 2). Total nitrogen in both vermicompost and soil was estimated by the Kjeldahl method using concentrated sulphuric acid, mineral nitrogen in soil by the Kjeldahl method using potassium chloride, available phosphorus in soil and available potassium in soil (Jones, 1991; Keeney and Nelson, 1982; Olsen et al., 1954; Black, 1965).

Table 1: Rainfall and temperature distributions during the growing season.

Months	Growing season (2023-2024)		
	Temperature (°C)		Precipitation (mm)
	Max.	Min.	
November	16	7	31
December	8	4	52
January	8	4	67
February	15	4	15
March	26	14	4
April	29	19	13
May	30	14	5
Mean	19	9	27
Total	132	66	187

Source: Ministry of Defence, Meteorological Department, Masaken Barzeh Station, Damascus.

Table 2: Physical and chemical properties of the Abu Garash farm soil and vermicompost fertiliser.

Indicator	Soil characteristics of the experimental site before planting									
	Physical properties			Chemical properties						
	Sand (%)	Silt (%)	Clay (%)	N (%)	N (ppm)	P (ppm)	K (ppm)	pH	Ece (ds.m ⁻¹)	Om* (%)
Value	29.80	30.95	39.25	0.18	9	48	40	7.30	0.200	0.75
Description	Loamy clay soil			moderate		high	moderate	m. alkalinity	Natural	low
Chemical properties of vermicompost										
Indicator	N(%)	P(%)	K (%)	pH	Ece (ds.m ⁻¹)	Om (%)				
Value	0.94	0.8	1	7.3	2.3	37				

*Om: Organic matter.

Source: Labour of the Soil Department, Faculty of Agricultural Engineering, Damascus University, and National Commission for Biotechnology, Damascus.

2.2 Experimental Design

The experiment was conducted using a randomised complete block design (RCBD). Six lentil varieties (Idlib 1, Idlib 2, Idlib 3, Idlib 4, Idlib 5, and Ebla 1), two types of fertiliser (mineral and vermicompost), and four replications were included in the study. Thus, 48 experimental plots were created with a distance of 0.75 m between each plot. Each plot consisted of two 3 m long lines with 0.25 m intervals between each line, and 0.05 m intervals between plants within each line. Mineral fertilisers were applied at the recommended doses (30:60:80 N.P.K. kg.ha⁻¹), based on the soil analysis of the study site and the guidelines of the Syrian General Commission for Scientific Agricultural Research. Nitrogen was administered in the form of urea (46%), phosphorus as triple superphosphate (46%), and potassium as potassium sulphate (46%). Vermicompost fertiliser was added at a rate of 20.6 m³.ha⁻¹ in accordance with the fertiliser recommendations approved by the Syrian General Commission for Scientific Agricultural Research (Al-Zoubi et al., 2022).

2.3 Investigated Traits

Observations were recorded from the 10 inner plants of each plot to assess various morphological and seed yield-related traits. The following data were collected: primary branches per plant (branches), plant height (cm), pods per plant (pods), seeds per plant (seeds), 100-seed weight (g), seed yield per plant (g), biological yield per plant (g), and harvest index (%).

2.4 Statistical and Genetic Analyses

ANOVA was performed for all traits according to the randomised complete block design (RCBD) to identify significant differences among varieties, fertilisers and (varieties × fertilisers) using statistical software Genstat. 12v (Gomez and Gomez, 1984). Heritability, genetic coefficient of variation, phenotypic coefficient of variation, and genetic advanced values were estimated using TNAUSTAT software. Genetic correlation analysis and principal component analysis (PCA) were performed using Meta-R (Alvarado et al., 2020). Data from both fertiliser treatments were combined to determine the extent of the association between studied traits.

Heritability in the broad sense (H²), genetic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), genetic advance (GAM), and genetic correlation were estimated according to Singh and Chaudhury (1985) as follows:

$$P.C.V\% = \frac{\sqrt{P.V}}{\bar{X}} \times 100 \tag{1}$$

$$G.C.V\% = \frac{\sqrt{G.V}}{\bar{X}} \times 100 \tag{2}$$

PCV and GCV values were divided into three levels, where 0-10% is low, 10-20% are moderate, and >20%, high.

$$H^2 = \frac{G.V}{P.V} \tag{3}$$

H² values were divided into three levels, where 0-30% is low, 30-60% is moderate, and greater than 60%, high.

Genetic advance (GA) was estimated at selection intensities of 5% and 10%:

$$GA = H^2 \times K \tag{4}$$

Genetic advance in percentage was calculated using the following formula:

$$GAM = \frac{G.A}{Mean} \times 100 \tag{5}$$

Genetic advance as a percentage mean was divided into three levels, where 0-10% is low, 10-20% is moderate, and >20% denoted high.

Genotypic correlation was calculated using the following formula:

$$r_g = \frac{Covg(X1, X2)}{\sqrt{VargX1 \cdot VargX2}} \tag{6}$$

Principal component analysis (PCA):

$$Y_{ij} = \mu + Rep_i + Gen_j + \epsilon_{ij} \tag{7}$$

Y_{ij} is the trait of interest, μ is the overall mean effect, Rep_i is the effect of the i th replicate, Gen_j is the effect of the j th genotype and ϵ_{ij} is the effect of the error associated with the i th replication and j th genotype.

The angles between pairs of traits determine the relationship between traits in principal component analysis biplot (PCA). If the angle between two traits is less than 90°, their correlation is positive; if the angle equals 90°, the traits are uncorrelated; and if the angle exceeds 90°, a negative correlation exists between the two traits (Alvarado et al., 2020). The cosine of the angle (i.e., the value of the trigonometric function Cos) between two vectors representing two traits indicates the correlation coefficient between them.

3. RESULTS AND DISCUSSION

The results of the statistical analysis indicated the presence of significant differences ($P \leq 0.05$) in all the studied traits among the varieties, fertiliser treatments and their interactions, except for the biological yield. $plant^{-1}$ trait did not differ significantly after the addition of mineral fertiliser or vermicompost (Table 3).

Table 3: Analysis of variance for 8 quantitative traits in 6 Syrian lentil varieties.				
Sources	Variety	Fertiliser	Variety × Fertiliser	C.V
Traits	Mean Sum of Squares			
Primary branches. $plant^{-1}$	2.09**	14.79**	6.56**	13.70
L.S.D _{0.05}	0.62	0.36	0.88	
Plant height	242.01**	1327.50**	235.83**	12.00
L.S.D _{0.05}	5.97	3.45	8.44	
Pods. $plant^{-1}$	10092.87**	16664.06**	2489.77**	12.80
L.S.D _{0.05}	8.87	5.12	12.54	
Seeds. $plant^{-1}$	10583.90**	10659**	3138.10**	18.00
L.S.D _{0.05}	11.58	6.69	16.38	
100-seeds weight	2.72**	9.85**	2.19*	19.00
L.S.D _{0.05}	0.88	0.51	1.24	
Seed yield. $plant^{-1}$	10.88**	2.91**	1.30**	20.00
L.S.D _{0.05}	0.53	0.30	0.74	
Biological yield. $plant^{-1}$	52.63**	1.18 ^{NS}	1.95 ^{NS}	17.80
L.S.D _{0.05}	1.42	0.82	2.01	
Harvest index%	419.37**	93.87**	42.62**	12.70
L.S.D _{0.05}	3.57	2.06	5.04	

*, ** Significant at 0.05 and 0.01 probability levels.

Overall, vermicompost fertilisation led to a noticeable increase in plant height (54.20 cm) compared with the general average of mineral fertiliser (43.70 cm), with the highest average plant height recorded in the Ebla 1 variety under the influence of vermicompost addition (65.14 cm) (Figure, 2). An increase in the number of pods per plant was observed when applying vermicompost (87.00 pods) compared with (49.70 pods) in mineral fertiliser treatment, with the Idlib 2 variety showing the highest average number of pods (174.25 pods) under the influence of vermicompost (Figure 3). Treatment with vermicompost outperformed mineral fertiliser treatment in terms of the number of seeds (78.30 seeds compared to 48.50 seeds). The variety Idlib2 contained the highest number of seeds per plant when added with vermicompost (180.10 seeds) (Figure, 4).



Figure 2: Means of Plant height trait

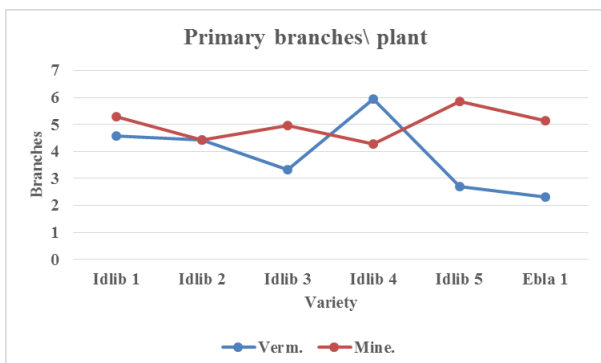


Figure 1: Means of Primary branches per plant trait

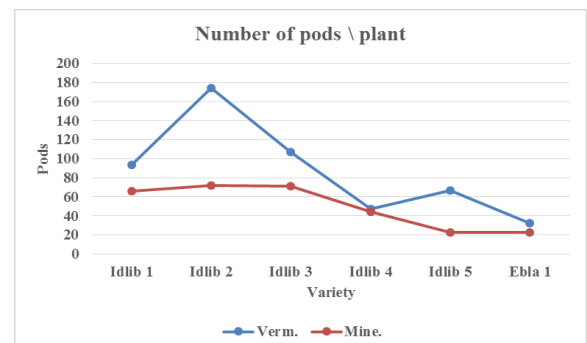


Figure 3: Means of number of pods per plant trait

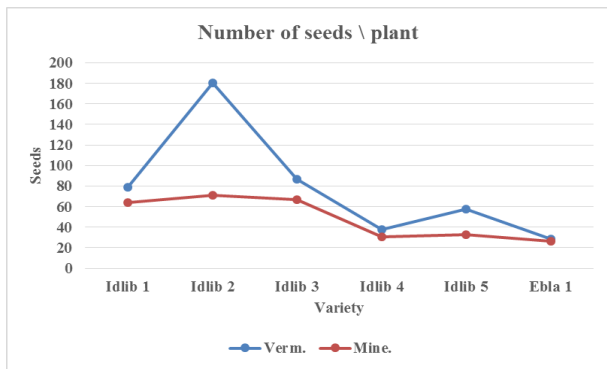


Figure 4: Means of number of seeds per plant trait

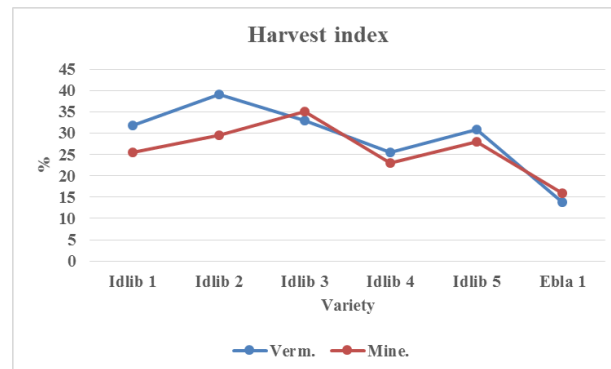


Figure 8: Means of harvest index trait

When comparing the average plant seed yield and harvest index, adding vermicompost led to a significant increase in both traits (2.50 g, 29.00% respectively) compared with the mineral fertiliser treatment (2.00 g, 26.20% respectively). The variety Idlib 2 (Figure, 6) achieved the highest plant seed yield (5.18 g) under the influence of adding vermicompost, which was equivalent to 4221 kg.ha⁻¹ and the highest harvest index (39.00%) for the same treatment (Figure, 8). The increase in seed yield due to the addition of vermicompost can be attributed to its content of plant growth regulators, such as auxins, gibberellins, and cytokinins. These substances enhance the plant's ability to absorb nutrients from the soil and use them optimally to generate a larger biomass, thereby increasing the amount of dry matter produced and facilitating the transfer of nutrients to seeds. This finding is consistent with that of previous studies (Patidar et al., 2024; Singh and Lakhan, 2022).

Estimation of the phenotypic coefficient of variability (PCV) and genotypic coefficient of variability (GCV) revealed slightly higher PCV values for most traits than GCV (Table, 4). Notably, high PCV values were observed for all traits, except plant height, which was moderate. Similarly, the GCV values were high for most traits, except for plant height and 100-seed weight, which were moderate (Table, 4).

Heritability in a broad sense (H²%) was high, accompanied by high expected genetic advance (GAM at 5% and 10%) values for primary branches, plant height, number of pods, number of seeds, seed yield, and harvest index% (Table, 4).

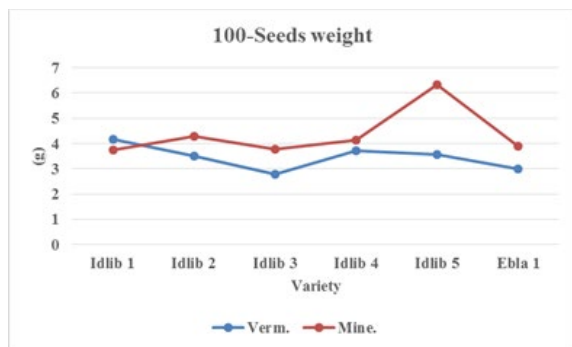


Figure 5: Means of 100-seeds weight trait

Traits	PCV%	GCV%	H ² %	GAM at 5%	GAM at 10%
Primary branches. plant ⁻¹	37.36	33.94	82.57	63.54	54.29
Plant height	19.88	15.39	59.92	24.54	20.96
Pods. plant ⁻¹	59.57	58.30	95.78	102.20	87.30
Seeds. plant ⁻¹	71.52	69.40	94.14	108.60	92.80
100-seeds weight	21.16	11.38	28.93	12.61	10.78
Seed yield. plant ⁻¹	64.65	59.94	85.96	114.47	97.80
Biological yield. plant ⁻¹	40.43	33.82	70.00	4.60	4.00
Harvest index%	31.29	29.12	86.57	55.81	47.68

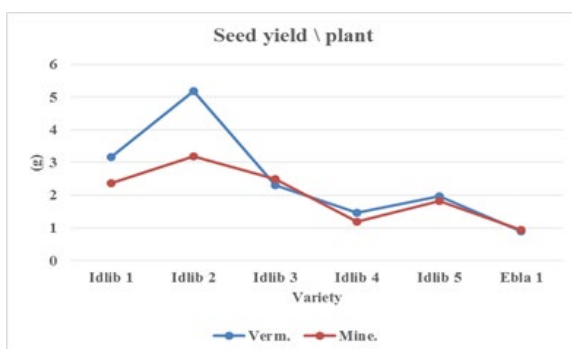


Figure 6: Means of seed yield per plant trait

The seed yield per plant exhibited a positive and highly significant correlation with the number of seeds per plant ($r = 0.99^{**}$), the number of pods per plant ($r = 0.98^{**}$), and the biological yield per plant ($r = 0.95^{**}$). In addition, it demonstrated a positive and significant correlation with the harvest index ($r = 0.80^*$). Conversely, the biological yield per plant was positively and significantly correlated with both the number of seeds per plant ($r = 0.95^{**}$) and the number of pods ($r = 0.90^{**}$). Furthermore, the harvest index was positively and significantly correlated with the number of pods ($r = 0.85^*$) and the number of seeds per plant ($r = 0.80^*$) (Table, 5). This finding is consistent with that of previous studies (Akter et al., 2020; Chowdhury et al., 2019).

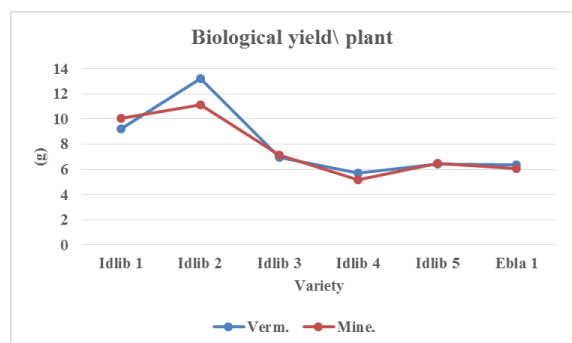


Figure 7: Means of biological yield per plant trait

Traits	NoB	PH	NoP	NoS	100-SW	SYP	GYP
PH	-0.02						
NoP	0.53	-0.72					
NoS	0.25	-0.53	0.99 ^{**}				
100-SW	-0.03	0.99 ^{**}	-0.15	-0.05			
SYP	0.35	-0.37	0.98 ^{**}	0.99 ^{**}	0.04		
GYP	0.24	-0.27	0.90 ^{**}	0.95 ^{**}	0.05	0.95 ^{**}	
HI	0.48	-0.29	0.85 [*]	0.80 [*]	0.24	0.80 [*]	0.58

*, ** Significant at 0.05 and 0.01 probability levels.

The number of principal components for phenotypic variation among the

varieties was found to be three based on the statistical analysis results (Figure, 9; Table, 6). However, only two principal components (PC1 and PC2) were used in the variation. The first principal component (PC1) accounts for 85.05% of the total variation, while the second principal component (PC2) accounts for 11.66% of the variation. Therefore, it can be concluded that the traits represented by the two principal components (PC1 and PC2) explain 96.71% of the variation among the varieties (Figure, 9). The first principal component includes the traits (number of pods. plant⁻¹, number of seeds. plant⁻¹, seed yield. plant⁻¹, biological yield. plant⁻¹, and harvest index%), while the second principal component includes the trait of the number of primary branches. plant⁻¹ (Table, 6). It was also observed from (Figure, 9) that the number of pods, number of seeds, biological yield, and harvest index were positively and significantly correlated with seed yield per plant due to the acute angles between these traits and seed yield. These results are similar to those reported (Pavithra et al., 2023; Chowdhury et al., 2019).

Table 6: Principal component analysis for 8 quantitative traits in lentil.			
Traits	Comp.1	Comp.2	Comp.3
Primary branches. plant ⁻¹	0.53	1.00	0.10
Plant height	-0.98	-0.06	0.23
Pods. plant ⁻¹	1.00	-0.03	0.15
Seeds. plant ⁻¹	0.98	-0.26	0.08
100-seeds weight	-0.95	-0.26	0.64
Seed yield. plant ⁻¹	0.98	-0.23	0.03
Biological yield. plant ⁻¹	0.95	-0.32	-0.43
Harvest index%	0.94	-0.02	1.00

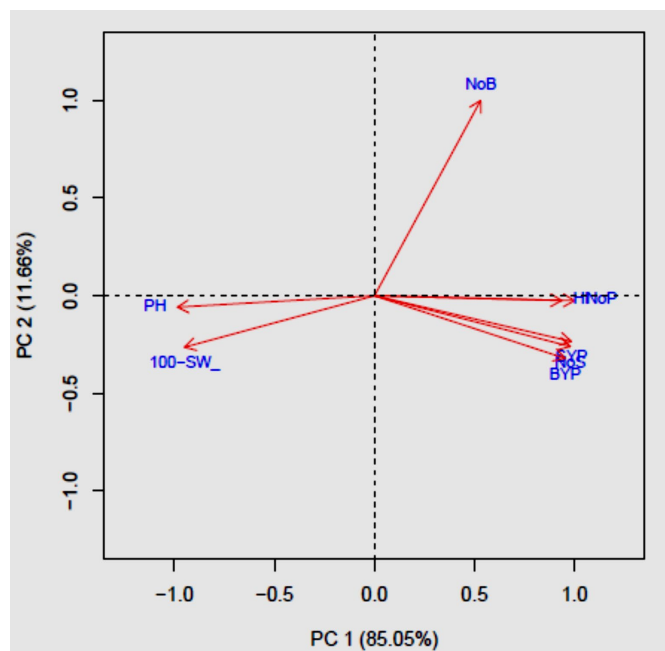


Figure 9: PCA biplot for (PC1) and (PC2)

4. CONCLUSION

Expand the application of vermicompost due to its positive effects on improving the seed yield of lentil crops under similar conditions and approve the Idlib2 variety with the addition of vermicompost at the appropriate rate after conducting soil analysis in the Damascus region. Relying on plant pod and seed number per plant trait as selective indicators of increased seed yield in lentil crops with high heritability (95.78%, 94.14% respectively) and genetic advance 10% (87.30%, 92.80% respectively). Additionally, these traits were genetically correlated with seed yield per plant ($r = 0.99^{**}$, $r = 0.98^{**}$ respectively), and contribute to the overall variation among the lentil varieties because they were located in the first principal component.

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