EFFECT OF NITROGEN RATE AND SOWING DATE ON THE GROWTH AND YIELD OF FRENCH BEAN (*Phaseolus vulgaris* L.) VARIETIES IN NORTHERN GUINEA SAVANNA OF NIGERIA

BY

Wasiu Adewale MUSIBAU

B. AGRIC (FUNAAB) 2013

P17AGAG8005

A DISSERTATION SUBMITTED TO SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE OF SCIENCE IN AGRONOMY

DEPARTMENT OF AGRONOMY,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

OCTOBER, 2021

DECLARATION

I hereby declare that the work in this dissertation titled `` Effect of sowing date and nitrogen rate on the growth and yield of French bean (*Phaseolus vulgaris* L.) varieties in northern Guinea savanna of Nigeria`` was performed by me in the Department of Agronomy, under the supervision of Prof. A. B. LAWAL and Prof O. O. OLUFAJO. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation has been presented to the best of my knowledge for award of degree or diploma at any institution.

……. Date……

WASIU ADEWALE MUSIBAU
(Student)

..... Date.....

Prof. A. B. Lawal
(Supervisor)

CERTIFICATION

This dissertation titled ``Effect of sowing date and nitrogen rate on the growth and yield of French bean (*Phaseolus vulgaris* L.) varieties in northern Guinea savanna of Nigeria`` by, Wasiu Adewale, Musibau meets the regulations governing the award of the degree of Master of science in Agronomy in the Department of Agronomy, Faculty of Agriculture, Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

..... Date.....
Prof. A. B. Lawal
(Chairman, Supervisory Committee)

..... Date…….
Prof. O. O. Olufajo
(Member, Supervisory Committee)

..... Date…….
Prof. A.I. Sharifai
Head, Department of Agronomy
Amadu Bello University
Zaria.

..... Date…….
Prof. S. Abdullahi
Dean, Postgraduate School
Ahmadu Bello University, Zaria.

DEDICATION

Dedicated to my parent Late Mr. Musbaudeen Alatise and Mrs. Balikis Musbaudeen.

ACKNOWLEDGEMENTS

Praise and adoration to Allah for His protection, blessings and guidance upon me and my family. With esteemed humility, my sincere appreciation goes to Prof A. B Lawal (Chairman Supervisory Committee) and Prof O. O Olufajo (Member Supervisory Committee) for their fatherly support, patience, guidance and technical contributions in the course and success of the research. The amiable Head of Department, Prof. A. I. Sharifai, wonderful staffs and member of the Department of Agronomy Ahmadu Bello University, Zaria Nigeria. I say thank you for your fruitful advice and words of encouragement that saw me through the successful outcome and better ending of this research. To my siblings Musbaudeen. Abdulateef, Usman, Abdulqadri and Abdulhakim thank you for the support and words of encouragement. I am grateful to all my wonderful colleagues and friends especially Shotunde Abiodun, Adeleke Abdullahi, Muhammad Aminu Nuhu, Lukman Musa, Ariyo Olalekan, Mudashiru Owoiya, Suleiman Maryam, Joy Adams, Peter Joy Yachat and Bamigboye Oluwayemisi for the knowledge and ideas shared

ABSTRACT

Field experiment was conducted to study the effect of nitrogen rate and sowing date on the growth and yield of French bean (*Phaseolus vulgaris* L.) varieties during 2018 rainy season at the research farm of the Institute for Agricultural Research (IAR), Samaru and College of Agriculture and Animal Science, Division of Agricultural Colleges (DAC) Mando, both located in the Northern Guinea Savanna agro-ecological zone of Nigeria. The treatments consisted of four rates of nitrogen fertilizer (0, 30, 60, and 90kgha^{-1}), three sowing date (late July, early August, and Late August) and two varieties of French bean (Premier and YCD1) which were laid out in a randomized complete block design (RCBD) with split plot arrangement and replicated three times. Results showed that nitrogen fertilizer had significant effect on growth and yield characters of French bean such as plant height, number of leaves per plants, total leaf area, relative growth rate, net assimilation rate and leaf area ratio with application of 90 kg N ha^{-1}. Yield varied with increase in level of nitrogen fertilizer, highest fresh pods (1632 kg ha^{-1} and 986 kg ha^{-1}) and grains yield (1.3 t ha^{-1} and 1.1 t ha^{-1}) were recorded with application of nitrogen at 60 kg N ha^{-1} Mando at and Samaru respectively. Sowing date recorded significant effects on growth and yield of French bean. French bean sown late July or Late August significantly resulted in higher values for plant height, number of leaves per plant, total leaf area, crop dry matter, crop growth rate, relative growth rate and leaf area ratio. French bean sown Late August had resulted in higher yield values for number of pods per plants, and pods length, late July sowing had significantly higher fresh pods yield (1004 kg ha^{-1} and 672 kg ha^{-1}) at Mando and Samaru respectively while late August sowing significantly recorded higher grains yield (919 kg ha^{-1}) at Mando. Varieties differ significantly in terms of growth and yield components; variety YCD1 had taller plants

(122.75 cm and 86.99 cm) while premier has shorter plants (119.22 cm and 82.24 cm) Mando at and Samaru respectively, YCD1 had higher fresh pod yield (690 kg ha^{-1}) at Samaru while premier (1071 kg ha^{-1}) at Mando, Premier recorded highest grain yield (893 kg ha^{-1} and 850 kg ha^{-1}) at both location respectively. Significant interaction between sowing date and varieties was recorded on plant height; where late July and late August sown variety Premier and late August sown variety YCD1 recorded taller plant, number of leaf per plant; late July or early August sown variety YCD1 resulted in more number of leaves per plant, number of grains per pod; applications of 30 and 60 kg N ha^{-1} for all sowing date and grain yield with nitrogen; application of 60 kg N ha^{-1} favoured grain yield of both varieties. Correlation matrix showed positive and significant relationship between grain yield and growth parameters such as number of leaves per plant, crop dry matter, leaf area index, pod length pod diameter and 100 grain weight at both locations. Application of nitrogen fertilizer at 60 kg N ha^{-1} was the best and gave the highest fresh pod yield of 1632 kg ha^{-1} and 986 kg ha^{-1} and grain yield of 1258 kg ha^{-1} and 1010 kg ha^{-1} at Mando and Samaru, respectively. Thereby giving higher incomes of ₦142,507 and ₦180,295 for pod yield and ₦75,958 and ₦59,046 for grain yield, respectively.

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ABBREVIATION

ANOVA: Analysis of Variance

Al: Aluminum

CaCl: Calcium Chloride

Ca: Calcium

CEC: Cation Exchange Capacity

CGR: Crop Growth Rate

DAP: Days After Planting

DMRT: Duncan Multiple Range Test

DRC: Democratic Republic of Congo

FAOSTAT: Food and Agriculture Organization Corporate Statistical Database

GM: Gross Margin

GR: Gross Return

H: Hydrogen

H_2O: Water

IARI: India Agricultural Research Institute

K: Potassium

LAI: Leaf Area Index

LAR: Leaf Area Ratio

Mg: Magnesium

MOP: Muriate of Potash

N: Nitrogen

Na: Sodium

NAR: Net Assimilation Rate

NPK: Nitrogen Phosphorous Potassium

NS: Not Significant

RGR: Relative Growth Rate

S: Sowing date

SSP: Single Super Phosphate

TVC: Total Variable Cost

V: Varieties (V)

WAS: Weeks After Sowing

CHAPTER ONE

1.0 INTRODUCTION

1.1. Origin and Distribution

French bean (*Phaseolus vulgaris* L.) belongs to the family *Fabaceae* and is thought to have originated from Central America where it was grown as an indigenous crop for the past 5,000 years. Spanish and Portuguese explorers introduced the legume to Europe and Africa, and by the 19th century the slim pods became a common vegeTable in France as haricot verts, hence it is called "French" beans. French bean is also known variously as haricot bean, kidney bean, green bean, common bean, snap bean, or navy bean (Pandey, 2003). It is a herbaceous annual plant, grown worldwide for its edible dry seeds or unripe pod (both commonly called beans) (Heuze *et al*., 2015).

1.2 Botany

Bush varieties form erect bushes 20-60cm tall, while pole or running varieties form vines 2-3m long. All varieties bear alternate, green or purple leaves, which are divided into three oval, smooth-edged leaflets, each 6-15cm long and 3-11 cm wide. The white, pink, or purple flowers are about 1cm long, and produced pods 8-20 cm long and 1-1.5cm wide. These may be green, yellow, black or purple in color, each containing 4-6 beans. These beans are smooth, plump, and kidney-shaped, up to 1.5cm long, range widely in colour, and are often mottled in two or more colours.

As the name implies, freshly harvested snap bean breaks easily when the pods are bent, giving off a distinct audible snap sound. The pods of snap beans are harvested when they are rapidly growing, fleshy, and tender, especially for those to be consumed as vegeTable. Some however, prefer them in the form of pulses.

1.3 Climatic and Soil Requirements

The French bean is a warm season legume that does well under sub-tropical and temperate conditions. It can be found in tropical areas but does not do well under very wet conditions, which induces fungal attack and flower drop. It can be advantageously replaced by cowpea in such condition. French bean grows from sea level up to an altitude of 2200-3000m where annual rainfall is between 300 and 4300mm, with an optimum between 500 and 1500mm and with average temperature range between 15^{o}C and 23^{o}C. The crop can grow under higher temperatures (35^{o}C) but this may hamper seed production (Heuze *et al*., 2015). It is slightly frost tolerant, but growth stops below 10^{o}C and frost at various stages of growth depresses yield (Wortman, 2006). Dry weather during the maturity stages benefits seed preservation. The French bean grows well on soils with pH ranging from 5.5-6.8. It does better on well drained, sandy loam or silt loam.

1.4 Production Trend of French bean

According to data from the 2017 FAOSTAT, the world produced 24.2 million tonnes of fresh French bean on 1.6 million ha areas, while dried beans produced was 31.4 million tonnes on 3.6 million ha areas. The largest dry beans producing country is India (accounts for 20.4% of world production), Myanmar (17.4%), Brazil (9.7%), United States of America (5.2%), China mainland (4.2%), Mexico (3.8%), Tanzania (3.6%), and Uganda (3.3%) are the other major dry French bean producer countries. Largest producer (100,000-600,000 ha annually) in tropical Africa are Congo (Democratic Republic of Congo), Rwanda, Burundi, Ethiopia, Kenya, Uganda, Tanzania, Malawi, Angola and Mozambique. Smaller producers (2,000-100,000 ha) are Cape Verde, Nigeria, Cameroon, Sudan, and Zimbabwe. Most of the bean

produced in tropical Africa is consumed by the producers (subsistence), but about 40% are marketed to supply urban areas and for export (Messiaen and Seif, 2004).

1.5 Uses, Economic and Nutritional Importance

French bean is a good source of protein, carbohydrate, calcium, iron, phosphorus and vitamins, particularly Vitamin B (Messina, 2014). Similar to other beans, French bean or common bean is high in starch, protein, and dietary fiber, and is an excellent source of iron, potassium, selenium, molybdenum, thiamine, vitamin B_6, and folate. Dry beans will keep almost indefinitely if stored in a cool, dry place, but as time passes, their nutritive value and flavour become degraded and cooking time lengthens. Dried beans are cooked by boiling, often after being soaked in water for several hours. Although soaking is not strictly necessary, it shortens cooking time and result in more evenly textured beans. In addition, soaking removes 5-10% of the gas producing sugars that can cause flatulence for some consumers (Rombauer 2002, and Press 2002). The methods include simple overnight soaking and the power soak method, in which beans are boiled for three minute and then set aside for 2 to 4 hours. Before cooking, the soaking water is drained off and discarded. Dry French bean takes longer to cook than most pulses; cooking times varied from 1 to 4 hours but are substantially reduced with pressured cooking. French bean is valued for their protein (23%) rich seeds. Seeds are also rich in calcium, phosphorus and iron. The fresh pods and green leaves are consumed as vegeTable. The anti-metabolites contained in dry beans can be removed by cooking and soaking in water. Bean leaves have been used to trap bed-bugs in houses (Syndler, *et al.,* 2013).Microscopic hairs (trichomes) of the bean leave entrap the insects (Syndler, *et al.,* 2013).*P. vulgaris* has been linked to several health benefits such as reduction of cholesterol and coronary heart diseases, suppress ion of cancer as well as

diabetes and obesity (Bazzono *et al.,* 2001; Hangen and Bennick 2002). It also has antioxidant capacity (Heimler *et al.,* 2005). However, the consumption of *P. vulgaris* is limited due to the presence of certain anti-nutritional components such as phytic acid, saponins, lectins, thus needs for prolonged cooking (Lyimo *et al.,* 1992)

1.6 Justification and Objectives

French bean in developing countries is usually produced in rotation with other vegeTables or in crop mixtures (Messiaen, 1992). The yield of French bean in Nigeria is far less than the attainable yield (2.5-3.6 tonnes ha^{-1}) under good management conditions (Central Statistical Authority, Ethiopia 2011/12). This might be due to poor management practices, such as application of inadequate amount of nitrogen fertilizer, non-adoption of optimum sowing date and use of unimproved varieties among others. Therefore, to increase the productivity of the crop in the northern Guinea savanna, where the climatic parameters favour the cultivation of this crop, it is important to increase the awareness of farmers towards the use of improved varieties and utilization of improved agronomic practices such as nitrogen fertilizer application, appropriate time of sowing, etc.) This will contribute to high yield, increase food security while boosting farmers' earnings. The production of French bean is often limited by low availability of soil nutrient (Tahar, 2009). Fertilizer application in most soils of Nigerian savanna is very important, as they are low in nitrogen, organic carbon, available phosphorus and cation exchange capacity (Agbede, 2009; Odunze *et al.,* 2014).The use of fertilizer increases crop growth and prevent failure in poor marginal soil. Low nitrogen in the soil often limits growth and productivity of common bean (Singh, 2006). Thus, application of inorganic fertilizer (primarily nitrogen) to satisfy nutrient demand of the crop is crucial.

Nutrient requirements of French bean in Nigeria savannah have not been established, and production remains limited due to little documented research report on the crop's nutrient (especially nitrogen) requirements. French bean is a fertilizer responsive crop (El-Awadi *et al.,* 2011; Dauda *et al.,* 2015).It responds well to nutrition as research have shown that the crop lacks biological N fixation ability due to poor or no nodulation and as a result responds to the application of nitrogen (Ahlawat, 2012).

Sowing date is an important factor for the growth and yield of French bean. Vyas *et al.,* (1990) reported seed yield variation of French bean due to different sowing date. Farmers often sow the seeds of French bean either early or late without knowing the optimum sowing time. Their sowing date often determined by time of harvest of preceding crop, growth and development of earlier sown crop(s) in a relay or out rightly dependent on farmer's work schedule. All these adversely affect the crop yield. The sowing times has marked effects on growth and yield of most crops in different parts of the world as delay in sowing beyond the optimum time usually results in yield reduction (Vange and Obi, 2006; Mehrnosh and Noriani 2019).

In view of the above, the present study was carried out with the following objectives;

i. To determine optimum nitrogen fertilizer rate for growth and yield of French bean in the northern Guinea Savanna.
ii. To study the effect of sowing date on the growth andyieldof two varieties of French bean, with a view to identifying suiTable variety for the northern Guinea Savanna ecology.
iii. To determine the economic viability of cultivating the two French bean varieties in northern Guinea Savannah.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Growth and Yield Performance of French Bean Varieties

Barcchiya and Kushwah (2017) in an experiment conducted on French bean varietyreported that among the varieties of French bean use, SwarnaPriya recorded the highest values for growth, yield parameters and yield among others (ArkaKomal and Contender) varieties, while earliest flowering was recorded in variety Contender followed by ArkaKomal. Similarly, in a trial conducted by Sharma *et al.*,(2013),among the varieties of French bean used, 'SVM-1' significantly outperformed 'Luxmi' and 'Kentucky Wonder' for seed yield with a respective increase of 63 and 44% in yield, furthermore, SVM^{-1} performed better in terms of number of pods per plant and straw yield.

An experiment was carried out for two seasons by Kamanu *et al.,* (2012) to determine the performance of two French bean varieties, variety Serengeti had higher number of nodule per plant than Amy in both seasons. There are no varietal differences with respect to nodule dry weight. Variety Serengeti had higher shoot dry weight, pod weight and total grain yield than Amy. Balvant, (2011) reported that variety SwaranPriya recorded taller plant height, followed by ArkaKomal and Contender with significant difference at all the growth stages. Though, the difference between ArkaKomal and Contender at early growth phase was not significant. Ramakrishna *et al.,* (2002) reported that growth and yield of any crop is a function of it genotype expressed under growing environmental condition including nutrients availability. Filho *et al*., (2007) in an experiment conducted to evaluate the response of common bean varieties (Perola and IAC Una) reported that variety Perola, in comparison with IAC Una showed greater response and efficiency, and this resulted in higher yield.

Ahmed, (2017) also reported that variety premier is superior in growth and growth yield parameter and recorded higher value for number of branches, canopy spread, leaf area index, relative growth rate, and grainyieldkg ha^{-1}, pod length per plant, 100 seed weight, number of pods per plant, number of seed per pod, pod diameter and attained 50% flowering early. Contender and YCD1 produced taller plant than premier did. Also Uddin *et al.,* (2017) reported significant variation in growth, crop characteristics and yield of French bean varieties with BARIJharsheem-3 being superior toBARIJharsheem-1 and BARIJharsheem-2.Wodimu and Tana, (2017) reported that the French bean variety Awash Melka was found to be the best combination under Mechara's agro-ecology (Ethiopia) as it recorded highest number of seeds per pods and shoot tissue resulted in higher values for yield and most of yield related traits for common bean.

2.2 Effect of Nitrogen Fertilizer on Growth and Yield of French Bean

Adequate amounts of nitrogen fertilization led to improve growth, yield and quality of pods (El-Awadi *et al.,* 2011). Nitrogen is essential for all biological process that occurs in the plant, sub-optimal supply of N limits the expression of yield potentials of green bean varieties (Dauda *et al.,* 2015). Gupta *et al.,* (1996) observed that French bean responded to nitrogen up to 120 kg N ha^{-1} and there was 57.2% positive and significant increase in yield over control. Similarly, Lad *et al.,* (2014) reported that application of nitrogen (100 kg ha^{-1}) resulted in positive and significantly high grain and straw yield of French bean. Shamima (2019) observed gradual increase in pod length with the increasing dose of nitrogen fertilizer. The longest length of green pod of bush bean (17.51 cm) was found in the crop grown with the higher dose of nitrogen (40 kg N ha^{-1}) and shortest was observed from the control treatment. In addition, at final harvest the maximum plant height (43.82cm) was obtained

from the plant grown with 40 kg N ha^{-1} and the minimum (37.85cm) was recorded from untreated control. Sena *et al.,* (2010) also reported significant increase in yield and yield components of French bean to different levels of nitrogen. Nasrin *et al*., (2018) observed significant influenced on most of the studied yield contributing characters and yield of French bean, with taller value for plant height (54.75 cm), number of pods $plant^{-1}$ (7.65), length of pod (12.81 cm), number of grains pod^{-1} (6.1), and grain yield of(1.95 t ha^{-1}) attainted at 80 kg N ha^{-1}.Bildiric and Yilmaz (2005) observed nitrogen application exerted a significant and positive effect on number of pod per plant, grain yield and raw protein proportion, whereas no significant effect was observed on number of grains per pod and weight of thousand seeds. Kashinath and Ramakrishna (2015) found significantly higher pod yield and N uptake at different growth stages with the application of 62.5 kg N ha^{-1}

Singh and Singh(2000) reported that yield component values of French bean increased with increasing N rates but were generally highest with 80 kg ha^{-1} N. Ahmed (2017) working in Samaru reported no significant response of the crop to nitrogen in first year but found significant increase in growth and yield characters in subsequent years. Similarly, Singh (2011) reported that application of nitrogen significantly influences growth, yield and seed quality parameters. Maximum plant height, number of leaves per plant, number of branches per plant, leaf area index, fresh weight and dry weight of shoot per plant were observed with application of nitrogen fertilizer (100 Kg ha^{-1} N followed by 125Kg ha^{-1} N, 75 Kg ha^{-1} N, Kg ha^{-1} N, 25 Kg ha^{-1} Nin descending order. Ahmed, (2017) in an experiment conducted reported that application nitrogen fertilizer at 30 or 60 kg ha^{-1} Nrecorded higher values for growth parameters such as plant height, number of branches per plant, number of leaves per plant and total leaf area, untreated plots (control)had no significant difference on yield

characters. Mehrnosh, and Noriani (2019) reported highest dry matter accumulation with application of 90 $kgha^{-1}$nitrogen fertilizer treatment and nonuse of nitrogen fertilizer (control treatment) showed the lowest dry matter accumulation.

2.3 Effect of Sowing Date on Growth and Yield of French Bean

Sowing date had great effects on the yield of green bean (Uddin *et al.,* 2017). Early sowing of snap bean resulted in higher yield and plant height but lower pod diameter, dry matter and pod length than the late sowing (Yoldas and Esiyok, 2007). According to Marlene *et al*.,(2008) mean pod width (diameter) were greater in the late sown (17 mm) than in the early sown crop (15–16 mm).Among the date of sowing, first fortnight of June recorded significantly higher harvest index value (44.20%) closely followed by second fortnight of June (42.94%), which were at par. The lowest harvest index was recorded with second fortnight of July (37.56%) (Mallikarjun, 2004). Singh and Singh (2000) concluded from the experiment conducted on French bean that, sowing on October 30th increased the biomass, plant height, number of pods compared to 15th October sowing. Shehu *et al.,* (2001) observed significantly lower plant growth attributes of lablab sown in August compared to that sown in July. Khajehpour and Naeni (2002), conducted experiment on French bean with four dates of sowing (28th April, 13th May, 28th May and 13th June) and observed significant increase in plant height, number of branches in late sowing compared to early sowing. Begum *et al*., (2003) reported that the best morphological and reproductive characters of French bean were observed in early sown crops. Significantly, value for higher plant height and leaf area was recorded with crop sown on 25th May compared to 3rd June.

Patel *et al.,* (2003) in the experiment conducted on mung bean *Vignaradiata* in Gujarat with different dates of sowing in summer season (15th February 1st March and 15th March)

revealed higher plant growth attributes with 1st March sowing. While at Pantnagar on mung bean, Gurusharan and Sharma, (2004) observed increased number of pods and pod weight from March 11th sown crop compared to February 25th, March 26th and April 10th sowing.

Jena, (2003) concluded that 30th November sown crop of French-bean recorded positive and significantly higher green pod yield compared to early sowing (30th October and 15th November) and late sowing (15th and 30th December).

Moniruzzaman *et al*., (2007) in an experiment on French bean having three varieties (BARI Jhar Seem-1, BARI Jhar Seem-2 and Local) and six sowing date at 10 days interval from (November 01 to December 20) to find out the suiTable variety and optimum sowing date for getting higher pod yield. Both the varieties of BARI Jhar Seem-1 and BARI Jhar Seem-2 yielded higher than local variety, but the first two varieties were statistically at par in respect of pod yield. BARI Jhar Seem-1 and BARI Jhar Seem-2 produced maximum pod yield of French bean when sown on either November 10 or November 20. Similarly, Jamil, (2017) reported that the highest seed yield (0.65 t ha^{-1}) of French bean was obtained using BARI Jhar Sheem-3 variety from 20 November sowing and the lowest one (0.36 t ha^{-1}) was obtained using BARI Jhar Sheem-2 from 5 November sowing. Yoldas and Esiyok, (2007) reported widest pod diameter at the late sowing date than for early sown attributed to the availability of more moisture for the early sown that enhanced the vegetative growth, which consequently resulted in widest diameter and higher yield. Mozumder *et al*., (2003) found that earlier (15 October) planting of rajmah required maximum time for flowering (48.53 DAP) while late planting (15 December) gave earlier flowering (44.90 DAP). Also reported that both the plantings of 15 October (18.46) and 15 November (19.46) produced higher number of pods per plant than 15 December planting (14.79). Uddin *et al*., (2017) concluded

that sowing date had significant influence on growth and yield parameters of French bean at harvest, the tallest plant (41.20 cm) and longest dry pods (10.86 cm) were obtained from 5 November, whereas heavier seeds plant^{-1} (5.23 g), 1000 seeds weight (396.40 g), seed yield (0.65 t ha^{-1}) from 20 November, and number of pods plant^{-1} (5.29), seeds pod^{-1} (4.56), seeds plant^{-1} (18.47) and the highest stover yield (1.28 t ha^{-1}) from 5 December sowing.

2.4 Interaction of Variety and Nitrogen on Growth and Yield of French Bean

Wodimu and Tana (2017) in an experiment conducted reported significant interaction between French bean variety (Awash Melka) and application of 27 kg Nha^{-1} to be the best combination under Mechara's agro-ecology as it gave highest number of seeds per pod (4.60) and the highest nitrogen content (3.89%) of the shoot tissue and also gave higher values for yield and most of yield related traits for French bean. Vishwakarma *et al.,* (2002) also recorded significant interaction between French bean varieties (*Phaseolus vulgaris* L.) and nitrogen rates on growth and yield attributes. Abdela *et al.,* (2017) observed significant interaction between French bean variety and N by P on root volume and optimum total pod yield with application of N and P at the rates of 82 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} respectively and beyond those rates there is a non-significant yield increment.

2.5 Interaction of Variety and Sowing Date on Growth and Yield of French Bean

Sharma *et al.,* (2013) reported that interaction of variety 'SVM-1' and sowing date, performed significantly better on all four dates of sowings (1st June, 8th June, 15th June and 22nd June, respectively) than 'Luxmi' and 'Kentucky Wonder' for number of pods per plant, seed and straw yield over the years, and concluded that early sowing on 1st June of variety 'SVM 1' was the most ideal combination to obtain higher seed yield of pole French bean under sub-humid temperate environment. Uddin *et al.,* (2017) reported significant

interaction on yield contributing characters and yield of French bean varieties, between 20 November and variety BARI Jhar Sheem-3which produced highest seed yield (0.76 t ha^{-1}) compared to early or late sowing condition and variety.

2.6 Interaction of Nitrogen Rate and Sowing Date on Growth and Yield of French Bean

Askalu (2020) in an experiment conducted on French bean variety and nitrogen rate reported significant interaction between nitrogen and variety of French bean on most agronomic traits, increase in nitrogen rate from 0 to 69 kg N ha^{-1} delayed days to flowering and days to maturity while highest grain yield (4.58 t ha^{-1}) was recorded for the variety Beshbesh at 69 kg Nha^{-1}. Aminu (2008) observed significant interaction between sowing date and nitrogen rate in respect of yield of green pod per hectare, the treatment combination of 15 November sowing and 90 kg Nha^{-1} produced the highest yield, while the lowest was found from the treatment combination of 30^{th} December with 0 kg Nha^{-1}.

2.7 Correlation on Growth and Yield of French bean

Rafat and Sharifi (2015) observed highly significant positive correlation between plant height and yield factors viz. pod length, pod breadth and fresh pod yield whereas plant height had significant negative correlation with number of pods per plant, pods weight per plant and pod yield per ha. Similarly, Haluk and Vahdettin (2013) reported that number of branches per plant exhibited significant positive correlation with number of pods per plant, pods weight per plant and pod yield per hectare. EsraaAbd (2020) reported that plant height had negative and highly significant ($P < 0.01$) correlation with seed yield per plant, 1000 seed weight, seed diameter, pod weight, fresh pod yield and number of pods per plant. Number of branches per plant had negative and highly significant ($P< 0.05$) correlation with seeds yield per plot, weight of 1000 seeds; seed diameter and seed length while number of pod per plant had

positive and significant correlation with seeds yield plant and was negative significant correlation among seeds yield per plant, number of seeds per pod and with green pod length.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Sites

The study was conducted during 2018 wet season at two locations; at the Research farms of College of Agriculture and Animal Science, Mando ($10^{o}43^{o}$N, 6^{o}34'E, 508m above sea level) and Institute for Agricultural Research, Samaru (11^{o}11'N, 07^{o}38'E, 686m above sea level) Kaduna, both in the Northern Guinea Savanna agro-ecological zone of Nigeria.

3.2 Meteorological Data

Meteorological data including daily temperature, rainfall data, and relative humidity during the period of the experiment were obtained from meteorological stations of National water resource institute Mando and Institute for Agricultural Research Samaru, for Mando and Samaru respectively.

3.3 Soil Analysis

Soil samples were randomly collected from both locations at a depth of 0-30 cm by using hand held auger. The soil samples in each location was bulked, dried, ground, sieved and composite samples were taken and subjected to physical and chemical analyses using standard procedure as described by Black (1965).

3.4 Treatments and Experimental Design

The treatments consisted of two varieties of French bean (YCD1 and Premier),four levels of nitrogen fertilizer (0, 30, 60, and 90 kg ha^{-1}) and three sowing date (end of July, early August and late August) corresponding to 29th July, 12th August, and 26th August and 27th July, 10th August, and 24th August for Mando and Samaru respectively. The treatments were laid out in

a Randomized Complete Block Design with split plot arrangement replicated three times with nitrogen and sowing date allocated to the main plot while variety was allocated to the sub-plot.

3.5 Varietal Descriptions

3.5.1 YCD1

The flowers are purple, slightly flat, broad and robust pods about 15cm long, it takes 75-80 days fruits and pods yield of 9.75t ha^{-1}. Dark purple seeds with about6.3tonnes ha^{-1} of grains yield under good management. (IARI, India)

3.5.2 Premier

The flowers are rose pink. Each pod contains about 5-6 seeds. It takes about 40-45 days to flower and it is adapted to late sowing. The seeds are black with some white patches. Pod yield is about 5-7tonnes ha^{-1} under good management. (IARI, India)

3.6 Plot size

The gross plot size consisted 6 ridges (rows), 4m in length and 60cm apart (with size 4m x 3.6 = 14.4m^2). The net plot measured 4m x 2.4m (9.6m^2) and consisted of four inner ridges. For purpose of estimating yield however, the net plot (9.6m^2) was divided into two (4.8m^2) a half for yield was harvested as green vegeTable bean and the other half for dry grains.

3.7 Cultural Practices

3.7.1 Land preparation

The experimental fields were harrowed twice to obtain the desired tilt for proper germination and growth of the crop and ridged 60cm apart. The fields were then demarcated into plots

using a measuring tape and pegs. Thereafter, the plots were appropriately labelled using metallic sheet and paint.

3.7.2 Sowing

The seeds were treated with Apron star (Thiamethoxam 25% + Mefenoxam 24% + Difenoconazole 25%) at the rate of 10g per 3kg of seed before sowing. Three seeds were sown per hill at inter and intra row spacing of 60cm x 25cm, and after germination was thinned to 2 plants per stand thereby giving 133,333 plants per stand. Three sowing date were adopted as treatment in this trial namely; late July, early August and midAugust corresponding to 29th July, 12th August, and 26th August for Mando and 27th July, 10th August, and 24th August for Samaru.

3.7.3 Fertilizer application

Basal application of nitrogen, phosphorus and potassium was made at 30 kg ha^{-1} in all plots using NPK (15-15-15) except in the control. The control (0 kg N ha^{-1}) plots received only phosphorus and potassium using Single Super Phosphate (SSP) 18%, P_2O_5 and Muriate of Potash (MOP) 60% K_2O respectively. The balance of nitrogen was made up with urea (46% N) for plots that received 60 kg N ha^{-1} and 90 kg N ha^{-1}.

3.7.4 Weed, pest and disease control

Paraquat at 1.44 a.i ha^{-1} was used to control emerged weeds on the experimental plots few days prior to land preparation. Thereafter, hoe weeding's were done at 6 and 10 weeks after sowing to keep the plots weed-free throughout the period of the trial. No noTable pest nor diseases were encountered during the trial.

3.7.5 Harvest

Half of the net plot was harvested at green tender immature pod stage of development as vegeTable, and the other half at physiological maturity, when grains within pods were fully formed, 95% of the pods were dried and most pods had turned yellow or golden from dull green. Fresh pod harvest was carried out at when pods are fully matured corresponding to 7th October, 21st October, 4th November and 5th October, 19th October and 2nd November for Mando and Samaru respectively. The dried pods were harvested when the pods were dried and turned golden corresponding to 11th November, 25th November 24th December and 9th November, 23rd November 17th December for Mando and Samaru respectively. Harvesting was done by hand picking, fresh succulent immature pod and dried or partially dried pods, periodically. The net plot (9.6 m^2) was divided in two for purpose of harvest on one part; vegeTable French bean was harvested and on the other pulses (dry) French bean was harvested for proper estimation of yield. Immature pod harvested (over several harvest) as vegeTables was weighed at each harvest and recorded to obtain a cumulative yield of fresh pods. While the other portion of net plot was left to mature and harvested, weighed and extrapolated on per hectare basis, that is 4.8m^2 of sub net plot. Extrapolated factors being 2083.33

3.7.6 Threshing and winnowing

After harvesting the dried pods, they were further sun dried before threshing and winnowing to the grains.

3.8 Observations and Data Collections

Data collection on growth parameters commenced from four weeks after each sowing. Five plants were tagged (using conspicuously coloured wool) per plot and growth parameters were

measured based on these tagged plants. Yield characteristics were estimated on the basis of subnet plot ($4.8m^2$).

3.8.1 Growth parameters

3.8.1.1 Plant height

Plant height was measured in centimeter (cm) from the ground level to the growing tip of the plant a meter rule. Measurements were taken from five (5) tagged plants and the average height was calculated and recorded as per treatment.

3.8.1.2 Number of leaves per plant

Number of leaves per plant of the five (5) tagged plants within net plot was counted and the average number of leaves per plant recorded.

3.8.1.3 Number of branches per plant

The branches on the tagged plants were counted and average number of branches per plant was computed and recorded for each plot.

3.8.1.4 Crop dry matter

Three plants were evaluated for the crop dry matter, these were taken from border rows and carefully enveloped and labeled appropriately at 4, 8 and 12 WAS stages of growth. The sampled plants were oven dried at 70^oC for at least 48 hours until constant weight was achieved and the mean crop dry weight per plant recorded.

3.8.1.5 Total leaf area per plant

Five plants were sampled from each plot outside the net plot and the leaves were detached from each, to determine the leaf area using leaf area (cm^2) meter (Li-3100).

3.8.1.6 Leaf area index (LAI)

Using the total leaf area obtained from 3.9.5 above, the leaf area index was determined using the following formula;

$$\text{LAI} = \frac{\text{Total Leaf Area}}{\text{Area of land per plant}}$$

3.8.1.7 Crop growth rate (CGR)

Crop growth rate (CGR) is the rate of dry matter production per plant per unit time. It was 6calculated by using the using the formula described by Radford (1967), expressed as $g^{-1}wk^{-1}$ at 4, 8 and 12 WAS.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} gwk^{-1}$$

Where, W_1= dry weight of the plant at time t_1 and W_2= dry weight of the plant at time t_2.

3.8.1.8 Relative growth rate (RGR)

It is rate of increase in dry weight per unit dry matter present and is expressed in g $g^{-1}wk^{-1}$. Relative growth rate (RGR) at various stages was calculated as suggested by Radford (1967) at 4, 8 and 12WAS.

$$RGR = \frac{log_{eW_2} - log_e W_1}{t_2 - t_1} gg^{-1}wk^{-1}$$

Where, W_1= dry weight of plant (g) at time t_1 and W_2= dry weight of plant (g) at time t_2

Value derived from the calculation was recorded on per treatment basis.

3.8.1.9 Net assimilation rate (NAR)

Net assimilation rate (NAR) is the rate of dry weight increased per unit leaf area per time. The dry matter increment per unit time was computed as described by Radford, (1967) as follows:

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \; X \; \frac{log_e A_2 - log_e A_1}{A_2 - A_1} gcm^{-2} wk^{-1}$$

Where, W_1= dry weight of plant at time t_1, W_2 = dry weight of plant at time t_2, A_1 = total leaf area presents on the plant at time t_1 and A_2 = total leaf area presents on the plant at time t_2

3.8.1.10 Leaf Area Ratio (LAR)

Leaf Area Ratio (LAR) is the ratio of assimilating materials per unit of plant material present.

It is the ratio of leaf area to entire dry weight, and was computed using

$$LAR = \frac{\frac{A_1}{W_1} + \frac{A_2}{W_2}}{2}$$

Where, W_1= dry weight of plant at time t_1, W_2 = dry weight of plant at time t_2, A_1 = total leaf area at time t_1 and A_2 = total leaf area at time t_2

3.8.1.11 Days to anthesis

This was determined by counting the number of days from sowing to the time when flowers were produced by 50% of the plants in each net plot

3.8.1.12 Root study

Three plants per plots were carefully uprooted from moist soil in order to allow for root study evaluation especially in respect of number of total nodules. This was done using plant harvested for total dry matter on the discard section of each plot. This evaluation was carried out at 4, 8, and 12 WAS of the crop.

3.8.2 Yield Parameters

3.8.2.1 Number of pods per plant

Number of pods produced per plant was determined by counting the total number of pods from the 5 tagged plants in each net plot over several harvests, and the cumulative mean recorded on per plant basis

3.8.2.2 Pod length

The length of 5 pods from the tagged plants in each net plot was measured (cm) using meter rule from base to the tip of pod and the average recorded.

3.8.2.3 Pod thickness

Thickness of 5 pods from the tagged plants in each net plot was measured (cm) using Vernier caliper and the average recorded.

3.8.2.4 Number of grains per pod

The number of grains per pod was recorded from 5 pods from the tagged plants within each net plot and the mean recorded.

3.8.2.5 100 grain weight

This was determined by weighing three sets of 100 grains obtained from threshed, winnowed harvested grains produced from each net plot.

3.8.2.6 Yield

This was determined by weighing the grain yield obtained from each net plot. The harvested pods were properly dried, threshed and winnowed and the grains then weighed and value obtained was extrapolated to per hectare basis and recorded. The other half harvested as fresh pods, were harvested while grain-filling; harvested immature pods were weight over several harvests and cumulative weight of immature pods extrapolated on per hectare basis.

3.8.2.7 Threshing percentage

The threshing percentage was estimated using the formula as described by (Usman, 1997).

$$Threshing\% = \frac{Grain\ weight\ after\ threshing\ and\ winnowing}{unthreshed\ Pod\ weight}\ x\ \frac{100}{1}$$

3.8.2.8 Economic Analysis of production

This was done to determine the profitability of two varieties of French bean production using Gross Margin analysis. This was obtained by subtracting the total variable cost (TVC) from total gross return (GR) as suggested by Erhabor and Kalu, (1993).

GM = TVP-GR

Where,

GM= Gross Margin

TVC= Total Variable Cost

GR= Gross Return

3.9 Statistical Analysis of Data

All the data collected were subjected to analysis of variance (ANOVA) as described by Steel and Torrie (1987) and treatment means were compared using Duncan Multiple Range Test (DMRT) (Duncan, 1955) at 5% probability level. The magnitude and type of relationship between characters was assessed through simple correlation analysis (Little and Hill, 1978). The polynomial response of French bean yield to nitrogen fertilizer rate was determined by regression analysis (Barr and Goodnight, 1972).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Physical and Chemical Properties

The physical and chemical properties of the experimental sites at 0-30 cm depth are shown in Table 1. The analysis showed that soil at Mando is clay loam, acidic (pH.53) and also moderate in available phosphorus (11.71 mg kg^{-1}) content while Samaru site had a loam texture, acidic (pH5.81) and moderate in available phosphorus (6.36 mg kg^{-1}) content. The content of organic carbon (g kg^{-1}) was high (14.98 and 12.60) at both locations though higher in Mando, and total nitrogen (g kg^{-1}) was higher at Mando (1.28) but low at Samaru (0.90). The exchangeable bases (cmol kg^{-1} soil) Mg (0.34 and 0.47) and Na (0.21 and 0.23) were slightly high at both locations, while Ca (2.06 and 2.51) and K (0.11 and 0.13) were low at Samaru and high at Mando respectively. The cation exchange (cmol kg^{-1} soil) capacity was also low (2.98 and 3.58) at both sites.

4.2 Plant Height

The effect of nitrogen rates and sowing dates on plant height (cm) of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 2. There was significant difference statistically between nitrogen rates on plant height of French bean at both locations across all sampling periods where application of 90 kg N ha^{-1} produced the tallest plants and 0 kg N ha^{-1} produced the shortest plants.

Sowing date had significant effects on plant height of French bean varieties where plants sown Late August were taller than on other dates.

Table 1: Physical and chemical properties of soils at the experimental sites during the 2018 rainy season

Soil Composition	Depth of Soil (0 – 30cm)	
	Mando	Samaru
Particle size distribution (g kg^{-1})		
Sand	460	450
Silt	250	430
Clay	290	120
Textural class	Sandy loam	Loam
Chemical composition		
pH in H_2O (1:2.5)	5.53	5.81
pH in 0.01M $CaCl_2$ (1:2.5)	4.26	4.98
Organic Carbon (g kg^{-1})	14.98	12.60
Total Nitrogen (g kg^{-1})	1.28	0.90
Available Phosphorus (mg kg^{-1})	11.71	6.36
Exchangeable cations (cmol kg^{-1})		
Calcium (Ca^{2+})	2.06	2.51
Magnesium (Mg^{2+})	0.35	0.47
Potassium (K^{+})	0.11	0.13
Sodium (Na^{+})	0.21	0.23
Aluminum and Hydrogen (Al^{3+} H^{+})	0.25	0.24
Cation Exchange Capacity (C.E.C)	2.98	3.58

Analyzed at the Department of Agronomy, Ahmadu Bello University Zaria.

Table 2: Effect of Nitrogen rates and sowing date on plant height (cm) of French bean varieties during 2018 rainy season at Mando and Samaru

	Plant height (cm)					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	13.74d	57.27d	89.63d	11.53d	22.41d	46.27d
30	17.33c	77.29c	109.38c	15.51c	33.25c	79.88c
60	21.58b	90.98b	132.66b	19.84b	40.18b	95.98b
90	27.72a	106.22a	152.29a	2551a	48.96a	116.93a
SE±	1.014	3.351	6.290	0.883	0.901	1.506
Significance	**	**	**	**	**	**
Sowing (S)						
Late July	22.09a	80.95b	113.18b	14.90b	31.39c	79.55b
Early August	16.34b	90.35a	139.72a	15.39b	34.23b	85.92a
Late August	21.35a	77.53b	110.06b	24.03a	43.08a	88.83a
SE±	0.878	2.902	5.448	0.764	0.780	1.304
Significance	**	**	**	**	**	**
Variety (V)						
YCD1	19.86	86.65a	122.75	18.98	36.09	86.99a
Premier	20.33	79.23b	119.22	17.24	36.29	82.24b
SE±	0.717	2.369	4.448	0.624	0.367	1.065
Significance	NS	**	NS	NS	NS	**
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	**	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS = Not significant. * = Significant ** = Highly significant. WAS = Weeks after sowing.

Varietal response was also significant on plant height of French bean at Mando 8WAS and Samaru 12WAS where variety YCD1 was taller than variety premier.

The interaction was significant between variety and sowing date at Mando 4WAS. Table 3 shows interaction between sown date and variety on plant height at 4WAS in Mando, where early and late sowing variety premier (either in late July or late August) produced significantly taller plants compared to mid sowing (early August) while late sowing variety YCD1 (late August) resulted in taller plants compared to late July and early August sowing variety. Early and late sowing of variety premier and late sowing of variety YCD1 significantly induced taller plants.

Table 3: Interaction between sowing date and variety on plant height (cm) at 4WAS during 2018 rainy season at Mando

Variety	Sowing date		
	Late July	Early August	Late August
YCD1	20.17bc	18.08cd	21.32abc
Premier	24.01a	15.59d	21.83ab
SE± 1.303			

Means follow by the same letter(s) are not significantly different using DMRT at 5%

4.3 Number of Leaves per Plant

The effect of nitrogen rates and sowing date on number of leaves of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 4.Each increase in nitrogen fertilizer rates from 0 kg N ha^{-1} to 90 kg N ha^{-1} significantly influenced number of leaves per plants throughout the sampling periods from 4 to 12WAS of the trial at both locations, each increase in fertilizer rates resulted in progressive increase in number of leaves from 0 kg N ha^{-1} to 90 kg N ha^{-1}. This is true for all sampling dates, except at 12 and 8WAS

at Mando and Samaru respectively. At Mando application of nitrogen fertilizer at 30 kg N ha^{-1} significantly influenced number of leaves per plant at 12WAS, this was statistically at par with 60 kg N ha-1. Further increase to 90 kg N ha^{-1} resulted in increased French bean leaves per plant. For Samaru 8WAS, increasing rates of nitrogen from 0 kg N ha^{-1} to up 60 kg N ha^{-1} had no significant influence on number of leaves per plant, further increase from 60 kg N ha^{-1} to 90 kg N ha^{-1}however increased number of leaves per plant significantly.

Sowing French bean in early August resulted to low number of leaves per plant at both locations. However, 12WAS at Mando higher values for number leaves per plant was recorded for plant sown in early August. For Samaru later sampling periods 8 and 12WAS recorded no significant difference on number of leaves per plant due to variation in sowing date.

Varietal influence was only significant on this character at 12WAS at Mando where YCD1 produced more leaves than premier.

Table 5; shows the interaction between sowing date and variety on number of leaves per plant of French bean was highly significant at 12WAS in Mando, where early sowing variety YCD1 (either late or early August) resulted in more leaves per plant compare to late sowing (late August), while irrespective of sowing date variety premier consistently produced fewer number of leaves per plant. Early sowing of YCD1 (late July and early August) significantly favour leafiness.

Table 4: Effect of Nitrogen rates and sowing date on number of leaves per plant of French bean varieties during 2018 rainy season at Mando and Samaru

	Number of leaves per plant					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	14.05d	51.56d	100.68c	11.74d	19.45b	27.02d
30	20.21c	73.69c	130.53b	17.24c	26.28b	33.04c
60	25.31b	92.40b	152.89b	24.46b	32.40b	40.35b
90	30.32a	114.71a	118.96a	33.33a	58.59a	47.61a
SE±	0.920	4.204	8.157	0.532	8.331	1.225
Significance	**	**	**	**	**	**
Sowing (S)						
Late July	24.94a	85.59ab	148.61a	17.58c	39.58	38.68
Early August	17.48b	76.07b	152.89a	20.67b	29.18	35.56
Late August	24.93a	87.61a	120.78b	26.83a	33.58	36.67
SE±	0.800	3.641	7.064	0.461	7.215	1.064
Significance	**	**	**	**	NS	NS
Variety (V)						
YCD1	22.22	84.43	158.42a	22.23	30.06	38.14
Premier	22.68	81.75	123.11b	22.15	30.29	35.78
SE±	0.654	2.973	5.768	0.376	5.891	0.868
Significance	NS	NS	**	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	*	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).

NS=Not significant. * =Significant. ** =Highly significant.

Table 5: Interaction between sowing date and varieties on number of leaves per plant at 12WAS during 2018 rainy season at Mando.

Variety	Sowing date		
	Late July	Early August	Late August
YCD1	182.96a	163.80ab	128.51c
Premier	114.27c	141.99bc	113.06c
SE± 10.372			

Means follow by the same letter(s) are not significantly different using DMRT at 5%

4.4 Number of Branches per plant

Effect of nitrogen rates and sowing date on number of branches per plant of French bean variety during 2018 raining season at Mando and Samaru is shown in Table 6, where plants that received 30 kg N ha^{-1}had significantly fewer number of branches per plant than those treatment with 60 kg N ha^{-1} at Samaru.

The effect of sowing date was not significant on number of branches per plant at Samaru throughout the sampling periods, however at Mando French bean sown in late August branched more than those sown in early August.

Varietal response was not significant at Mando throughout the sampling period; this was however different at Samaru where premier significantly produced more branches at 4 and 8 WAS. However, 12WAS, YCD1 produced more branches per plant than premier.

None of the interactions (first and second order) were significant with respect to number branches per plant of French bean varieties.

4.5 Total leaf Area

Effects of nitrogen rates and sowing date on total leaf area of French bean varieties during 2018 rainy season at Mando and Samaru is show in Table 7. Increase in nitrogen rate from lowest (0 kg N ha^{-1}) to highest (90 kg N ha^{-1}) significantly enhanced total leaf area of French

bean varieties at both locations throughout the sampling period except at Mando 8WAS when no significant difference was recorded. However, at later sampling 8WASinSamaru 60 kg N ha^{-1} and 90 kg N ha^{-1}significantly produced high leaf area, while plant receiving 0 kg N ha^{-1} recorded higher leaf area at 12WAS.

Effects of sowing date on total leaf area of French bean were not significant at later sampling dates of 8WAS at both locations and 12WAS at Samaru. However, the total leaf area of late August sowing were significantly higher at both locations and were statistically comparable to late July and early August sowing at 12WAS at Mando.

Varietal response has no significant effects on total leaf of French bean at 8WAS in Mando and throughout the sampling period at Samaru. However, at Mando 4WAS premier significantly produced more leaf area, which was statistically comparable to YCD1 at 12WAS. None of the interactions were significant with respect to total leaf area of French bean.

4.6 Number of Nodules per plant

Effect of nitrogen rate and sowing date on number of nodules per plant of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 8. Application of nitrogen rate had no significant effect on number of nodules per plant throughout the sampling dates at Mando and at 4and 12WAS at Samaru. However, at 8WAS in Samaru, application of nitrogen at 30kg N ha^{-1} significantly enhanced French bean nodules which are statistically at par to application of nitrogen 90kg N ha^{-1}.

Sowing date and varieties had no significant influence on number of nodules of French bean throughout the sampling period at both locations. None of the interactions was significant for this character.

Table 6: Effect of Nitrogen rates and sowing date on number of branches per plant of French bean varieties during 2018 rainy season at Mando and Samaru

	Number of branches per plant					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	3.04	3.27	4.79	1.59	2.34ab	3.33
30	3.04	3.04	4.00	1.42	2.21b	3.26
60	2.85	3.10	4.35	1.63	2.54a	3.51
90	3.13	3.07	4.79	1.45	2.35ab	3.13
SE±	0.188	0.208	0.283	0.123	0.099	0.126
Significance	NS	NS	NS	NS	*	NS
Sowing (S)						
Late July	3.10ab	3.24a	3.96b	1.39	2.39	3.43
Early August	2.64b	2.53b	4.21b	1.63	2.43	3.30
Late August	3.29a	3.55a	5.23a	1.55	2.29	3.19
SE±	0.163	0.179	0.245	0.107	0.085	0.109
Significance	*	**	**	NS	NS	NS
Variety (V)						
YCD1	2.92	3.12	4.56	1.04b	1.99b	3.04a
Premier	3.10	3.09	4.37	2.01a	2.75a	3.57b
SE±	0.133	0.146	0.200	0.087	0.069	0.089
Significance	NS	NS	NS	**	**	**
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 7: Effect of Nitrogen rates and sowing date on total leaf area plant(cm^2) of French bean varieties during 2018 rainy season at Mando and Samaru

	Total leaf area (cm^2)					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) ($kgha^{-1}$)						
0	224.18d	1603.40	543.54d	365.21c	2085.60b	2349.70a
30	418.90c	3309.00	794.05c	472.99c	2330.80b	1520.70b
60	608.82b	2307.00	993.96b	644.71b	2863.60a	1502.40b
90	821.31a	2552.00	1245.5a	922.8a	3097.20a	1062.50b
SE±	19.132	617.995	57.854	39.498	99.854	264.316
Significance	**	NS	**	**	*	**
Sowing (S)						
Late July	576.26a	2176.10	928.37a	434.41b	2637.70	1713.70
Early August	378.84b	2119.70	979.09a	426.52b	2524.20	1336.00
Late August	599.82a	3032.70	779.83b	943.57a	2621.00	1631.40
SE±	16.569	535.199	50.103	34.207	86.476	288.900
Significance	**	NS	*	**	NS	NS
Variety (V)						
YCD1	460.56b	2115.10	964.03a	609.39	2633.94	1423.70
Premier	576.05a	2770.50	827.50b	593.48	2554.70	1697.00
SE±	13.518	436.989	40.909	27.929	70.608	186.899
Significance	**	NS	*	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 8: Effect of Nitrogen rates and sowing dates on number of nodules per plant of French bean varieties during 2018 rainy season at Mando and Samaru

	Number of nodules per plant					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	1.55	2.69	5.67	1.39	2.40b	5.11
30	1.52	2.98	5.17	1.37	2.68a	5.40
60	1.50	2.79	6.00	1.35	2.50b	5.11
90	1.58	2.87	6.17	1.42	2.73a	5.55
SE±	0.085	0.107	0.196	0.076	0.079	0.176
Significance	NS	NS	NS	NS	*	NS
Sowing (S)						
Late July	1.51	2.79	5.73	1.36	2.49	5.15
Early August	1.58	2.94	6.10	1.42	2.68	5.49
Late August	1.22	2.77	5.73	1.36	2.56	5.26
SE±	0.073	0.092	0.169	0.065	0.068	0.153
Significance	NS	NS	NS	NS	NS	NS
Variety (V)						
YCD1	1.58	2.88	6.03	1.42	2.63	5.43
Premier	1.49	2.78	5.74	1.32	2.53	5.17
SE±	0.059	0.013	0.023	0.009	0.009	0.021
Significance	NS	NS	NS	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant.

4.7 Crop Dry matter per plant

Effect of nitrogen rates and sowing date on crop dry matter of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 9. Increase in nitrogen rates from 0 kg N ha^{-1} to 60 kg N ha^{-1} progressively and significantly influenced French bean crop dry matter at 4WAS at both locations, further increase in nitrogen rate to 90 kg N ha^{-1} had no significant on this character at Samaru, at other sampling dates, while at 8 and 12WAS at Mando each increase in nitrogen fertilizer 0 kg N ha^{-1} to 90 kg N ha^{-1} resulted in significant and progressive increase in crop dry matter of French bean plant.

Sowing French bean late August significantly enhanced crop dry matter at 8 and 12WAS in Mando, while early August sowing favoured crop dry matter at late stage 8 and 12WAS at Samaru.

French bean varietal response had no significant effects on crop dry matter throughout the sampling period sat both locations.

None of the interactions were significant with respect of crop dry matter of French bean varieties.

4.8 Leaf Area Index

Effects of nitrogen rates and sowing date on leaf area index of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 10. Application of nitrogen progressively and significantly increased in leaf area index of French bean, 90kg N ha^{-1} resulted in higher leaf area index at 4 and 8WAS at both locations. Increase from 0 kg N ha^{-1}60 kg N ha^{-1}at Samaru, 12WASin had no significant effect on leaf area index, further

increase to 90 kg N ha^{-1}had highest leaf area index while 0 kg N ha^{-1} recorded lowest leaf area index which was statistically at par with 30 and 60 kg N ha^{-1}.

Sowing French bean in late July significantly influenced leaf area index at 4 and 12WAS also late August sowing at 4WAS in Mando, while early and late August sowing enhanced leaf area index at 4WAS in Samaru.

Variety premier significantly enhanced higher leaf area index than YCD1 at 4WAS at Mando, while variety YCD1 favoured leaf area index at Mando respectively.

None of the interactions were significant with respect toleaf area index of French bean.

4.9 Crop Growth Rate (CGR)

Effects of sowing date and nitrogen rates on crop growth rate of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 11. The application of 0 or 30kg N ha^{-1} consistently resulted in lower crop growth rate at 4 and 8WAS at Mando and at 4WAS at Samaru.

French bean sown late July and late August significantly enhanced crop growth rate at 4 and 12WAS, also at 8WAS for early August at Samaru, while late July and early August influenced crop growth rate at 4WAS and late August sowing at 12WAS in Mando.

Varietal response was not significant on crop growth throughout the sampling periods at both locations.

None of the interactions were significant with respect of crop growth rate of French bean.

Table 9: Effect of Nitrogen rates and sowing date on the crop dry matter per plant (g) of French bean varieties during 2018 rainy season at Mando and Samaru

	Crop dry matter (g)					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	3.89b	12.48d	25.04d	2.99b	16.54	25.77
30	4.24b	16.53c	30.36c	2.80b	17.12	28.28
60	4.69a	20.54b	33.31b	3.27ab	16.42	26.42
90	4.93a	23.65a	36.78a	3.70a	16.54	24.46
SE±	0.149	0.493	0.418	0.172	1.140	1.653
Significance	**	**	**	**	NS	NS
Sowing (S)						
Late July	4.59a	18.31	30.53b	3.27a	15.30b	24.01b
Early August	4.15b	18.71	30.97b	2.74b	21.58a	29.24a
Late August	4.58a	17.88	32.62a	3.56a	13.09b	25.45b
SE±	1.296	0.427	0.362	0.149	1.126	1.009
Significance	*	NS	**	**	**	**
Variety (V)						
YCD1	4.51	18.48	31.21	3.34	17.04	26.68
Premier	4.38	18.12	31.53	3.04	16.27	25.79
SE±	0.325	0.349	0.296	0.121	0.919	0.824
Significance	NS	NS	NS	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. **=Highly significant.

Table 10: Effect of Nitrogen rates and sowing date on the leaf area index of French bean varieties during 2018 rainy season at Mando and Samaru

	Leaf Area Index					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	0.09d	0.17	0.24d	0.12c	0.69b	0.35b
30	0.19c	1.47	0.35c	0.16c	0.78d	0.43b
60	0.27b	1.03	0.44b	0.21b	0.95a	0.51b
90	0.37a	1.13	0.55a	0.31a	1.03a	0.78a
SE±	0.009	0.275	0.026	0.013	0.033	0.088
Significance	**	NS	**	**	**	**
Sowing (S)						
Late July	0.26a	0.97	0.41a	0.14b	0.88	0.57
Early August	0.17b	0.94	0.44a	0.14a	0.84	0.45
Late August	0.27a	1.35	0.35b	0.31a	0.87	0.54
SE±	0.007	0.283	0.022	0.011	0.028	0.076
Significance	**	NS	*	**	NS	NS
Variety (V)						
YCD1	0.20b	0.94	0.43a	0.20	0.88	0.57
Premier	0.26a	1.23	0.37b	0.19	0.85	0.47
SE±	0.001	0.032	0.003	0.002	0.004	0.010
Significance	**	NS	*	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 11: Effect of Nitrogen rates and sowing date on crop growth (g/wk) rate of French bean varieties during 2018 rainy season at Mando and Samaru

	Crop Growth Rate ($g^{-1}wk$)					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) ($kgha^{-1}$)						
0	0.97b	2.15d	3.14	0.74b	3.39	2.31
30	1.05b	3.07c	3.46	0.70b	3.58	2.79
60	1.17a	3.96b	3.19	0.82ab	3.29	2.50
90	1.23a	4.68a	3.28	0.93a	3.21	1.98
SE±	0.037	0.122	0.138	0.043	0.317	0.372
Significance	**	**	NS	**	NS	NS
Sowing (S)						
Late July	1.15a	4.42	3.05b	0.81a	3.01b	2.18a
Early August	1.04a	3.64	3.07b	0.68b	4.71a	1.92b
Late August	1.14b	3.33	3.68a	0.89a	2.38b	3.09a
SE±	0.032	0.105	0.119	0.037	0.274	0.322
Significance	*	NS	**	**	**	*
Variety (V)						
YCD1	1.13	3.49	3.18	0.76	3.50	2.41
Premier	1.01	3.44	3.35	0.84	3.23	2.38
SE±	0.038	0.085	0.098	0.030	0.224	0.263
Significance	NS	NS	NS	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

4.10 Relative Growth Rate (RGR)

Effects of nitrogen and sowing date on relative growth rates of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 12**.** Relative growth rate significantly increased with increase in nitrogen rate from 0 kg N ha^{-1} to 90 kg N ha^{-1} at 4 and 8WAS at Mando. At Samaru, application of 90 kg ha^{-1} had highest relative growth rate while others had lowest and at par with each other.

Sowing date significantly had significant effect on relative growth rate of French bean varieties where plant sown late August had higher relative growth rate at 4 and 12WAS at both locations than other sowing date.

Varietal effect was not significant at all sampling periods at both locations during 2018 rainy season. The interactions were not significant for this character.

4.11 Net Assimilation rate (NAR)

Effect of nitrogen rate and sowing date on net assimilation rate of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 13. Application of nitrogen fertilizer of 0 or 30kg ha^{-1} resulted in lower net assimilation rates at 8WAS in Mando, while the untreated plot (control) had higher net assimilation rate at 4WAS in both locations.

Sowing had no significant influence on net assimilation although the sampling periods, except at 4WAS in Mando where early August significantly had highest net assimilation rate than those sown late July and late August. However, at Samaru 4 and 8 WAS recorded significant high assimilates for French bean sown early August sowing which is statistically at par with those sown late July and late August at 4 and 12WAS respectively.

Varietal response of French bean had no significant effect at both locations throughout sampling periods except 4WAS at Mando where YCD1 significantly produced more assimilate than premier. None of the interactions were significant with respect to net assimilation rate of French bean.

4.12 Leaf Area Ratio

Effect on nitrogen rate and sowing date on leaf area ratio of French bean varieties during 2018 rainy season at Mando and Samaru shown in Table 14. In Mando 4WAS leaf area ratio increased with increase in nitrogen fertilizer from 0 to 90 kg Nha^{-1}. However, at Samaru application 90 kg ha^{-1} produced plant with highest leaf area ratio while lowest leaf area ratio was recorded from other rates.

French bean sown in late August had highest leaf area ratio at both locations across all sampling periods, while other sowing date recorded lower leaf area ratio.

Varietal influence was significant at early growth stage 4WAS at Mando with premier having superior leaf area ratio over YCD1. None of the interactions were significant with respect to leaf area ratio of French bean.

Table 12: Effect of Nitrogen rates and sowing date on relative growth rate (g/g/wk) of French bean varieties during 2018 rainy season at Mando and Samaru

	Relative Growth Rate ($gg^{-1}wk$)					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) ($kgha^{-1}$)						
0	0.15c	0.23c	0.27	0.12b	0.26	0.21
30	0.16b	0.27b	0.28	0.11b	0.28	0.24
60	0.17a	0.29a	0.27	0.12b	0.26	0.23
90	0.17a	0.32a	0.27	0.14a	0.26	0.21
SE±	0.003	0.007	0.005	0.006	0.017	0.018
Significance	**	**	NS	*	NS	NS
Sowing (S)						
Late July	0.16a	0.28	0.27b	0.13a	0.26b	0.21b
Early August	0.15b	0.29	0.27b	0.10b	0.31a	0.20b
Late August	0.17a	0.27	0.29a	0.13a	0.22b	0.25a
SE±	0.003	0.007	0.005	0.006	0.017	0.018
Significance	**	NS	**	*	**	**
Variety (V)						
YCD1	0.16	0.28	0.27	0.13	0.27	0.22
Premier	0.15	0.28	0.28	0.12	0.26	0.23
SE±	0.002	0.015	0.003	0.004	0.012	0.012
Significance	NS	NS	NS	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 13: Effect of Nitrogen rates and sowing date on Net assimilation rate of French bean varieties during the 2018 rainy season at Mando and Samaru

	Net Assimilation Rate ($gcm^{-2}wk$)					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) ($kgha^{-1}$)						
0	0.012a	0.005b	0.013	0.006a	0.005	0.008
30	0.007b	0.006b	0.018	0.005b	0.006	0.013
60	0.005bc	0.008a	0.008	0.004bc	0.005	0.007
90	0.004c	0.009a	0.009	0.003c	0.005	0.006
SE±	0.706	0.491	0.005	0.385	0.575	0.002
Significance	**	**	NS	**	NS	NS
Sowing (S)						
Late July	0.007b	0.007	0.008	0.006a	0.005b	0.006b
Early August	0.009a	0.007	0.018	0.005a	0.008a	0.006b
Late August	0.006b	0.007	0.009	0.003b	0.005b	0.013a
SE±	0.611	0.426	0.005	0.334	0.498	0.002
Significance	**	NS	NS	*	**	*
Variety (V)						
YCD1	0.009a	0.007	0.010	0.005	0.006	0.008
Premier	0.006b	0.007	0.013	0.004	0.005	0.009
SE±	0.080	0.058	0.001	0.045	0.068	0.001
Significance	*	NS	NS	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 14: Effect of Nitrogen rates and sowing date on leaf area ratio of French bean varieties during the 2018 rainy season at Mando and Samaru

	Leaf Area Ratio					
	MANDO			SAMARU		
Treatment	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kgha^{-1})						
0	30.59d	98.88	79.42	59.59c	142.28b	104.11b
30	49.09c	151.78	115.81	85.56b	126.60b	100.43b
60	65.57b	122.12	71.56	109.39ab	222.48a	144.88a
90	83.88a	138.15	71.22	126.44a	234.83a	157.01a
SE±	2.926	19.929	19.977	8.527	16.102	13.206
Significance	**	NS	NS	**	**	*
Sowing (S)						
Late July	63.18a	126.13ab	77.99	66.40b	166.88b	136.13a
Early August	43.66b	101.39b	73.03	84.47b	152.38b	91.25b
Late August	64.99a	155.67a	102.48	134.87a	252.38a	152.45a
SE±	2.53	17.259	17.301	7.384	13.945	11.535
Significance	**	*	NS	**	**	**
Variety (V)						
YCD1	50.02b	108.60	73.88	101.72	181.73	152.88
Premier	64.54a	146.86	95.12	88.77	199.37	127.34
SE±	0.344	2.349	2.354	1.005	1.897	1.569
Significance	**	NS	NS	NS	NS	NS
Interaction						
N x S	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS
N x S x V	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

4.13 Days to Anthesis

Effect of nitrogen rate and sowing date on number of days to anthesis of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 15. Application of nitrogen fertilizer had no significant influence on days to anthesis of French bean at both locations.

Effect of sowing date on number of days to anthesis French bean varieties was not significant all through at both locations during the 2018 rainy season

Varietal response of French bean to number of days to anthesis was highly significant at both locations with variety premier consistently flowering earlier than variety YCD1. None of the interactions were significant with respect of days to anthesis of French bean.

4.14 Cumulative Number of Pods per plant

Effects of nitrogen rates and sowing date on cumulative number of pods per plant of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 16. There was significant difference statistically between the nitrogen rates on number of pods per plant at Mando where application of 60 kg N ha^{-1} produced plants with highest number of pods per plant which was statistically at par with 30 kg N ha^{-1} followed by 0 kg N ha^{-1}, while the highest rate of nitrogen 90 kg N ha^{-1} resulted to plants with fewer number of pods per plants. However, there was no significant difference statistically between the rates on number pods per plant at Samaru.

The effect of sowing date on number pods per plant of French bean varieties was not significant at Samaru. However, at Mando sowing date significantly enhanced number of pods per plant, where French bean sown early August significantly produced plant with

highest number of pods per plant, while plants sown late July produced plants with lowest number of pods per plant.

Variety premier significantly outperformed YCD1 on number of pods per plant at both locations. None of the interactions were significant with respect to number of pods per plant of French bean.

Table 15: Effect of Nitrogen rates and sowing dates on number of days to anthesis of French bean varieties during 2018 rainy season at Mando and Samaru

	Days to anthesis	
Treatment	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	51.39	51.33
30	51.00	52.33
60	50.00	51.44
90	51.94	51.56
SE±	1.146	1.043
Significance	NS	NS
Sowing (S)		
Late July	50.67	50.13
Early August	51.94	50.71
Late August	51.38	54.17
SE±	0.992	0.903
Significance	NS	NS
Variety (V)		
YCD1	48.97b	49.31b
Premier	53.19a	54.03a
SE±	0.135	0.123
Significance	**	**
Interaction		
N x S	NS	NS
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).

NS=Not significant. ** =Highly significant.

Table 16: Effect of Nitrogen rates and sowing date on cumulative number of pods per plant of French bean varieties during 2018 rainy season at Mando and Samaru

Treatment	Number of pods per plant	
	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	31.72b	20.20
30	34.84a	20.20
60	36.02a	20.56
90	28.53c	20.09
SE±	0.809	0.673
Significance	**	NS
Sowing date (S)		
Late July	28.51c	21.35
Early August	36.74a	19.84
Late August	33.58b	20.35
SE±	0.701	0.583
Significance	**	NS
Variety (V)		
YCD1	24.49b	19.12b
Premier	41.07a	21.91a
SE±	0.572	0.476
Significance	**	**
Interaction		
N x S	NS	NS
N x V	NS	NS
S x V	NS	NS
N x S x V	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).

NS=Not significant. * =Significant. ** =Highly significant.

4.15 Pod length

Effect of nitrogen rate and sowing date on pod length of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 17. At Mando, application 60kg N ha^{-1} produced plants with longest pods length although statistically at par with 90kg N ha^{-1} which was followed by 30 kg N ha^{-1} while 0 kg N ha^{-1} produced plants with shortest pods length. However, at Samaru application of 60 $kgha^{-1}$ produced plants with the longest pods which was statistically at par with 90 and 30 kg N ha^{-1}. The shortest pod length was recorded for plants that received 0 kg ha^{-1}.

Sowing date significantly enhanced pod length at Mando, where late August sowing was responsible for significantly longer pods compared to late July and early August sowing which were statistically similar.

The effect of varieties on pods length was highly significant, where premier produced significantly longer pod than YDC1 at both locations. All possible interactions were not significant with this character.

4.16 Pod thickness

Effects of nitrogen rates and sowing date on pod thickness of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 18. Application of nitrogen from 0 to 90 kg N $ha^{-1}$was insignificant on pod thickness at both locations.

The effect of sowing date was not significant on pod thickness of French bean plant at both locations. Varietal response of French bean on pod thickness was not significant at both

locations neither was any possible interaction. None of the interactions were significant with respect to pod thickness of French bean varieties.

Table 17: Effect of Nitrogen rates and sowing date on pod length of French bean varieties during 2018 rainy season at Mando and Samaru

Treatment	Pod length (cm)	
	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	5.06c	3.51b
30	8.97b	5.14a
60	9.44a	5.26a
90	9.43a	5.23a
SE±	0.101	0.068
Significance	**	**
Sowing (S)		
Late July	8.09b	4.77
Early August	8.03b	4.71
Late August	8.45a	4.88
SE±	0.087	0.058
Significance	**	NS
Variety (V)		
YCD1	7.54b	4.56b
Premier	8.84a	5.01a
SE±	0.012	0.008
Significance	**	**
Interaction		
N x S	NS	NS
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. ** = Highly significant.

Table 18: Effect of Nitrogen rates and sowing date on pod thickness (cm) of French bean varieties during 2018 rainy season at Mando and Samaru

Treatment	Pod thicknessper (cm)	
	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	0.58	0.32
30	0.62	0.52
60	0.66	0.26
90	0.58	0.23
SE±	0.037	0.015
Significance	NS	NS
Sowing (S)		
Late July	0.63	0.25
Early August	0.58	0.23
Late August	0.61	0.24
SE±	0.033	0.013
Significance	NS	NS
Variety (V)		
YCD1	0.62	0.25
Premier	0.59	0.24
SE±	0.004	0.002
Significance	NS	NS
Interaction		
N x S	NS	NS
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). NS=Not significant.

4.17 Numbers of grains per pod

Effect of nitrogen rate and sowing date on number of grains per pod of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 19. There was significant difference statistically between the nitrogen rates on number of grains per pod at mando where application of 90 kg N ha^{-1} produced plants with highest number of grains per pod although statistically at par with 30 and 60 kg N ha^{-1} while plants that received 0 kg N ha^{-1} had lowest number of grains per pod. Similar trend was observed in Samaru.

Sowing date has no significant on number of grains per pod of French bean crop at both locations.

Variety premier significantly outperformed YCD1 on number of grains per pod of French bean at both locations. There was significant interaction between nitrogen and sowing date on number of grains per pod.

Table 21; shows the interaction between sowing date and nitrogen fertilizer rate where early sowing (late July) resulted in increased in number of grains per pod with increase in nitrogen fertilizer rate from 0 up to 30 kg N ha^{-1}. Further increase nitrogen rates from 30 to 90 kg N ha^{-1} had no significant influenced on number of per pod. While early August sowing recorded higher number of grains in either 30 kg Nha^{-1} or 60 kg N ha^{-1} and 60 kg N ha^{-1} for French bean sown late August.

4.18 Threshing Percentage

Effects of nitrogen rates and sowing date on threshing percentage of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 20. Applications of 90 kg N ha^{-1} significantly higher threshing percentage of French bean varieties although statistically at par with 60 and 30 kg N ha^{-1}, while application of 0 kg N ha^{-1} resulted to lower

percentage of French bean at Mando. However, at Samaru, application of 30 kg N ha^{-1} produced French bean plant with highest threshing percentage, which was statistically similar to 60 kg N ha^{-1}, while application of 90 kg N ha^{-1} resulted into lower threshing percentage although statistically at par with 0 kg ha^{-1}.

Sowing date has no significant influence on threshing percentage of French bean at both locations.

Varietal response showed YCD1 had significantly higher threshing percentage than premier at both locations. None of the interactions were significant with respect of threshing percentage of French bean.

4.19 100 grain weight

Effect of nitrogen rates and sowing date on 100 grains weight of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 22. There was significant difference statistically between the nitrogen rates on 100 seed weight of French at both locations. At Mando, application of 90 kg N ha^{-1} resulted to plants with heaviest 100 seed weight which was statistically at par with 60 and 30 kg a^{-1}, while application of 0 kg N ha^{-1} produced plants with highest 100 seed weight, similar trend was observed in Samaru.

Sowing date significantly influenced weight of 100 grains of French bean plant where late July or late August sowing significantly enhanced heavier test weight at both locations.

Variety YCD1 significantly outperformed premier with respect to 100 grain weight of French bean crop at both locations.

None of the interactions were significant with respect to this character.

Table 19: Effect of Nitrogen rates and sowing date on number of grains per pod of French bean varieties during 2018 rainy season at Mando and Samaru

Treatment	Number of grains per pod	
	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	4.33b	3.32b
30	5.12a	3.55a
60	4.96a	3.48a
90	5.18a	3.57a
SE±	0.101	0.048
Significance	**	**
Sowing (S)		
Late July	4.91	3.54
Early August	4.99	3.49
Late August	4.78	3.41
SE±	0.183	0.014
Significance	NS	NS
Variety (V)		
YCD1	4.58b	3.35b
Premier	5.21a	3.56a
SE±	0.012	0.007
Significance	**	**
Interaction		
N x S	NS	*
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 20: Effect of Nitrogen rates and sowing date on threshing percentage of French bean varieties during 2018 rainy season at Mando and Samaru

Treatment	Threshing percentage per plot	
	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	17.32b	7.65b
30	28.74a	12.77a
60	28.98a	12.57a
90	31.97a	7.67b
SE±	2.422	0.835
Significance	**	**
Sowing (S)		
Late July	29.67	12.16
Early August	25.41	10.44
Late August	25.18	11.79
SE±	2.098	0.723
Significance	NS	NS
Variety (V)		
YCD1	33.43a	13.69a
Premier	20.07b	9.24b
SE±	0.285	0.950
Significance	**	**
Interaction		
N x S	NS	NS
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). NS=Not significant.
** =Highly significant.

Table 22: Effect of Nitrogen rates and sowing date on 100 grains weight of French bean varieties during 2018 rainy season at Mando and Samaru

Treatment	100 grain weight (g)	
	MANDO	SAMARU
Nitrogen (N) (kgha^{-1})		
0	13.54c	4.54c
30	21.94b	7.30b
60	23.16ab	7.71ab
90	23.85a	7.93a
SE±	0.536	0.178
Significance	**	**
Sowing (S)		
Late July	21.78a	7.25a
Early August	18.83b	6.28b
Late August	21.27a	7.08a
SE±	0.536	0.178
Significance	**	**
Variety		
YCD1	23.37a	7.85a
Premier	17.89b	5.89b
SE±	0.073	0.024
Significance	**	**
Interaction		
N x S	NS	NS
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). NS=Not significant. ** =Highly significant.

Table 21: Interaction effect between nitrogen rates and sowing dates on number of grains per pods during 2018 rainy season at Samaru during

Sowing Date	Nitrogen N (kg/ha)			
	0	30	60	90
Late July	3.14cd	3.61a	3.67a	3.74a
Early August	3.35bc	3.59a	3.54ab	3.50b
Late August	3.21cd	3.43b	3.54ab	3.47b
SE± 0.077				

Means follow by the same letter(s) are not significantly different using DMRT at 5%

4.20 Cumulative Fresh Pods yield

Effects of nitrogen and sowing date on cumulative fresh pods yield of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 23. Significant difference was statistically observed between the nitrogen rates on fresh pod yield of French bean varieties. At Mando application of 60 kg N ha $^{-1}$ produced plants with highest fresh pod yield followed by application of 30 kg N ha^{-1}, while application of 0 kg N ha^{-1} resulted into plants with lowest fresh pods yield. However, at Samaru application of 60 kg N ha^{-1}resulted to plants with highest pod yield followed by 90 and 30 kg N ha^{-1} which were statistically at par. The lowest fresh pod yield was observed with plants that received 0 kg N ha^{-1}.

Sowing date has significantly effect on fresh pods yield at both locations. At Mando plants that were sown late July recorded the highest fresh pod yield while plants sown late August recorded the lowest fresh pod yield. Similar trend was observed in Samaru.

Variety premier out significantly performed better than YCD1 with regards to fresh pod yield at Mando and the reverse was the case at Samaru.

None of the interactions with this character were significant.

4.21 Grain yield

Effects of nitrogen and sowing date on grains yield ($kgha^{-1}$) of French bean varieties during 2018 rainy season at Mando and Samaru is shown in Table 24. At Mando application of 60 kg N ha^{-1} produced plants with highest grain yield (kg ha^{-1}). However, at Samaru application of 60 kg N ha^{-1} plants with highest grain yield (kg ha^{-1}) which was followed by plants that received 90 kg N ha^{-1} although statistically at par with those that received 30 kg N ha^{-1} while the lowest grain yield was recorded for plans that received 0 kg N ha^{-1}.

The effect sowing date was not significant on grains yield of French bean plant at Samaru. Sowing French bean in late August significantly enhanced grain yield ($kgha^{-1}$) production this was followed by early August and late July sowing at Mando.

Varietal response on grain yield of French bean was highly significant, where premier significantly outperformed YCD1 at both locations.

Table 26; shows the interaction ($0 \leq 0.01$) between nitrogen and variety on grain yield ($kgha^{-1}$) showed that for both varieties yield was highest at 60 kg N ha^{-1} and lowest at 0 kg N ha^{-1}. However, premier statistically performed better than YCD1.

Table 25: Interaction of nitrogen rate and variety on grain yield during 2018 rainy season at Mando during

Variety	Nitrogen rate ($kgha^{-1}$)			
	0	30	60	90
YCD1	339.72g	945.27d	1218.98b	829.78f
Premier	361.54g	1010.65c	1296.75a	903.62e
SE			7.969	

Means follow by the same letter(s) are not significantly different using DMRT at 5%

Table 23: Effect of Nitrogen rates and sowing date on cumulative fresh pod yield ($kgha^{-1}$) of French bean varieties during 2018 rainy season at Mando and Samaru

	Fresh pod yield ($kgha^{-1}$)	
Treatment	MANDO	SAMARU
Nitrogen (N) ($kgha^{-1}$)		
0	337.64d	306.27c
30	1051.36b	658.45b
60	1631.64a	985.99a
90	770.73c	650.76b
SE±	13.507	7.627
Significance	**	**
Sowing (S)		
Late July	1003.69a	671.67a
Early August	958.62b	652.38b
Late August	881.21c	627.04c
SE±	11.697	6.605
Significance	**	**
Variety (V)		
YCD1	824.33b	689.67a
Premier	1071.36a	611.07b
SE±	9.551	5.393
Significance	**	**
Interaction		
N x S	NS	NS
N x V	NS	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT).
NS=Not significant. * =Significant. ** =Highly significant.

Table 24: Effect of Nitrogen rates and sowing date on the grain yield per plot of French bean varieties during 2018 rainy season at Mando and Samaru

	Grains yield ($kgha^{-1}$)	
Treatment	MANDO	SAMARU
Nitrogen (N) ($kgha^{-1}$)		
0	350.63d	387.09c
30	977.95b	821.53b
60	1257.87a	1010.23a
90	866.70c	849.07b
SE±	5.635	42.916
Significance	**	**
Sowing (S)		
Late July	801.21c	735.42
Early August	869.80b	801.11
Late August	918.86a	764.40
SE±	4.903	36.647
Significance	**	NS
Variety (V)		
YCD1	833.44b	683.74b
Premier	893.14a	850.21a
SE±	0.667	4.987
Significance	**	**
Interaction		
N x S	NS	NS
N x V	**	NS
V x S	NS	NS
N x S x V	NS	NS

Means followed by the same letter (s) within a column and Treatments group are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). NS=Not significant. * =Significant. ** =Highly significant.

4.22 Correlation Analysis

The Table 26 and 27 shows the correlation matrix between French bean yield and growth at Mando and Samaru respectively. The results showed there was a positive and highly significant ($P \leq 0.01$) relationship that exist between number of leaves per plant, crop dry matter, leaf area index, pod length and grains yield, positive and significant relationship was also observed at ($P \leq 0.05$) with number of grains per pod at Mando. However, number of branches per plant, number of pods per plant, pod diameter and 100 grain weight were all positively correlated but had no significant effects on the relationship. The results at Samaru shows positive relationship and highly significant correlation on number of leaves per plant, leaf area index, pod length, number of grains per pod, 100 grain weight and grains yield (kg ha^{-1}) at ($P \leq 0.05$), number of branches per plant, crop dry matter, were negatively correlated with no significant effects on the relationship. Furthermore, days to anthesis, number of pods per plant were positively correlated but had no significant relationship.

4.23 Economics Analysis

Data on economic parameters are presented in Table 28 and 29. Cost of cultivation was the same for all treatments with the same fertilizer rate and increased with increase in nitrogen fertilizer rate from 0 to 90 kg N ha^{-1}. Gross and net revenues increased with increase in nitrogen fertilizer rate 30 to 90 kg N ha^{-1} while highest gross and net revenues were recorded at 60kg N ha^{-1}. Variety premier at Mando recorded highest return on yield while YCD1 had highest yield return at Samaru.

4.24 Regression

The regression analysis of yield against nitrogen rates is presented in Figure 1. The results indicated that the yield response of French bean at both locations was quadratic with the

equation Y = 0.2922x2 + 32.719x + 303.4 r^2 = 0.9901 which gave expected yield of 3.3tonnes ha^{-1}at Mando and equation Y = 0.1714x2 + 20.883x + 362.08, r^2 =0.9985 with expected yield of 2.2 tonnes $ha^{-1`}$at Samaru.

Table 26: Correlation matrix between yields some growth parameters as influenced by nitrogen rates and sowing date of French bean varieties at Mando

	1	2	3	4	5	6	7	8	9	10	11	12
Plant height	1											
Number of leaves per plant	0.604**	1										
Number of branches per plant	0.019	0.001	1									
Crop dry matter	0.507**	0.473**	-0.031	1								
Leaf Area index	0.645**	0.939**	0.025	0.617**	1							
Days to anthesis	0.028	-0.251**	0.096	-0.014	-0.101	1						
Number of pods per plant	0.139	0.222	-0.058	0.032	0.055	0.289*	1					
Pod length	0.445**	0.311**	-0.124	0.719**	0.439**	0.074	0.439**	1				
Pod diameter	0.016	0.143	0.038	0.042	-0.061	-0.114	-0.075	-0.061	1			
Number of grains per pod	0.279*	0.064	-0.212	0.373**	0.168	0.178	0.474**	0.597**	-0.061	1		
100 grain weight	0.224	0.468**	-0.076	0.598**	0.408**	0.296*	-0.418**	0.417	0.186	0.044	1	
Grain yield (kgha^{-1})	0.386**	0.299*	0.136	0.646**	0.378**	0.016	0.309**	0.873**	0.116	0.437**	0.508**	1

1. Plant height 2. Number of leaves per plant 3. Number of branches per plant
4. Crop dry matter at 12WAS 5. Leaf area index at 12WAS 6.Days to anthesis
7. Number of pods per plant 8. Pod length 9. Pod diameter
10. Number of grains per pods 11. 100 grain weight 12. Grain yield (kgha^{-1})

* =Significant (P = 0.05) **= highly significant (P = 0.01) DF (N-2) = 70

≥ 0.232 (*) ≥0.302 (**) r (5%) = 0.232 r (1%) = 0.302

Table 27: Correlation matrix between yields some growth parameters as influenced by nitrogen rates and sowing date of French bean varieties at Samaru

	1	2	3	4	5	6	7	8	9	10	11	12
Plant height	1											
Number leaves per plant	0.715**	1										
Number branches per plant	-0.023	-0.005	1									
Crop dry matter per plant	-0.028	-0.186	0.097	1								
Leaf Area index	0.366**	0.269*	0.123	-0.066	1							
Days to anthesis	0.048	-0.105	0.302**	0.011	-0.122	1						
Number of pods per plant	0.034	0.006	0.184	-0.204	0.539	0.280	1					
Pod length	0.782**	0.583**	0.130	-0.070	0.168	0.199	0.111	1				
Pod diameter	0.007	0.093	-0.091	0.075	-0.006	-0.108	-0.060	0.073	1			
Number of grains per plant	0.436**	0.377**	0.142	0.046	0.158	0.225	0.198	0.596**	-0.061	1		
100 grain weight	0.503**	0.618**	0.251*	-0.065	0.157	-0.152	-0.028	0.417**	0.192	0.115	1	
Grain yield (kgha^{-1})	0.619**	0.393**	0.084	-0.032	0.157	0.180	0.225	0.732**	0.092	0.418**	0.335**	1

1. Plant height
2. Number of leaves per plant
3. Number branches per plant
4. Crop dry matter at 12WAS
5. Leaf area index at 12WAS
6.Days to anthesis
7. Number of pods per plant
8. Pod length
9. Pod diameter
10. Number of grains per pod
11. 100 grain weight
12. Grain yield (kgha^{-1})

* =Significant (P = 0.05) **= highly significant (P = 0.01) DF (N-2) = 70

≥ 0.232 (*) ≥0.302 (**) r (5%) = 0.232 r (1%) = 0.302

Table 28: Gross margin Analysis on production of French bean varieties with different nitrogen fertilizer rates at Mando

Treatments		Yields (kgha^{-1})		Revenue (₦)		Gross Return(₦) (GR)	Costs (₦)		Total Cost (TC)(₦) (TFC + TVC)	Gross Margin(₦) (GR – TC)
Nitrogen (Kgha^{-1})	Variety	Fresh pods	Grains	Fresh pods	Grains		Total Fixed	Total Variable		
0	YCD1	35.47	326.17	10641	55449	66090	5750	128050	133800	-67710
	Premier	54.00	342.50	16200	58225	74425	5750	128050	133800	-59375
30	YCD1	186.97	1088.90	56091	185113	241204	6100	132746	138846	102358
	Premier	238.93	1138.87	71679	193607	265287	6100	132746	138846	126441
60	YCD1	215.2	1330.57	64560	226196	290757	10600	137650	148250	142507
	Premier	290.03	1420.80	87009	241536	328545	10600	137650	148250	180295
90	YCD1	128.3	821.30	38490	139621	178111	10700	142137	152837	25274
	Premier	180.17	881.89	54051	149918	203969	10700	142137	152837	51132

Table 29: Gross margin Analysis on production of French bean varieties with different nitrogen fertilizer rates at Samaru

Treatments		Yields ($kgha^{-1}$)		Revenue (₦)		Gross Return(₦) (GR)	Costs (₦)		Total Cost (TC)(₦) (TFC + TVC)	Gross Margin(₦) (GR – TC)
Nitrogen ($Kgha^{-1}$)	Variety	Fresh pods	Grains	Fresh pods	Grains		Total Fixed	Total Variable		
0	YCD1	75.97	242.90	22791	41293	64084	5750	128050	133800	-69116
	Premier	73.65	653.43	22095	111083	133178	5750	128050	133800	-622
30	YCD1	122.98	687.50	36894	116875	153769	6100	132746	138846	14923
	Premier	105.66	979.17	31698	166459	198157	6100	132746	138846	59311
60	YCD1	136.68	1077.67	41004	183204	224208	10600	137650	148250	75958
	Premier	111.73	1022.22	33519	173777	207296	10600	137650	148250	59046
90	YCD1	120.09	861.10	36027	146387	182414	10700	142137	152837	29577
	Premier	102.77	884.80	30831	150416	181247	10700	142137	152837	28410

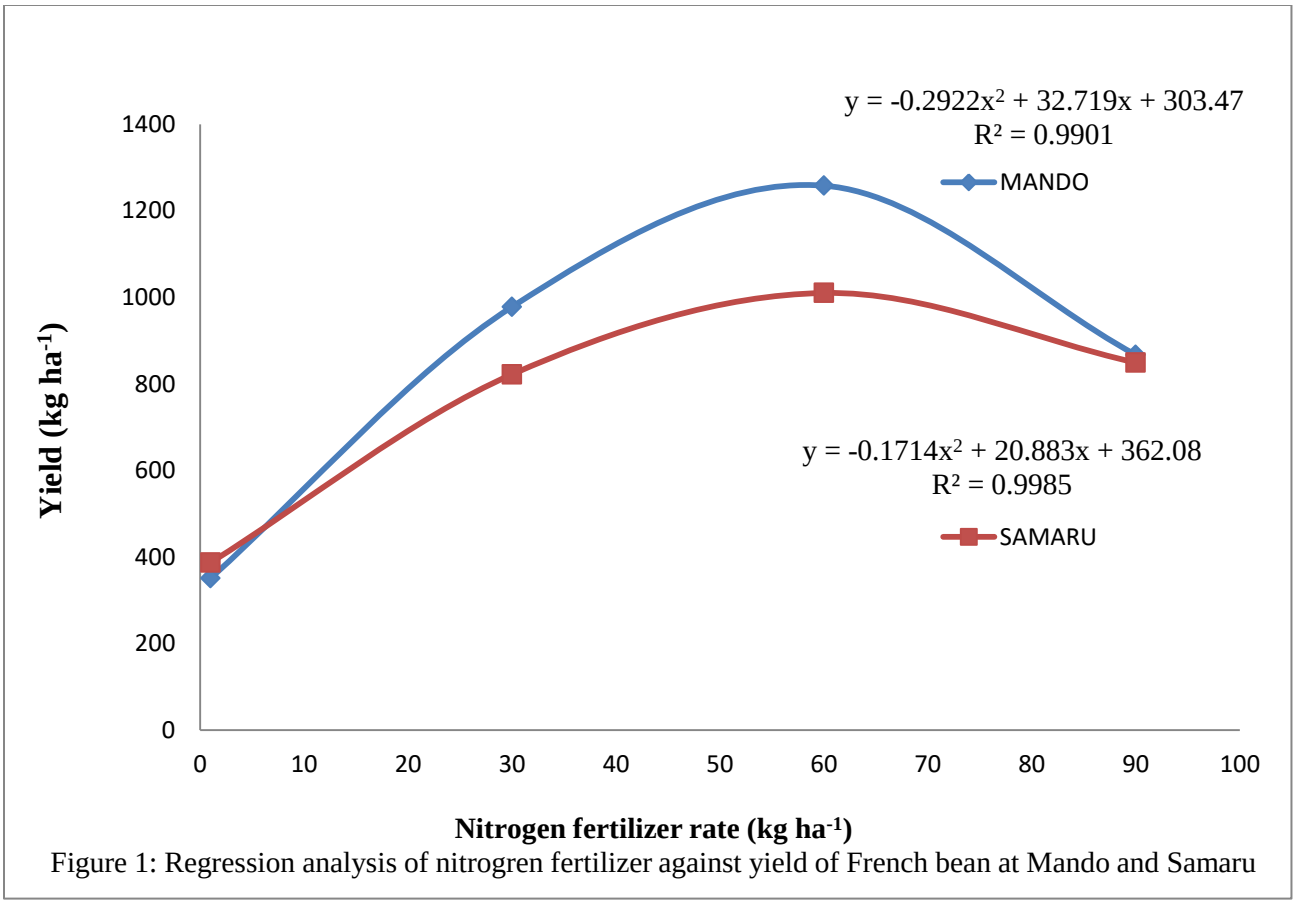


Figure 1: Regression analysis of nitrogren fertilizer against yield of French bean at Mando and Samaru

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 General Observations

The growth and yield performance of the French bean varieties were better at Mando than at Samaru, the trend was however similar. The difference could be attributed to climatic and soil factors in Mando, where the soil was characterized by higher soil organic matter (14.98 versus 12.60), higher mineralized nutrients such as nitrogen (1.2 versus 0.90) and a fallowed period, which lasted eight years prior to this trial according to the farm manager. Tahar, (2009) reported that the production of French bean is often limited by low availability of soil nutrient. Research has shown that French bean do better on a well drained, sandy loam, silt loam or clay soils (Habtamu, 2017). The result of the soil analysis in Table 1 shows that soil at Mando has more Nitrogen (1.2 versus 0.90) organic carbon (14.98 versus 12.60)and phosphorus(11.71 versus 6.36) than soil at Samaru which could have contributed to the better performance in Mando as the young seedlings had more (available) nutrient for initial take off and establishment. This is in line with the findings of Mehrnosh and Noriani (2019) who concluded that mineral is essential for plant growth, development and productivity of French bean plants. Ahlawat (2012) also reported that French bean lack biological N fixation ability due to poor nodulation and as a result actively responded to the application of Nitrogen. Early rain (565.10 mm) in Mando at the onset of the trail also encouraged early establishment and development of critical phase of the crop, this was however different in Samaru as there was limited rain (232.10 mm) at the onset of the trail. The metrological data in appendix I showed other climatic factors such as temperature, relative humidity and sunshine hours that favoured better performance at Mando.

5.2 Effects of Nitrogen on Growth and Yield of French bean Varieties

Increase in nitrogen rates from 0 to 90 kg N ha^{-1} influenced growth parameters such as plant height, number of leaves per plant, total leaf area, crop dry matter, leaf area index and crop growth rates, relative growth rates, and leaf area ratio of French bean varieties which were mostly significant at 90 kg N ha^{-1}.For each increase in application of nitrogen fertilizer rate from 0 to 30 kg N ha^{-1}, 60kg N$ha^{-1}$and 90 kg N ha^{-1}led to increase in growth parameter at both locations. This corroborates the findings of Sahagufa *et al*., (2019) who reported significant influence on plant height and total leaf area with increase in nitrogen rate. Furthermore, with the findings of Mehrnosh, and Noriani (2019) who reported highest dry matter accumulation, leaf area index and relative growth rate with application 90kg N ha^{-1}. Although, increase in nitrogen rates varies on the yield components, which was different from the growth parameters, yield characters such as number of pods per plant, fresh pods weight, number of grain per pods, threshing percentage, 100 grain weight and grain yield per hectares were all significantly high at 30 kg N ha^{-1} and 60 kg N ha^{-1}, with 60 kg N ha^{-1} having higher grain yield per hectare at both locations. This is in conformity with the results of Ahmed (2017) which indicated that total pod yield as well pod quality of French bean were significantly enhanced with increase in level of nitrogen. Similarly, Nasrin *et al.,* (2018) observed significant influence on yield characters of French bean such as number of pods per plant, pod length, number of grains per pod and grain yield with increase in nitrogen rates. Days to anthesis show no significance at both locations this is in line with Tewain and Singh, (2002) who recorded a non-significant difference in number of days to 50% flowering due to N fertilization. Pod length response to nitrogen at 60kg N ha^{-1} and 90kg N ha^{-1} at Mando and

30 to 90 kg N ha^{-1} at Samaru. Shahid et al., (2015) who recorded significant pod length, pod weight, pod yield and net return with application of nitrogen fertilizer support this.

5.3 Effect of Sowing Date on Growth and Yield of French bean

Sowing date has significant effects on growth and yield of French bean, sowing French bean sown late July and late August significantly influenced growth parameter such as number of leaves per plant, number of branches per plant, total leaf area, leaf area index, crop growth rate, and relative growth rate. However, early August sowing enhanced leaf area index and net assimilation rate and crop dry matter at all sowing date while late August sowing influenced plant height and crop dry matter. This could be attributed to the effects of rainfall and other climatic condition such as radiation, relative humidity, temperature etc. thus; increase in rainfall provides adequate moistures need for plant growth and development, radiation enhanced photosynthetic activity (absorb sunlight, use it source as energy for photosynthesis) and therefore increase productivity of the crop. Temperature influenced most of the plant processes, increase respiration rate; enhanced photosynthesis, transpiration, germination and flowering. Temperature ^{o}C, radiation and moisture make near excellent conditions needed for crop growth in the presence of adequate crop nutrients, presented by soils analysis at both locations in Table 1. Enhanced crop productivity led to increased growth accumulation of biomass and subsequently increased yields. This is similar to the work of Kakon, (2018) who reported significant effect on plant height, crop growth rate and leaf area index with plant sown early November compared to those sown late November and late December. The yield parameters of French bean such as number of pods per plant, pod length, fresh pod weight 100 grain weight, and grain yield were significantly influenced by sowing date. Late July and early August sowing significantly increased fresh pods weight,

number of pods per plant and 100 grains weight. However, late August sowing greatly enhanced number of pods per plant, pod length, 100 grain weight and grain yield ($kgha^{-1}$). This is in support to the work of Yoldas and Esiyok, (2017) who reported that early sowing of French bean resulted in higher yield but lower pod diameter than the late sowing. This also corroborates Jamal *et al.* (2017) who reported that pods per plants, grain yield and seed per pod were all higher at late sowing date. Uddin *et al*., (2017) in an experiment reported that early November sowing significantly produced tallest plant and highest pod length, while early December sowing produced significant grains of weight per plant, weight of 1000 seeds, and grain yield while mid-November, had higher number of pods $plant^{-1}$

5.4 Varietal Response on Growth and yield Parameters of French bean.

Varieties significantly enhanced growth and Yield performance of French bean, YCD1has higher growth parameters of plant height, number of leaves per plant, total leaf area and net assimilation rates than premier. However, premier was higher with respect to total leaf area, leaf area index, number of branches per plant and days to anthesis. On yield component, premier significantly outperformed YCD1. The disparity in performance between the two varieties evaluated maybe ascribed to differences in their adaptability to climatic condition such as rainfall, temperature, relative humidity and solar radiation. The variety premier seems to have an edge over YCD1 in terms of number of pods per plants, fresh pod weight, pod length, number of grains per pods and grain yield ($kgha^{-1}$). Therefore influenced yield of premier over YCD1, this corroborate the findings of Ahmed (2017) working on the same crop in similar environment of Samaru who reported that premier has higher growth and yield parameters such as number of branches per plant, canopy spread, total leaf area, leaf area index, relative growth rate and grain yield ($kgha^{-1}$), pods length per plant, 100 seed

weight, number of pods per plant, number of seed per pod, pod diameter and attained 50% flowering earlier, while contender and YCD1 produced taller plant.

5.5 Interactions

Plant height and number of leaves per plant were significantly influenced by combined effect of variety and sowing date. This observation could be attributed to the fact that sowing date is an essential factor for optimum growth and yield of French bean. Varietal response could be attributed to its genotypic makeup, adaptability to soil condition of the growing environment. Premier been the tallest plant and YCD1 having the highest number of leaves at late July sowing each, which was followed by late August on plant height and early August on number of leaves per plant. The interaction between nitrogen rates and sowing date on number of grains per pod could probably be due to the exposure of the plant for long duration of rainfall in the growing season which resulted in higher vegetative and assimilates production for optimum number of grain per pods also could be attributed to the ability of nitrogen to synthesis necessary component in all structure leafy growth and carbohydrate production. The increase in nitrogen fertilizer rate from 30 to 90kg N ha^{-1} produced higher quantity of grains per pods at late July sowing, while 30kg N ha^{-1} produced higher grains per pods of French bean at early August sowing. The interaction between nitrogen and variety on grain yield $kgha^{-1}$ could be because nitrogen is a major component of chlorophyll for compound, which plant use early to produce sugar and water. Varietal response could be attributed to the efforts of the environment and the genetic component of the varieties. Increase in nitrogen rate at 60kg N ha^{-1}has higher grain yield per hectare with premier having superior grain yield; YCD1 also has more grain yield at 60kg N ha^{-1} this was followed by 30kg N $ha^{-1}$with both varieties. However, Premier produced more grain yield than YCD1

with increase in nitrogen rate. This corroborates with the findings of Uddin *et al.*, (2017) who reported significant effect on interaction between variety and sowing date on growth and yield parameter. Similarly, Sharma *et al.,* (2013) reported significant interaction between sowing date and variety on grains yield of French

5.6 Correlations

The significant and positive relationship between grain yield and some parameters such as plant height, number of leaves per plant, leaf area index, crop dry matter and yield indicated that these traits are very important yield determinant of French bean, the higher values of plant height and number of leaves per plant increased light interception which resulted in more dry matter production. This is similar to Rhaman *et al.,* (2018) who observed significant positive correlation among plant height with yield factors viz. pod length, pod breath, number of tender seeds per pods. Haluk and Vahdettins, (2013) also reported that number of branches per plant exhibited significant positive correlation with number of pods per plant, pod weight per plant and pod yield per hectare. Similarly, (Sharifi, 2005) reported that yield of pods showed highly significant positive correlation with number of branches per plant, number of pods per plant and pods weight per plant.

5.7 Economic Analysis

Increase in rates of nitrogen fertilizer, increased economic output of French bean due to its response to nitrogen fertilizer. Both varieties economically produced higher net return for the production at 60kg Nha^{-1}.

5.8 Regression

The regression analysis shows a quadratic equation yield of French bean against nitrogen rates at both locations, which indicated optimum nitrogen fertilizer rate for French bean, was attained at 60kg N ha^{-1}, which gives optimum grains yield at both locations.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMEDATIONS

6.1 Summary

The field experiment was conducted to study effect of sowing date and nitrogen rates on the growth and yield of French bean varieties (*Phaseolus vulgaris* L.) during 2018 rainy season at the research farm of Institute for Agricultural Research (IAR) Ahmadu Bello University, Samaru (11^o 11' N, 07^o 38' E and 686m above sea level) and the research farm of College of Agriculture and Animal Science, Division of Agricultural Colleges (DAC) Mando (10^o 43' N, 6^o 34' E and 508m above sea level), both located in the Northern Guinea Savannah ecological zone of Nigeria. The treatment consisted of four rate nitrogen fertilizer (0, 30, 60, and 90 kg ha^{-1}), three sowing date (late July, early August and late August) and two varieties of French bean (premier and YCD1) which were laid out in a randomized complete block design with split plot arrangement replicated three times.

The results of the trial shows that increase in nitrogen fertilizer rate significantly enhanced growth and yield parameters of French bean. Application of nitrogen fertilizer at 90 kg ha^{-1} significantly accumulated higher growth parameters this included plant height, number of leaves per plant, total leaf area, relative growth rate, net assimilation rate and leaf area ratio. Yield parameters however varied with increase in nitrogen fertilizer rate, French bean number of pods per plant; fresh pods weight, pod length, threshing percentage and grain yield were all significantly influenced with increase in rates of nitrogen fertilizer at 30 and 60 kg N ha^{-1}. The grains weight was optimum at 60 kg ha^{-1} with 1257.87 and 1010.23 kg gains ha^{-1} at Mando and Samaru respectively. Sowing date significantly enhanced growth and yield of French bean, sowing at late July and late August had similar and significant effects on

growth and yield parameters of French bean crop with late August having higher grain yield, 100 grains weight, pod length and number of pods per plant and late July with the highest fresh pod weight. The response of French bean varieties to nitrogen and sowing date was significant on growth and yield parameters. YCD1 significantly produced taller plant, number of leaves per plant, total leaf area and net assimilation rate. Premier however outperformed YCD1 on yield parameter such as number of pods per plant, days to anthesis, fresh pod weight, pod length, number of grains per pod and grains yield.

6.2 Conclusion

The results obtained from this study have shown that;

a. Application of nitrogen fertilizer enhanced growth and yield of French bean varieties compared to the control, increase in nitrogen from 30to 90kg N ha^{-1}influenced growth and yield performance of French bean. Application of 90kg N ha^{-1} had best performance in terms of growth, while 60kg N ha^{-1} resulted in greater yield of fresh pods and grains yield.
b. Sowing date influenced growth and yield of French bean, late July and late August sowing produced greater growth and yield compared to early August sowing. However, French bean sown late July and early August resulted in higher fresh pod yield, while late August sowing had higher grain yield. There was variation among varieties of French bean on growth and yield, with YCD1 having best growth parameters and fresh pods weight while premier outperformed YCD1 in grain yield.
c. Application of nitrogen fertilizer at 60kg N ha^{-1}(₦ 142,507 and ₦ 180,295) and (₦ 75,958 and ₦ 59,046) for YCD1 and premier respectively resulted in better performance and most profiTable in cultivation of French bean.

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APPENDICES

APPENDIX I: Meteorological data showing total rainfall amount, temperatures, relative humidity and solar radiation during 2018 rainy season at Mando

Month	Rainfall (mm)	Mean monthly Temperature (^{o}C)		Relative humidity (%)	Solar Radiation (Sunshine hours)
		Min.	Max.		
July	565.10	21.6	28.7	57.4	7.50
August	386.9	21.7	27.9	61.7	6.80
September	312.0	21.1	30.2	54.0	5.30
October	182.8	21.3	31.1	51.0	8.70
November	0.0	19.2	35.1	25.0	8.01
December	0.0	17.5	35.2	12.4	8.80

Source: National Water Resource Institute, Mando 2018. Reading taken at 10 a.m. (09:00 GMT)

APPENDIX II: Meteorological data showing total of rainfall amount, temperatures, relative humidity and solar radiation during 2018 rainy season at Samaru

Month	Rainfall (mm)	Mean monthly Temperature (^{o}C)		Relative humidity (%)	Solar Radiation (Sunshine hours)
		Min.	Max.		
July	232.10	20.03	30.87	85.19	5.43
August	638.10	19.61	30.29	80.12	4.96
September	256.70	18.97	31.93	76.70	6.75
October	22.0	18.09	44.09	64.45	8.09
November	0.0	19.65	38.61	16.90	6.9
December	0.0	12.48	31.35	13.00	8.85

Source: IAR Meteorological Unit Samaru, Zaria 2018. Reading taken at 10 a.m. (09:00 GMT)

APPENDIX III: Biography

Name:	Wasiu Adewale, MUSIBAU
Registration Number:	P17AGAG8005
Date of Birth:	5th October, 1987
State of Origin:	Oyo
Local Govt. Area:	Atiba
Marital Status:	Single
E-mail Address:	musibauwasiuadewale@gmail.com
Phone Number:	07066665666

Educational Qualifications

Institution	**Certificate Obtained**	**Year Obtained**
Foundation Nursery/Primary School Kawo	Primary School Certificate	1999
All saints international college Kagoro	Secondary School Certificate	2007
Federal University of Agriculture, Abeokuta	B. Agric.	2013
Ahmadu Bello University, Zaria	M.Sc. Agronomy in View	2018

Working Experience

Organization	**Post**	**Period**
UNIJOS Information and Technology Institute, Bokkos Annex	Information and Technology officer (NYSC)	2014 – 2015
3C Hub brand management LTD	Sales manager	2017-2020
Premium Agrochemicals ltd.	Agronomist	2020