D.B. Basnet et al. (2022) Int. J. Appl. Sci. Biotechnol. Vol 10(1): 31-40.
DOI: 10.3126/ijasbt.v10i1.44157

ISSN (Online): 2091-2609
DOI Prefix: 10.3126/ijasbt

International Journal of Applied Sciences and Biotechnology (IJASBT)

Research Article

Influence of Nitrogen Level on Growth Pattern and Yield Performance of French Bean (*Phaseolus vulgaris* L.) in Nepal

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Article Information

Received: 17 February 2022
Revised version received: 22 March 2022
Accepted: 24 March 2022
Published: 29 March 2022

Cite this article as:
D.B. Basnet et al. (2022) Int. J. Appl. Sci. Biotechnol. Vol 10(1): 31-40. DOI: 10.3126/ijasbt.v10i1.44157

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Keywords: Growth Pattern; French bean; Nitrogen; Yield

Abstract

A field experiment was carried out with an objective to study the effect of nitrogen levels in the growth and yield performance of French bean (Phaseolus vulgaris L.) (PDR 14 or Uday) at Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan, Nepal from October 2008 to March 2009. The experiment of nitrogen levels was carried out with five treatments of 0, 40, 80, 120 and 160 kg/ha with three dates of sowing in three replications in split plot design. The soil of the experimental plots was sandy loam with acidic (pH 6.33) in nature. The effect of nitrogen levels on growth pattern and grain yield was found significant. Significantly higher grain yield was obtained with 120 kg N/ha (2.57 t/ha) as compared to control (1.39 t/ha), 40 (1.84 t/ha), 80 (2.04 t/ha) and 160 (2.01 t/ha) kg N/ha, respectively. The yield increased significantly with nitrogen up to 120 kg/ha and then declined at 160 kg/ha. So, in order to achieve higher productivity of French bean, 120 kg N/ha can be considered as an optimum level of nitrogen application in the humid sub-tropical condition of inner Terai, Chitwan of Nepal.

Introduction

Pulses (grain legumes) are important in terms of nutrition and subsistence farming in Nepalese agriculture (Acharya *et al.*, 2019). It is a source of food security, income generation, employment and a way of livelihood for more than 60% of Nepalese population (MoALD, 2017). In Nepal, pulses are grown in 10% of cultivated land with annual production of 368,741 tons from area of 311382 hectare and productivity of 1.18 t/ha, and they are placed in fourth position after rice, maize and wheat in terms of area (Aryal *et al.*, 2020). Per capita consumption of grain legumes in Nepal is around 10 kg/annum or 27g/capita/day which is 3 times less than minimum requirement (80 g/capita/day) prescribed by WHO (Yadav, 2000).

French bean is an important nutritive legume having 22.25% protein in grain and 1-2.4% in green pods. It supplies 1.7 g protein, 50 mg calcium, 28 mg phosphorus, 1.7 mg iron, 132 mg carotene, 0.08 mg thiamine, 0.06 mg riboflavin, 24 mg vitamin C per 100 g. of edible pods. French bean is used in soups, chili dishes, baked, refried bean paste and fresh salads (Hardman *et al*., 1990). It is widely cultivated in the temperate, sub-tropical and tropical regions with the optimum mean temperature for French bean is 20-25ºC for its growth and better productivity (Dhakal *et al*., 2020).

Since French bean is a newly introduced crop, production technology for its cultivation is not well developed in Nepal. It does not nodulate with native rhizobia i.e. nitrogen-fixing bacteria (*Rhizobium phaseoli*) like other leguminous crops, so it requires nitrogen fertilizer as non-leguminous crops. However, farmers treat this crop as other nodulated legume crops for the case of fertilizer management. Nitrogen (N) is the mineral nutrient that crops require in the greatest amount. It has more influence on crop growth, production, and quality than any other nutrient (Ganeshamurthy *et al*., 2017). Pivotal N is required in larger quantity of about 1000 ug/kg dry matter, so, it is compulsory supplied to plants (Leghari *et al*., 2016).

In spite of it, Nepalese farmers grow French bean with a great variation in the dose of nitrogenous fertilizers. Due to these reasons, the average yield (1.9 t/ha) of French bean obtained in the farmers field of Chitwan (DADO, 2007) is low as compared to its potential (3.0 t/ha) yield (Yadav, 2000). Research information regarding the appropriate quantity of nitrogen application for the cultivation of French bean (*Phaseolus vulgaris* L.) is not sufficient. Keeping these facts in view, the present research as an attempt to develop the appropriate cultivation practices for higher production to fulfill the increasing demand of vegetable protein for growing population has been undertaken.

Materials and Methods

The experiment was conducted at the horticultural farm of Institute of Agriculture and Animal Science, Rampur, Chitwan during the period from October 2008 to March 2009 (27˚ 37′ N and 84˚ 25′ E, 256 m above mean sea level) to determine optimum nitrogen dose for french bean. The experimental site was under sub-tropical climate. The soil was sandy loam in texture with acidic in nature (pH 6.33), low in organic matter (2.03 %), total nitrogen (0.1%) and available potassium (108.33 kg/ha), but medium in available phosphorus (51.33 kg/ha). The experiment was carried out with the five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) with three dates of sowing (October 21st, November 5th, and November 20th) in three replications in split-plot design. The crop was grown applying 10 tons of FYM, 60 kg P_2O_5 and 40 kg K_2O/ha in all treatments. Half of the recommended dose of N and full dose of P and K were applied as basal dose, whereas remaining N was top-dressed in two equal splits at flower bud initiation and pod filling stages. Monthly average data related to different weather parameters i.e. maximum and minimum temperatures, total rainfall, sunshine (hrs.) and relative humidity were recorded at National Maize Research Program (NRMP), Rampur, Chitwan. The total rainfall of 87.43 mm was received during the entire period of experimentation. The mean maximum and minimum temperatures were 27.87ºC and 14.02ºC, respectively during the growing season of French bean with the extreme temperature record up to 4.5ºC at minimum and 33.7ºC at maximum (from October 2008 to March 2009). The sunshine hour and RH were recorded from 5.25 hours to 8.03 hours and 70% to 100% respectively during the growing season. French bean var. PDR 14 (Uday) was sown maintaining 45 cm distance between rows and 15 cm between plants. The crop was irrigated two times (at flower bud initiation and pod filling stages) during the crop growing period. Hoeing and earthing up was done at 28 days after sowing. Similarly, weeding was done manually at 28 and 56 days after sowing. Plant protection measures were carried out as per need. The crop was harvested manually in different times as per its maturity from February till March 2009. The data of different parameters was analyzed by using M-STAT, analysis of variance and compared by Least Significant Difference (LSD) test.

Physico-Chemical Characterization of Experimental Soil

Soil samples were taken randomly form three different spots of each replication at a depth of 0-20 cm using tube auger to record the initial soil physico-chemical properties of the experimental site. The soil samples were air dried, grounded and sieved through 2 mm sieve and subjected to test their properties. The physico-chemical properties of the experimental soils are presented in Table 1.

Total nitrogen was determined by Macro-Kjeldhal Method (Jackson, 1967), available phosphorus by Olsen’s method (Olsen *et al*., 1954) and available potassium by Flame Photometer method. Organic matter was determined by Walkley and Black method (Jackson, 1973), pH (1:1 soil: water suspensions) by Beckman Glass electrode pH meter (Wright, 1939; Pradhan, 2005) and soil texture by hydrometer method.

From soil analysis, sand was found dominant (81.21%) in physical properties of soil than silt and clay possessing the sandy loam texture (Table 1) (FAO, 1984). In chemical properties of soil; pH (6.33), organic matter (2.03%), total nitrogen (0.10%), available phosphorous (51.33 kg/ha) and potassium (108.33 kg/ha) were observed. The chemical properties of soil of the experimental field revealed that soil pH (6.33) was low which denotes the slightly acidic condition of the soil. French bean may be grown on soil with a pH ranging from 6–8.5 (Singh, 2005). The available potassium (108.33 kg/ha) in the soil was low but the available phosphorous (51.33 kg/ha) was medium. Finally, the total nitrogen content (0.10%) was low according to the rating scale described by Jaishy (2000). Moreover, the organic matter content (2.03%) in the soil was low (Jaishy, 2000).

Table 1: Physico-chemical characterization of the soil depth (0-20 cm) at the experimental site

Properties	Content	Class	Methods of determination
1. Physical properties			
Sand%	81.21	-	Hydrometer method
Silt%	13.21	-	
Clay%	5.33	-	
2. Chemical properties			
Soil pH	6.33	Acidic	1:1 Soil: water Ratio
Soil organic matter%	2.03	Low	Walkley and Black method
Total nitrogen%	0.10	Low	Macro-Kjeldhal Method
Available phosphorous (kg/ha)	51.33	Medium	Modified Olsen's Bicarbonate method
Available potassium (kg/ha)	108.33	Low	Flame Photometer method
3. Textural classes		Sandy loam	The textural triangle

Results and Discussion

Each type of plant is unique and has an optimum nutrient range as well as a minimum requirement level. Below this minimum level, plants start to show nutrient deficiency symptoms while excessive nutrient uptake can also cause poor growth because of toxicity (Silva & Uchida, 2000). Higher availability of nutrient does not mean of its increased utilization. Optimum availability of N is necessary for their proper intake by plants (Leghari *et al*., 2016). Therefore, judicious use of nitrogen fertilizers is required for appropriate timing and placement to coincide with peak utilization periods in improving N use efficiency and enhancing crop productivity (Ganeshamurthy *et al*., 2017). The proper amount of fertilizer application is thought a key role to increase crop and the judicious application of inorganic fertilizers can improve yield from 30-40% (Rahman *et al*., 2014).

Ample nitrogen has a tendency to encourage leaf development or to encourage above ground vegetative growth as it is an integral component of many compounds including protein and enzymes essential for plants growth (Brady, 1996).

Similarly, from environment prospects, appropriate use is equally important that minimizes the risk of causing pollution by loss of N through runoff, leaching, emissions to the air, or other mechanisms (Ganeshamurthy *et al*., 2017).

Phenological Stages

Influence in seed emergence was observed in French bean with the level of nitrogen (Table 2). Significantly early emergence was in all level of nitrogen application i.e. in control (11.0 DAS), at 40 kg/ha (12.2 DAS), at 80 kg/ha (12.5 DAS) and at 120 kg/ha (11.33 DAS) than the application of highest doses of nitrogen particularly 160 kg/ha (13.11DAS).

Significant delay in emergence at higher levels of nitrogen might be due to NH_4^+ toxicity which inhibits seed germination and seedling establishment (Cooke, 1962; Westwood & Foy, 1999). Further, the effect of N level was found significant only in the appearance of 1st pair of leaves. In control, the 1st pair leaf appeared significantly early than in 80 and 120 kg/ha N/ha which were similar to each other. However, nitrogen levels did not have significant influence on the appearance of flower buds and flowering stages.

Further, the maturity period was significantly longer (106.6 DAS) at the maximum (160 kg N/ha) than at the lower levels (0, 40 and 80 kg/ha) of nitrogen which were similar to each other. Maturity at 120 kg N/ha (105.3 DAS) was at par to both maximum (160 kg/ha) and lower levels (40 and 80 kg/ha). Maturity in control was significantly shorter than the application of highest two levels of nitrogen i.e. 160 and 120 kg/ha. N deficiency causes early maturity in some crops, which results in a significant reduction in yield and quality (Silva & Uchida, 2000).

Plant Height

Statistical analysis showed that the effect of nitrogen levels was significant on plants growth in height. Significantly higher plant height, at all growth stages, was with the increase in nitrogen levels from 0 to 120 kg/ha and then declined at the maximum level i.e. 160 kg/ha. On an average, the plant height of French bean in the experiment increased up to pod formation stage (60 DAS) and ranged from 15.80 cm (30 DAS) to 36.49 cm (60 DAS) and it was 29.16 cm at 45 DAS (Table 3). Moreover, at 60 DAS, the increments in plant height obtained by the application of 120 kg N/ha were 21.15, 11.83 and 11.63% as compared to 40, 80 and 160 kg/ha, respectively.

Table 2: Effect of nitrogen levels on the occurrence of different phenological stages of French bean at Rampur, Chitwan

Treatments N levels (kg/ha)	Phenological stages (DAS)					
	Emergence	True leaf (PL1)	Flower budding	Flowering	Pod formation	Maturity
0	11.00[c]	14.33[c]	36.67	53.00	57.67	103.7[c]
40	12.22[b]	14.56[bc]	36.67	53.00	58.11	104.6[bc]
80	12.56[b]	15.44[a]	37.00	52.89	58.11	104.6[bc]
120	11.33[c]	15.11[ab]	36.89	53.11	58.33	105.3[ab]
160	13.11[a]	14.56[bc]	36.78	53.78	58.89	106.6[a]
LSD (P=0.05)	0.41	0.59	Ns	Ns	Ns	1.48
CV%	3.50	4.12	2.20	3.83	3.71	1.45

DAS = Days after sowing, PL1 = First pair leaf, Treatments means followed by the common letter(s) within a column are non-significantly different based on DMRT at 5% level of significance.

Table 3: Plant height of French bean as influenced by nitrogen levels at Rampur, Chitwan

Treatments- N levels (kg/ha)	Plant height (cm)		
	Days after sowing		
	30	45	60
0	14.15[c]	24.64[d]	31.48[d]
40	15.06[c]	27.77[c]	34.47[c]
80	16.62[b]	30.27[b]	37.34[b]
120	17.89[a]	34.15[a]	41.76[a]
160	15.29[c]	29.00[bc]	37.41[b]
Grand mean	15.80	29.16	36.49
LSD (P= 0.05)	1.24	1.62	2.03
CV%	8.08	5.74	5.72

Treatments means followed by the common letter(s) within a column are non-significantly different based on DMRT at 5% level of significance.

Nitrogen is of special importance in the formation of protein in plants (Reddy & Reddi, 2005; Brady, 1996). Protein provides the frame work for chloroplasts, mitochondria and other structures in which most biochemical reactions occur. Thus, ample nitrogen has tendency to encourage above ground vegetative growth (Brady, 1996). Moreover, it is an integral part of chlorophyll which is the primary absorber of light energy needed for photosynthesis. Thus, an adequate supply of nitrogen is associated with high photo-synthetic activity and consequently with vigorous vegetative growth (Tisdale, 1985). Nitrogen deficiency causes abiotic stress to the crop which results into lower biomass and growth rate (Sanchez *et al*., 2001). The plant height declined significantly at 160 than 120 kg N/ha due to incomplete assimilation of nitrogen. When a nutrient is present in the soil in excess of plant requirement, the nutrient is absorbed in higher amounts which causes imbalance of nutrients or disorder in physiological processes (Reddy & Reddi, 2005). So, it might had affected on the conversion of NH_3 into glutamic acid in plants resulting in the retardation of crop growth character like plant height at maximum level (160 kg/ha) of nitrogen. Similar effect was recorded in leaf area index (Table 4) and total dry matter production per plant (Table 5) at 90 DAS resulting in lower values of yield attributes (Table 6) and yield (Table 7).

Moreover, according to Moniruzzaman et. al. (2008), amount of nitrogen beyond optimum level brings about nutrient imbalance and suppresses growth of the plant. Growth inhibition has been attributed to various factors such as toxic effects of free ammonia and carbohydrate limitation (Cramer & Lewis, 1993) due to excessive consumption of soluble sugars for NH_4^+ assimilation (de-toxification) (Walch-Liu *et al*., 2000). Ammonium induced inhibition of shoot growth has been reported for *Phaseolus vulgaris* L. (Chaillou *et al*. 1986). It is due to uncoupling of photophosphorylation, lack of carbohydrate and impairment of water status (Walch-Liu *et al*., 2000). Further, it was also related with the narrowing of the relationship between nitrogen and phosphorus (1: 0.38) at 160 than at 120 kg N/ha (1: 0.5) as phosphorus is also involved in protein synthesis (Basnyat, 2004) and translocation of photosynthates (Verma & Saxena, 1995). A decrease in plant height with the increase in nitrogen level from 150 (40.26 cm) to 200 kg/ha (39.61 cm) was also obtained by Rahman et. al. (2007). According to the research findings of Wani et. al. (1998) in 1993 and Verma and Saxena (1995) in 1989/90 and 1990/91, the plant height of French bean increased significantly with the increase in nitrogen level from 0 to 120 kg/ha. Leaf Area Index (LAI)

The leaves of a plant are normally its main organs of photosynthesis, and the total area of leaves per unit area of land surface, called leaf area index (LAI), as the best measure of the capacity of crop producing dry matter and called it as productive capital (Basnet, 2009; Arnon, 1972). As leaves grow, their ability to photosynthesize increases for a time and then, often even before maturity, begins slowly to decrease (Salisbury & Ross, 2001). For dry matter accumulation, LAI differs with the crop and their leaf orientation. Optimum LAI is between 3 to 4 for crops with horizontally oriented leaves and 6 to 9 for crops with upright leaves (Reddy & Reddi, 2005).

The effect of nitrogen levels on LAI was significant at all stages where LAI of 120 kg/ha was recorded significantly higher than 0, 40 and 80 kg N/ha. On average, the LAI was increasing up to 75 DAS and then declined at 90 DAS and ranged from 0.44 (30 DAS) to 1.85 (75 DAS) (Table 4).

Table 4: Effect of nitrogen levels on leaf area index (LAI) of French bean at Rampur, Chitwan

Treatments- N levels (kg/ha)	Leaf Area Index (LAI)				
	Days after sowing				
	30	**45**	**60**	**75**	**90**
0	0.30^{d}	0.79^{d}	1.28^{d}	1.45^{c}	0.79^{d}
40	0.40^{c}	1.03^{c}	1.60^{c}	1.69^{b}	1.10^{c}
80	0.46^{b}	1.18^{b}	1.70^{bc}	1.94^{a}	1.24^{bc}
120	0.61^{a}	1.48^{a}	1.96^{a}	2.08^{a}	1.63^{a}
160	0.45^{b}	1.32^{b}	1.88^{ab}	2.08^{a}	1.44^{ab}
Grand mean	0.44	1.16	1.68	1.85	1.24
LSD (P= 0.05)	0.04	0.14	0.19	0.22	0.20
CV%	10.18	12.57	12.18	12.53	17.29

Treatments means followed by the common letter(s) within a column are non-significantly different based on DMRT at 5% level of significance.

Table 5: Dry matter production of French bean as influenced by nitrogen levels at Rampur, Chitwan

Treatments- N levels (kg/ha)	Total dry matter (g/plant)				
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
0	1.37^{c}	4.22^{c}	7.88^{c}	12.51^{c}	12.14^{d}
40	1.77^{b}	5.62^{b}	9.12^{bc}	14.81^{b}	15.93^{c}
80	2.08^{b}	6.26^{b}	9.89^{b}	15.93^{b}	18.47^{b}
120	2.52^{a}	7.77^{a}	12.66^{a}	18.16^{a}	22.53^{a}
160	2.03^{b}	7.14^{a}	10.36^{b}	17.56^{a}	19.29^{b}
Grand mean	1.96	6.20	9.98	15.79	17.67
LSD (P= 0.05)	0.32	0.78	1.29	1.56	1.96
CV%	16.93	12.92	13.35	10.20	11.45

Treatments means followed by the common letter(s) within a column are non-significantly different based on DMRT at 5% level of significance.

Table 6: Yield attributing characters of French bean as influenced by nitrogen levels at Rampur, Chitwan

Treatments- N levels (kg/ha)	Yield attributing characters						
	Branches per plant	**Pods per plant**	**Pod length (cm)**	**Grains per pod**	**Grain weight per pod (g)**	**Thousand grain weight (g)**	**Shelling percentage**
0	3.98^{c}	7.09^{c}	8.44^{d}	2.40^{c}	1.03^{c}	423.00^{e}	74.17^{b}
40	4.46^{b}	8.47^{b}	8.70^{cd}	2.48^{bc}	1.12^{c}	445.20^{d}	76.74^{a}
80	4.68^{b}	9.27^{b}	9.00^{b}	2.69^{b}	1.30^{b}	473.80^{b}	77.40^{a}
120	5.99^{a}	16.13^{a}	9.92^{a}	3.56^{a}	1.81^{a}	508.60^{a}	78.33^{a}
160	4.64^{b}	8.92^{b}	8.95^{bc}	2.63b^{c}	1.25^{b}	463.80^{c}	77.12^{a}
Grand mean	4.75	9.97	9.00	2.75	1.30	462.89	76.75
LSD (P= 0.05)	0.42	1.25	0.26	0.25	0.12	9.86	2.31
CV%	9.11	12.91	3.06	9.44	9.59	2.19	3.09

Treatments means followed by the common letter(s) within a column are non-significantly different based on DMRT at 5% level of significance. In all treatments, uniform plant population (148.15 thousand/ha) was maintained.

However, LAI at 120 kg/ha was at par with the maximum level (160 kg/ha) only in the later part of the vegetation i.e. from 60 to 90 DAS. Higher LAI recorded at 120 kg N/ha assisted to accumulate significantly higher total dry matter (Table 5) and consequently yield attributing character (Table 6) and grain yield (Table 7) of French bean. The correlation between leaf area index and yield was positive ($r = 0.730^{**}$).

Moreover, vigorous vegetative growth with an adequate supply of nitrogen is associated with high photosynthetic activity as it is an integral part of chlorophyll which is the primary absorber of light energy needed for photosynthesis. It is because of this reason the number of leaves per plant also increased significantly at higher levels (120 and 160 kg/ha) of nitrogen at most of the growth stages. Similarly, plant absorbs nitrogen from the soil in the form of NH_4^+ and NO_3^- which are used to build protein and an abundant protein tends to increase the size of the leaves (Arnon, 1972). So, with the increase in number of leaves per plant and size of the leaves the LAI per plant was significantly greater at higher levels of nitrogen, particularly at 120 kg/ha, at most of the growth stages.

Similar trend was also found by Nandan and Prasad (1998) where the leaf area index (LAI) increased with increase in nitrogen level and was significantly higher at 120 than 40 and 80 kg N/ha at 90 DAS in 1992/93. The increase in LAI was due to favourable synthesis of growth favouring constituents in plant system due to better supply of nitrogen which led to enlargement in leaf area. Low nitrogen availability might cause a decrease in protein which consequently decreases the cell size and cell division (Basnet, 2012). Verma and Saxena (1995) also mentioned that the leaf area per plant of french bean increased significantly with the increase in nitrogen level from control to 120 kg/ha in the experiment of 1989/90 and 1990/91.

Dry Matter Production

The first prerequisite for high yield is a high production of total dry matter per unit area. The amount of dry matter production depends on the effectiveness of photosynthesis of the crop and furthermore, on plants which vital activities are functioning efficiently (Arnon, 1972). The total yield of dry matter is the total amount of dry matter produced, less the photosynthates used for respiration. Finally, the manner in which the net dry matter produced is distributed among the different parts of the plant will determine the magnitude of the economic yield (Arnon, 1972).

Statistical analysis of dry matter partitioning showed that it was affected significantly by nitrogen levels. On an average, the total dry matter produced (g/plant) by French bean plants was increasing from 30 to 90 DAS and at most of the growth stages, it increased with the increase in nitrogen level up to 120 kg/ha and then declined at 160 kg/ha. The total dry matter accumulation (22.53 g/plant) recorded with 120 kg N/ha at 90 DAS was significantly higher than control (12.14 g/plant), 40 (15.93 g/plant), 80 (18.47 g/plant) and 160 (19.29 g/plant).

The total dry matter production partitioning was found higher in leaves at the early vegetative stage (30 DAS) thereafter, gradually to stem growth and pod formation at 60 DAS and then formation of reproductive parts due to utilization of the assimilates accordingly. In contrast to vegetative parts, the partitioning of pods in total dry matter accumulation increased and was higher at the grain development stage (90 DAS). This is due to the fact that in young plants most of the assimilates are used for the production of stem and leaves (Basnet, 2012). As the plants enter reproductive stage, assimilates are partitioned to stem, leaf and inflorescence. Once the grains are set, most of the assimilates move to the grain (Reddy & Reddi, 2005). Moreover, the amount of economic yield depends on the manner in which the net dry matter produced is distributed among the different parts of the plant (Arnon, 1972). Thus, an increase in leaf number as well as LAI per plant (Table 4) with the increase in nitrogen level accelerated carbohydrate synthesis which in turn influenced on the accumulation of the total dry matter per plant significantly at 120 kg/ha than other doses of nitrogen at 90 DAS (Table 5). Similar trend was reflected in grain yield (Table 7).

Moreover, at the maximum level (160 kg/ha) of nitrogen, the total dry matter accumulated in plants decreased significantly at 30, 60 and 90 DAS as compared to 120 kg N/ha. Lower dry matter accumulation at 160 kg N/ha (excess nitrogen) might be due to ammonium ($NH4^+$) toxicity which indeed enhance photorespiratory rates (Zhu *et al*., 2000), suppress growth at high light and damage to the photosynthetic centers (Britto *et al*., 2002). Similar result was obtained by Singh and Singh (1999). According to them, the dry matter of French bean increased significantly with the increase in nitrogen levels from 0 to 120 kg/ha where the relation between NPK was 1: 0.7: 0.3 in 1994/95 and 1995/96, respectively. Verma and Saxena (1995) also found significantly higher dry weight per plant of French bean at 120 kg N/ha than control and 60 kg N/ha in the experiment of 1990/91.

The nitrogen fertilization increases the rate of photosynthate accumulation which finally results in increased dry matter production in plant (Nandan & Prasad, 1998). Moreover, increase in photosynthetically active area and its efficiency to utilize solar radiation might have been the possible causes for higher dry matter accumulation with increased nitrogen availability (Rana *et al*., 1998).

Yield Attributing Characters

The statistical analysis in this experiment showed most of the yield attributes of French bean varied significantly due to nitrogen levels. All yield attributing characters were significantly superior at 120 kg N/ha than other (0, 40, 80 and 160 kg/ha) levels of nitrogen (Table 6). Only the shelling percentage at 120 kg N/ha was at par with all the doses of nitrogen except control. Similar trend was observed in grain yield of French bean (Table 7).

The branches per plant was significantly higher at 120 (5.99) than 40 (4.46), 80 (4.68) and 160 (4.64) kg N/ha and all the application with control. In legume crop the number of branches per plant play an important role to produce the more number of pods per plant for better yield (Basnet, 2009). Wani et. al. (1998) in 1993 and Singh et. al. (1996) in 1992/93 reported similar finding that the branches per plant of French bean increased significantly with the increase in nitrogen level up to 120 kg N/ha.

As in branches per plant, significantly higher pods per plant was found at 120 kg N/ha (16.13) and all the remaining treatments with nitrogen (40, 80 and 160 kg/ha recorded 8.47, 9.27 and 8.92 pods per plant respectively) were significantly superior to control (0.79) (Table 6). Verma and Saxena (1995) also reported that pods per plant of French bean increased significantly with the increase in nitrogen level from 0 to 120 kg/ha. Similar findings of the pods per plant of French bean was significantly higher at the nitrogen level of 120 kg/ha as compared to 80, 40 and 0 kg/ha in 1993 (Wani *et al*., 1998). Further, Rahman et. al. (2007) reported that the pods per plant was significantly higher at 150 kg N/ha as compared to 0, 100, 150 and 200 kg N/ha doses at Joydebpur, but at Jamalpur the pods per plant increased significantly with the increase in nitrogen level up to 150 kg N/ha and then decreased.

The average pod length of French bean was 9.0 cm (Table 6) where the maximum (9.92 cm) pod length was at 120 kg N/ha (significantly higher than all the remaining levels) and minimum (8.44 cm) in control. Optimum level of nitrogen (120 kg/ha) increases the rate of photosynthesis by chlorophyll formation and thus more assimilates were made and pod length increased (Moniruzzaman *et al*., 2008). Similarly, Rahman et. al. (2007) reported that the pod length increased significantly when the dose of nitrogen was increased from 100 to 150 kg/ha at Joydebpur.

The grains per pod was found to increase with the level of nitrogen from 0 to 120 kg/ha and then declined at 160 kg/ha (Table 6). The maximum number of grains per pod (3.56) was obtained with 120 kg N/ha and minimum (2.40) in control. This is in conformity with the results obtained by Singh and Verma (2002) that grains per pod increased significantly with increasing level of nitrogen up to 120 kg/ha. These findings are in agreement with Saxena and Verma (1995) that the increase in the nitrogen level from 0 to 120 kg/ha increased grains per pod significantly in French bean in 1989/90 and 1990/91.

Similarly, the grain weight per pod and thousand grain weight were increased significantly with the increase in the level of nitrogen from 40 to 120 kg/ha and then declined at 160 kg/ha (Table 6). The shelling percentage increased with the level of nitrogen up to 120 kg and then declined at 160 kg N/ha.

Application of nitrogen assists to improve yield components through increased crop growth (Verma & Saxena, 1995), but the optimum level of nitrogen application depends on the type of soil and the crop (Singh *et al*., 1998). Of this experiment for French bean in the sandy loam soil, all yield attributes were significantly higher at the level of 120 kg N/ha. Further, a significant decrease in the values of yield attributes with the increase in nitrogen level from 120 to 160 kg/ha was associated with significant decrease in pods as well as total dry matter production per plant at the grain formation stage (90 DAS). Moreover, it might be due to insufficient supply of phosphorus as the relationship between nitrogen and phosphorus was narrower at 160 kg N/ha (1:0.3) than at 120 kg/ha (1:0.5) because phosphorus is essential for pod and grain formation (Das, 1998). This was also obvious from the data of thousand grain weight which was significantly higher at 80 kg N/ha with the ratio of 1:0.7 between nitrogen and phosphorus than at 160 kg N/ha (1:0.3). Moreover, it is well known that the role of phosphorus is to supply energy through ATP for the translocation of assimilates from source to sink (Rana *et al*., 1998). The higher value of almost all the yield attributing characters produced by the application of 120 kg N/ha also assisted to give significantly higher grain yield than other levels of nitrogen (Basnet, 2012).

Grain Yield

The statistical analysis showed that the nitrogen levels with its different treatments significantly influenced on grain yield of French bean (Table 7). The grain yield of French bean was increasing significantly with the increase in the level of nitrogen from 0 to 120 kg/ha (significantly higher than all levels) and then declined at the highest dose (160 kg/ha). Similarly, the yields achieved in all levels (40 to 160 kg/ha) of nitrogen were significantly superior to control. The productivity of French bean was recorded 1.39, 1.84, 2.04, 2.57 and 2.01 t/ha with different level of nitrogen (control, 40, 80, 120 and 160 kg N/ha) application.

The increments in yield with 120 kg/ha dose of nitrogen were 84.90, 39.67, 25.98 and 27.86% as compared to control, 40, 80 and 160 kg N/ha, respectively. At the maximum level (160 kg/ha) of nitrogen, the grain yield (2.01 t/ha) declined significantly as compared to 120 kg/ha (2.57 t/ha) but was significantly superior to minimum (40 kg/ha) level of nitrogen and control. Too little application of nitrogen directly reduces crop yield while excess of N also causes negative effects on plant (Leghari *et al*., 2016).

Application of nitrogen increases size of the cells, meristematic activities and formation and function of protoplasm, which consequently increase the crop growth (Black, 1967). The increased crop growth improves the yield components and finally the grain yield (Verma & Saxena, 1995).

Table 7: Effect of nitrogen levels on grain yield of French bean at Rampur, Chitwan

Treatments- N levels (kg/ha)	Grain yield (t/ha)
0	1.39[d]
40	1.84[c]
80	2.04[b]
120	2.57[a]
160	2.01[b]
Grand mean	1.97
LSD (P= 0.05)	0.15
CV%	8.01

Treatments means followed by the common letter(s) within a column are non-significantly different based on DMRT at 5% level of significance. In all treatments, uniform plant population (148.15 thousand/ha) was maintained.

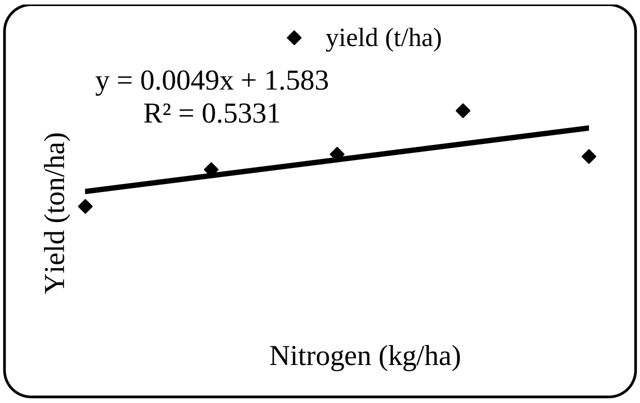

Fig. 1. Relationship of nitrogen levels (kg/ha) and grain yields (t/ha) of French bean

Thus, a significant increase in LAI and total dry matter production per plant assisted to improve significantly all yield attributing characters at 120 kg N/ha which was positively reflected on grain yield. Grain yield also increased with the increasing nitrogenous fertilizer doses (Hara *et al*., 1985). Singh and Verma (2002) also reported that owing to better vegetative growth and yield attributing characters like thousand grain weight, higher grain yield was achieved at 120 kg N/ha. Nitrogen application favours cell division and cell elongation which in turn leads to better plant growth and assimilation of more photosynthates and ultimately the higher yield (Shanker *et al*., 1998).

Moreover, Wani *et al*. (1998) found that the grain yield increased significantly with the increase in nitrogen level from 0 to 120 kg/ha. Further, on average of two years result, significantly higher yield (1.41 t/ha) was found at 120 kg/ha by Nandan and Prasad (1998) compared with 80 (1.25 t/ha) and 40 (0.92 t/ha) kg N/ha. Similarly, Singh et. al. (1998) reported that grain yield increased significantly up to 90 kg N/ha then declined. Grain yields obtained at 60, 90 and 120 kg N/ha were 895, 1180 and 988 kg/ha. French bean is a leguminous crop; it unlike other leguminous crop does not nodulate with native rhizobia (Ali & Shankar, 1991) and hence high response to nitrogen. The contribution of nitrogen in grain yield formation was 53.3% while other parameters was 46.7% (Fig. 1).

The reasons for obtaining significantly lower grain yield at 160 kg N/ha as compared to 120 kg/ha was related to significantly lower dry matter production per plant at higher level (160 kg/ha) than the optimum (120 kg/ha) level of nitrogen at 90 DAS (Table 5) (Basnet, 2012). It was particularly due to significantly lower pod dry matter accumulation at 160 kg N/ha than 120 kg/ha. Moreover, it was due to significantly lower yield attributing characters formed at 160 than 120 kg N/ha. It is because of the fact that at higher level (160 kg N/ha), the relationship between nitrogen and phosphorus becomes narrow (1: 0.3) which is needed for fruit setting and grain formation (Das, 1998). Yield depressions from ammonium toxicity among sensitive species, e.g. French bean, can range from 15-60% (Chaillou *et al*., 1986; Britto *et al*., 2002).

Conclusion

French bean, unlike other leguminous crops, does not nodulate with native rhizobia i.e. nitrogen-fixing bacteria (*Rhizobium phaseoli*) and because of this reason it requires nitrogen fertilizer as non-leguminous crops. In Nepal, average yield of French bean in farmers field is comparatively low than its yield potential due to a great variation in the dose of nitrogenous fertilizers. Appropriate quantity and its application methods of nitrogen is essential for efficient and quality crops production. Nutrient deficiency hampers in the crop growth and development while excessive nutrient uptake can also cause poor growth because of toxicity. In addition, applying the excess dose of nitrogen is not only toxic to the crop but also harmful to the soil health and increases environmental pollution. Half dose of total nitrogen with full dose of potash and phosphorus fertilizers were incorporated at sowing time and the remaining half dose of nitrogen fertilizer was top dressed into two splits at flower budding and pod formation stage. So, 120 kg N/ha can be considered as an optimum level of nitrogen for higher productivity of French bean in the humid sub-tropical condition of inner Terai.

Authors' Contributions

D.B. Basnet conducted research and wrote paper. K.B. Basnet and P. Acharya reviewed and provided the suggestions to finalize the paper.

Conflict of Interest

The authors declare that there is no conflict of interest regarding publication of this manuscript.

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