

RESEARCH PAPER

# Influence of Irrigation and Soil Amendments on Growth, Yield, and Quality of French Beans in Salt-affected Soils

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Received: 29-08-2024

Revised: 23-11-2024

Accepted: 02-12-2024

## ABSTRACT

French beans (*Phaseolus vulgaris* L.) are crops grown mainly due to their nutritional benefits. The irrigation methods and soil amendments aid in amelioration of salt-affected soils as well as improving the productivity of crops. The experimental site was located in Kabaa irrigation scheme in Machakos County. The study was carried out in two consecutive seasons during the short rains (October-December 2021) and the long rains (March-May 2022). This study evaluated the effects of irrigation and soil amendments on the growth, yield and quality of French beans. The experiment was set up in a Randomized Complete Block Design (RCBD) in a split plot arrangement with the main plots (basin and furrow irrigation) and the sub-plots (gypsum + farmyard, fertium non-salt, vermicompost, control, and farmyard manure) replicated thrice. The data collected was subjected to Analysis of Variance (ANOVA) using R-Software 2023, version 4.0.3. Where significant differences were observed, means were separated using the Least Significance Difference (LSD) at a 5% level of significance. The findings from this current research indicate that in terms of the soil amendments, gypsum and farmyard blend resulted in the maximum plant height (67.80cm), pod length (15.97) and pod dry weight (0.41g). Furrow irrigation resulted in the lowest mean values of the parameters in season one and season two. The findings reveal that gypsum + farmyard and basin irrigation contributed to significant improvements in growth, yield and quality of French beans. The study therefore recommends the adoption of gypsum + farmyard mixture and basin irrigation method in boosting French bean productivity by farmers. The policy makers can propose to farmers the soil amendments for sustainable saline soil management.

## HIGHLIGHTS

- Basin irrigation was consistently superior to furrow irrigation in eliciting yield and quality attributes of French beans in both seasons.
- Gypsum + farmyard manure under basin irrigation resulted in longest pod lengths out of all the treatments which may be attributed neutralization of salinity levels in water, improved electrical conductivity and exchangeable sodium percentage that provided conducive plant development conditions. Pod length is considered key quality attribute of French bean.
- Decision or policy-makers need to focus on more integrative approaches as alternative tools and opportunities to increasing access to soil amendments to ameliorate the effects of soil salinity/sodicity for increased French bean yield and quality.

**Keywords:** Gypsum, vermicompost, pod length, calcium enhancement, sodicity, salinity

**How to cite this article:** Mogire, E.O., Miriti, J., Gitari, H. and Joseph P Gweyi-Onyango. (2024). Influence of Irrigation and Soil Amendments on Growth, Yield, and Quality of French Beans in Salt-affected Soils. *Int. J. Bioresource Sci.*, 11(02): 97-108.

**Source of Support:** IUCEA; **Conflict of Interest:** None



French bean (*Phaseolus vulgaris* L.), also called snap beans is a horticultural crop that produces a characteristic sound during harvesting of pods from the bean plant (Serawat *et al.* 2020). Despite the many advantages to farmers, its full potential is affected by low organic matter percentages, low irrigation water quality among many other stress factors (Maggio *et al.* 2007). Soil amendments are added to improve the soils chemical, physical and biological characteristics as a way of alleviating soil salinity which is the major cause of depleted soil fertility status (Diacono and Montemurro, 2015). Vermicompost as an organic material is prepared through the action of the earthworms on plant materials during the decomposition process (Shah *et al.* 2019; Rahimi *et al.* 2023). It plays a vital role in releasing hormones such as gibberellins and auxins after its application in the soil (Makkar *et al.* 2023). Farmyard manure is the accumulated animal waste such as urine and droppings which when added in the soil improves the soil organic carbon, water holding capacity, soil structure and formation of roots (Naresh, 2019; Mwadalu *et al.* 2022). Fertium non-salt is an organic fertilizer in liquid form enriched with complex calcium solution that makes the soil porous and improves its permeability enabling water to move in the soil profile (Lopes *et al.* 2012). The application of fertium in soils with high salinity levels eliminates sodium through displacement of the ions (Wijewardana *et al.* 2018). Gypsum and farmyard combination enables high moisture retention, electrical conductivity and bulk density reduction (Qadir *et al.* 2007).

Irrigation is the artificial application of water into the soils to supplement crops with adequate moisture during the dry seasons (Satchithanantham *et al.* 2014). Low quality water especially from industries affects the soil biodiversity and the soil chemical attributes such as the soil adsorption ratio and pH. The poor soil characteristics is an indication that the soils are structurally deformed (Omondi, *et al.* 2016). The basic methods of irrigation include furrow and basin irrigation. Basin irrigation is through flooding a whole area that is enclosed by a dyke whereby water is then allowed into the basins through the inlets whereby it will be held for some time for crop use (Khanna and Malano, 2006). Furrow irrigation involves water flowing through the gates whereby the furrows are dug along the contours to minimize

soil erosion (Boru *et al.* 2024). The evaporation that occurs in the furrows leads to water loss, salt accumulation and loss of water through seepage into the ground (Devkota *et al.* 2022). The furrows comprise of various sizes and their selection by famers relies on their ability to reduce salinity levels in the soil (Zaremanesh *et al.* 2017).

## MATERIALS AND METHODS

### Site Description

The experimental site was located in Kabaa irrigation scheme in Machakos County. The study was carried out in two consecutive seasons during the short rains (October-December 2021) and the long rains (March-May 2022). The longitude and latitude at the experimental site were 37.461776 and -1.247922 respectively. The site was located in Machakos Ccounty which is usually experiences low rainfall arising from climatic change effects. Machakos lies in the upper highlands agroecological zone and therefore classified as a semi-arid zone (Mairura *et al.* 2022). The county records an average annual temperature of 21.1°C with an altitude of 1000 -2100 m above sea level. The soils at the site were heavy clay to silty loam, deep and well drained. The soil chemical characteristics are tabulated as below (Table 1).

**Table 1:** Soil chemical characteristics at the experimental site

Parameter	Unit
pH	8.41
Electrical Conductivity	4.35 ds/m
Organic carbon	0.2%
Total nitrogen	0.05%
Available phosphorus	0.01%
Available potassium	0.05%
Cation Exchange Capacity	39 cmol/kg
Exchangeable Sodium Percentage	15.8
Lead	87.5 mg/kg
Copper	38.4 mg/kg
Cadmium	1.2 mg/kg
Copper (irrigation water)	3.5 mg/l
Lead (irrigation water)	5.5 mg/l
Cadmium (irrigation water)	0.05 mg/l



## Experimental Design and Crop Establishment

The experiment was set up in a Randomized Complete Block Design (RCBD) in a split plot arrangement with the main plots (basin and furrow irrigation) and the sub-plots (gypsum + farmyard mixture, fertium non-salt, vermicompost, control, and farmyard manure) replicated thrice. The seedbed had a total of 30 plots with each plot measuring 3 m by 3 m with 0.5 m within subplots and 1m between the blocks. The land was prepared early to improve aeration and kill weeds. Harrowing followed thereafter to create a proper tilth for planting of the seeds. The variety selected was Samantha and was sown in single rows at a spacing of 30 cm (inter-row) by 15cm (intra-row) at the rate of one seed in every hole. The planting depth was 1-2 inches and soil were covered lightly. Agronomic practices were carried uniformly in all the plots after planting.

## Field Measurements and Plant Tissue Sampling

Marking was done at the center of each subplot in a whole net area of 1 m<sup>2</sup> which was the marked area for data collection. This followed random selection of the plants and then tagging with a string for easier identification during measurement of the parameters. The parameters collected include plant height, pod dry weight and pod length on weekly basis until maturity. The plant height was measured by use of meter rule in centimeters at two, four and six weeks after the crop emerged from the ground to the main shoot tip. The pod dry weight was taken by drying them in an oven at sixty degrees Celsius (60°C) in the laboratory for six hours. This was then followed by measuring their weights using a digital weighing balance. The pod length was measured using a standard ruler in centimeters. Five randomly tagged plants were used in the measurement of the mentioned parameters.

## Soil sampling and analysis

An auger was used at a depth of 0-10 cm to collect soil samples from the experimental site using a traverse method of soil sampling. This was then followed by mixing, drying, grinding and sieving the composite sample obtained. The obtained soil samples were then put in clean bags and carried to the laboratory for further analysis.

## Statistical Data Analysis

The data collected was subjected to Analysis of Variance (ANOVA) using R software 2023, version 4.4 and where significant differences were observed, means were separated using Least Significance Difference (LSD) at 5% significant level.

## RESULTS

### Plant height

#### *Effects of irrigation and soil amendments on plant height*

Basin and furrow irrigation methods resulted in a significant increase ( $p \leq 0.05$ ) in plant height. Basin irrigation showed superior performance, with the highest plant height (53.98 cm) being observed at 6WAE in season two and the least plant height (9.86 cm) at 2WAE in season one. In season one, the plant heights were 8.95 cm at 2WAE, 43.69 cm at 4WAE, and 49.57 cm at 6WAE respectively under furrow irrigation. In season two, plant heights were 10.10cm at 2WAE, 45.14 cm at 4WAE, and 50.67 cm at 6WAE respectively (Table 2) under furrow irrigation.

Soil amendments had a significant influence ( $p \leq 0.05$ ) on plant height, with Gypsum + farmyard mixture resulting in plants with the highest plant height (67.80 cm) in season two at 6WAE, and control with the least mean height (5.68 cm) in season one at 2WAE. Plant response to soil amendments performance were recorded in the order of gypsum + farmyard mixture with the highest plant height, followed by vermicompost, farmyard, fertium, and control with the least across the two seasons (Table 2).

#### *Interactive effects between irrigation and soil amendments on plant height*

The interactive effects between irrigation and soil amendments showed significant ( $p \leq 0.05$ ) differences in plant height. The results revealed that gypsum + farmyard and basin irrigation interactions led to the highest plant height (69.00 cm) at 6WAE in season two, followed by gypsum + farmyard under furrow (66.59 cm) at 6WAE in season two with the least plant height at the control treatment under furrow (5.46 cm) at 2WAE (Table 3).

**Table 2:** Effects of irrigation and soil amendments on plant height (cm)

Factor	Treatment	2021 Short rains			2022 Long rains		
		2WAE	4WAE	6WAE	2WAE	4WAE	6WAE
Irrigation	Basin	9.86a	46.96a	52.55a	10.93a	48.49a	53.98a
	Furrow	8.95b	43.69b	49.57b	10.10b	45.14b	50.67b
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Soil Amendments	Gypsum+farmyard	13.09a	60.62a	66.39a	14.22a	63.83a	67.80a
	Vermicompost	11.36b	55.49b	56.97b	12.39b	56.59b	58.04b
	Farmyard	9.69c	44.34c	50.98c	11.18c	45.41c	52.42c
	Fertium	7.21d	37.44d	43.60d	8.32d	38.48d	44.96d
	Control	5.68e	28.74e	37.36e	6.45e	29.77e	38.42e
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter in a column are not significantly different at  $p \leq 0.05$ ; WAE = Weeks after Emergence.

**Table 3:** Interactive effects between irrigation and soil amendments on plant height (cm)

Treatments	2021 Short rains			2022 Long rains		
	2WAE	4WAE	6WAE	2WAE	4WAE	6WAE
Gypsum+Farmyard Basin	13.54a	62.00a	67.27a	14.65a	65.38a	69.00a
Gypsum+Farmyard Furrow	12.63b	59.24b	65.51a	13.80b	62.28b	66.59b
Vermicompost Basin	11.75c	57.42c	58.97b	12.81c	58.56c	60.04c
Vermicompost Furrow	10.96d	53.56d	54.97c	11.97d	54.61d	56.04d
Farmyard Basin	10.60d	45.86e	52.63d	10.66e	46.94e	54.44e
Farmyard Furrow	8.79e	42.81f	49.33e	9.71f	43.87f	50.39f
Fertium Basin	7.52f	39.06g	45.07f	8.65g	40.10g	46.52g
Fertium Furrow	6.91f	35.81h	42.13g	7.00h	36.86h	43.39h
Control Basin	5.90g	30.44i	38.84h	6.88i	31.47i	9.90i
Control Furrow	5.46g	27.03j	35.89i	6.02j	28.08j	36.95j
p-value		<0.05	<0.05	<0.05	<0.05	<0.05

Means followed by the same letter in a column are not significantly different at  $p \leq 0.05$ ; WAE = Weeks after Emergence.

## Pod dry weight

### *Effects of irrigation and soil amendments on pod dry weight*

The research findings revealed a significant difference between basin and furrow at  $p \leq 0.05$  on pod dry weight. Basin irrigation elicited the highest pod dry weight (0.26 g) compared to furrow irrigation (0.24 g) at 8WAE in season two. In season one, pod dry weight of 0.18 g was recorded under basin irrigation while furrow irrigation resulted in (0.14 g) at 8WAE. This result indicates that basin irrigation had higher pod dry weight compared to furrow irrigation across the seasons.

The soil amendments resulted in a significant difference ( $p \leq 0.05$ ) on pod dry weight, with gypsum + farmyard resulting in the highest pod

dry weight (0.41 g), followed by vermicompost (0.34 g), farmyard (0.24 g), fertium (0.14 g), and control (0.12g) with the least at 8WAE in season two. A similar trend in treatments was observed in season one, with gypsum + farmyard resulting in the maximum pod dry weight (0.34 g), vermicompost (0.19 g), farmyard (0.13 g), fertium (0.09 g), and control (0.04 g) with least pod dry weight at 8WAE (Table 4).

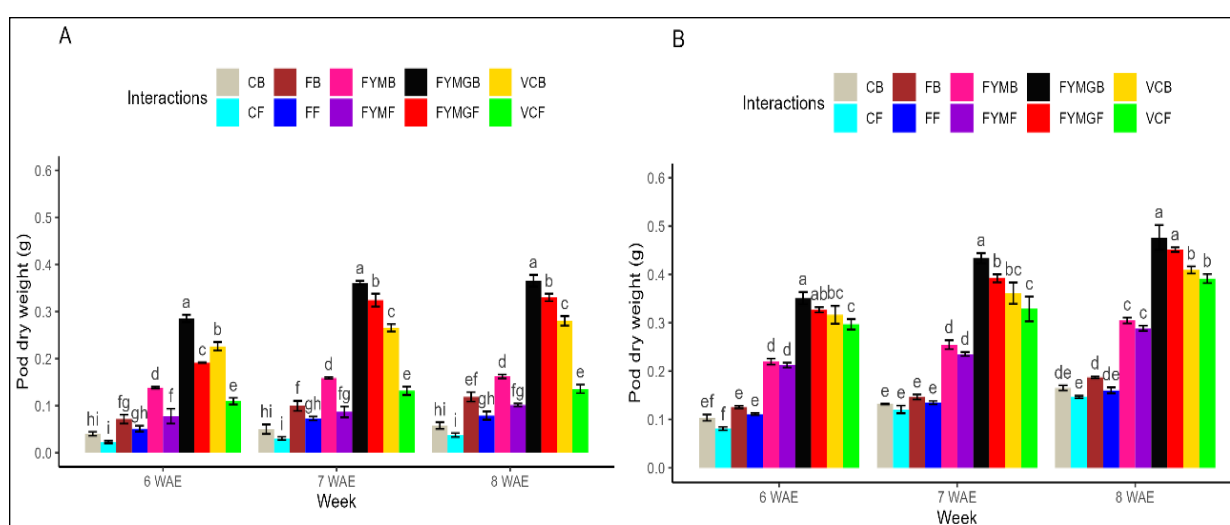
### *Interactive effect between soil amendments and irrigation on pod dry weight*

The interactions between soil amendments and irrigation method resulted in a significant difference ( $p \leq 0.05$ ) in pod dry weight. In season one, gypsum + farmyard against basin interaction resulted in a maximum pod dry weight (0.36 g) at 8WAE, and

**Table 4:** Effects of irrigation and soil amendments on pod dry weight (g)

Factor	Treatment	2021 Short rains			2022 Long rains		
		6WAE	7WAE	8WAE	6WAE	7WAE	8WAE
Irrigation	Basin	0.15a	0.17a	0.18a	0.17a	0.22a	0.26a
	Furrow	0.09b	0.12b	0.14b	0.12b	0.20b	0.24b
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Soil Amendments	Gypsum + farmyard	0.25a	0.34a	0.34a	0.33a	0.34a	0.41a
	Vermicompost	0.16b	0.18b	0.19b	0.18b	0.30b	0.34b
	Farmyard	0.10c	0.12c	0.13c	0.11c	0.21c	0.24c
	Fertium	0.06d	0.08c	0.09d	0.08c	0.11d	0.14d
	Control	0.03e	0.04d	0.05e	0.04d	0.09e	0.12d
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter in a column are not significantly different at  $p \leq 0.05$ ; WAE = Weeks after Emergence.



**Fig. 1:** Interactive effect between soil amendments and irrigation on the number of pod dry weight (g). Means followed by the similar letter above the error bar shows that treatment are not significantly different at  $p \leq 0.05$ . WAE = weeks after emergence, CB = Control Basin, CF = Control + furrow, FB = Fertium + Basin, FF = Fertium + Furrow, FYMB = FYM Basin, FYMF = FYM Furrow, GFYMB = Gypsum + FYM + Basin, GFYMF = Gypsum + FYM + Furrow, VB = Vermicompost + Basin, VF = Vermicompost + Furrow, A = 2021 Short rains and B = 2022 Long rains.

control under furrow irrigation had the least pod dry weight (0.03 g) at 8WAE (Fig. 1). Moreover, Gypsum + farmyard and basin interaction resulted in maximum pod dry weight (0.43 g) in season two at 8WAE, with control under furrow interaction recording the least pod dry weight (0.12 g) at 8WAE. This result revealed a decreasing order of dry weight (Fig. 1).

## Pod length

### *Effects of irrigation and soil amendments on pod length*

Basin and furrow irrigations resulted in a significant influence at  $p \leq 0.05$  on pod length. Basin irrigation

resulted in a maximum pod length (13.42cm), and furrow irrigation with lower pod lengths (12.76 cm) at 8WAE in season two. For season one, basin irrigation had a maximum pod length (13.40 cm), and furrow irrigation (12.46cm) at 8WAE. Basin irrigation resulted in longer pods (11.65 cm) and furrow irrigation with shorter pods (10.64 cm) at 6WAE (Table 5).

Soil amendments resulted in a significant influence at ( $p \leq 0.05$ ) on pod length. Gypsum + farmyard resulted in the longest pods (15.97cm), followed by vermicompost (14.59 cm), farmyard manure (13.67 cm), fertium (11.69 cm), and control (10.03 cm) with shortest pods at 8WAE. In season one, the lowest

**Table 5:** Effects of irrigation and soil amendments on pod length (cm)

Factor	Treatment	2021 Short rains			2022 Long rains		
		6WAE	7WAE	8WAE	6WAE	7WAE	8WAE
Irrigation	Basin	11.65a	12.18a	13.40a	12.72a	13.32a	13.42a
	Furrow	10.64b	11.39b	12.46b	11.83b	12.47b	12.76b
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Soil Amendments	Gypsum + farmyard	13.46a	14.55a	14.85a	14.64a	15.58a	15.97a
	Vermicompost	12.10b	13.08b	13.24ab	13.28b	14.11b	14.59ab
	Farmyard	11.89b	12.34c	12.63ab	13.00b	13.43b	13.61b
	Fertium	9.99c	10.29d	10.65b	11.19c	11.42c	11.69c
	Control	8.31d	8.68e	8.93b	9.27d	9.94d	10.03d
p-value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter in a column are not significantly different at  $p \leq 0.05$ ; WAE= Weeks after Emergence.

**Table 6:** Interactive effects between irrigation and soil amendments on pod length (cm)

Treatments	2021 Short rains			2022 Long rains		
	6WAE	7WAE	8WAE	6WAE	7WAE	8WAE
Gypsum+Farmyard Basin	13.77a	14.75a	15.10a	14.87a	15.52a	15.92a
Gypsum+Farmyard Furrow	13.15ab	14.35a	14.83ab	14.42ab	15.24ab	15.49a
Vermicompost Basin	12.61bc	13.60b	13.80b	13.79bc	14.65b	14.83ab
Vermicompost Furrow	12.38c	12.58c	12.74b	13.44cd	13.69c	14.35bc
Farmyard Basin	11.59d	12.56c	12.67b	12.77d	13.57c	13.74c
Farmyard Furrow	11.39d	12.11c	12.52b	12.56de	13.18c	13.48c
Fertium Basin	10.53e	10.72d	11.38b	11.71e	11.88d	12.39d
Fertium Furrow	9.45f	9.85e	9.93b	10.68f	10.96de	10.99e
Control Basin	8.98f	9.24f	9.65b	9.80f	10.49e	10.55e
Control Furrow	7.65g	8.11g	8.30b	8.74g	9.39f	9.51f
p-value		<0.05	<0.05	<0.05	<0.05	<0.01

Means followed by the same letter in a column are not significantly different at  $p \leq 0.05$ ; WAE = Weeks after Emergence.

pod length was recorded at the control (8.31 cm) at 6 WAE, with the longest (14.85 cm) at 8WAE (Table 5).

### ***Interactive effects between irrigation and soil amendments on pod length***

Irrigation and soil amendments interaction resulted in a significant effect ( $p \leq 0.05$ ) on the pod length. In season two, the gypsum + farmyard and basin irrigation interaction resulted in highest pod length (15.52 cm), and control furrow interaction (8.74 cm) with the minimum at 6WAE cm. For season one, under control furrow interaction, the maximum pod length (15.10 cm) was recorded at 8WAE, with the minimum pod length (7.65 cm) at 6WAE. Based on this result, gypsum + farmyard basin interaction resulted in the longest pods, followed by the vermicompost basin interaction, farmyard

manure basin interaction, fertium basin interaction, and control basin interaction (Table 6).

## **DISCUSSION**

### **Plant height**

#### ***Effects of irrigation and soil amendments on plant height***

The maximum plant heights under basin irrigation might be attributed to high moisture retention in the basins prompting more cell turgidity, division and enlargement, the argument that resonates with those of Momolu *et al.* (2016). This outcome is in agreement with different researchers whose findings in a study with sorghum showed that high moisture levels contribute to better plant heights (Kaaria *et al.*



2023). Minimum plant heights levels under furrow irrigation might be ascribed to high salt levels that increased electrical conductivity which damaged root execution and osmotic potential, limiting the plant water retention capacity and consequently affect root water pressure (Keskin *et al.* 2010). Comparative studies on tomato production have been documented and shows that exposure to salt pressure decreases osmotic potential and cause reduced height levels (Devkota *et al.* 2022; Seleiman *et al.* 2021).

Gypsum and farmyard manure blend resulted in greatest plant heights due to double calcium and sulfur supply as nutrients that caused the displacement of sodium particles and improvement of assimilates for cell augmentation (Narayan *et al.* 2022). This outcome is in agreement with other reports on gypsum and gypsum mix which resulted to more condusive soil pH and electrical conductivity for better productivity (Makoi and Ndakidemi, 2007). Greater heights due to vermicompost treatment might be credited to a blend of plant hormones such as auxins and humic acids into soil which supported the plants heights (Atiyeh *et al.* 2002). This outcome is in accordance with other previous results that showed greatest plant heights of tomatoes when vermicompost was applied (Olle, 2016). Farmyard manure results might be ascribed to constant provision of nitrogen and phosphorus in stable forms required for extension and enlargement of plant cells (Muhammad and Khattak, 2011). These findings are in line with other past findings (Altieri and Nicholls, 2012). The minimum plant height under control may be attributed to high salinity levels that reduced photosynthetic rates because of leaf sensitivity to salts (De Lacerda *et al.* 2003). This finding is in line with other authors (Carillo *et al.* 2011).

#### ***Interaction between irrigation and soil amendments on plant height***

Gypsum + farmyard mixture interaction result may be ascribed to improved soil porosity, moisture retention and calcium solubility for better growth conditions (Qadir, 2003). These results are in line with previous findings on gypsum and farmyard interactions (Abbas *et al.* 2023). The outcomes on vermicopost and basin irrigation interaction might be attributed to the balance of pH and improvement

of soil microorganisms essential for mineralization during plant development process (Murmu *et al.* 2013). Similar findings have been accounted for by Bhat *et al.* (2017). Farmyard and basin irrigation interaction finding might be attributed to the role of organic matter in the stockpile of organic matter combined with adequate moisture from the basins which caused cell expansion hence the plant heights recorded (Sharpley *et al.* 2015). This outcome is in conformity with past reports on farmyard manure and their phosphorus discharge in soil (Urvashi *et al.* 2007). Control treatment under furrow interaction outcome might be credited to decrease of carboxylase chemicals causing disposal of significant micronutrients required by the plant thus least plant heights (Zhu, 2007). This outcome is in accordance with different findings on soil salinity (Yadav *et al.* 2011).

#### **Pod dry weight**

##### ***Effects of irrigation and soil amendments on pod dry weight***

Furrow irrigation result may be attributed to high salt accumulation in the rhizosphere, causing decline in the chemical and physical attributes. The decline in the soil properties caused moisture stress and reduced photosynthesis and poor development of pods (Ouzounidou *et al.* 2014). This result is in agreement with other reports on amelioration of salt stress as a way of improving photosynthetic apparatus in plants (Mbarki *et al.* 2018). Basin irrigation result might be ascribed to high moisture content in the rhizosphere, expanding supplements movement and carbohydrate assimilation for pod attributes (Hafez *et al.* 2021). This outcome is in concurrence with other scientists on biomass partitioning under varied moisture levels (Morales-Elias *et al.* 2021).

Gypsum + farmyard combination result might be ascribed to further developed soil structure, water holding limit, flocculation, high moisture maintenance and decreased spillover for better pod formation (Chancellor, 2013). This outcome is in concurrence with different authors on increments on weights of pods under gypsum and farmyard manure mix (Saddiq *et al.* 2021). Vermicompost result might be attributed to strength in organic compounds and macronutrients in available forms

promptly used by plants (Parwada and Chipomho, 2023). This outcome resonates well with different findings on the role of vermicompost as an asset of soil maintainability and plant development in arid soils (De Lavôr *et al.* 2024). Farmyard manure result contrasted with fertium and might be ascribed to the development of photosynthetic apparatus emerging from better vegetative development areas (Naima *et al.* 2014). This outcome is in line with different reports on the role of organic matter in yield components of cabbages (Zango *et al.* 2009). Fertium result may be attributed to the role of calcium ions in pectin formation in cell walls hence sturdier pod formation (Delmer *et al.* 2024). This result is in line reports of other authors on pectin control and cell wall mechanics in plants (Peaucelle *et al.* 2012).

### ***Interaction between irrigation and soil amendments on pod dry weight***

Control treatment under furrow irrigation interactions resulted in least pod dry weights which may be attributed to excess water and wash aways in nitrogen and potassium nutrients from the root zone causing imbalance in soil and therefore poor pod yield components (Poch-Massegú *et al.* 2014). Such result is in line with other previous findings on sodicity and salinity's detrimental effects on metabolic and biomass quotients (Singla and Garg, 2005). Gypsum+farmyard under basin irrigation resulted in maximum pod dry weight which may be attributed to double benefits by reducing serious salinity effects in soil and improved soil chemical properties from calcium and sulfur nutrients (Bhattacharyya *et al.* 2015). This outcome is in concurrence with past researchers on related works (Sundha *et al.* 2020). Vermicompost under basin irrigation results might be credited to the arrangement of sufficient soil supplements and moisture for microorganism abundance improving better pod developments (Yang *et al.* 2015). This outcome is in concurrence with different authors (Masciandaro *et al.* 2014). Farmyard manure and furrow interaction result might be attributed to uneven soil moisture retention which caused partial organic matter breakdown prompting less nutrient supply expected for pod development (Sierra *et al.* 2015). This outcome is in concurrence with previous results on how organic matter decay occurs in poor soils (Sahrawat, 2003). Fertium and basin

irrigation interaction result might be ascribed to the movement of calcium into plant roots that assumed fundamental part in restricting center lamella for appropriate pod development (Ahmad and Wani, 2013). This outcome is in accordance with different findings (Läuchli and Bielecki, 2012).

### **Pod length**

#### ***Effects of irrigation and soil amendments on pod length***

Basin irrigation resulted to longest pods which might be ascribed to expanded metabolic cycles and cell growth from high moisture content in basins (Reddy *et al.* 2003). This result is in concurrence with other reports (Ford, 2024). Furrow irrigation result may be attributed to minimized calcium absorption by the plants required in pod development due to more salinity and sodium levels hence reduced pod lengths (Kadirimangalam *et al.* 2022). This result is in line with reports of other authors (Singh *et al.* 2023). Gypsum and farmyard mixture result may be attributed to synergistic influence in promotion of aeration and soil drainage encouraging stronger root formation for adequate nutrient uptake needed for pod formation (Lal and Stewart, 2013). This result is in agreement with other reports on improved soil structure and reduced soil salinity under application of organic amendments (Irin and Hasanuzzaman, 2024). Vermicompost results may be ascribed to role of humic acids and important hormones which stimulated growth of different plant components (Angmo *et al.* 2024). This result is in agreement with other authors' findings on vermicompost role in hormone and nutrient supply required by plants during growth period (Cruz *et al.* 2024). Farmyard recorded longer pods than fertium which may be attributed to supply of phosphorus into soil and finally to plants that played crucial role in transfer of energy and conducting photosynthetic environment for better pod qualities (Katara *et al.* 2022). This result is in agreement with other findings on the impact of biofertilizers on the soil properties under production of chickpeas (Patel *et al.* 2024). Fertium resulted into longer pods than control which may be attributed to the role of calcium supplied in the formation of healthy cell membranes reducing the leakage of cell contents, improved better cell function and reduced abortion of ovules (Xiloyannis



*et al.* 2008). This result is in agreement with other findings (Ge *et al.* 2007). Control treatment's may be attributed to more salts in the growth medium that were absorbed by the plants hindering leaf growth, reduced enzyme activities and the photosynthetic efficiency (Farooq *et al.* 2021). This result is in concurrence with other findings (Hualpa-Ramirez *et al.* 2024).

### **Interaction between irrigation and soil amendments on pod length**

Control treatments under furrow irrigation resulted in least pod length compared to control treatment under basin treatment which may be attributed to poor water infiltration in the soil due to increased sodium adsorption ratio in water hindering the water uptake by plant needed for better quality pods (Wakchaure *et al.* 2023). Similar results have been reported by Naorem *et al.* (2023). Vermicompost under basin irrigation results may be attributed to organic matter for retention of moisture and provision of growth regulators hence longer pods (Ebrahimi *et al.* 2021). This result is in line with previous ones on the role of vermicompost and irrigation on the productivity of cucumber plants (Piri *et al.* 2022).

Gypsum+farmyard manure under basin irrigation resulted in longest pod lengths out of all the treatments which may be attributed neutralization of sodicity levels in water, improved electrical conductivity and exchangeable sodium percentage that provided conducive plant development conditions (Grover *et al.* 2024). These findings agree with the results of Sundha *et al.* (2018). Fertium under basin irrigation outcome may be explained by the absorption of calcium by the plant that is thought to aid in the prevention of ovule abortion and therefore the pods expansion (Kadirimangalam *et al.* 2022). This result is in conformity with other reports on foliar application of calcium in the reproductive stages of soybean (Fioreze *et al.* 2017).

## **CONCLUSION**

The results revealed that gypsum + farmyard manure combination and basin irrigation resulted in best French bean growth yield and quality attributes compared to other treatments. The interaction between gypsum + farmyard manure basin showed superior French beans performance. Therefore,

based on our results, we suggest that decision or policy-makers focus on more integrated approaches to provide alternative tools and opportunities like increasing access to soil amendments to ameliorate the effects of soil salinity for increased French bean yield and quality.

## **ACKNOWLEDGMENTS**

The authors hereby acknowledge the financial support from KCSAP project through KALRO, Kenyatta University and Karlo-Kabete for their technical support in the outcome of this study.

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