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The effect of cow manure combined with foliar sprays of black jack (*Bidens pilosa* L.) and comfrey (*Symphytum officinale* L.) leaf extracts on the growth, yield and nutritional quality of common bean (*Phaseolus Vulgalis* L.)

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Abstract

Common bean (Phaseolus vulgaris L.) is important legume crop for nutritional and food security in Kenya. Declining soil fertility in small holder farms, as a result of limited or non-application of inorganic fertilizer, because of rising costs, has resulted in low production. The aim of the study was to investigate the effect of cow manure combined with foliar sprays of black jack (Bidens pilosa L.) and comfrey (Symphytum officinale L.) extracts on growth, yield and nutritional quality of common bean. A 4 x 6 factorial experiment in a randomized complete block design (RCBD) with 3 replicates was conducted in Egerton University's research Field 7 for two cropping seasons. Four fertilizer levels were 0, 5, 10 t ha^{-1} of cow manure and 148.15 kg ha^{-1} NPK (27-27-27) fertilizer, as a positive control. In addition, six foliar spray treatments; no spray (control), comfrey spray applied once(C1) or twice weekly(C2), black jack spray applied once(B1) or twice (B2) weekly and commercial Easy Grow spray (EG) (positive control), applied every 14 days at the rate of 3 kg ha^{-1} were used. Soil samples were collected before the experiment set up for analysis of initial chemical and physical properties. Data on yield parameters, including harvest index, hundred seed weight, yield per ha^{-1}, and protein content in seeds were collected at harvest. The Shapiro-Wilk test was used to ascertain the normality of data and analysis of variance was performed using Proc GLM in Statistical Analysis Software (SAS). Tukey's Honestly Significant Difference was used to compare the means at $P<0.05$. Compared to lesser manure rates, treatment M2 (10 t ha^{-1}) of cow manure performed better than other manures and control, it produced taller plants, more branches, higher biomass, great pod number, high seed weight, and yield than the control and lower manure rates. The effects of foliar spraying varied by stage; at the V4 stage, comfrey once a week (C1) and Black Jack sprayed twice a week (B2) increased plant height and the leaf area index, while C2 (comfrey twice a week) produced the most grain. The combination of M2 and C2 produced the maximum yield (2373.88 kg ha^{-1}), which can be recommended for beans production.

Keywords: Common beans, Cow manure, Foliar spray

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Introduction

Common bean (*Phaseolus vulgaris* L.*)* is a crucial legume crop globally (DI *et al.*, 2021; Nadeem *et al.*, 2021). In Kenya, common bean plays a vital role in food and nutrition security for many Kenyan households and stands as an important dietary staple, particularly among low-income populations (Shoko, 2021). The crop is valued for its protein, fiber, vitamins and minerals (Keller *et al*., 2020). Its adaptability to various climates and soils renders it indispensable, offering sustenance and economic stability to farmers. The estimated average production of common beans in Kenya in 2023 was 610,000 metric tons, with an average yield of about 0.6 tons per hectare (Oteng, 2023). It is grown by approximately 1.5 million smallholder farmers across one million hectares, mainly in the Rift Valley, eastern, and Lake Victoria regions (Duku *et al*., 2020). National consumption of common beans is estimated at about 755,000 metric tons annually, leading to a supply deficit of approximately 145,000 metric tons (Kavoi *et al*., 2022). Despite its nutritional importance, common bean cultivation faces challenges from various biotic and abiotic factors (Diaz *et al*., 2018). According to Nadeem *et al*. (2019) the productivity and quality of common bean crops are often hindered by abiotic stresses such as drought and low soil fertility, particularly low phosphorus, potassium and nitrogen availability. Low yields, however, persist in small holder farms as inorganic fertilizers are typically not applied directly to the beans (Rurangwa *et al*., 2018). Instead, farmers commonly apply fertilizers to associated crops, except in cases where beans are intercropped with them. This practice arises due to various reasons, including the high costs associated with synthetic fertilizers and the specific nutrient requirements of other crops. Consequently, common beans often face nutrient deficiencies, leading to a notable yield gap between their potential (2.5 t ha^{-1}) and actual yield (1.2 t ha^{-1}) in Kenya. Moreover, the adverse effects of synthetic fertilizers on human health and the environment highlight the urgent need for alternative soil enrichment methods in bean cultivation. Using comfrey manure even in foliar sprays is highly beneficial for organic gardening, promoting plant health, vigor, yield, improving soil fertility and structure (Waddington, 2019). Comparing to animal manure, the ratio of NPK are relatively low in comfrey; however, its nutrients are more immediately bioavailable to plants, especially in liquid form(Amy, 2014). Black jack, with its rich nutrient content and diverse chemical composition (Chatepa & Masamba, 2020), holds significant promise for improving crop health and yield when incorporated into foliar spray liquid manure. Its contribution of essential nutrients, polyphenols, and flavonoids not only enriches the foliar feeds but also provides antioxidant properties crucial for crop resilience (Ramabulana *et al.*, 2020). Additionally, bioactive compounds such as alkaloids, tannins, and flavonoids found in black jack can further boost plant growth and defense mechanisms (Mboya, 2018). Cow manure is a valuable organic fertilizer for common beans, offering several benefits. It improves soil structure and fertility by increasing water-holding capacity and aeration, allowing for better root growth and water absorption (Musaninkindi, 2010). Additionally, manure contains macro- and micro-nutrients that promote plant growth and development, including nitrogen, phosphorus, and potassium. The nitrogen content in cow manure is particularly beneficial for common beans, as it supports leaf growth and development (Basdemir *et al*., 2022). However, there is insufficient knowledge regarding the combined effects of cow manure and foliar sprays of comfrey and black jack extracts on common bean growth, nutrient uptake, nutritional quality and yield. In this study, cow manure was used in combination with extracts of comfrey and black jack to enhance nutrient uptake, nutritional quality, growth and yield of common bean.

Materials and methods

Description of Experimental Site

The study was carried out in Field 7 research field, located within Egerton University's Njoro campus in Kenya. The university is situated in latitude 0.1801° S and longitude 35.9718° E in the Rift Valley region of Nakuru County, Njoro. The region is situated at an elevation of roughly 2,238 meters above sea level. About 1200 mm of rain falls on average each year and its distribution is bimodal, with short rains occurring from October to December and long rains from April to June. Because of the high elevation, the temperatures are generally mild all the year, its average range is between 10.2°C and 22.0°C (Taiy, 2017). The soils at the experimental site consist of well-drained, dark reddish clays that are classified as mollic Andosols (Agutaa, 2015). The field experiment was conducted in two cropping seasons; March to June 2024 and September to December 2024.

Experimental Materials

Test Crop

Nyota bean, a popular common bean variety in Kenya, was used in the study. It is known for its exceptional taste, versatility, and high nutritional value. It was bred by the Kenya Agricultural and Livestock Research Organization (KALRO) specifically for the Kenyan market (Pgoldstein, 2022a). Nyota beans are typically determinate, meaning they have a more compact growth habit and stop growing once they reach a certain size (Millicent, 2022). Nyota beans are usually mottled or speckled in color, often brown or red. They generally mature in about 70-90 days, depending on environmental conditions. Nyota beans are known for their high yield potential, making them a popular choice among farmers. The yield of Nyota beans typically ranges from 1400 to 2200 kg per hectare (Pgoldstein, 2022b), approximately 6 to 10 bags (90 kg each) per acre. Under optimal conditions, some farmers have reported yields of up to 12 bags per acre. The seeds were sourced from Agro Science Park, Egerton University.

Analysis of cow manure

Cow manure was analyzed for organic carbon, nitrogen, phosphorus, potassium, and moisture content. The process began by collecting cow manure from farms at Egerton University, then drying the manure in an oven for 24 to 48 hours at 75 °C. The target moisture content after drying was around 10% to 20%, ensuring optimal nutrient concentration and stability for effective use as organic fertilizer. The dried manure was stored in a dry and well-ventilated area to prevent mold growth and maintain its quality. Total nitrogen was measured using the Kjeldahl method at soil laboratory (Crops, Horticulture and soils department) which involved digesting the sample in sulfuric acid to convert nitrogen into ammonium sulfate, followed by distillation and titration to determine the nitrogen content (Lithourgidis *et al.*, 2007). The total phosphorus content in cow manure was determined using the molybdenum blue method, which involved digesting the sample to convert various forms of phosphorus into orthophosphate. The orthophosphate then reacted with ammonium molybdate and ascorbic acid, resulting in the formation of a blue complex. The intensity of this blue color was measured using a UV-Vis

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spectrophotometer at a wavelength of 420 nm, and it was directly proportional to the concentration of phosphorus in the cow manure (He *et al*., 2003). The potassium was measured using the ammonium acetate method, where the sample was extracted with an ammonium acetate solution, and then the extracted potassium was measured using an Atomic Absorption Spectrophotometer (Bazargan *et al*., 2022). The Walkley-Black method was used for organic carbon present (Enang *et al.*, 2018) and the moisture content was determined by drying a 200g of the cow manure sample in an oven at 105°C until a constant weight was reached, with the difference in weight before and after drying representing the moisture content.

Preparation and analysis of content of comfrey and Black jack teas

Fresh leaves from comfrey (*Symphytum officinale* L.), grown in field 7, and black jack (*Bidens pilosa* L.) present in the fields at Egerton University were collected. The extracts from the plants were prepared in separate buckets using a proportion of 1 kg of comfrey and black jack leaves and 5 liters of non-chlorinated water (Rozie, 2022). The mixture was stirred every 1-2 days. After 1-3 weeks, when no more foam forms during stirring, the extracts was ready for use (Scheuerell & Mahaffee, 2002)**.** Initially, 1 kg of leaves was mixed with 5 liters of water, resulting in a concentration of 0.2 kg/L. Before application, 1 liter of this resulting solution was diluted with 10 liters of water, increasing the total volume to 11 liters. Since 1 liter of the original solution contained 0.2 kg of leaves, the final concentration after dilution was calculated as 0.2 kg divided by 11 liters, resulting in a final concentration of approximately 0.01818 kg/L for each extract. For spraying on an entire hectare of common beans, approximately 200 kg of comfrey leaves and 200 kg of black jack leaves are needed to prepare nutrient-rich solutions (*foundations for farming*)

Figure 1: Comfrey and black jack foliar sprays preparation

To analyze the nutrient content present in comfrey and black jack extracts, 0.3 ml of each solution has been taken, then it was analyzed from nitrogen, phosphorus and potassium using the same methods as those used for cow manure analysis.

Soil preparation and planting

Prior to the start of the rainy season, land management activities such as ploughing and harrowing were undertaken. Bean seeds were planted directly to plots already prepared to a fine tilth at a spacing of 50 cm between the rows and 20 cm between the crops on the same row. Each plot had 40 plants. Planting was carried out manually, with seeds being sown at a depth of 2.5 cm. After sowing, the seeds were lightly covered with soil. Weeding commenced two weeks after the seeds had emerged, followed by a second weeding three weeks later.

Experimental Design and Layout

The field experiment was conducted at Field 7 of Egerton University, encompassing setups for both the short and long rainy seasons, using a 4x6 factorial design implemented in a randomized complete block design (RCBD). The individual plot size was 2 m x 2 m, with blocks and plots separated by 1 m and 0.5 m respectively. The factors included fertilizers applied directly to the soil during planting and foliar feeds applied through spraying. Four fertilizer treatments were used: no cow manure (negative control), 5 tonnes ha^{-1} (50 g per hole) cow manure, 10 tonnes ha^{-1} (100 g per hole) cow manure, and NPK at a rate of 148.15 kg ha^{-1} as a positive control. For foliar feeds, two leaf extracts-*Symphytum officinale* (Comfrey) and *Bidens pilosa* (Blackjack)-were applied at different frequencies (once and twice per week), along with a positive control consisting of Easy Grow (Easy Grow vegetative NPK ratio of 27:10:16 and Easy Grow fruit and flower NPK ratio of 14:11:33) applied every two weeks for a total duration of six weeks, and a negative control with no foliar application. The leaf extracts were applied as foliar sprays two weeks after germination in a ratio of 1:10 (1 liter of each plant tea diluted with 10 liters of water). This study consisted of a total of 24 treatments, replicated across 3 blocks, making a total of 72 plots.

Table 1: Treatments and their levels

Factor A(Fertilizers), 4 levels	Factor B (Foliar feeds), 6 levels
M0: no application of cow manure	C1: Comfrey spray, once a week
M1: 5 tonnes ha^{-1} or 50 g per hole of cow manure	C2: Comfrey spray, twice a week
M2: 10 tonnes ha^{-1} or 100g per hole of cow manure	B1: Black jack, once a week
NPK (27-27-27): application of 148.15 kg ha^{-1} of NPK, also acted as a positive control	B2: Black jack, twice a week
	F0: no foliar spray, which acted as a negative control
	EG: Easy grow (Easy grow vegetative at NPK ratio 27:10:16 and Easy grow fruit and flower at NPK ratio 14:11:33)

Table 2: Treatment combinations

M0 C1	M0 C2	M0 B1	M0 B2	M0 EG	M0 F0
M1 C1	M1 C2	M1 B1	M1 B2	M1 EG	M1 F0
M2 C1	M2 C2	M2 B1	M2 B2	M2 EG	M2 F0
NPK C1	NPK C2	NPK B1	NPK B2	NPK EG	NPK F0

Soil analysis before experiment:

Before setting up the experiment, soil samples were collected and analyzed for chemical and physical properties, including total nitrogen (N), available phosphorus (P), available potassium (K), and pH. The process began by dividing each block into sections

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and then, using a zigzag pattern, selecting five different points within these sections for representative composite samples for each block. Necessary tools, including soil augers, plastic bags, permanent markers, sample containers, a clean mixing surface, and labels, were gathered in preparation. Soil samples were collected from a depth of 0–20 cm. At each sampling point, soil cores were extracted using a soil auger, combining samples from each block into clean containers. The soil was mixed thoroughly on a clean plastic sheet to form a composite sample. Subsamples of about 500 grams were taken from each composite mix, clearly labeled with relevant information, and stored in airtight containers to prevent contamination and moisture loss. To analyze soil samples for available nitrogen (N), phosphorus (P), potassium (K), and water holding capacity (WHC), specific techniques were employed.

The Kjeldahl method was used for available nitrogen analysis, involving sulfuric acid digestion and ammonia distillation (Sáez-Plaza et al., 2013). Available phosphorus was analyzed using the molybdenum blue colorimetric method, with perchloric acid digestion (King, 1932). pH was measured using a pH meter (Bishnoi *et al*., 2006), and potassium analysis was conducted through acid digestion followed by Atomic Absorption Spectroscopy (AAS). WHC was assessed by drying soil samples at 105°C overnight and calculated the moisture content (Ross, 1989). In addition to the previously mentioned soil analyses, initial soil analysis was also included the assessment of soil texture and organic carbon content. Soil texture was determined by the hydrometer method (Mozaffari *et al*., 2024), which revealed the proportions of sand, silt, and clay, influencing water retention, drainage, and nutrient availability (Osanyinpeju & Dada, 2018). Organic carbon content was analyzed by the Walkley-Black method (Bhattacharyya et al., 2015). **% moisture content=**

$$\frac{Weight\ of\ moist\ soil - weight\ of\ dry\ soil}{Weight\ of\ dry\ soil} X\ 100 \ldots\ldots\ldots\ldots \textbf{Equation 1}$$

Growth and yield component analysis
For growth analysis, three crops per plot were randomly selected and monitored for each growing stage. The parameters measured included plant height, biomass, number of pods, days to 50% flowering, days to 50% pods, grain yield, harvest index and hundred seed weight. Plant height was measured from the soil surface to the tip of tallest leaf/pod using a ruler, then recorded in centimeters. Biomass was calculated by drying three harvested above-ground plant samples at stage R1 at 65°C until a constant weight was reached, providing the shoot dry weight (Aserse *et al.*, 2020). Hundred seed weight was calculated by accurately counting and weighing 100 pure seeds, then recorded weight in gram (ISTA, 2023). This data was collected at every growing stage throughout the season, starting from the initial establishment of the crops and continuing until physiological maturity.

To calculate the yield data, the Harvest Index (HI) was calculated as the ratio of the dry weight of the grain to the total dry weight of the crop.

According to Kemanian *et al*. (2007) the formula for Harvest Index is:

$$HI: \frac{Dry\ weight\ of\ the\ grain}{Total\ crop\ dry\ weight} \ldots\ldots\ldots\ldots\ldots\ldots \textbf{Equation 2}$$

While, the total yield was calculated.

***Yield*(*kg/hectare*)**(Mekbib,2003)

$$: \frac{Average\ seeds\ per\ pod\ X Average\ pods\ per\ plant X plant\ per\ hectare}{Average\ seeds\ per\ kg} \ldots\ldots \ldots \textbf{Equation 3}$$

For quality, protein content was determined using the Kjeldahl method (Mutungi *et al*., 2022). The used nitrogen-to-protein conversion factor for calculating protein content was 6.25

Statistical analysis
The data obtained from this study was first be tested for normality using the Shapiro-Wilk test. Following, Analysis of Variance (ANOVA) was performed using a random effects model in the statistical software SAS 9.4 general linear model (GLM) technique developed by Anthony James (Vanderziel *et al*., 2025). Where significant differences were detected, means were separated using Tukey's Honestly Significant Difference (HSD) test at a 5% significance level. Additionally, correlation analysis was performed at a 5% significance level to explore the relationships between growth, yield, and quality metrics of the common beans.

Result and discussion

Height

At third trifoliate leaf fully expanded (V3)
The findings of the study showed that the main effect of manure on bean height at V3 was statistically significant (p<0.05) (Table 3). Treatments M2 and M1 had the tallest plants; 10.76 and 10.07 cm height, respectively. Treatment M0 (no manure application) resulted in lowest mean height (8.25 cm) (Table 3). The main effect of foliar spray on common bean height, on the other hand, was not statistically significant at p<0.05) (Table 3). Similarly, the interaction effect of foliar spray and manure was not significant at p<0.05.

Table 3: Main effect of foliar spray and manure on the height (cm) of common beans at V3 stage of growth

Manure treatment	Mean height (cm)	Foliar treatment	Mean height (cm)
M2	10.76a	C1	10.33
M1	10.07ab	EG	10.06
NPK	9.74b	F0	9.77
M0	8.25c	C2	9.42
MSD (α = 0.05)	1.091	B2	9.35
		B1	9.3
		MSD (α = 0.05)	1.498

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week.

Fourth trifoliate leaf fully expanded (V4)
At V4 growing stage of common beans, the main effects of manure and foliar spray on common bean height at V4 were significant (p<0.05). Common bean in treatments M2, M1 and NPK were significantly (p<0.05) taller than the control (M0) (table 4). The tallest plants were observed in treatments M2 and M1. There were

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no significant differences in treatments M1 and NPK. For foliar sprays, treatment C1, EG, B2 and F0 produced the tallest plants. Common bean height in treatment C1 was significantly different (p<0.05) from treatment B1 and C2, which produced the shortest beans (Table 4). No significant difference was observed for interaction of foliar spray and manure treatments at p <0.05.

Table 4: Main effect of manure and foliar spray on the height of common beans at V4 stage of growth (cm)

Manure treatment	Mean height (cm)	Foliar treatment	Mean height(cm)
M2	15.85a	C1	15.44a
M1	15.33ab	EG	15.22ab
NPK	14.71b	F0	14.77ab
M0	12.49c	B2	14.34ab
MSD(α=0.05)	1.0173	B1	13.93b
		C2	13.88b
		MSD (α=0.05)	1.3898

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week EG =Easy grow, C2= Comfrey spray twice a week.

Fifth trifoliate leaf fully expanded (V5) and full pod fill stage (R6)

The main effect of manure on height of common bean at V5 growing stage was significant (p<0.05). Common beans were taller in treatments M2 (mean = 20.73 cm), M1 (mean = 19.61 cm) and NPK (mean = 19.56 cm) than the control (M0) (mean = 15.90 cm). There were no significant differences in the height of common beans in M2, M1 and NPK treatments (Table 5). For foliar spray treatments, no statistically significant differences at p<0.05 were detected. The foliar treatments had means ranging from 19.65 cm (C1) to 18.11 cm (C2) (Table 5). Analysis of Variance (ANOVA) showed no statistically significant (p<0.05) interaction effect of manure and foliar spray on height of common bean at V5.

At the full pod fill stage (R6), the main effect of cow manure on common bean height was statistically significant (p<0.05). Common beans treated with M2, M1, and NPK attained significantly greater average heights compared to the control (M0) (Table 5). The main effect of foliar spray was not statistically significant (p<0.05). Common bean height ranged from 24.60 to 22.43 cm in the foliar treatments.

Table 5: Main effect of manure on the height (cm) of common beans at V5 and R6 stages of growth (cm)

Manure	Mean height(cm) at V5	Mean height(cm) at R6
M2	20.72a	26.25a
NPK	19.73a	25.00a
M1	19.56a	24.78a
M0	17.33b	19.64b
MSD(α=0.05)	1.6314	1.8987

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27)

The interaction effect of manure and foliar spray on height of common bean at R6 was significant at (p<0.05) (Table 6). Common beans were significantly taller in the interactions; NPK × F0, M2 ×B1, M1 ×C1, M2×C1, NPK×C1, M1×EG and M2×EG (Table 6).

Table 6: Interactive effect of manure and foliar spray on the height of common beans at R6 stage of growth (cm)

Manure	Foliar Sprays					
	F0	B1	B2	C1	C2	EG
M0	22.14 e	22.79 e	15.75 f	19.47 f	17.95 f	19.71 f
M1	23.29 de	24.66 bcd	24.38 cde	26.55 a	24.64 bcd	26.49 a
M2	24.46 cde	27.68 a	24.84 bc	26.41 ab	26.97 a	27.15 a
NPK	26.60 a	23.29 de	24.76 bc	25.29 abc	23.99 de	24.74 bc

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week) EG =Easy grow, C2= Comfrey spray twice a week.

The summary of the results shows that the height of common bean plants at each of the four growth stages V3, V4, V5, and R6 was greatly impacted by the application of manure. At every stage, the tallest plants were those treated with M2 (10 t ha^{-1}), followed by M1 (5 t ha^{-1}) and NPK fertilizer. In contrast, the control group (M0) had the shortest plants all along (Figure 2a). In addition, common bean height was reliably increased by foliar sprays C1 and EG at every growth stage, but particularly at the crucial V4 stage. In comparison to the control and other sprays, these treatments produced taller plants (Figure 2b).

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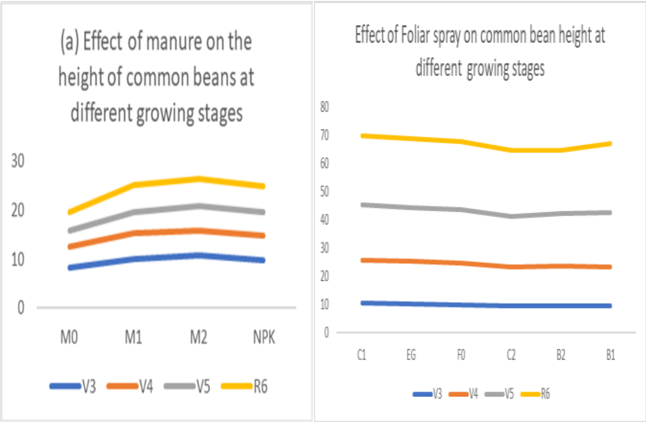

Figure 2: Height of common bean at different growing stages in response to cow manure (a) and foliar spray (b)

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week, V3: Third trifoliate leaf visible, V4: Fourth trifoliate leaf visible, V5: Fifth trifoliate leaf visible, R6: Full pod fill stage

Number of Branches

The main effect of manure on number of branches at V5 and R6 growth stages was statistically significant (p<0.05). Treatments M2, M1 and NPK had the greatest number of branches at both stages. The means of these treatments were significantly higher than the control (M0) mean (Table 7). There were no significant differences at in number of branches amongst the foliar spray treatments or their combination with manure treatment at both stages at p<0.05. At growing stage V5, Foliar spray treatments C1 and F0 had the highest number of branches (3.83), while B1 and C2 had the lowest (3.42)**.** The same results were found at stage R6, where the highest number of branches was observed in F0 (7.42), while C2 had the lowest (6.75), but all were statistically grouped under the same turkey grouping. For treatments combination, the highest number of branches (4.67) was observed in M2× EG, while the lowest (2.33) occurred in M0× C2 at growing stage V5, but no significant difference was revealed. At R6, the highest number of branches (8.67) was recorded in M2×C2 and NPK×F0, while the lowest (4.67) occurred in M0×B2 and M0×C2 but they were not significant.

Table 7: Main effect of manure on the number of branches at V5 and R6 stages of growth.

Manure Treatment	Mean number of branches (V5)	Mean number of branches (R6)
M2	4.06a	8.11a
M1	3.83a	7.22a
NPK	3.78a	7.22a
M0 MSD(α=0.05)	3.00b 0.6712	5.61b 1.3745

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27).

Biomass

The main effects of both manure and foliar spray on the biomass of common bean were statistically significant (p<0.05) at flowering stage (R1) (Table 8). The highest biomass (47.45 g) was observed in treatment M2 (Table 8) followed by NPK (42.55 g). Treatment M1 and the untreated control (M0) had the lowest biomass of 36.83 g and 36.80g, respectively. Significantly, higher biomass was observed in treatments C1 and EG than C2 and B1 at p<0.05 for foliar sprays (Table 8).

Table 8: Main effect of manure and foliar spray on biomass of common beans at R1 stage of growth (g)

Manure	Mean Biomass(g)	Foliar	Mean Biomass(g)
M2	47.45a	C1	45.01a
NPK	42.55b	EG	43.62a
M1	36.83c	B2	40.82ab
M0	36.80c	F0	40.53ab
MSD(α=0.05)	3.73	C2	37.79b
		B1 MSD(α=0.05)	37.68b 5.0955

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week.

The effect of interaction between manure and foliar spray on biomass of common bean was significant (p<0.05) (Table 9). The combinations with the highest mean biomass were: M2×EG, M2×C1, M2 ×C2, M1× C1, M2× B1, NPK× F0, NPK× B2, NPK× C1, M2 ×B2, M1× EG, and M0× F0.

Table 9: Interactive effect of manure and foliar spray on the biomass of common beans

	Foliar spray					
Manure	F0	B1	B2	C1	C2	EG
M0	44.81 abcd	39.61 cde	31.98 e	38.49 cde	31.50 e	34.38 de
M1	30.83 e	27.29 e	41.41 bcd	46.01 abc	31.40 e	44.05 abcd
M2	41.46 bcd	45.13 abc	43.99 abcd	50.10 ab	49.24 ab	54.76 a
NPK	45.02 abc	38.70 cde	45.88 abc	45.46 abcd	39.00 cde	41.26 bcd

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Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week

Days to 50% flowering and pods

The results showed no significant effects of manure, foliar spray, or their interaction on number of days to 50% flowering of common beans and days to 50% pods formed at p<0.05. In comparison to beans without manure (M0), which took an average of 46.06 days to reach 50% flowering, beans treated with NPK took high average of 46.94 days. For foliar sprays, 46.75 days was the longest average number of days to 50% blooming under treatment B1, while 46.17 days for B2 was the shortest. In terms of interaction effects, NPK × B1 and NPK × C2 recorded the longest time to flowering (48.33 days), while the combination M0 × EG produced the shortest time to flowering (44.67 days). For pods, treatment M0 took the lowest mean days to develop 50 % pods (54.33 days), whereas M2 took more days (56.06). On the other hand, for foliar spray, treatment B1 had the lowest mean (55.00 days) and EG, the highest mean (56.3 days) to develop 50% of pods. For interaction, treatment M0×F0 developed 50% of pods earlier (53.33 days), whereas NPK× B1 took longer (58.33 days).

Number of Pods

The main effect of manure treatments on the average number of pods in common bean was significant (p<0.05). On the contrary, foliar spray treatments and the combination of manure and foliar spray did not have any significant effect on the number of pods at p<0.05. The analysis of variance (ANOVA) revealed that the model explained 40.9% of the overall variability in pod production. With mean of 14.39 pods per bean, M2 performed significantly better than all other treatments. Treatment NPK came in second with 12.61 pods, while treatment M1 came in third with 12.39 pods (Table 10). Treatment M0, produced the least pods at 9.33. For foliar sprays, the number of pods per plant varied from EG spray, which produced the most pods on average (13.25), followed by B1 (12.67) and F0 (12.33). In the B2 treatment, the fewest pods were found (10.67), but these differences were not statistically significant. Treatment combinations ranged from a low of 6.00 pods observed under M0 × B2 to a high of 16.00 pods recorded in multiple treatments including M1 × EG, M2 × C2, and M2 × EG. Also, no significant difference recorded.

Table 10: Main effect of manure on the number of pods per common bean

Manure Treatment	Mean Pods/Plant
M2	14.39a
NPK	12.61a
M1	12.39ba
M0	9.33b
MSD(α=0.05)	0.5308

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27).

Leaf Area Index at V4 and R6 growth stage

Leaf Area Index (LAI) at V4 growing stage was significantly affected (p<0.05) by both foliar spray (Table 11) and the manure-foliar spray interaction (Table 12). The mean LAI values for manure ranged narrowly from 0.12 (M0) to 0.14 (M1)**.** Although M1 treatment recorded the highest average LAI, followed by M2, NPK, and M0, the differences among them were not statistically significant at p<0.05**.** For foliar sprays, treatment C1 produced beans with high leaf area indexes and it was significant different from treatment C2 and F0 (p<0.05).

Table 11: Main effect of foliar spray on leaf area index of common beans at V4 growth stage

Foliar	Mean LAI (V4)
C1	0.1475a
EG	0.1400ab
B1	0.1308ab
B2	0.1292ab
C2	0.1200b
F0	0.1133b
MSD(α=0.05)	0.0326

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: F0 =Control (nothing applied), B1=Black jack spray once a week, B2 =Black jack spray twice a week, C1 =

Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week

The combinations of manure and foliar spray treatments were significant different (p<0.05).

The highest LAI (0.170) was observed under the M1 × C1 treatment. In contrast, the lowest LAI (0.090) was recorded in M0 × C2 and M1 × F0. Treatments involving M1 manure generally resulted in higher LAI values, particularly when combined with foliar sprays like C1 and EG (Table 12).

Table 12: Main effect of manure and foliar sprays interaction on leaf area index of common beans at stage V4 growing stage

	Foliar spray					
Manure	**B1**	**B2**	**C1**	**C2**	**EG**	**F0**
M0	0.117 bcde	0.137 abcd	0.117 bcde	0.090 e	0.157 abc	0.130 abcd
M1	0.150 abcd	0.143 abcd	0.170 a	0.137 abcd	0.160 ab	0.090 e
M2	0.140 abcd	0.113 cde	0.157 abc	0.120 bcde	0.100 de	0.140 abcd

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NPK	0.117 bcde	0.123 bcde	0.147 abcd	0.133 abcd	0.143 abcd	0.093 e

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week

At R6 growing stage, all levels (M0, M1, M2, and NPK) fell into the same statistical group; they had no discernible effect on leaf area index (LAI) at p<0.05. The range of LAI values for manure treatments was 0.15 for the control (M0) to 0.16 for treatment M1. For foliar spray treatments, though no statistical significance were revealed (p<0.05); C1 recorded the greatest LAI (0.15), while F0 recorded the lowest (0.11). For interaction, also there was no statistical significance, but M1 × C1 (0.190) and M1 × EG (0.1867) generated the highest LAI values while M0 × C2 (0.1233) and M1 × F0 (0.120) had the lowest LAI values.

Harvest Index (HI)

Both manure and foliar spray had significant main effects on harvest index HI (p<0.05), whereas the interaction effect (manure and foliar spra**y**) was not significant (p<0.05**).** The highest HI (0.40389) was found in M2, which was comparable to NPK and significantly different from M0 and M1(Table 13). Among foliar sprays, C2 and B1 showed significant different HI compared to EG and F0 (Table 13).

Table 13: Main effect of manure and foliar spray on the harvest index (HI) of common bean.

Manure	Mean HI	Foliar spray	Mean HI
M0	0.32 b	C1	0.38abc
M1	0.34 b	C2	0.40a
M2	0.40 a	B1	0.40a
NPK	0.39 ab	B2	0.39ab
MSD(α=0.05)	0.0409	EG	0.34c
		F0 MSD(α=0.05)	0.32 bc 0.0560

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week

Hundred Seed Weight (HSW)

The analysis of variance (ANOVA) results for a hundred seed weight (HSW) revealed significant main effects of both manure and foliar spray (p<0.05). The highest mean HSW of all the manure treatments was 45.51 g for M2, 43.96 g for M1, and 43.35 g for NPK fertilizer (Table 14). The control (M0) had the lowest HSW, measuring 41.06 g and was significant different from M2 and M1 (Table 14). For foliar spray, F0 had the lowest mean weight (40.45 g), while treatment C1, B2, and EG had higher HSW values (above 44 g) than the control (F0) (p<0.05) (Table 14).

Table 14: Main effect of manure and foliar spray on Hundred Seed Weight (HSW) of common beans

Manure	Mean HSW (g)	Foliar Spray	Mean HSW (g)
M2	45.51a	C1	44.49a
M1	43.96a	B2	44.48a
NPK	43.35ab	EG	44.39a
M0	41.06b	B1	43.90ab
MSD(α=0.05)	2.6801	C2	43.11ab
		F0	40.45b
		MSD(α=0.05)	3.6613

Means followed by the same letter in a column are not significantly different at *p*<0.05

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week) EG =Easy grow, C2= Comfrey spray twice a week, HSW= Hundred Seed Weight

The effect of interaction of manure and foliar spray on HSW was not significant at p>0.05. The HSW were observed in M2 combined with B2 (47.95 g) and B1 (47.06 g) while the lowest weights were recorded in M0 with C2 (37.37 g) and F0 (38.93 g).

Yield per ha

The analysis of variance (ANOVA) showed that main effects of foliar sprays, manure, and their combination on yield of common bean were significant at p<0.05. An excellent fit was indicated by the model's explanation of 86.37% of the total variation (R2 = 0.8637). All other manure treatments were greatly outperformed by the application of treatment M2, which produced the greatest mean yield (1652.31 kg ha^{-1}) and was significant different from M1 (1334.89 kg ha^{-1}) and NPK (1380.90 kg ha^{-1}), which were both significantly higher than the control (M0) (1016.05 kg ha^{-1}). In comparison to all other foliar treatments, treatment C2, had the highest yield (1669.77 kg ha^{-1}) which was significant different from treatment EG (1401.57 kg ha^{-1}), B2 (1348.65 kg ha^{-1}), B1 (1333.04 kg ha^{1}) and C1 (1282.16 kg ha^{-1}) and F0 (Table 15). With a yield of 1041.04 kg ha^{-1}, the treatment F0 was the least productive of all the foliar treatments.

Table 15: Main effect of manure on the yield of common beans ($kgha^{-1}$)

Manure	Mean yield ($kgha^{-1}$)	Foliar spray	Mean yield ($kgha^{-1}$)
M2	1652.31a	C2	1669.77a
NPK	1380.90b	EG	1401.57b
M1	1334.89b	B2	1348.65b
M0	1016.05c	B1	1333.04b
MSD(α=0.05)	139.05	C1	1282.16b

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		F0	1041.04c
		MSD(α=0.05)	189.96

Means followed by the same letter in a column are not significantly different at $p<0.05$

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week.

For interaction, M2× C2 and M2×B1 showed the maximum yield, while M0× F0, M1×F0, M0×C2, M0×B2 had lowest yield (Table 16).

Table 16: Interactive effect of manure and foliar spray on yield of common beans ($kgha^{-1}$)

	Foliar spray					
Manure	B1	B2	C1	C2	EG	F0
M0	1137.65 gh	928.18 ij	1133.49 gh	934.07 ij	1063.81 hi	899.09 j
M1	1192.35 fgh	1405.50 de	1116.79 gh	1694.41 bc	1658.28 bc	942.02 ij
M2	1776.93 ab	1678.95 bc	1334.61 ef	2373.88 a	1462.49 cd	1287.01 ef
NPK	1225.23 fg	1381.95 de	1543.77 cd	1676.71 bc	1421.71 de	1036.04 hi

Means followed the same letter in a column are not significantly different at $p<0.05$.

Key: M0 = Control, M1 = 5t ha^{-1}, M2 =10t ha^{-1}, NPK =NPK (27-27-27), F0 =Control (nothing applied), B1-Black jack spray once a week, B2 =Black jack spray twice a week, C1 = Comfrey spray once a week, EG =Easy grow, C2= Comfrey spray twice a week

Protein in seeds

The results from the analysis of protein content in response to different manure and foliar spray treatments showed that the main effects of manure, foliar spray and their interaction were not significant at p<0.05. For manure treatments, protein content ranged from 24.87% in M2 to 19.37% in M0. For foliar sprays, mean values of 23.95% in B2, 23.23% in C2 and 19.29% in F0 were observed. Although the manure and foliar spray interaction was not significant at p <0.05, the combination of treatment M2 with treatment EG or C2 foliar sprays produced the high protein contents 27.07% and 26.30%, respectively.

Discussion

Soils in the experimental site had sandy loam texture, moisture content of 24.87% and pH of between 5.45 to 6.21, which is slightly acidic. The soil pH was suitable for common bean growth, which generally prospers in values between 5.8 and 6.5 (Bhattacharjee *et al*., 2024). The organic carbon content of the soils ranged between 2.72–3.48% while cation exchange capacity between 15–24 meq $100g^{-1}$, which is moderate (Hoyle and Murphy, 2018). The values indicate good fertility and nutrient retention capacity of soils which support microbial activity and nutrient cycling crucial for legume growth (Gou et *al.*, 2023). Soil nitrogen levels of the experimental site were moderate (0.21–0.94%)(Nascente *et al.*, 2017). The phosphorus content of soils ranged from 38-60 ppm while for potassium the values ranged between 12 to 24 ppm. These nutrient values indicate need for supplementation given the high nutrients demand of common beans, especially under short growth cycles and apparent root systems (PMC Article, 2023). The organic fertilizers had varied nutrient contents and pH. Comfrey extract had a pH of 6.14 and exhibited high nitrogen (5.13%) and phosphorus (247.67 ppm) contents but low potassium (0.033%). Normally, comfrey leaves have a high potassium compared to nitrogen and phosphorus, however, since the experiment involved use of foliar sprays derived from extracts, potassium concentration had been reduced due to dilution (Leigh & Wyn Jones, 1984). When applied as green manure, comfrey enhances early nutrient availability and promote vegetative growth (Luo *et al.*, 2024). Black jack extract showed a similar nutrient pattern with slightly lower nitrogen (4.9%) and phosphorus (223.5 ppm), compared to comfrey, and potassium concentration of 0.032% while the pH was 6.50. Cow manure used in this study had moisture content of 21.07%, moderate nitrogen content (1.4%) but exceptionally high phosphorus (2047.6 ppm) and potassium (7500 ppm), along with huge organic carbon (17.28%), therefore serves as a comprehensive soil amendment that improves both nutrient supply and soil physical properties (Agegnehu *et al.*, 2016). The results of this study demonstrated significant increases in common bean height at vegetative and reproductive stages (V3, V4, V5, and R6) after manure application. The manure levels M2 (10 t ha^{-1}) M1 (5t ha^{-1}) and NPK (27-27-27) as positive control consistently produced tallest beans comparing to no-manure control (M0). This can be attributed to nitrogen supply from manure mineralization and fertilizer. Nitrogen promotes leaves, stems, and other vegetative parts of plants and consequently helps in growth and development (Rainah and Mazahar, 2022). Similar results were shown in study conducted by Francine *et al*. (2021) which reported that the climbing beans treated with cow manure produced highest average height (243.39cm) while the control treatments produced shortest beans (97.81cm). For foliar spray treatment, only at growing stage V4, was the effect was revealed, where treatment C1(comfrey spray once a week), (EG: Easy grow, both vegetative and flower and fruits), B2(Black jack twice a week) and F0 (without foliar spray).

When compared to other growth stages, the observed lower efficacy of treatment C1 and B2, specifically at the V4 growth stage, was probably due to important physiological traits of common bean plants at this stage. Rapid stem extension and the

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onset of lateral branches characterize the V4 stage, a crucial time in common bean vegetative growth(Mamo *et al*., 2023). The plant becomes less receptive to treatments that primarily encourage vegetative growth after the V4 stage as resource allocation starts to shift toward reproductive development(Costa *et al.*, 2013). The greater effect of foliar treatments at V4 compared to earlier stages may be explained by this physiological shift and also at this stage, stomata are more opened to absorb more nutrients. The fact that treatment C1 (comfrey applied once weekly) worked better than treatment C2 (comfrey applied twice weekly) indicates that applying comfrey too frequently may have negative consequences, presumably as a result of phytotoxicity or foliar overload, which can cause symptoms like leaf burn. However, B2 (Black Jack sprayed twice a week) slightly outperformed B1 (Black Jack sprayed once a week) (not significantly different at $p<0.05$), suggesting that increasing the frequency of black jack spray boosted vegetative development, most likely as a result of better nutrient or bio stimulant delivery. It is interesting to note that the untreated control (F0) outperformed both B1 and C2, suggesting that some foliar spray applications can actually hinder rather than promote growth.

Branching was significantly enhanced by manure application at both V5 and R6 stages, with M2, M1, and NPK treatments yielding more branches than the control (M0). This is consistent with the findings of (Fekadu *et al*., 2018) who reported that the application of cow manure increased the number of branches for common beans due to high nitrogen content of cow manure and potassium which favored vegetative growth . Sharifi *et al*. (2024), also reported that 10 t ha^{-}1 of cow manure improved the number of branches per plant comparing to the control with average of 26 branches per plant. For the lack of significant effect from foliar sprays or their interaction with manure on branching shows that soil nutrient status is the primary determinant of branching in beans, with foliar nutrients playing a minor role unless soil deficiencies are present which implies that the soil was containing ample soil nutrients due to manure application (Kinrade, 2025). Biomass production was significantly influenced by both manure and foliar spray treatments, as well as their interaction. The highest biomass was observed with M2 (10 t ha^{-1}), followed by NPK (27-27-27, 185kg ha^{-1}), while M1(5t ha^{-1}) and M0 (no manure) produced the lowest biomass. The study conducted by Ngakou *et.al* (2008) reported that cattle manure application resulted in high mean biomass (8.54g/plant) and was significant different from the control that yielded low biomass beans (1.31g/plant). Among foliar sprays, comfrey applied once a week (C1) and Easy Grow (EG) resulted in the greatest biomass, suggesting that these treatments may enhance nutrient uptake or physiological efficiency under certain conditions. This agrees with the results of Byan (2014) who reported that the snap beans treated with licorice extract produced high dry and wet weight comparing to the control. The combination of M2 and EG yielded the highest overall biomass, which supports the concept of integrated nutrient management as advocated by Agegnehu *et al*. (2017), who found that combining organic amendments with targeted foliar applications maximizes growth and yield in legumes. Neither manure nor foliar spray treatments, nor their interactions, had a significant effect on the number of days to 50% flowering and pods. This indicates that the timing of reproductive development in common beans is relatively insensitive to variations in nutrient supply from the tested amendments. This agrees with the findings of Wilczek *et al.*(2010) and Selvakumar *et al*. (2025), who noted that phenological events as well as development timing such as flowering are more strongly influenced by genetic and environmental factors than by moderate differences in nutrient availability. However, numerical tendencies were observed; plots without manure (M0) reached 50% flowering and pods development earliest while those with the highest manure rate (M2, 10 t/ha) took the longest. Among foliar sprays, treatment B1 was rapid to develop flower and pods comparing to EG. The combination of no manure and no foliar spray (M0 × F0) produced the earliest to flower time comparing to NPK × B1 combination which was the latest. These trends suggest that higher manure rates may slightly delay reproductive development, possibly due to increased vegetative growth (Zewide & Ademe, 2025), although these differences were not statistically significant. In contrast, the number of pods per plant was significantly influenced by manure application ($p <0.05$). The highest pod number was achieved with the application of 10 t/ha of cow manure (M2, 14.39 pods/plant), which was significantly greater than the control (M0, 9.33 pods/plant). NPK and M1 (5 t/ha manure) produced also high number of pods (12.61 and 12.39 pods/plant, respectively) compared to the control. Similar results were found in an okra experiment with tested different levels of cow manure, where the highest pods number was found in 12t ha^{-1} of cow manure (Vincent *et al*.,2004). Foliar sprays did not significantly affect pod number, with all treatments statistically similar, although EG and B1 had numerically higher pod counts. The interaction between manure and foliar sprays was also not significant for pod number. This highlights the primary importance of soil fertility, particularly organic amendments, in supporting reproductive output in beans. Leaf area index (LAI) at the V4 stage was significantly affected by foliar spray and the interaction between manure and foliar spray ($p <0.05$), but not by manure alone. The highest LAI was observed with C1 (Comfrey, once a week, 0.1475), while treatment C2 (comfrey spray twice a week) and F0 (without foliar spray) recorded low LAI. The study conducted by Jeevaa *et al*,.2025*)*, showed that foliar spray fertilizers may boost growth including leaf area index by supplying nutrients directly to leaves, promoting faster growth and expansion. This can lead to larger, more efficient leaf development during key growth stages compared to manure applied fertilizers. For combinations, M1×C1 recorded high LAI while M0×C2 and M1×F0 produced low LAI, which implies that high frequency of applying comfrey can cause various harmful effects including toxicity and leaf burn. Treatment without foliar spray produced beans with low LAI, which implies the inadequacy of nutrients for vegetative growth since manure nutrient release is very slow. At the R6 stage, treatment effects were not significant, although C1 and EG maintained the highest LAI. These results suggest that foliar sprays, especially comfrey applied once in a week may enhance early canopy development, but this effect does not necessarily persist to later stages. For harvest index, significant effects of both manure and foliar spray treatments were observed. For manure, the best results were found in the highest rate (M2, 0.40389) while for foliar sprays, in C2 (Comfrey, twice a week) and B1 (Black jack, once a week). Manure derived organic matter enhances soil health, nutrient availability, and water retention, all of which can have a good impact on grain yield and biomass production, potentially raising HI (Mahmood *et al.*, 2017). The ability of foliar sprays to improve the HI, indicates that foliar applications can enhance the efficiency of resource allocation towards economic yield (Kinaci & Gulmezoglu, 2007).Though interaction was not significant, but the highest HI values were seen when M2 was paired with either B1 or C2. This indicates that both organic manure and targeted foliar nutrition can improve the

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efficiency of biomass partitioning into grain. Hundred seed weight (HSW) was also significantly affected by both manure and foliar spray treatments. The highest HSW was recorded for M2 (45.51 g), followed by M1 (43.96 g) and NPK (43.35 g), while the control (M0) had the lowest (41.06 g). Among foliar sprays, C1, B2, and EG all exceeded 44 g, while the unsprayed control (F0) was lowest at 40.45 g. Although the interaction was not significant, the combination of M2 and B2 produced the highest HSW (47.95 g), suggesting that optimal seed filling occurs under high soil and foliar nutrient availability. According to Tadesse *et al.*(2022), farmyard manure (FYM) improved soil health and nutrient availability, which led to a considerable rise in hundred seed weight. They reported that FYM levels of 2.5–5 t/ha increased seed weight because of enhanced nutrient uptake and root development. Additionally, by encouraging microbial activity, this organic input improved plant development and produced heavier seeds. Most notably, yield per hectare was highly responsive to all factors and their interaction ($R^2 = 0.8831$). The highest yield was achieved with treatment M2 (1652.31 kg ha^{-1}), significantly outperforming all other manure treatments. This goes in line with Agronomiques *et al.*, 2020b, who reported that common beans treated with manure produced high yield (838.58 kg ha^{-1}) comparing to the control(651.72 kg ha^{-1}). Among foliar sprays, C2 (Comfrey, twice a week) produced the highest yield (1669.77 kg ha^{-1}). The interaction between manure and foliar spray was also substantial. The combination of M2 and C2 resulted in the maximum yield (2373.88 kg ha^{-1}), while the combination of no manure and no foliar spray (M0 × F0) produced the lowest yield (899.09 kg ha^{-1}). This demonstrates a strong synergistic effect when high rates of manure are combined with frequent foliar application of Comfrey. For the effect of treatments on the protein contents of common beans seeds, no main or interaction significant effects were revealed. A study by Lm and Pw (2019), on the effect of fertilizer inputs on climbing bean production in Mbeere North subcounty, showed that organic fertilizers at least under the conditions of the study, did not lead to any noticeable changes in the protein levels of the beans. The findings draw attention to the fact that although fertilizer can help boost bean yield, it may not always raise the protein content of the beans.

Appendix: Nacosti permit


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RESEARCH LICENSE

This is to Certify that Miss.. Regine Ingabire of Egerton University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: EFFECT OF COMBINING COW MANURE, FOLIAR SPRAYS OF BLACK JACK (Bidens pilosa L.) AND COMFREY (Symphytum officinale L.) EXTRACTS ON PERFORMANCE OF COMMON BEAN (Phaseolus vulgaris L.) for the period ending : 30/December/2025.

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