

Enhancing the growth and pod yield of snap beans through nitrogen fertilization in Northwest Ethiopia

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Abstract

Snap bean (*Phaseolus vulgaris* L.) is a valuable cash and export crop in Ethiopia. Nevertheless, its production is restricted to specific localized areas within the Amhara Region. The varieties suited to the area are not extensively researched, and the crop's need for nitrogen fertilizer is unclear. The objective of this study was therefore evaluating the effects of variety and nitrogen fertilizer on growth and pod yield of snap bean in Bahir Dar. The experiment was conducted at Woramit Horticulture Research and Training Sub-center during the 2024 irrigation season in Bahir Dar Zuria District of Amhara Region. The study involved two snap bean varieties (Ampere and Davis) and six levels of nitrogen fertilizer (0, 18, 37, 55, 74 and 92 kg N ha⁻¹) with 2x6 factorial arrangements in a Randomized Complete Block Design in three replications. The collected growth and yield related data were analyzed using SAS statistical software version 9.4. The variance analysis showed that both variety and nitrogen fertilizer significantly affected most of the examined growth and yield-related factors of snap bean. The Davis variety yielded significantly more marketable pods (11.21 t ha⁻¹) than the Ampere variety. Likewise, nitrogen fertilizer affected ($P < 0.001$) nearly all growth and yield factors. The supply of Davis variety with 74 kg ha⁻¹ N has been resulted the highest number of pods per plant (36.33), marketable (14.37 t ha⁻¹), and total (17.12 t ha⁻¹) fresh pod yields. The partial budget analysis indicated that the Davis variety receiving 74 kg ha⁻¹ of N achieved the greatest net benefit (567,625 ETB ha⁻¹ N) with a satisfactory marginal rate of return (983.97%). The use of nitrogen typically boosted the growth and pod yield of snap beans, with the application of 74 kg ha⁻¹ N for the Davis variety to be the most effective and advisable for economical production of snap bean in Bahir Dar area. As the study was conducted in one season and location, it is also advisable to repeat the study in multi-location and season.

1. Introduction

The snap bean (*Phaseolus vulgaris* L.) is primarily grown for its tender and immature pods [1]. The young pods are consumed as fresh, preserved, or frozen products. It is a fantastic source of vitamins, minerals, proteins and soluble fiber with little calorie contents [2].

The global cultivated area for snap beans spans 134,522 hectares, yielding a total production.

of 1,375,583.9 tons and an average yield of 10.2 t ha⁻¹ FAOSTAT [3]. China,

Indonesia and India are the leading producers of snap (green) beans FAOSTAT [3]. Across Africa, 244,271.8 tons of fresh pods are grown across 9,960 hectares of land with the average productivity of 24.5 t ha⁻¹, where Egypt, Morocco, and Kenya are the top producers FAOSTAT [3]. Ethiopia's production of snap bean reached 7,384 tons with an average productivity of 4.14 t ha⁻¹, which is significantly very low compared to other African countries. In recent years the production of snap bean for domestic as well as for export markets is in increasing trend in Ethiopia [4]. Especially during the winter season where the production of snap bean in Europe is reduced, Ethiopia has emerged as a significant supplier of the crop to the European markets [5].

The yield and pod quality of snap beans grown in Ethiopia remains quite low, which

necessitates agricultural measures. The use of low-producing varieties and inadequate soil fertility management is one of the other significant factors that limit the yields of crops such as snap beans [6]. Nitrogen is the primary nutrient that limits yield for numerous crops and its use in both inorganic and organic forms is crucial to enhance

and maintain snap bean production [7]. The amount of nitrogen to be added depends on the fertility status of the soil, the yielding capacity of the variety and environmental conditions of the growing areas [8]. In this regard, El-Ghamry [9] reported that the tallest plant height, the highest number of primary branches per plant, and pod yield of snap beans were obtained by the application of $120 \text{ kg ha}^{-1} \text{ N}$. In research conducted in the central rift valley area of Ethiopia, the application of nitrogen at the rate $92 \text{ kg ha}^{-1} \text{ N}$ enhanced growth of primary branches and pod length of snap bean compared to plants without nitrogen fertilizer [10]. Tesfaye Wossen [11] reported that the application of $92 \text{ kg ha}^{-1} \text{ N}$ and $69 \text{ kg ha}^{-1} \text{ P}_2\text{O}_5$ improved the pod length of snap bean in Teda, North Gondar Zone, Amhara Region. In East Hararghe, Ethiopia, application of $150 \text{ kg ha}^{-1} \text{ NPSB}$ has led to the maximum aboveground biomass, seed yield number of pods per plant and number of primary branches [12].

Both fertilizer and variety affected the performance of green beans. In this context, the variety Haramaya in the East Hararge zone of Ethiopia yielded the greatest quantity of primary branches, quantity of pods per plant, aboveground biomass, and seed production as stated by [12]. Research conducted by [13] in Nedjo, Western Ethiopia, also showed that the highest number of pods per plant was recorded by the variety Beshbesh fertilized with 46 kg N ha^{-1} , representing an increase of approximately 75% in comparison to the control treatment which had no fertilizer added. Application of 150 kg ha^{-1} of NPS fertilizer for BC4.4 variety also recorded the highest total and marketable pod yield in Gambela, Western Ethiopia [14].

Utilizing the correct fertilizer rates and employing varieties suited to particular environmental conditions is essential for boosting snap bean yields and enhancing the income and livelihood of smallholder farmers [7]. The objective of the study was evaluating the different rates of nitrogen fertilizer on growth and yield performance of snap bean varieties with the aim of enhancing the profitability of snap bean farming in Northwest Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The field trial was carried out in the 2024 irrigation season at the Woramit, Horticulture Research and Training sub-center, Bahir Dar, Ethiopia. The sub-center (Figure. 1) is located at the shore of Lake Tana, Northwest Bahir Dar City, at an altitude of 1840 meters above sea level [15]. Geographically, it is located at $11^{\circ}38' \text{ N}$ latitude and $37^{\circ}10' \text{ E}$ longitude [15]. The soil of the experimental site is Nitisol with the pH of 6.4. The soil texture is clay with the textural classification of sand (13%), silt (33%) and clay (54%) [16]. Different types of vegetable crops including tomatoes, onion, cabbage, potatoes and sap bean are cultivated around Bahir Dar City where the research has been conducted.

2.2 Description of the Experimental Materials

Ampere and Davis varieties were used as a test plant. Both of the snap bean varieties are bushy type (determinate) in their growth habit. They were developed by different agricultural research centers in Ethiopia (Table 1). Urea ($\text{CO}(\text{NH}_2)_2$ (46%N)) was used as a source of nitrogen.

Table 1
Snap bean variety used in the study

Variety name	Year of release	Releasing center	Morphology (determinate or indeterminate)	Productivity (Marketable yield)	Altitude	Rainfall	Temperature
Davis	1982	Adapted by Hawassa Agricultural Research Center (HaARC)	Determinate	7.5–9.14 t/ha	Medium to high elevation	Moderate	18°C – 29°C
Ampere	2009	Melkassa Agricultural Research Center (MARC)	Determinate	6–8 t/ha	Low altitude	Moderate	16°C – 29°C

2.3. Experimental Treatments and Design

The treatments consisted of two snap bean varieties (Ampere and Davis) six rates of nitrogen (0, 18, 37, 55, 74 and 92 kg ha⁻¹). The nitrogen levels were determined based on previous research results [17].

Treatments were layout by 2x6 factorial designs in Randomized Complete Block Design (RCBD) with three replications. Each experimental unit had a plot size of 1.2 m length and 2 m width with the gross plot size of 2.4m². The net plot area was 1.44 m². Each plot consisted of five rows, which were 40 cm apart and each row contained 12 plants with the intra row spacing of 10 cm.

2.4. Management of the experimental plants

Healthy seeds of the snap bean varieties were purchased from the Koga Agricultural Development PLC. The company is producing different vegetable crops at Koga Irrigation Scheme. Two snap bean seeds per hole were sown on the experimental plots where the spacing of 10 and 40 cm was kept between seeds and rows, respectively [18]. Following germination and establishment, one robust and healthy seedling was retained while the other was removed. The quantity of urea was applied in two equal portions. One half of the nitrogen was applied during seeding while the second half was applied at 50% flowering stage of the plants [18, 19]. On the other hand, the recommended rate of phosphorus at the rate of 46 kg ha⁻¹ P₂O₅ was applied uniformly to all plots in the form of TSP (46% P₂O₅) during sowing [6].

2.5. Data Collection

2.5.1. Phenology and Growth Parameters

Days to 50% flowering (days): It was measured by tallying the number of days elapsed from date of sowing to the date at which 50% of the plants flowered using visual inspection [20].

Plant height (cm)

The heights of five randomly selected plants cultivated in the net plot area were measured from the ground level to the top of the main stem using measuring tape at the first harvesting stage and mean value was computed.

Number of primary branches per plant

The primary branches originated from the main stem were counted from five randomly selected plants grown in the net plot area during the first harvest stage and the mean values were computed for analysis.

2.5.2. Yield and Yield Related Parameters

Number of pods per plant

Pods collected from five randomly selected and labeled plants grown in the net plot area were counted during each harvest and summed. The mean values were computed for further analysis.

Pod length (cm)

It was collected by measuring the lengths of twenty randomly selected pods harvested from the net plot area at every harvest and average computed values were utilized for analysis.

Marketable pod yield (t ha^{-1})

Pods which are free from any damages, uniform in color, straight but slightly curved at the end were considered as marketable [5]. Such pods collected from the net plot at each harvest were weighed with a precise balance, totaled, and reported as tons per hectare.

Unmarketable pod yield percentage (%)

Pods which are bleached and damaged by insect and disease, malformed, and mechanically damaged are considered as unmarketable [21, 22]. Accordingly, pods harvested from the net plot area were measured and expressed in percentage in relation to the total pod yields.

Total pod yield (t ha^{-1}): This parameter was determined by the summation of marketable and unmarketable pod yields.

2.6. Data Analysis

All gathered data were analyzed using the variance analysis with SAS computer software version 9.4 program using proc GLM model. Whenever, the ANOVA indicated significant difference, mean separation was done using Least Significant Difference (LSD) at 5% probability value.

2.5. Economic Analysis

Partial budget analysis was done for the economics of each treatment following the procedures described by CIMMYT [23] where the costs of nitrogen fertilizer and seeds and labor cost for fertilizer application were considered as variable costs. Costs common for all treatments were not considered in partial budget analysis. For estimating economic parameters, the average open market price for snap beans pods was set at 45.00 Birr per kg, while 150 Birr per person per day of labor cost was estimated for fertilizer application. The price of urea was 85 Birr per kg, while the cost of seeds was 600 and 610 Birr per kg for the Ampere and Davis varieties, respectively. The expenses for other inputs and production methods stay the same and are deemed not

significant between treatments. Net benefit (NB) was evaluated by the subtraction of total costs from the gross benefits for every treatment as indicated by CIMMYT [23].

Dominance analysis was conducted first by arranging the treatments in order of ascending variable costs. The Marginal Rate of Return (MRR) (%) was calculated by dividing the change in net benefit (Δ NB) by the change in total variable cost (Δ TVC) and multiplying by one hundred [24].

3. Results and Discussion

3.1 Influence of Variety and Nitrogen on Growth and Phenology of Snap Bean

3.1.1 Plant height

The main effects of variety and nitrogen fertilizer rate influenced ($P < 0.001$) the plant height, while their interaction did not affect this parameter of snap bean ($P > 0.05$). The variety Davis recorded higher plant height (51.32 cm) compared to the variety Ampere (48.97 cm) as indicated in Fig. 2. The difference in plant height could be associated with the genetic makeup of the varieties in their nature [5]. The results of the present study are in line with the findings of different scholars who reported variations in the plant height among snap bean varieties [17].

Snap bean plants supplied with 92 kg ha^{-1} and 74 kg ha^{-1} nitrogen produced the longest plant heights with the values of 58.77 cm and 57.33 cm, respectively, although they were statistically similar. On the other hand, those plants without nitrogen fertilizer recorded the shortest plant height (38.77 cm) (Table 2).

Nitrogen is considered as one of the major limiting nutrients in plant growth and the adequate supply of the nutrient enhances the photosynthetic activity leading to the vigorous growth of the plants resulting taller plants [10, 25]. The enhanced height and vegetative growth of plants with increased rate of nitrogen fertilizer was also reported by different scholars [9, 10, 26 and 27], which is in line with the results of the present study.

3.1.2 Number of primary branches per plant

Variety ($p < 0.01$) and nitrogen rate ($p < 0.001$) influenced the number of primary branches of snap bean while their interaction did not affect this parameter. Davis variety produced about 8.23 primary branches while the Ampere variety produced 7.62 primary branches per plant (Fig. 2). Davis variety is genetically taller than Ampere variety which obviously contributes to the production of more primary branches. Scholars also characterize the Davis variety as taller, more robust, and high-yielding compared to many other varieties including the Ampere variety [28]. Differences in the number of primary branches among the snap bean varieties were also reported [5, 17].

In the case of nitrogen, application of 92 kg ha^{-1} N recorded the highest number of primary branches (10.17) while plants without nitrogen fertilizer recorded the lowest number (5.38) as indicated in Table 2. Generally, increasing the nitrogen rate increased the number of primary branches per plant in the present study, which could be due to the fact that nitrogen is needed for photosynthesis activities leading to the growth and development of plants [10, 29, 30 and 31].

PH = plant height (cm); PB = primary branch; NPB = number of primary branches, SE ($\pm$): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

3.1.3 Days to 50% flowering

Nitrogen fertilizer rate influenced ($p < 0.001$) 50% flowering while the interaction effect and variety didn't influence ($p > 0.05$) the parameter. The application of $92 \text{ kg ha}^{-1} \text{ N}$ significantly prolonged 50% flowering (45.5 days) compared to other treatments (Table 2).

Increasing the rate of N fertilizer from 0 to $92 \text{ kg ha}^{-1} \text{ N}$ generally prolonged the time required for 50% flowering and pod initiation as indicated in the present study, which is obviously associated with the excessive vegetative growth the plants leading to the delay of flower initiation and pod setting as observed by different scholars [6, 11, 17 and 30].

According to Hailye Negussie [17], snap bean varieties show difference in days required for flowering, which is not observed in the present study. Days to flowering and pod initiation are generally influenced by environmental conditions and the genetic makeup of varieties [32].

Table 2
Effect of N level on the growth and phenology of snap bean

N rate (kg ha^{-1})	Plant height (cm)	No. primary branches	Days to 50% flowering (days)
0	38.77 ^e	5.38 ^f	43.50 ^d
18	44.25 ^d	6.02 ^e	43.50 ^d
37	49.75 ^c	7.2 ^d	44.00 ^{cd}
55	52 ^b	8.72 ^c	44.33 ^{cb}
74	57.33 ^a	9.55 ^b	44.83 ^b
92	58.77 ^a	10.17 ^a	45.50 ^a
LSD (5%)	2.12	0.59	0.55
Significance level	***	***	***
SE ($\pm$)	1.0216	0.2848	0.2643
CV (%)	4.63	6.22	1.03

Means followed with different letters in column are significantly different at 95% probability;

***: very highly significant at $P < 0.001$. SE ($\pm$): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

3.2 Yield and Yield Related Parameters of Snap Bean

3.2.1. Pod length

Pod length of snap bean is one of the most important parameters associated with the yielding potential of the crop. It was influenced by the main effects of variety ($P < 0.01$) and nitrogen fertilizer level ($P < 0.001$) while their interaction did not affect ($P > 0.05$) the pod length of snap bean. The variety Davis had longer pod length (12.58 cm), while Ampere variety produced the shorter (12.42 cm) pods (Fig. 3). The differences in pod length are probably due to with the morphological differences between the varieties, which vary with the genetic variations of the varieties. The results are in line with the findings of [5, 17 and 33]. Pod length among varieties ranged from 12.00 to 13.56 cm, which might be due to the genetic variations of the varieties [17].

Similarly, application of nitrogen at the rate of 92 kg ha^{-1} produced the longest (13.60 cm) pods while plants without nitrogen fertilizer produced the shortest pods (11.60 cm). Application of adequate nitrogen fertilizer obviously improves the growth and development of the plants including pod length through accumulation of photosynthetic products and cell divisions leading to the production of longer pods. Various researchers also reported that plants supplied with nitrogen produced longer pods while those plants without nitrogen produced the shortest pods of snap beans [6, 8, 10, 11, [17. According to Usha [26], however, the pod length of snap bean was not influenced by the application of N up to the level of 160 kg ha^{-1} , although the pod yield increased proportionally up to this level of nitrogen.

PL: Pod length, SE ($\pm$): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

3.2.2 Number of pods per plant

Variety ($p < 0.05$), nitrogen rate ($p < 0.001$) and their interaction ($P < 0.01$) influenced the pod number of snap bean plants. Application of 74 kg ha^{-1} N for Davis variety recorded the highest pod number per plant (36.33) which was statistically similar with pod numbers produced by Davis variety supplied with 55 kg ha^{-1} N. Davis variety grown with the absence of nitrogen fertilizer recorded the lowest number of pods (22.40) (Table 3).

A balanced nutrient supply supports the overall growth and development of plants including snap bean. It also enhances plant health and increases pod production, and helps to tolerate drought stress [34]. Appropriate rate of nitrogen supports the development of flowers leading to more pod production. Excessive nitrogen fertilizer on the other hand may lead to vigorous plant growth with the expense of pod production [7]. Snap bean varieties have varying genetic potentials for growth, yield, disease resistance and nutrient use efficiency where application of certain rate of fertilizer acts differently in different varieties. Similarly, varieties with different growth habit may have different nitrogen requirement and efficiencies in utilizing available nutrients [35]. The results of the present study are in agreement with the findings of different scholars who reported difference in the response of snap bean varieties towards the application of nitrogen fertilizer [10, 17 and 31].

3.2.3 Marketable pod yield

The analysis of variance revealed that the marketable pod yield of snap bean was influenced by variety ($p < 0.05$), nitrogen level ($p < 0.001$) and their interaction ($p < 0.05$). Application of 74 kg ha^{-1} N on Davis variety recorded the highest marketable pod yield (14.37 t ha^{-1}) while both varieties of snap bean without nitrogen produced the lowest marketable pod yields (Table 3).

The supply of 74 kg ha^{-1} nitrogen to Davis and Ampere varieties increased the marketable pod yield by 96.85% and 108.75%, respectively, compared to their respective control. This increment is obviously associated with the supply of nitrogen fertilizer leading to proportional vegetative growth, timely flowering and pod setting that

enhanced the pod yield. However, excessive N fertilizer may lead to excessive vegetative growth that may cause greater risk of disease infestation and reduced marketable pod yield of snap bean [36]. Adequate nitrogen not only boosts quantity but also improve the quality of the pods, making them more marketable [37]. Healthy plants tend to produce uniform, high-quality pods that are more appealing the consumers [38].

The difference in pod yield between snap bean varieties observed in the present study could be due to their varying genetic potentials for yield, growth habit, disease resistance and nutrient use efficiency [5]. Similar to the present study, different scholars reported that increasing the nitrogen level up to a certain level increased the marketable pod yield of snap beans while further increasing reduced the pod yields [5, 6, 17 and 29].

3.2.4 Unmarketable pod yield percentage

Nitrogen fertilizer level influenced ($P < 0.001$) the percentage of unmarketable pod yield of snap bean varieties while variety and their interaction effect didn't influence ($P > 0.05$) the parameter. Davis variety recorded higher (17.51%) while Ampere recorded 17.26% unmarketable pod yield percentage of Snap bean.

Application of nitrogen fertilizer generally increased the unmarketable pod yield percentage, where the highest unmarketable yield percentage (23.73% of total pod yield) was recorded by the application of $92 \text{ kg ha}^{-1} \text{ N}$ while application of 18 and $37 \text{ kg ha}^{-1} \text{ N}$ levels produced the lowest (14.58 and 14.14% unmarketable yield percentage respectively) which had no significant differences with each other as indicated in the Fig. 4. The results of the present study clearly showed that increasing the nitrogen rate is necessary to check the proportion of unmarketable pod yield in snap bean. Similarly, Hailye Negussie [17] reported the proportional increase of unmarketable pod yield of snap bean with increased nitrogen fertilizer rate. According to the author, increasing the rate of nitrogen to $160 \text{ kg ha}^{-1} \text{ N}$ increased the unmarketable pod yield by 54.25% compared to the control treatment without nitrogen fertilizer. Moreover, application of excessive nitrogen fertilizer leading to vigorous plants that creates suitable conditions for disease infestation and resulting to the increased unmarketable pod yield [39]. Nitrogen rich plants are also succulent and may attract more aphids or other insect pests leading to higher unmarketable yield [40].

SE ($\pm$): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

3.2.5 Total Pod Yield

The total pod yield was influenced by the main and interaction effects ($p < 0.01$) of variety and nitrogen fertilizer. The highest total pod yield (17.12 t ha^{-1}) was obtained from the treatment combination of Davis variety and $74 \text{ kg ha}^{-1} \text{ N}$, whereas the lowest was recorded from Ampere (8.65 t ha^{-1}) and Davis (9.07 t ha^{-1}) varieties grown without nitrogen fertilizer, which are statistically similar when compared each other (Table 3). Supplying Davis variety with $74 \text{ kg ha}^{-1} \text{ N}$ increased the total pod yield by 88.8% compared to the respective control without nitrogen.

Application of appropriate nitrogen fertilizer rates enhances the overall growth and development of plants, pod formation and development [17]. On the other hand, application of too much nitrogen may result in excessive vegetative growth at expense of pod formation [17]. In this regard, Hailye Negussie [17] reported that increasing the nitrogen rate up to $80 \text{ kg ha}^{-1} \text{ N}$ increased the total yield (14.48 t ha^{-1}) of green bean. However, further increase to $120 \text{ kg ha}^{-1} \text{ N}$ didn't increase the pod yield (15.1 t ha^{-1}). Different snap bean varieties have varying

genetic potentials for yield, growth habit, disease resistance and nutrient use efficiency as reported by various scholars [6, 10, 14 and 17].

Table 3
Influence of variety and nitrogen level on yield parameters of snap bean

Variety	Nitrogen (kg ha ⁻¹)	NPP (No.)	MPY (t ha ⁻¹)	TPY (t ha ⁻¹)
Ampere	0	25.33 ^{gef}	6.4 ^g	8.65 ^g
	18	26.93 ^{def}	10.29 ^e	11.87 ^e
	37	31.33 ^{bc}	11.57 ^d	13.5 ^d
	55	31.87 ^{bc}	12.92 ^{cb}	15.43 ^b
	74	29.40 ^{dc}	13.36 ^b	15.9 ^b
	92	27.67 ^{de}	10.07 ^e	13.23 ^d
Davis	0	22.40 ^g	7.3 ^g	9.07 ^g
	18	24.07 ^{gf}	9.17 ^f	10.9 ^f
	37	32.67 ^{bc}	12.48 ^c	14.5 ^c
	55	34.73 ^{ba}	13.46 ^b	16.03 ^b
	74	36.33 ^a	14.37 ^a	17.12 ^a
	92	31.67 ^{bc}	10.5 ^e	13.73 ^{dc}
LSD (5%)		3.5	0.81	0.78
Significance level		**	*	**
SE (±)		1.6868	0.3905	0.3778
CV (%)		6.99	4.33	3.47

* = significant at $p < 0.05$, ** = significant at $p < 0.01$; TPY = total pod yield, MPY = marketable pod yield, NPP = Number of pods per plant. SE (±): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

3.3. Partial Budget Analysis

The partial budget analysis results indicated that the treatment combination of variety Davis and 74 kg ha⁻¹ N yielded the highest net benefit of 567,625 Ethiopia Birr ha⁻¹, while the treatment combination of variety Davis with 55 kg ha⁻¹ N had a net benefit of 534,170 Birr ha⁻¹ (Table 4). Likewise, the Davis variety of snap bean provided with 74 kg ha⁻¹ N achieved a 983.97% MRR (Marginal rate of return) (Table 5). Consequently, an investment of one unit of nitrogen may yield an extra return of 9.839 ETB. CIMMYT [23] states that treatments showing MRR exceeding 100% are permissible in developing nations such as Ethiopia.

Table 4
Partial budget analysis of nitrogen fertilizer on snap bean varieties

Variety	N rate (kg ha ⁻¹)	MPY (kg ha ⁻¹)	Adj MPY (kg ha ⁻¹)	GB (Birr ha ⁻¹)	Total variable cost (Birr ha ⁻¹)	NB (Birr ha ⁻¹)
Ampere	0	6,940	6,246	281,070	600	280,470
	18	10,290	9,261	416,745	4,150	412,595
	37	11,570	10,413	468,585	7,550	461,035
	55	12,920	11,628	52,3260	10,950	512,310
	74	13,360	12,024	541,080	14,350	526,730
	92	10,070	9,063	407,835	17,750	390,025
Davis	0	7,300	6,570	295,650	610	295,040
	18	9,170	8,253	371,385	4,160	367,225
	37	12,480	11,232	505,440	7,560	497,880
	55	13,460	12,114	545,130	10,960	534,170
	74	14,370	12,933	581,985	14,360	567,625
	92	10,500	9,450	425,250	17,760	407,490

ETB ha⁻¹ = Ethiopian Birr per hectare, kg ha⁻¹ = kilogram per hectare, GB = gross benefit, NB = net benefit, MRR = marginal rate of return, MPY= Marketable pod yield, Adj MPY = Adjusted Marketable pod yield by 10%.

Table 5
Dominance analysis

Variety	N rate (kg ha ⁻¹)	TVC (ETB ha ⁻¹)	NB (ETB ha ⁻¹)	MRR (%)
Ampere	0	600	280470	-
Davis	0	610	295040	145700
Ampere	18	4,150	412,595	3320.7
Davis	18	4,160	367,225	D
Ampere	37	7,550	461,035	1,424.7
Davis	37	7,560	497,880	368450
Ampere	55	10,950	512,310	425.66
Davis	55	10,960	534,170	218600
Ampere	74	14,350	526,730	D
Davis	74	14,360	567,625	983.97
Ampere	92	17,750	390,085	D
Davis	92	17,760	407,490	D
ETB = Ethiopian Birr, TVC = total variable cost, GB = gross benefit, NB = net benefit, MRR = marginal rate of return, D= dominated				

Conclusions

Nitrogen fertilizer rate and variety influenced most of the tested growth and yield parameters of snap bean. Plants of Davis variety were taller in height, had more primary branches per plant, longer pod and relatively had more unmarketable yield compared to Ampere variety. On the other hand, increasing the application rate of nitrogen up to certain level (74 kg ha⁻¹ N) increased the pod yield of snap bean in the present study. When compared to other treatment combinations, the Davis variety supplied with 74 kg t ha⁻¹ N had highest number of pods per plant and marketable yield (14.37 t ha⁻¹). The combination Davis variety and 74 kg t ha⁻¹ N also recorded the highest net benefit (567,625 ETB ha⁻¹) and an adequate marginal rate of return (983.97%). Nitrogen application generally increased snap bean growth and pod yield. Application of 74 kg ha⁻¹ N for Davis variety increased snap bean productivity and can be advised for the study area and areas with comparable environmental conditions.

Declarations

Data availability statements

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Conflict of interest

The authors stated that publishing the work would not present a conflict of interest.

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Figures

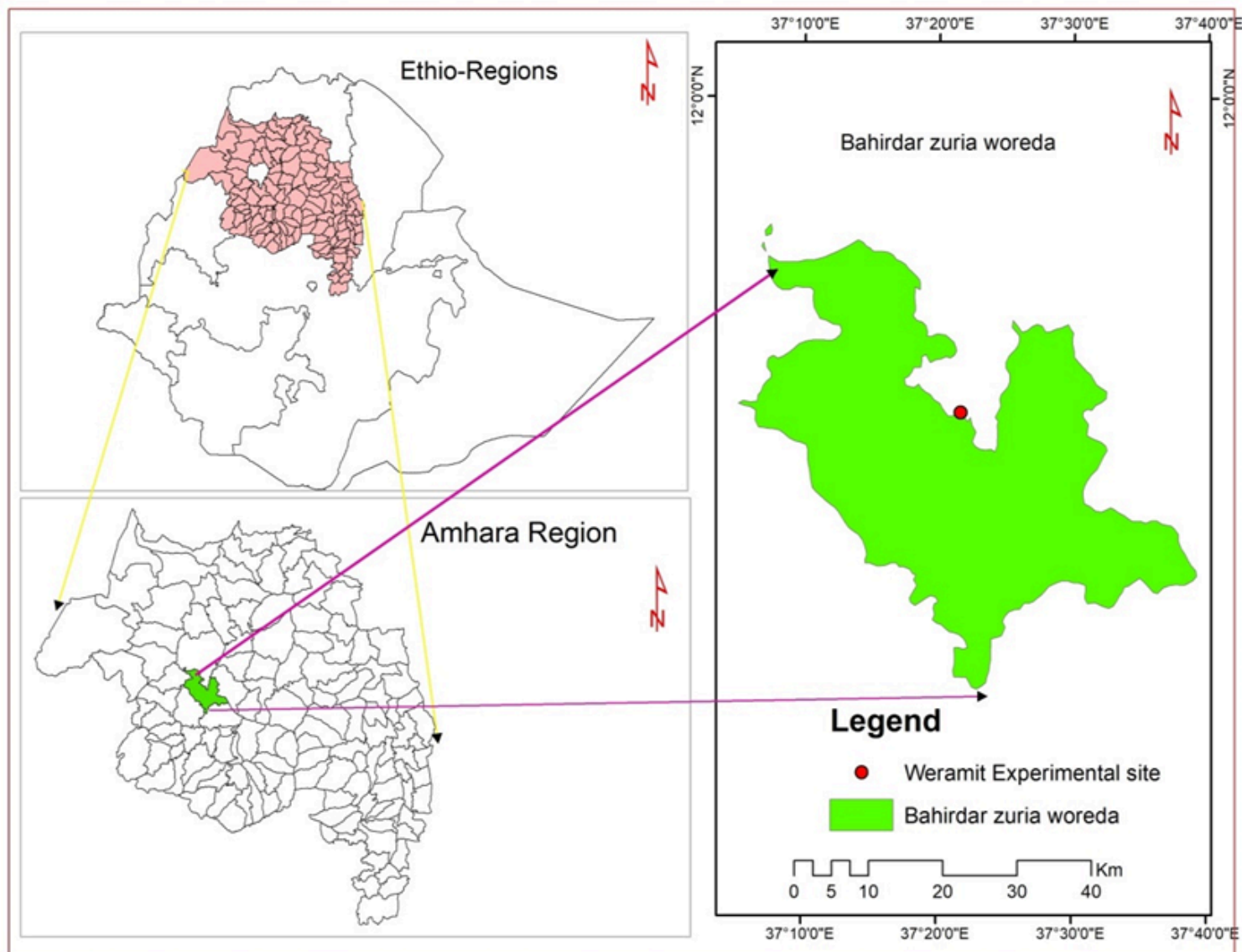


Figure 1

Map of the study area

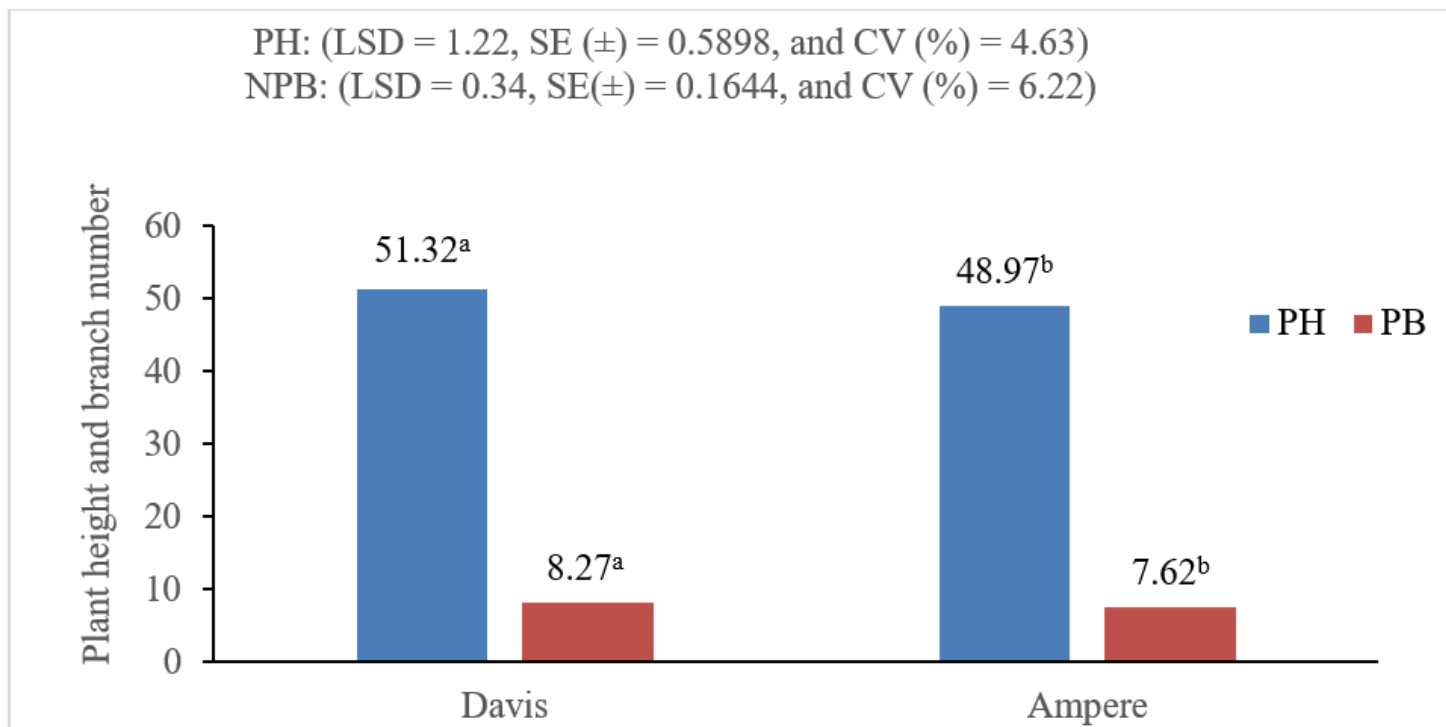


Figure 2

Plant height and number of primary branches as influenced by snap bean varieties

PH = plant height (cm); PB = primary branch; NPB = number of primary branches, SE ($\pm$): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

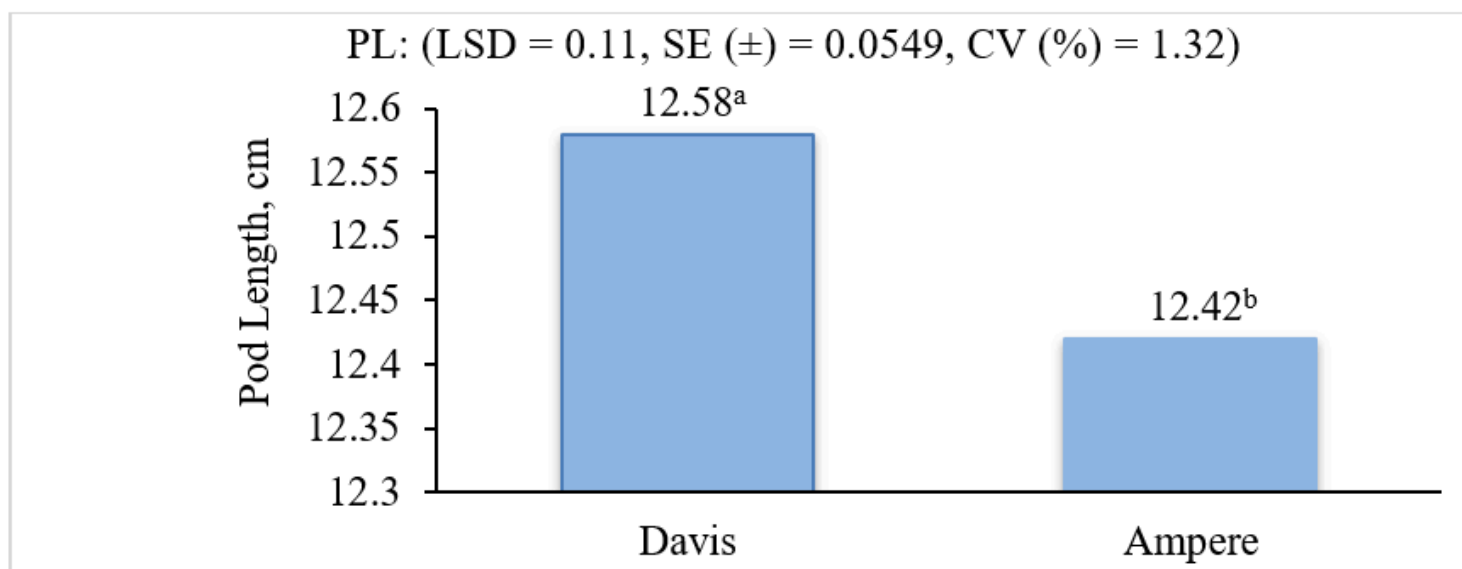


Figure 3

Pod length as influenced by snap bean varieties

PL: Pod length, SE ($\pm$): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference

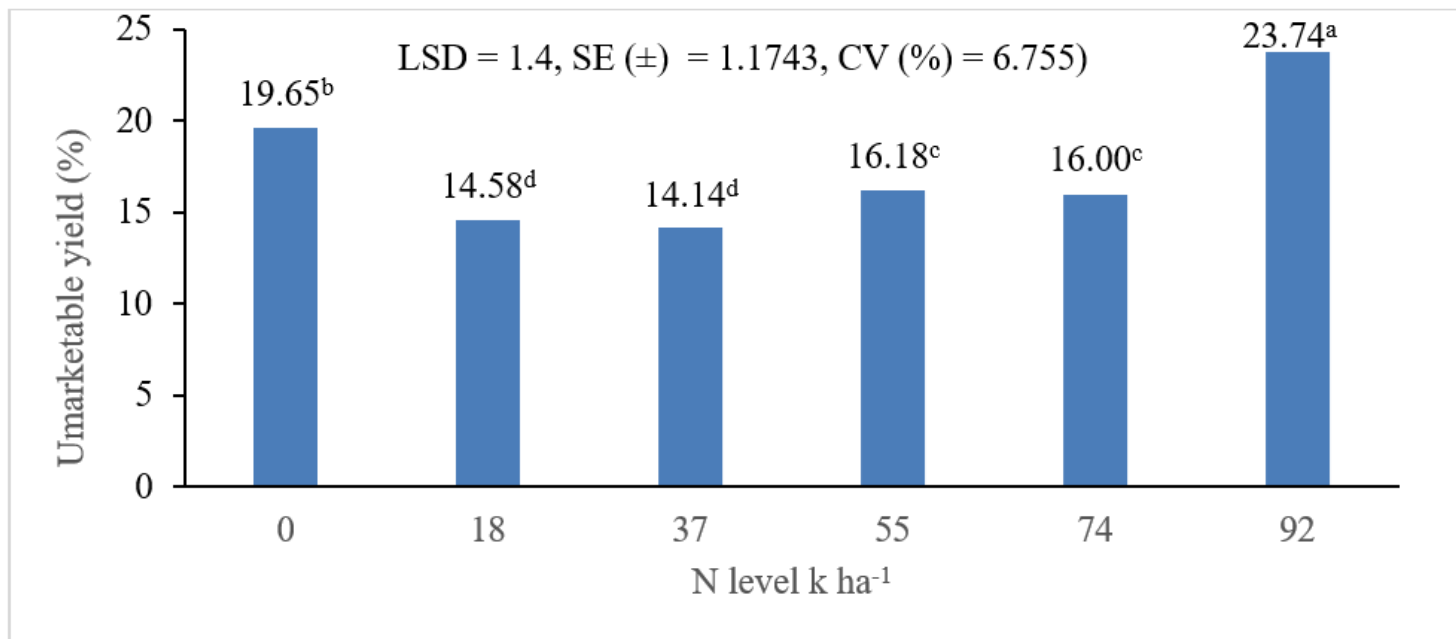


Figure 4

Effect of N level on unmarketable pod yield percentage

SE (±): Standard error, CV%: Coefficient of Variation, LSD: Least Significant Difference