



## **Heterogeneous Nutrient Sources Exhibit Varying Associations of Vegetative and Reproductive Parameters of Irish Potato (*Solanum tuberosum* L.)**

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### **Authors' contributions**

This work was carried out in collaboration among all authors. Author TDA and DKN designed the study. Author DKN wrote the protocol. Author TDA performed the statistical analysis and managed the write up of the manuscript. Authors AAN, DN and TDA managed the analyses of the study. All authors read and approved the final manuscript.

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### **ABSTRACT**

The aim of this study was to evaluate the associations of vegetative and reproductive parameters of Irish potato from different organic and inorganic nutrient sources. The study was done in the west region of Cameroon, specifically in Bougham, a village in the western highlands. The seeds were sown on the 4<sup>th</sup> of May 2016. Harvesting was done in August 2016. A total area of 250m<sup>2</sup> was

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cleared and prepared in to a Randomized Complete Block Design (RCBD). Each block was divided into nine ridges. Eight fertilizer treatments: inorganic (NPK 15:15:15, NPK 11:11:22), organic (Pig dropping, Poultry dropping), composite (four bi-combinations of the animal and NPK-based fertilizer) and a control treatment were randomly assigned to each ridge per block. General agronomic practices were adopted from local farmers. Data were collected on vegetative and reproductive parameters. Correlation analysis was also evaluated between parameters. This was followed by principal component analysis with varimax rotation. Principal components were selected based on eigen value criteria – a component was selected if its eigen value was greater than 1. All analyses were done using PAST (ver. 3.26b) Analysis revealed significant correlations between some vegetative and reproductive parameters notably between emergence and plant height ( $r = 0.45$ ,  $P < 0.05$ ), emergence and plant harvested ( $r = 0.867$ ,  $P < 0.05$ ), and between plant cover and plant height ( $r = 0.546$ ,  $P < 0.05$ ). According to the eigen value criteria (eigen value  $> 1.0$ ), 4 principal components were retained from organic and inorganic nutrient sources each, and 3 principal components were retained from composite nutrient source. Reproductive parameters were more aggregated in the first principal component for organic nutrient source, accounting for 35.87% of all variations while they were more aggregated in the second principal component (25.61%) from inorganic nutrient sources. From the composite nutrient source, the reproductive and vegetative parameters were almost equally distributed between the first (31.80%) and second (27.82%) principal components. In this study, that varied nutrient sources (organic. Inorganic and composite) affects Irish potato differently. Consequently, both organic and inorganic nutrient sources should be seen as synergistic and not mutually exclusive for holistic production of Irish potato.

**Keywords:** NPK; poultry; pig; fertilizer; vegetative; reproductive parameters; principal component analysis; Cameroon.

## 1. INTRODUCTION

Irish potato (*Solanum tuberosum* L.) is one of the most important vegetable crops in the world and it is fourth among food crops after rice, wheat and maize [1]. Annual production is about 300 million tons from approximately 20 million hectares of arable land [2]. Potato, which belongs to the family Solanaceae, is cultivated worldwide and it provides income to many households [3,4]. Potato is widely cultivated due to its cheap source of vitamins (B<sub>1</sub> and C), carbohydrates and as well as minerals [5]. It is estimated that 100 g of potato tuber contains 79.9 g water, 78 kcal Energy, 16.8 g carbohydrates, 2.4 g protein, 36.0 g mg calcium, 49.0 mg phosphorus, 31.0 mg ascorbic acid, 2.2 mg niacin, 1.1 mg iron, 0.12 mg thiamine and 0.06 mg riboflavin [6].

Most farmers exclusively rely on inorganic fertilizers (NPK 20:10:10 and NPK 12:6:20) in order to increase yield. Owing to the constant rise in cost of chemical fertilizers, scarcity or non-availability in many remote areas, organic manure is now taking center stage as a source of cheap plant nutrients [7]. Organic manure like cow dung, fowl droppings, turkey manure, pig droppings and farmyard manure have been since time immemorial incorporated in crop production. They are cheap and readily available to many

poor resource farmers especially in rural communities.

Many scientists concur that not only do organic manure provide plant nutrient, but that they also have the potential to restore soil physiochemical characteristics which are often degraded by inorganic fertilizers [8-10]. Organic manures are soil-incorporated or broadcasted pre-plant or during plant growth [11].

Many researchers have focused on the effect of organic manure on some growth and yield parameters of organic manure on potatoes, and in some cases vis-à-vis inorganic fertilizers. In Bangladesh (Narayanpur), the effect of cow dung and mustard cake oil on yield and growth parameters of potatoes was investigated by Hossain et al. [12]. Poultry manure, nitrogen and potassium were investigated on growth and yield parameters and chemical contents of two cultivars of potatoes in Alexandria Egypt by Gehan [4]. In addition, the effect of manure, mineral fertilizer and a combination of both on growth and yield parameters of potatoes were investigated in Lithuania [13], Algeria [14], Bulgaria [15] and Cairo Egypt [16] and in Cameroon [7]. Very little to a few researches have focused on the possible associations and variations of these growth and yield parameters under different fertilizer regimes. For the most part, many researchers such as [16,7] have

focused on the simplistic pair-wise correlations between these factors. The concept of fertilization especially in organic farming is far greater than merely the use of different manure. The simplistic pair wise correlation is limited in revealing the complex associations between these varied parameters in different nutrient sources. In this study, it is hypothesized that heterogeneous nutrient sources can result in a spectrum of vegetative and reproductive parameters associations beyond the basic pair wise correlations.

## 2. MATERIALS AND METHODS

### 2.1 Study site

The study was conducted in Bougham, Cameroon, west of Africa. In Cameroon, potato is cultivated mainly in the highland zones (Altitude: 1000 to 3000 m above sea level) and in six of the ten regions of the country. The West and North West regions jointly accounts for about 80% of the total national production [17]. Bougham is part of the mountainous West Region of Cameroon located in 5°28N, 10°25E and about 100 om above sea level. Bougham is characterized by dense vegetation, rich agricultural soil, and a humid equatorial climate with moderate rainfall. These conditions are very good for potato cultivation. Inhabitants are predominantly farmers, growing vegetables, fruits and rearing animals. There is abundant animal waste in this region, and the farmers incorporate this to crop production activities.

### 2.2 Land Preparation and Field Layout

A total of 250 m<sup>2</sup> area was cleared, tilled and harrowed with hand-held hoes. The experimental design was a randomized complete block design (RCBD). The field was divided into four blocks measuring 13x6 m. Each block was divided into eight ridges measuring 6x1x0.3 m. The block-block and a ridge-ridge gap were 2.5 m and 0.5

m respectively. The ridges were randomly assigned different fertilizers treatments.

### 2.3 Plant Material

Potato variety used in this experiment was “Pamina”, distributed by AFRISEM GIE and imported from France. It is very smooth, pale yellow – white skinned and elongated tubers. This variety is widely used by farmers in the area.

### 2.4 Fertilizer (Nutrient source)

Inorganic fertilizer (NPK – 15:15:15 and NPK – 11:11:22), organic fertilizer (poultry and pig droppings) and composite (organic + inorganic fertilizer) was used (Table 1). The fertilizers were applied pre-plant. At moulding (hilling up), a nitrogen rich fertilizer was broadcasted to boost growth in all treatment. Sulphate nitrate (100 kg/ha), calcium nitrate (75 kg/ha) and potassium nitrate (25 kg/ha) were applied in a composite (200 kg/ha).

### 2.5 Planting/Sowing

Potato tuber (approximately 40mm in diameter) was planted 10 cm deep on the 4<sup>th</sup> of May 2016. Each ridge had 20 plants separated by 0.25 m.

### 2.6 Agronomic Practices

The herbicide Glycot was sprayed pre-emergent for weed control. The next weed control was done bi-weekly by hand. The field was irrigated at the start of the trial, followed by rain fed irrigation. The fungicide Mancolax (Mancozeb 100 ml/18l) and the insecticide Cypercot (Cypermethrine 100 EC) were used to control diseases and insect pests respectively. The ridges were mould in order to cover the broadcasted fertilizer after a month of sowing. The plants haulms were removed two weeks before harvesting so as to improve hardening of tubers.

**Table 1. Shows the different fertilizer treatments**

	<b>Types of Fertilizer (Treatment)</b>	<b>Quantity</b>
Organic	Poultry dropping	3150 kg/ha
	Pig dropping	3150 kg/ha
Inorganic	NPK (15:15:15)	650 kg/ha
	NPK (11:11:22)	650 kg/ha
Composite	NPK (15:15:15) + poultry dropping	325 kg/ha + 1575 kg/ha
	NPK (11:11:22) + poultry dropping	325 kg/ha + 1575 kg/ha
	NPK (15:15:15) + pig dropping	325 kg/ha + 1575 kg/ha
	NPK (11:11:22) + pig dropping	325 kg/ha + 1575 kg/ha

## 2.7 Data Collection

The Data was collected on plant emergence, leaf area index (LAI), plant height (cm), number of stems, plant cover (m<sup>2</sup>), number of plant harvested, number of tubers per plant harvested and number of tubers per treatment at harvest. These parameters were measure according to Achiri et al. [7].

## 2.8 Data Analysis

Pair wise Pearson correlation was conducted to evaluate possible correlations of parameters per treatment. In order to further evaluate other possible associations and variations amongst these parameters, a principal component analysis (PCA) was conducted. PCA was conducted for all treatments (organic, inorganic and composite) independently. Later, PCA was conducted for all treatment as a whole. Components were selected based on eigen value criteria – components with eigen values greater than 1 were considered significant [18]. Analysis of covariance (ANCOVA) was done in order to determine the location difference in each parameter measured. Parameter scores for each common component were loading in bar charts. Scatter plots were also produced for each treatment, showing the distribution of observations in space. Biplots were also constructed to show possible associations and their variations of measured parameters from heterogeneous nutrient sources. All analyses were conducted using the PAlaeontological STatistics PAST statistical package (version 3.26 b).

## 3. RESULTS AND DISCUSSION

### 3.1 Correlation Matrix for Some Vegetative and Reproductive Parameters of Potato as Influenced by Heterogeneous Nutrient Sources

Pair wise Pearson correlation matrix showed that some significant correlations ( $P < 0.05$ ) existed between many parameters (Fig. 1). A significant positive correlation ( $r = 0.45$ ,  $P < 0.05$ ) was observed between the number of plants that emerged and plant height. Other significant positive correlations were observed: Number plants that emerged and number of plants harvested ( $r = 0.867$ ,  $P < 0.05$ ), plant height and number of plants at harvest ( $r = 0.653$ ,  $P < 0.05$ ), plant cover and plant height ( $r = 0.546$ ,  $P < 0.05$ ). A significant negative correlation ( $r = -0.589$ ,  $P < 0.05$ ) was observed between the numbers of

tubers per plant and the number of plants at harvest. In addition, a significant negative correlation ( $r = -0.231$ ,  $P < 0.05$ ) between the number of tubers per plant and plant height. All correlations in the correlation matrix that are boxed are significant at  $\alpha = 0.05$ . Significant Pearson pair wise correlations between growth and yield parameters of potatoes are widely reported. The findings of the current research are in line with that of Amara and Mourad [19]. In addition, Shaaban and Kiset [20] reported a significant negative correlation between plant height and tuber yield of Irish potato.

### 3.2 Principal Component Selection Eigen Value Criterion

Significant principal components were selected according to the eigen value criteria – components with eigen value greater than 1 were selected. The number of significant components selected ranged from 3 – 4 according to nutrient sources (Table 2). Four principal components were selected from organic and inorganic nutrient sources. The four principal components from organic and inorganic nutrient sources explained 93.16% and 86.46% of the total variance, respectively. On the other hand, three components were observed from composite and combination of all nutrient sources (Total). The three nutrient sources from composite and total nutrient sources explained 75.76% and 67.16% of total variance, respectively.

### 3.3 Factor Loading, Scatter Plot and Biplot of Principal Components by Vegetative and Reproductive Parameters of Irish Potato from Heterogeneous Nutrient Sources

#### 3.3.1 Factor loading, scatter plot and biplot of principal components from organic nutrient sources

The factor loading of principal components from organic nutrient sources are presented in Fig. 2. The leading parameters in component 1 were number of tubers per treatment, number of tubers per plant, number of plants harvested and number of stems. Leaf area index was the leading parameter in component 2. In component 3, emergence and plant height were the leading parameters. In component 4, the leading parameters were number of stems, plant cover and number of plants harvested. It should be noted that some parameters had significant loadings (absolute score value  $\geq 0.30$ ) in more than one component.

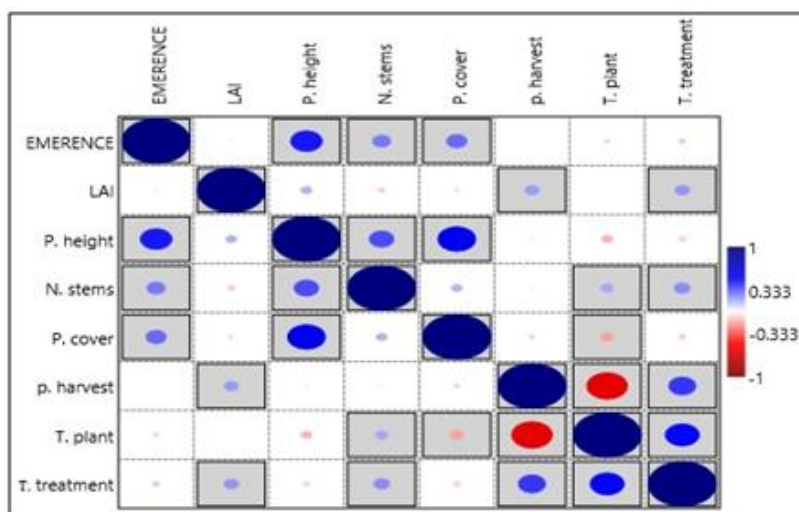
The association and variations in space of some growth and yield parameters of Irish potato cultivated on organic nutrient source is shown in Fig. 3 (A & B). The result is reported for the first two dimensions which account for the most variations (58.628%) from organic nutrient source. The number of tubers per treatment, the number of tubers per plant and the number of plant harvested were the main influencers of component 1. The leaf area index and emergence were the main influencers of component 2, however on opposite directions.

**3.3.2 Factor loading, scatter plot and biplot of principal components from inorganic nutrient sources**

The factor loading of principal components from inorganic nutrients sources are presented in Fig. 4. The leading parameters in component 1 were emergence, leaf area index, plant height and

number of tubers per plant. Plant height and number of tubers per treatment were leading parameters in component 2. In component 3, the leading parameters were plant cover and number of tubers per plant. In component 4, the number of stems was the leading parameters. It should be noted that some parameters had significant loadings (absolute score value  $\geq 0.30$ ) in more than one component.

The association and variations in space of some growth and yield parameters of Irish potato cultivated on inorganic nutrient source is shown in Fig. 5 (A & B). The result is reported for the first two dimensions which account for the most variations (60.225%) from inorganic nutrient source. The number of tubers per plant, leaf area index and plant height were the main influencers of component 1. The number of plants harvested and the number of tubers per treatments were the main influencers of component 2.



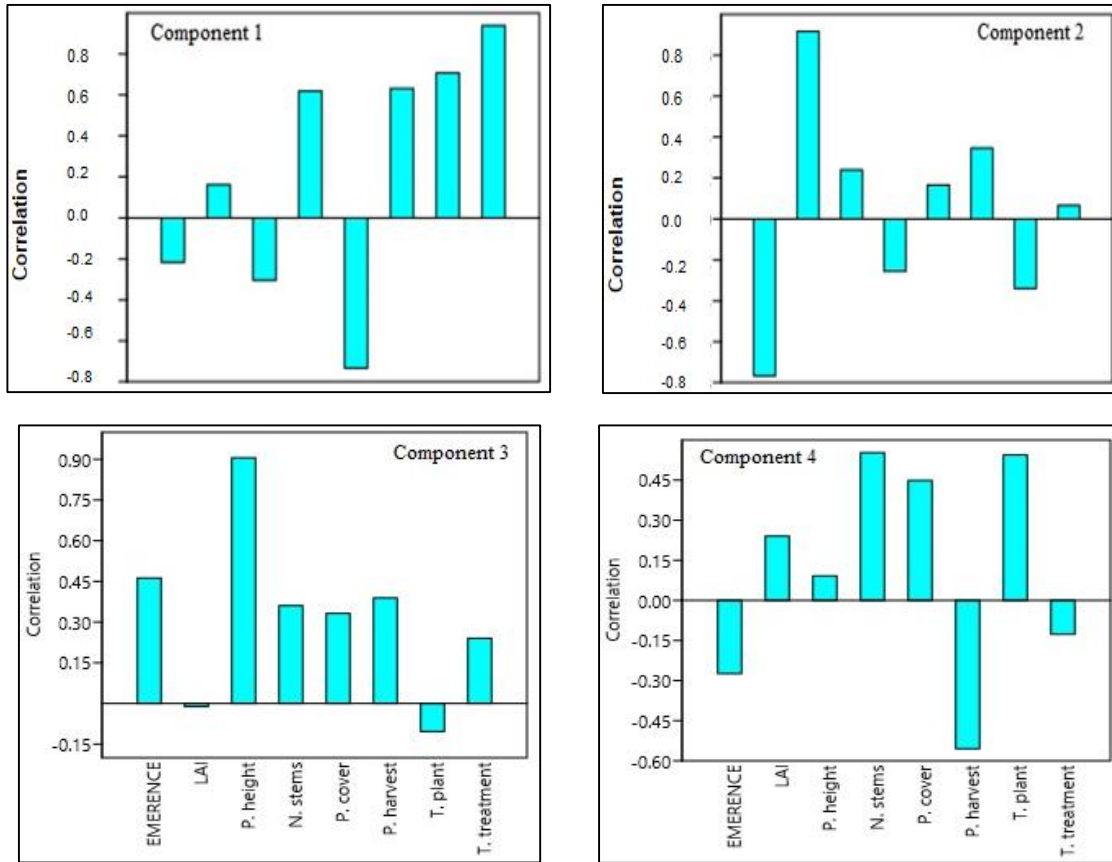
**Fig. 1. Correlation matrix for some vegetative and reproductive parameters of potato under heterogeneous nutrient sources**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment

**Table 2. Eigen values for selected components according to heterogeneous nutrient sources for Irish potato**

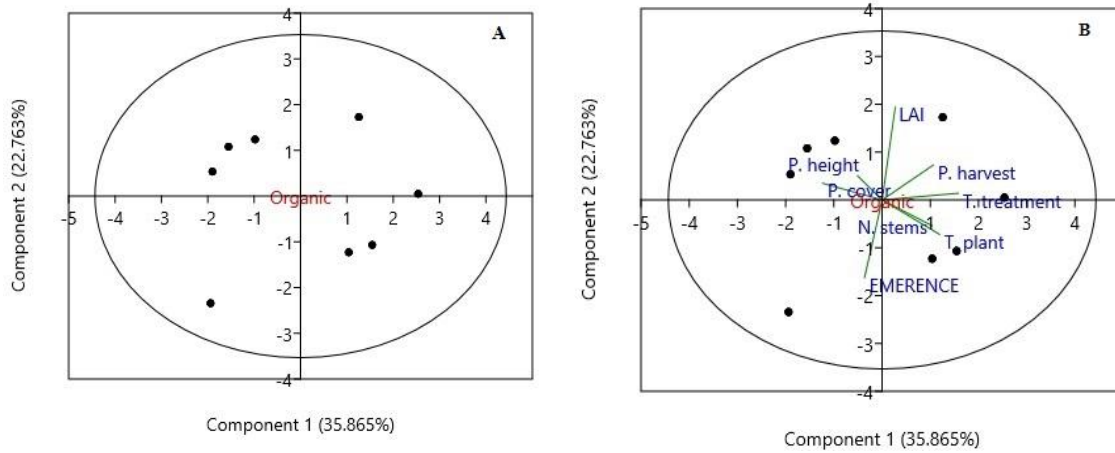
Components	Organic		Inorganic		Composite		Total	
	Eigen value	Variance (%)	Eigen value	Variance (%)	Eigen value	Variance (%)	Eigen value	Variance (%)
Comp. 1	2.869	35.865	2.764	34.618	2.544	31.798	2.093	26.16
Comp. 2	1.821	22.763	2.049	25.607	2.225	27.819	1.744	21.81
Comp. 3	1.495	18.690	1.085	13.569	1.291	16.141	1.535	19.19
Comp. 4	1.267	15.842	1.013	12.664				
<b>Total variance</b>		<b>93.16%</b>		<b>86.458%</b>		<b>75.758%</b>		<b>67.16%</b>

Comp. – component



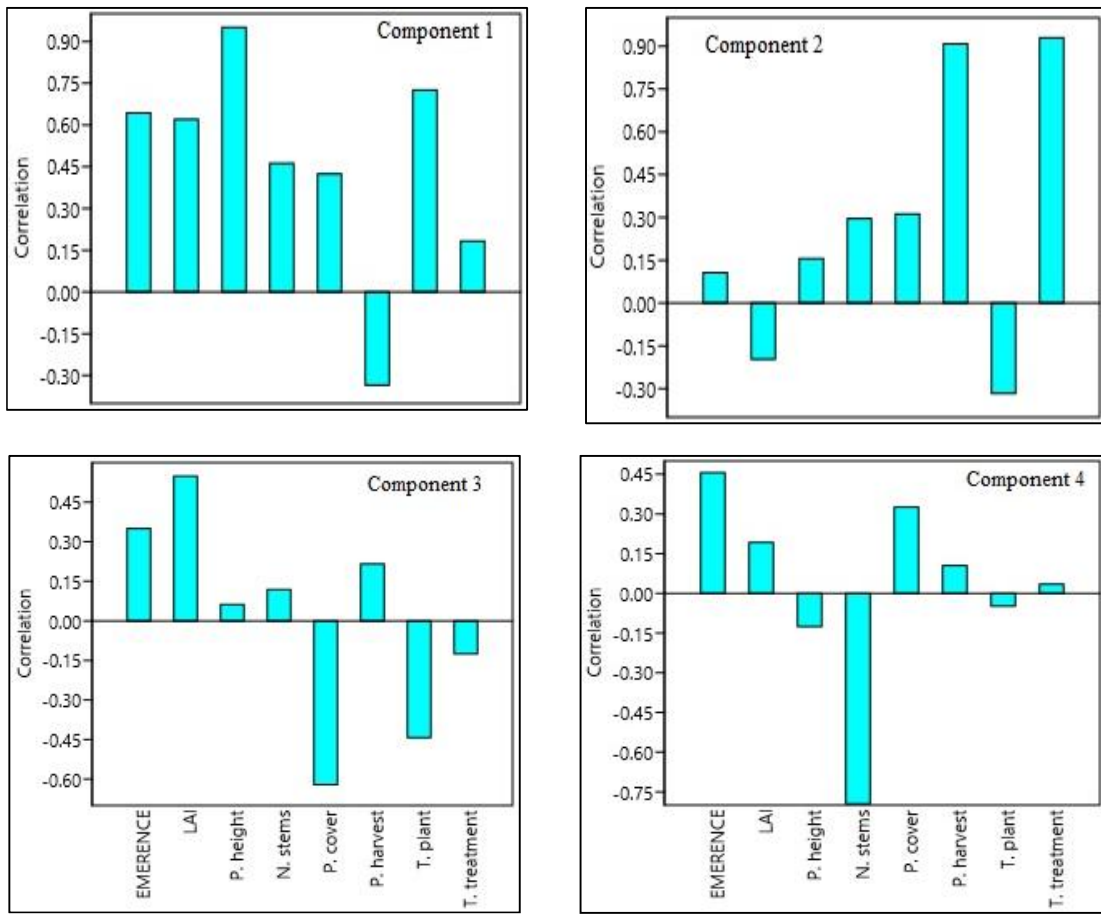
**Fig. 2. Factor loading of principal components from organic nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment



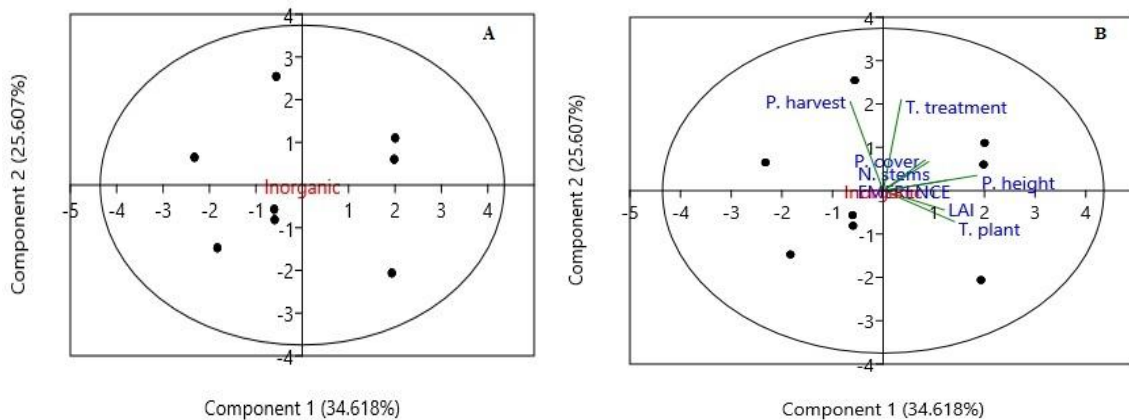
**Fig. 3. Scatter plots and biplots for organic nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment



**Fig. 4. Factor loading of principal components from inorganic nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment



**Fig. 5. Scatter plots and biplots for inorganic nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment

### 3.3.3 Factor loading, scatter plot and biplot of principal components from composite nutrient sources

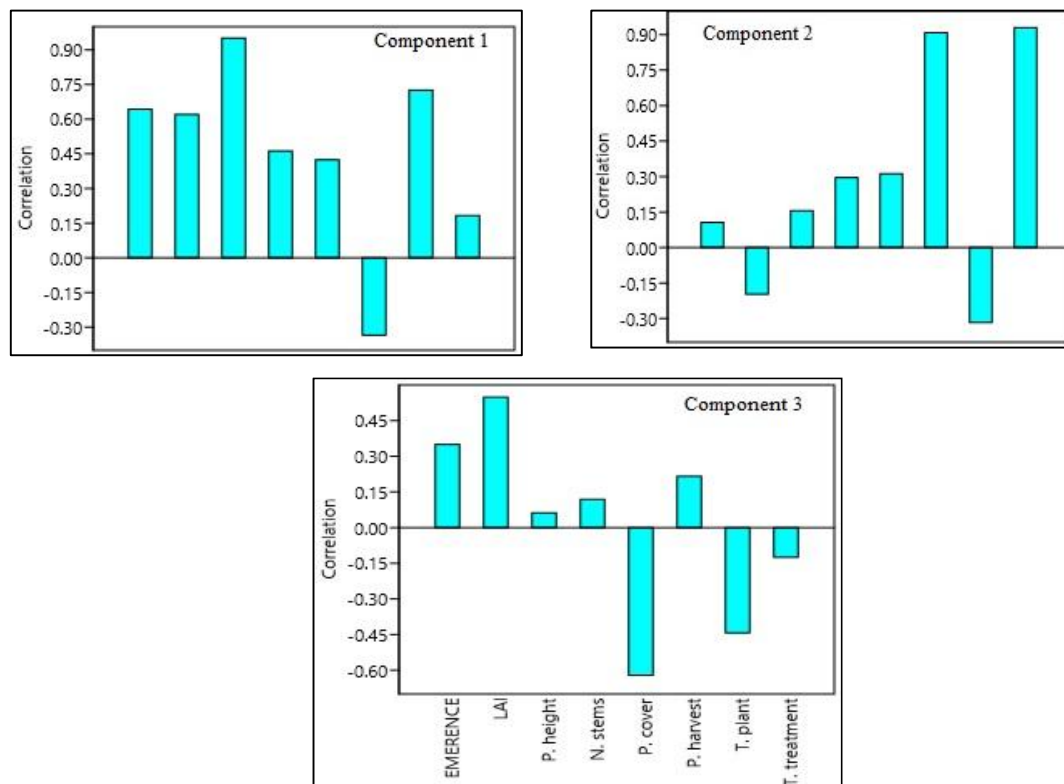
The factor loading of principal components from composite nutrient sources are presented in Fig. 6. The leading parameters in component 1 were emergence, leaf area index, plant height and number of tubers per plant. The number of plants harvested and the number of tubers per treatment were the leading parameters in component 2. In component 3, plant cover and the number of tubers per plant were the leading parameters. It should be noted that some parameters had significant loadings (absolute score value  $\geq 0.30$ ) in more than one component.

The association and variations in space of some growth and yield parameters of Irish potato cultivated on composite nutrient source is shown in Fig. 7 (A & B). The result is reported for the first two dimensions which account for the most variations (59.727%) from composite nutrient source. Plant height and plant cover were the

main influencers of component 1. The number of tubers per plant and the number of plants harvested were the main influencers of component 2 although in opposite directions. Interestingly, the number of stems and the number of plants that emerged influenced component 1 and component 2.

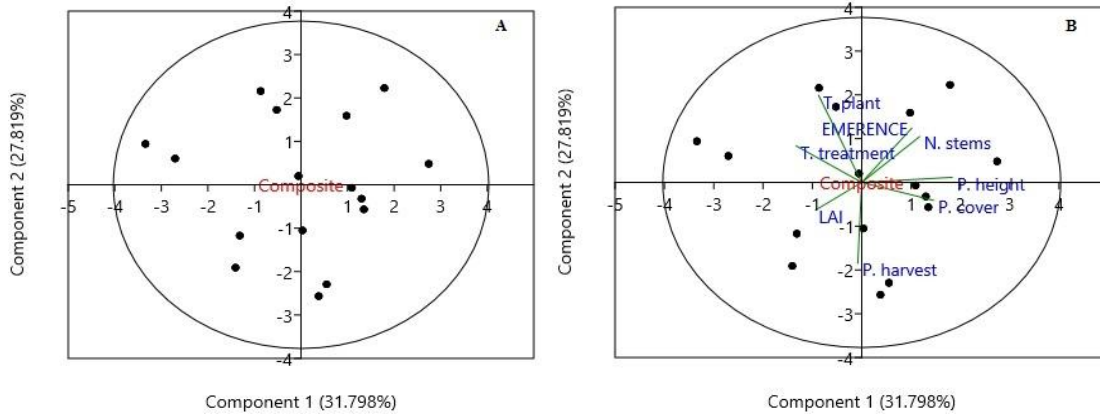
### 3.3.4 Factor loading, scatter plot and biplot of principal components from combined (Total) nutrient sources

The factor loading of principal components from all nutrient sources (Total) are presented in Fig. 8. The leading parameters in component 1 were emergence, plant height and plant cover. Number of stems and number of tubers per plant were the leading parameters in component 2. In component 3, leaf area index, number of plants harvested and the number of tubers per treatment were leading parameters. It should be noted that some parameters had significant loadings (absolute score value  $\geq 0.30$ ) in more than one component.



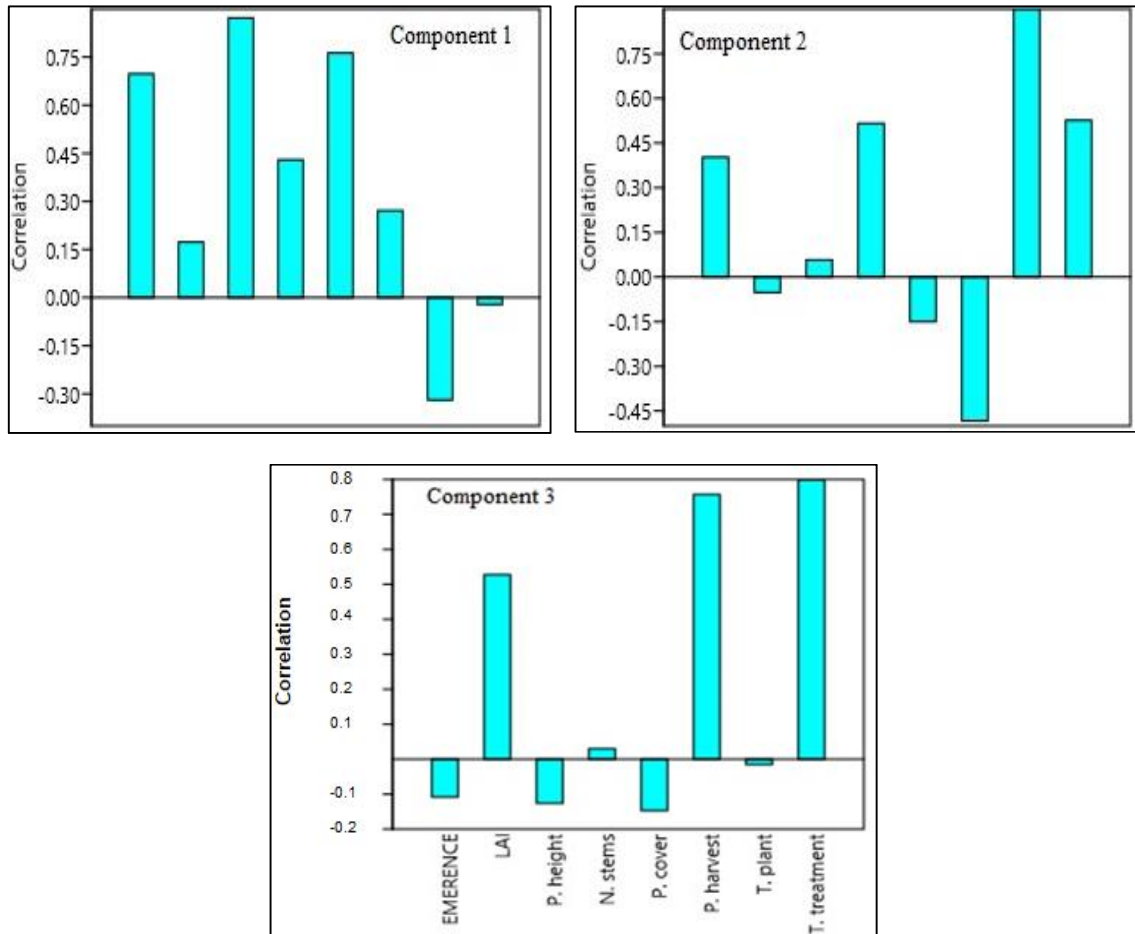
**Fig. 6. Factor loading of principal components from composite nutrient source**  
 LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment





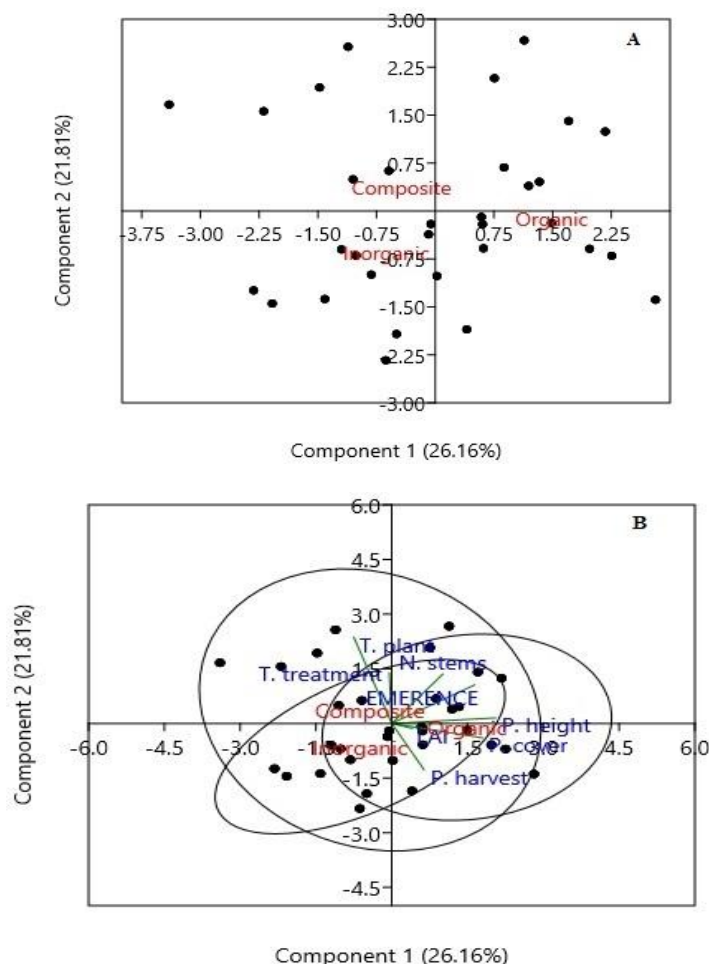
**Fig. 7. Scatter plots and biplots for composite nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment



**Fig. 8. Factor loading of principal components from total nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment



**Fig. 9. Scatter plots and biplots for combined (Total) nutrient source**

LAI – Leaf area index; P. Height – Plant height; N. stems – number of stems; P. cover – Plant cover; P. harvest – number of plants at harvest; T. plant – number of tubers per plant; T. treatment – number of tubers per treatment

The association and variations in space of some growth and yield parameters of Irish potato cultivated on heterogeneous nutrient sources is shown in Fig. 9 (A & B). The result is reported for the first two dimensions which account for the most variations (47.97%) from composite nutrient source. The plants that emerged, the plant height and plant cover were the main influencers of component 1. Component 2 was mainly influenced by number of stems, number of tubers per plant and number of tuber per treatments. The biplots shows that plant height, plant cover and the number of plants at harvest were influenced by organic nutrient source. Inorganic source strongly influenced plant cover, plant height, emergence and the number of plants at harvest. Composite nutrient source influenced all parameters.

#### 4. DISCUSSION

Principal component analysis is a suitable method to analyze the interaction between many parameters influenced by many factors. The technique has been exploited in many related studies. The goal of this study was to evaluate interactions and associations of a growth and yield parameters of Irish potato as influenced by different nutrient sources. In particular, this study was to deviate from the traditional pair wise correlation. It is clear that a holistic view of the role of fertilizers, especially organic fertilizer in the growth and yield parameters will improve its utilization. The findings of this study reveal that the performance and association of growth and yield parameters varied across different nutrient sources.

The scatter plots and biplots of organic nutrient sources showed that the two yield parameters (number of tubers per plant and number of tubers per treatment) were strong influencers of component 1. On the other hand, vegetative factors were strong influencers of component 2. A different pattern was observed from the scatter plots and biplots of inorganic nutrient sources. Plant height, LAI and number of tubers per plant were the major influencers of component 1 while number of plants harvested and number of tubers per treatment were the main influencers of component 2. Interestingly, composite nutrient sources revealed a mixed (if not almost equal) of reproductive and vegetative parameters in each component. The biplots and scatter plots of all nutrient sources combined showed that reproductive parameters were skewed more towards organic nutrient sources, vegetative parameters were skewed more toward inorganic nutrient sources and both vegetative and reproductive parameters were encompassed in composite nutrient source.

## 5. CONCLUSION

We conclude that varied nutrient sources (organic, inorganic and composite) affects Irish potato differently. Consequently, both organic and inorganic nutrient sources should be seen as synergistic and not mutually exclusive for holistic production of Irish potato.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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