GROWTH, SEED YIELD AND QUALITY OF POLE SNAP BEANS (*Phaseolus vulgaris* L.) AS AFFECTED BY PLANTING DATE AND POPULATION DENSITY

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ABSTRACT

The study was conducted to generate component technologies for pole snap bean seed production planted on October, November and December 2011 at varying population densities of one, two and three plants per hill.

The field experiment was conducted at the Ifugao State University (IFSU), Lamut, Ifugao from September 2011 to March 2012. Experimental plots were laid out in a 3 x 3 x 2 factorial experiment arranged in a split-split-plot design with three replications.

Planting date and variety showed a highly significant influence on the days to flowering and seed maturity. December planting matured the earliest (60.17 days) than October (71.94 days) and November (62.44 days) plantings. Burik variety significantly matured two (2) and half days earlier than variety Alno. No significant interaction effects were detected.

Number of seeds per pod, total seed yield per plot and computed seed yield per hectare were significantly affected by planting date. November planting gave the highest number of seeds per pod (7.50) and total seed yield of 1,304 g. Three (3) plants per hill produced the highest seed yield of 1,185 g per plot and 19.55 tons per hectare. Lowest of 939 g per plot and 16.1 tons per hectare (16.21 tons) was produced by one (1) plant per hill. Alno significantly produced higher number of seeds per pod while Burik significantly produced higher weight of 1000 seeds per plot. A highly significant interaction effect was observed by date of planting and variety on the weight of seed yield per plot.

December planting produced the highest percent good seeds (97.52 % ) per plot, lowest was 91.28 % planted in October. Burik seeds germinated rapidly (74.94 %) than Alno (60.76 %). A highly significant interaction effect by date of planting and variety was noted in percent germination and speed. A significant interaction effect by date of planting and population density was observed on percent good seeds.

Keywords: Population density, planting date, component technology
INTRODUCTION

Background of the Study

Snap bean (*Phaseolus vulgaris* L.) popularly called “Baguio bean” is also known as French bean, green bean, string bean, kidney bean, and haricot bean. It is one of the most widely cultivated vegetable legumes in the Philippines. Like other legumes, snap bean is a rich source of proteins and contains about 20% more energy on a dry mass basis than bread; it is rich in vitamins A and C (Norman, 1992). It is a short-season crop, usually maturing in 65-110 days after planting, and exhibits a rich diversity in seed characteristics, size, shape and color, growth habits and adaptive traits (Van Schoonhoven, 1993).

Snap bean grows well in temperatures between 15 to 30 °C, with higher temperatures resulting to poor pod set (Norman, 1992). Soils suitable for growth of snap beans are deep, well-drained, loamy soils, with a pH of 5.5 to 7.0. It grows under an annual rainfall range of 700-1000 mm (BSU, 2010).

With climate change conditions characterized by rainfall variation, increasing temperature, drought and typhoons, appropriate sowing dates is an important determinant essential for successful cropping. Site-specific sowing dates and cultural practices influence yield and yield characteristics. Selection of the most suitable sowing date, population density and applying cultural practices appropriate for the place help improve quality and yield. Among the various factors, “optimum” sowing date and “best” variety are of primary importance to obtain potential yield (Amanullah et al., 2002).

The Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) in collaboration with the Department of Science and Technology national agenda for agriculture, forestry and natural resources for 2010-2016 (PCARRD, 2009) on climate change proposed researches on the modification of farming practices and by changing the management philosophy through, adjusting planting dates of major crops, test of varieties tolerant to climatic changes, irrigation and organic farming. Studies on these areas will help solve the problems brought about by climate change.
Sowing dates and population density affect seed yield through its association with seedling stand, anthesis and maturity. Planting dates partition a growing season into several subseasons resulting to different growing conditions for plant growth and development. Crop response in a season or a subseason is highly influenced by environmental variables including temperature and precipitation (Henderson, Johnson & Schneiter, 1998). Water plays an important role in the production of snap bean. The need of optimizing water consumption has received attention from several investigators. Abd El Gawad, El-Bagoury, Salem (1970) stated that there was a reduction in the number of days required for snap bean pods to reach their greatest length and greatest diameter from flower to anthesis by delaying the time of sowing. Planting date of bean production has been studied by many investigators (Stolk and Cools, 1983; Escalante, 1989) who found that seed sowing from October to December showed a pronounced effect on number of pods per plant of climbing beans (Phaseolus vulgaris).

Plant population density on the other hand is of great importance in the production of any crop. Attempts have been made by farmers to maximize the use of the land for bean production (Leakey, 1972). Quite often, small-scale farmers do not increase crop yield when they use recommended population density, which is 200,000 plants per hectare with 10 cm between seeds (Duke, 1983). Maximizing the yield of snap beans is very important, hence it requires a review of the currently used plant population density in order to determine a population that could produce the highest seed yield of good quality, maximize the use of the land and help solve problems on weed management, disease and insect pest incidence and low yield.

Snap bean is one of the important legumes grown by farmers in the Cordillera Administrative Region (CAR). It is one of the priority commodities in the Department of Agriculture in the CAR for 2008-2013 and one of the flagship commodities of the Highland Agriculture and Resources Research and Development Consortium (HARRDEC) - CAR.

Snap bean Production in Ifugao registered the highest land area of 413 hectares among vegetables grown (Bureau of Agricultural Statistics, 2004). It is one of the important money making crops grown by majority of farmers in the province and serves as the major source of income of
farmers particularly in Kiangan, Tinoc, Asipulo, Aguinaldo and some parts of Lamut. This legume is either raised as monocrop or in rotation with other vegetable crops.

The year-round demand for this vegetable in the province of Ifugao and the lowlands like Nueva Vizcaya is high but production has been low hence, the demand cannot readily be met. High yielding varieties and strains have already been identified like Blue Lake, Kentucky Wonder, Stone Hill, BSU Selection No. 1, Canaya Black Valentine, Contender and other organically grown snap beans yet, the yield in farmers field remained low (Comaad, 1993). A Survey on agricultural problems of farmers conducted by the Research Department of the Ifugao State College of Agriculture & Forestry, 2008 showed that one of the major problems of farmers is the insufficient supply of good seeds of snap beans for planting. Seeds used for planting are produced by farmers and often times these seeds are of inferior quality thus contributing to low yield. Studies on these areas will help solve the current problems on the insufficiency of good quality seeds for planting.

**Statement of the Problem**

With the advancement of agricultural technologies, low supply of good quality seeds, low production and inferior seed quality has still remained a problem in Ifugao despite the fact that this legume has long been cultivated by the farmers. With the negative impact of climate change on crop production in general, inferior seeds used by farmers aggravate the problem on low production and poor quality of harvest. Determining the plant population density is needed in order to attain high yield per unit area. Planting date is important to maximize yield and produce good quality seeds for planting because good quality seeds that are tolerant to environmental stresses would ensure high yield during unpredictable climatic conditions.

**Objectives of the Study**

This study was undertaken to develop a component technology for high seed yield and seed quality of pole snap beans under Ifugao condition.

Specific Objectives

The specific objectives of the study are the following;
1. To evaluate the single and combined effects of planting date, population density and variety on the growth, seed yield and seed quality of pole snap beans;
2. To identify the better variety for pole snap bean seed production;
3. To determine the most appropriate planting date for pole snap bean seed production;
4. To determine the most appropriate population density for pole snap bean seed production; and
5. To determine the most appropriate combination of employed interventions for pole snap bean seed production.

Significance of the Study

Snap beans (*Phaseolus vulgaris* L.) is an indispensable legume and one of the most important economic vegetable crops grown in the Cordillera Region. It ranks first in terms of land area cultivated in Ifugao and remains as one of the main sources of income of majority of farmers particularly in cooler parts of the province. The result of the study will be of great value to the following groups of stakeholders.

**Farmers.** Results obtained from this study will provide basic information on the appropriate date of planting and population density for snap bean farmers will serve as their guide in producing quality seeds thus maximizing the use of their land and increasing yield.

**Researchers and Extension programs.** The findings of this study will serve as baseline data for further researches to be conducted and extension programs of the university and line agencies like the Department of Agriculture.

**Instruction.** The findings of this study can be used for instruction purposes. The information generated will contribute in solving the problem on the dearth of literature about pole snap beans and other legume crops. Furthermore, the result of the study will be used as inputs in the production of techno guide for snap bean seed production in the province of Ifugao.

Scope and Delimitation of the Study
This study focused on three interventions: planting date, population density and variety for pole snap bean seed production. Seed quality parameters included the percent germination, speed of germination and percent good seeds. Seed yield parameters included number of pods per plant, number of seeds per pod, weight of 1000 seeds per plot, seed yield per plot and computed seed yield per hectare.

**Time and Place of the Study**

The study was conducted at the Model Farm of the Ifugao State University (IFSU), Nayon, Lamut, Ifugao from September 2011 to March 2012. Seed quality test was conducted at the science laboratory building of the university from April 3-15, 2012.

**Definition of Terms**

The following terms are defined to obtain clearer understanding of the study.

**Abnormal seeds.** These are seeds that are small, deformed in size, discolored, damaged or contaminated with pathogens.

**Component technology.** It refers to a set of production techniques covering a variety of operations that needs to be carried out in the production of crop. Such components refers to land preparation, planting, nutrient management, pest management, irrigation, drainage, harvest, post harvest and handling.

**Days to flowering.** It refers to the number of days from seedling emergence to flower bud formation when 90% of the plants produced flower buds.

**Days to maturity.** It refers to the number of days from flower bud formation to seed maturity when 50% of the pods turned brown in color.

**Germination speed.** It refers to the number of seeds that germinated daily over the total test period (days) when all viable seeds germinated.

**Germination.** The emergence and development of the seedling to a stage where the aspects of its essential structures developed under favorable conditions in the laboratory (ISTA 1996).
**Good seeds.** It refers to seeds that are plump, full and uniform in size, viable and free from diseases, insect pests and other matters.

**Interplant competition.** It refers to competition for resources within and among plants growing next to one another in a field. The competition may affect yield per unit area.

**Lateral branches.** It refers to the lateral branches developed during the vegetative stage of the bean plants.

**Pathogens.** Is an entity, usually microorganism that can incite disease. In a literal sense a pathogen is any agent that causes pathos (ailment, suffering) or damage. It denotes living organisms (Fungi, bacteria, virus, nematodes) but not nutritional deficiencies.

**Percent germination.** Known also as germination capacity is the proportion of seeds that germinated during the test period. It expresses the proportion of the total number of seeds that are alive. It is determined through controlled tests and actual counts of the number of seeds that germinate.

**Photoperiodism.** The relative duration of day and night, the influence of the daily cycle of light and darkness on the physiology and behavior of plants.

**Planting date.** It refers to the month when seeds are sown in the experimental area.

**Plant population density.** The number of plants per hill in a given area.

**Seed maturity.** It refers to the process comprising a series of morphological, physical, physiological and biochemical changes that occur from ovule fertilization to the time when seeds become physiologically independent of the parent plant. It refers also as a seed dehydration process while still attached to the parent plant (Copeland et al., 2001).

**Seed quality.** It is the degree of excellence when compared to an acceptable standard primarily genetic purity, good health and physiological purity (viability and vigor) and other attributes to be referred as quality seed.

**Seed yield.** It is the weight of dried seeds after harvest with moisture content of 14 percent.

**Seed vigor.** Is the sum total of those properties of the seed which determine the potential level of activity and performance of the seed or seed lot during germination, seedling emergence abd seedling growth. Peformance include rate and uniformity of seed germination and seedling growth,
seedling emergence and growth in the field, emergence ability of seedlings under unfavourable environmental conditions.

**Short day plants.** It refers to plants that form flowers only when day length is less than about 12 hours. These plants begin flowering when the days are shorter than their critical day length.

**Seed-borne diseases.** It refers to the particular plant diseases that are transmitted by seed. These diseases infected seeds externally or internally during the course of development and maturation in fruit or pod. Most of these diseases survive as long as seed remains viable.

**Variety.** A taxonomic category consisting of members of a species that differ from others of the same species in minor but heritable characteristics.

**REVIEW OF RELATED LITERATURE**

**Planting Date**

Sowing time is the most critical factor for achieving higher productivity of snap beans. Advanced or delayed sowing may cause substantial reduction in yield because of the seed’s sensitivity to low or high temperature. High temperature during the early stage of the crop is not conducive for proper growth. Advanced planting induces early flowering on account of high atmospheric temperature which ultimately leads to poor seed setting hence, low yield. On the other hand, late sown crop does not attain required vegetative growth and consequently results to poor yield (Sardana et. al. 2000).

Determining the best combination of variety and choice of planting date may be crucial for farmers in view of optimizing the bean yields. A study conducted by Ngueguim et al., (2011) have shown that delaying bean planting beyond the first week of October caused yield reductions in Cameroon, Nigeria and even serious grain quality deterioration as seed yield and the weight of 1000 seeds significantly reduced with delayed planting time. Within each of the growth types (bush, semi-climber and climber), the weight of 1000 seeds consistently dropped with the lateness of planting although this reduction was not significant for the climbers.
According to Suratman et al., (2004) planting date at 2-week interval and cultivar influence significantly the average pod yields of snap beans. He further stated that climatic conditions during the planting dates like temperature, water and frost affect the yield of snap beans at different planting dates.

Kudan (1991) cited also that October to November is recommended for planting snap beans. He further mentioned that snap beans is a short day plant and that based on observation, there was a higher percentage of pod set (62.5 %) obtained from October to November cropping period than February to March cropping period.

Comaad (1993) cited that under Ifugao condition, October to November is conducive for snap bean production since the climate during these months is favorable for pole snap bean production.

The effect of cultivar and planting season on growth development and pod yield of snap beans showed that the phenology, pod production and quality differed significantly among snap bean cultivars. Planting season had a significant effect on most pod traits except of seeds per pod, length, thickness, soluble solids content, tenderness and string and this effect varied markedly among environments (Barbeito, 2007).

Henderson et al. (1998) reported that planting date may affect seed yield through its association with seedling stand, anthesis and maturity.

As cited by Balasubramanian and Vandenberg (2004), planting date may affect seed yield through its association with seedling stand, anthesis and maturity (Henderson, et al., 1998).

In the work of Dapaah et. al. (1999) on the influence of six sowing dates and irrigation on the growth and yield of pinto beans (Phaseolus vulgaris) in a sub-humid temperate environment, both irrigation and sowing date had a marked effect on growth and yield. He further stated that there was a faster pod growth rate and higher percentage of stored assimilates that contributed to the pod growth when planted mid-to late November with irrigation than those planted late October to early November.

Yoldas and Esiyok (2009) stated that when planting is delayed, the yield of snap beans will decrease significantly. Delayed planting affects growth, yield and yield components. Late planting
results to decreased yield because of the short vegetation period of the crop. Delayed planting decreased the number of days as well as the thermal time from emergence to harvest.

According to Tibig (2008), the impact of climate change can be positive or negative; yield of any crops can be increased when activities are at the right time i.e., planting dates, application of irrigation, use of pesticides and others. Climate change can be devastating in areas where agriculture is the only source of income. Decreased rainfall, warmer temperature can damage crops and can reduce yield because animals and plants are more susceptible to disease and insect pests.

Smith and Pryor (1962) studied the best dates for planting bean varieties. Five varieties of beans for dry seed production were planted in dates varying from late April to late July at two weeks intervals. Results indicated that four out of five varieties increased in production between late April plantings up to mid-June and early July, when yields were maximum. The yields of the late-July plantings declined in all varieties. They also studied the effect of high temperatures on growth, development and yield of bean plants and have indicated that high temperature reduced the percent of flowers that set seed. If plants were to bloom on days of high temperatures, there was a high mortality. They further indicated that the low yields of the June and July plantings can be attributed to the adverse effects of the high temperatures at the time of flower-bud differentiation and during flowering period or pod set of bean plants.

**Plant Population Density/ Seeding Rate**

Plant density is an important agent that affects yield and yield components of legumes. The reflex of legume plants to different plant densities was studied by several researchers. Plant density is one of the important and effectual factors in the fixation of crop yield and is not stable for one variety in different climate conditions (Dahmardeh et al., 2010).

Dahmardeh et al., (2010) studied the effects of plant density and cultivars on the growth, yield and yield components of faba beans and found that the number of pods per plant and number of seeds per pod were not affected by plant density and cultivars but the seed weight per plant and seed yield per hectare were significantly affected by plant density and cultivars under arid conditions in the southeast region of Iran. The highest and lowest seed yields were obtained with the highest
and lowest plant density respectively. Raising seed yield by increasing plant density was reported also by El-Douby et al., (1996) and Hassan et. al. (1997).

Chandhla (2001) in his study on the effect of plant density on the number of pods per plant and seed yield per plant reported that seed yield per plant decreased with increasing plant density stating that the highest yield was observed at the lowest plant density and a reduction in seed yield was observed between the medium and high population density. The number of pods per plant differed significantly between the medium and high plant densities. The highest number of pods was observed at the low plant density, followed by the medium plant density treatment. While the highest number of seeds per pod was observed in the low and high plant density treatments. The reduction in seed yield per plant was associated with the reduced number of pods per plant.

Research studies with several annual crop species have shown that yield can be increased by growing appropriate cultivars at extremely high plant densities (Grafton, Schneiter & Nagle, 1988). Kwaptata & Hall (1990) stated that cultivars with different plant morphologies would require different optimum densities to express their full seed yield potential.

Yield of beans, on a unit basis, has been static over the past decade in comparison to the marked increases in cereal crops such as rice and corn. These higher cereal yields have been primarily due to the improved plant architecture and increased response to high density planting. Beans, on the other hand, have been conventionally grown in wider space. Nagle (1988) Kwapta & Hall (1990) stated that yield can be increased by growing appropriate cultivars at extremely high plant densities. Cultivars with different plant morphologies would require different optimum densities to express their full seed yield potential. While plant density may influence light distribution in plant canopies, partitioning of photosynthates in soybeans was barely influenced by density. Philbeam, Hebblewaite & Clark (1989) indicated that plant density, distance between adjacent rows of plants, or a combination of the two, influence interplant competition of all environmental resources. They further indicated that interplant competition intensifies if the plant density increases and the inter row spacing remains constant, or if the distance between the rows decreases while plant density remains unchanged. Any inter-plant competition may be expected to affect the growth and development of the plant and ultimately its yield.
As reported by Moniruzzaman, et al., (2009) yield components viz., branches per pod, pod length, pod width, number of green pods per plant and green pod weight per plant of French beans recorded the highest values at lower plant density. However, it was not reflected in the pod yield per hectare because higher plant population density and medium plant density out-yielded the lower plant density.

According to Philbeam et. al., (1989) the effect of row width on the yield of Faba bean (*Vicia faba* L.) has shown that seed yield increased as inter-row width decreased. However, these studies have used only the conventional indeterminate cultivars. Grafton et al., (1988) reported that yield increase in determinate cultivar with increased plant population while row spacing x population interaction had no effect on yield for both determinate and indeterminate cultivars. Goulden (1976) reported that yield per hectare of snap beans generally increased with increased plant density. Greater yields under high plant densities have been reported for other leguminous crops such as soybeans, broad beans and in lupins. As observed by Lucas and Milbourn (1976) increased density led to a decrease in number of branches per plant in *Phaseolus* and in soybean cultivars.

Response to plant density is greatly dependent on the cultivar and its growth habit. In a study involving different indeterminate varieties of pole snap beans, greater seed yields (kg/ha) were obtained at higher plant density than lower plant densities (Edje et al., 1974).

The rate of seeding influences the degree of light penetration and interception. The study of Ethreded (1989) showed that increasing plant population decreased light interception per plant although the total light intercepted by the plant community increased. Likewise, seeding rate also affected yield and dry matter accumulation (Alim and Tripathi, 1987). Lower density produced significantly higher pods/plant than the higher density because low plant density had more space which favored better branching and consequently more pods. They further stated that plant population showed considerable impact on dry matter accumulation.

Ali and Kushwaha (1987) stated that adequate plant population is pre-requisite for achieving good yields. Seed rate of 120-150 kg/hectare depending on the seed size was sufficient for timely sown crop.
McCollum (1975) reported that garden cultivars of bean type are commonly spaced to 2-4 inches apart with the closer spacing usually producing larger yield but requiring more seeds per hectare. He pointed out that the rate of six seeds thinned out into 4 seeds per foot with 3 feet apart would require 90 pounds of stringless green pod seeds to plant an acre. Studies cited by Kudan (1991) showed that two seeds could be planted per hill with the spacing of 20 cm by 20 cm amounting to 280,000 plants per hectare or an equivalent of 60 kg of bean seeds per hectare. As reported by PCARRD, (2009), two (2) to three (3) seeds per hill were suggested. The seeds were planted in double rows spaced 20 cm by 25 cm with a total population of 200,000 to 300,000 plants per hectare equivalent to 40 to 50 kg of seeds.

Barbeito (2007) reported that there was a constant significant superior yield of high plant populations over those of low plant populations of plastic house beans. Nevertheless, phosphorus content of the pods was increased as planting density decreased. He pointed out that although, the highest planting density (10 cm x 30 cm) gave the highest percent of early yield (93 %) in comparison with the total yield, it was among the lowest yielding ability and tended to give pods with lower N, P, K and protein contents.

Stoffeila and Sandsted (1981) as cited by Abubaker (2008) mentioned that more stem hypocotyl diameter of bean plants occurred with the increased row spacing. Variation of plant population affects total bean yields. He further indicated that bean yield increased as densities increased. Higher planting densities gave 7-48 % higher bean yields in seven out of nine field experiments.

Zwane and Rhykerd (2006) reported that there is a positive correlation between plant population and seed yield. The plant population of 66,667 plants/hectare had a significantly lower total seed yield than the 400,000 plants/hectare plant population. He further pointed out that though seed yields were low compared to other studies conducted, plant population density, nevertheless, contributed to the total seed yield of the crop.

According to Crothers & Westermann, (1976); Shirtliffe & Johnston, (2002), high population density in Phaseolus vulgaris led to higher seed yield. The effect of of plant population on seed yield was also reported by Ayaz et al. (2001) stated that seed yield approximately doubled as
population increased from 100,000 to 400,000 seeds sown per hectare. Herbert and Hill (1978) reported that as plant density increased, intensity of interplant competition also increased, and yield/plant would decline, although total yield/unit area might increase. They stressed likewise that dry beans in all market classes had the potential for higher yields with narrower spacing (higher plant populations).

Sanders (1993) reported that increasing the plant population per acre tends to reduce the number of beans per plant but increases the total number of pods (yield) per acre. He further mentioned that this will also result to pods being borne closer to the stem and higher in the plant canopy, and plants being more upright. When these factors coupled with increased distance between plants in the row, they tend to compensate for the reduced distance between rows and the potential reduced air drainage. This seems to result to such planting that is not susceptible (and no more resistant) to gray and white mold than conventionally spaced beans under normal condition. He stated that at any given plant population, reducing spacing between rows allows increased distance between plants in the row.

**Variety**

Varietal evaluation is vital in assessing the performance of certain varieties of snap beans that are of economic importance to commercial production. It is important to determine high yielding varieties that can boost high production. According to Bautista and Mabesa (1977), varieties to be selected should be high yielding, insect and disease resistant as well as early maturing to ensure lesser expenses with more profit. In order to obtain high pod yield, the pole snap bean variety must flower early, mature earlier, have high number of flowers per plant and more clusters per plant (Regmi, 1990).

Choice of improved variety is important to tremendously increase yield. In Benguet, a number of snap bean varieties have been found to be performing well (Snap bean techno guide, 1989).

In the Philippines, after years of field trials in the different geographical locations, BSU-IPB – HCRS had identified six promising varieties of snap beans for commercial production (Blue Lake,
BSU Selection 1, Burik, Patig, Alno and Bush Blue Lake) for the Cordilleras and highlands of Regions 1, 11, 1V and V (Tandang, 1990). Among these varieties, both pole Blue Lake and Bush Blue Lake 274 were identified to be highly resistant to bean rust (Uromyces phaseoli var. typical) and anthracnose. Atos (1987) and Tandang (1988) showed that the pole bean varieties yielded from 17.24 to 23.02 t/ha.

Liebenberg (1989) indicated that the yield components of beans are believed to be genetically independent and that under stress situations, negative correlations arise as induced relationships.

According to Graham et al., (1997) common beans differ in their ability to supply carbohydrates to the roots and nodules. Late maturing cultivars are reported to supply more soluble carbohydrates to roots than the early maturing cultivars. In late maturing cultivars, there is a delay in the onset of competition for photosynthates between the developing pods and the nodules and have long leaf area duration since they shed their lower leaves late. This enables these cultivars to maintain their active assimilatory surface longer (Mohamed, 1998).

The relationship between photosynthates, carbohydrate assimilation and crop yield is very complex. This is mainly because of the dependence of crop yield on the net assimilation value, which in turn is determined by photosynthetic rate as well as leaf surface size, leaf area duration, canopy structure, dark and light respiration, translocation and partitioning of assimilates (Liebenberg, 1989). Photosynthesis mostly takes place in the leaves hence leaf area is a major component of whole plant yield. Leaf area has then been divided into leaf number and leaf size and photosynthetic production increases with increasing leaf area per unit ground area, referred to as leaf area index (LAI).

The flowering pattern of beans differs depending on the growth habits. In indeterminate cultivars, the first opened flower appears on first, second or upper axil of main stem. On the other hand, the first opened flower appears in the axil of the upper most nodes on the main stem of determinate cultivars (Ojehomon et al., 1973).

White et al., (1989) observed that small seeded genotypes were predominantly day neutral, while medium and large seeded genotypes were predominantly photoperiod sensitive.
Studies with several annual crop species have shown that yield can be increased by growing appropriate cultivars at high plant densities (Cooper, 1977, Grafton et al. 1988). According to Pilbeam et al., (1989) plants with different morphologies may exploit the space available for them more or less effectively. Agreeing with the aforesaid, Kwapata & Hall (1990) reported that cultivars with different morphologies require different optimum densities to express their full seed yield potential. Achievement of high seed yield at very high density requires that a cultivar should efficiently use photosynthetically active radiation and effectively partition photosynthates to seed (Kwapata & Hall, 1990). They further observed constant partitioning coefficients during flowering and pod and concluded that that variation in pod and seed number may be more closely related to crop growth rate than the ability of the plant to allocate assimilates to the developing fruit.

Physiological maturity, the stage where no further increase in dry mass of seeds takes place, may be reached in the earliest varieties in only 65 days from planting (Polhill & van der Maese, 1985).

Maturity at harvest is the most important factor that determines postharvest and final quality of fruit-vegetables. Dry beans have a moisture content of about 50 % at physiological maturity. The beans however are only ready for harvesting when the moisture content drops to 16 %, the ideal being 15 %. Seeds may split during threshing when the moisture content is less than 12 % and such seeds are rejected by canners and seed companies. Dry beans should be harvested when all pods have turned yellow, but before they have become so dry that the pods begin to shatter (Liebenberg, 2001).

As reported by Zvalo and Respondek (2007), snap beans seeds are ready for harvesting when seeds are at 18 % moisture, which when some pods are brown and the majority are yellow and dry. Low seed moisture content can result in mechanical injury or split seed coat. It is imperative that plants have reached physiological maturity before being harvested. Unevenness of maturity can lead to problems of shattering or abrasion, discoloration or disease of immature beans. Delayed harvesting too long after maturity will cause sprouted blemished seed, darkened seeds and shattering. Seed damage at harvest is related to too low seed moisture content (Zvalo and Respondek, 2007).
Bailly et al. (2001) observed that seed germination was highest at physiological maturity when snap bean seeds were harvested 25 days after flower opening.

A study involving bean cultivars Rosecoco and Mwezi Moja, Muasya (2001) observed that physiological maturity, the moment of maximum seed dry weight, was achieved at 58 % seed moisture content. Harvest maturity occurred at 20 % moisture content. At physiological maturity, the percentage of viable seeds was still increasing. It became maximum closer to harvest maturity implying that seed development does not stop at physiological maturity. Seed vigor as measured was maximum at physiological maturity and remained constant until harvest maturity.

**Seed Quality**

Seed is the basic and crucial input for successful crop production and which holds the key of the farm productivity and profitability. Seed is a living product and must be grown, harvested and processed correctly to maximize its vitality and the subsequent crop productivity. According to IRRI (2011), good quality seeds must be sown to realize the yield potential of all varieties. Good quality seeds can increase yields by 5-20 %. The extent of the increase is directly proportional to the quality of seed sown. Seed quality can be considered as the summation of all factors that contribute to seed performance. High quality seeds enable farmers to attain crops, which have:

- The most economical planting rate
- A higher percentage of seed emergence in the field
- A vigorous seedling establishment
- A more uniform stand
- Faster growth rate, and greater resistance to stress and diseases
- Uniformity in maturity and minimum replanting.

Seed quality is determined by genetic and physiological characteristics. The genetic factors that can influence quality include: genetic make-up, seed size, bulk density while the physical or environmental characteristics include: injury during planting and establishment, growing conditions during seed development, nutrition of the mother plant, physical damage during production or storage, moisture and temperature during storage and age or maturity of the seed.
Deterioration in seed quality may begin at any point in the plant’s development stage from fertilization onward. Seed quality depends upon the physical conditions that the mother plant is exposed to during growth stages, as well as harvesting, processing, storage and planting. Temperature, nutrients and other environmental factors also affect seed development and influence seed quality.

Seeds of high quality should be true to its kind or variety, contain a minimum of impurities and have high establishment rates in the field. The criteria for describing seed quality are; varietal characteristics, seed lot characteristics and seed viability (IRRI, 2001).

As reported by McGee (1995) the quality of planted seeds has a critical role on the ability of crops to become established and to realize their full potential of yield and value. A complex technology is required to ensure high standards of seed quality that involve producing, harvesting, processing, storing and planting the seed.

As stated by Mekbib (1999) good quality seeds are produced from the variety which grows best in their particular microclimate. Green snap beans should mature early, produce pods which delay seed formation in the pod, and produce pods for the longest period of time, while also resistant to various indigenous bugs and diseases. He further mentioned that the best seeds are the first pods produced and allowed to grow to full maturity and then saved for seeds. The same procedure can be used for many types of seeds. Good quality seeds are physically pure, no physical defects, not mixed, not crinkled, uniform size and shape.

It is estimated that good quality seeds of improved varieties can contribute to about 20-25 percent increase in production. Thus good quality seeds are seeds of green revolution (Agriquest, 2012).

As defined by the International Seed Testing Association (ISTA) 1993, seed quality is a concept made up of different attributes, namely purity, moisture content and germination. The main criteria for describing seed quality can be considered under the following; varietal characteristics, seed lot characteristics and seed viability. A description of the seed lot includes the level of impurities, seed size and damaged, deformed or diseased seed. Varietal purity can be described by its physical, chemical and crop attributes.
Seed quality encompasses several factors such as seed health, varietal and physical purity, germination, vigor, and size or seed weight which have some potential to influence crop yield (Ellis, 1992).

Seed germination tests measure the number of healthy well-developed seedling under laboratory conditions. The process of seed germination is complex and can be affected at different stages by many factors and interactions of factors such as temperature, water availability, oxygen, light, substrate, maturity of seed, physiological age of seed. In laboratory germination tests these factors are optimized in order to measure the maximum number of seeds capable of producing healthy well-developed seedlings. A laboratory germination test does not take into account the effects of non-optimal conditions on the seed. It is therefore useful to view a laboratory germination test result as potential rather than absolute emergence (Maile L. 2008).

Under field conditions rapid germination is obviously an advantage for seedling establishment. Speed of germination is an expression of seed vigor. It is anticipated that high quality or high-vigor seeds germinate faster than poor or low-vigor seeds under any conditions. The number of normal seedlings recorded in the first count represents the population of fast germinating seeds and thus functions as a vigor measurement (AOSA Seed Vigor Testing Handbook). Germination speed has been used as an indicator of seed vigor and it is an important measurement used to model seed germination (Bradford, 1990). Germination speed and early seedling growth are key parameters for describing seed lot quality beyond standard germination (McDonald et al., 1990).

Climate

Generally, beans can grow in any given altitude and latitude. Temperature requirement ranges from 16-24 °C (PCARRD, 2009). Uniform distribution of rainfall is ideal for obtaining high yield which ranges from 25-100 cm. The prevailing day length in the Philippines appears to be just right for string bean production. The growth of string beans increases greatly in October to February with short days and cloudy conditions. Beans require between 200 and 400 mm of rainfall as comparable residual soil moisture during growth and development, with the well watered area reaching globally up to only 7 % (Broughton and Hernandez, 2003).
Beans require between 200 and 400 mm of rainfall as comparable residual soil moisture during growth and development, with the well watered area reaching globally up to only 7% (Broughton and Hernandez, 2003). For snap beans soil moisture of 250-450 mm is usually sufficient (Rubatzky and Yamaguchi, 1977). Varga and Kszegi (1987) reported that water consumption of snap beans falls on the cooler times, thus less water use can be expected and higher water consumption on warmer times, thus more water use can be expected.

Field beans grow well in temperatures between 15 °C and 24 °C, with higher temperature resulting to poor pod set (Norman, 1992).

Snap bean plants (*Phaseolus vulgaris*) are relatively sensitive to environmental stress that may occur in the field compared to most vegetable crops which negatively affects its growth, yield and even the quality of pods. Many investigations indicated that snap bean plants is very sensitive to different environmental stresses such as drought.

As reported by Singh (2001) high temperature (> 30 °C day and/or > 20 °C night) in tropical lowlands and production in temperate zones are a major limiting factor in the production of common beans. Temperate production areas experience brief and problematic seasonal heat waves during flowering resulting to blossom drop, and in the case of snap bean, a split set. Singh (1995) further reported that water stress during flowering and grain filling reduced seed yield and seed weight, and accelerated maturity of beans. Reductions in yield during flowering are the result of both fewer pods and seeds per pod. According to Rubatzky and Yamaguchi (1997), moisture stress also affects pod color, fiber and firmness.

As reported by Tsukaguchi et. al, (2003), pod yield of snap beans is severely depressed under a high temperature condition. It is determined by the number of pods, which is a product of the number of flowers and pod-set-ratio. Since pod-set-ratio is strongly affected by pollen fertility under high temperature condition, pod yield deterioration in the summer cropping might be due to the decrease of pollen fertility. Often a high temperature coincides with a high solar radiation and causes excessive transpiration. This excessive transpiration leads to temporal water deficit in plants in the daytime, even when soil moisture content is adequate and plants can take up a sufficient amount of water in the nighttime. Decline in water potential or vegetative and reproductive organs in snap bean
plants was considerably larger under high temperature than that under optimal temperature conditions.

PCARRD (1999) stated that snap beans require constant supply of moisture during the growing season. Irrigation is important to ensure plant growth, a uniform pod set, and robust development. Water deficiency or stress, especially during the blossom pod set period can cause blossom and pods to drop, resulting to poor seed quality and reduced yield. Excess water at anytime during the growth of the plant can increase the plant’s susceptibility to root rot infection which also reduces yield.

Singh (1995) reported that water stress during the vegetative stage delayed flowering, while water stress during the reproductive and grain-filling stages hastened plant development. Also, water stress during the vegetative stage retarded root development, as well as vegetative growth. Total number of pods and pod fresh weight of bush beans were significantly reduced by water stress occurring at preflowering, flowering or post flowering stages.

According to Devlin and Witham (1983), long day plants will normally flower and reproduce seeds where days are relatively long. While short day plants flower only when the daylength is less than certain critical length. Devlin and Witham further stated that daylength in excess of the critical point would keep the short day flowering plant vegetative.

Irit et al. (1990) reported that temperature affect yield and abscission of flower buds, flowers and pod. Under moderate temperature (17°C) the onset of pod development was associated with cessation of flower bud production and with enhanced abscission of flower buds. Raising night temperature from 17 °C to 27 °C strongly reduced pod production, mature pod size and seeds per pod, while an increase in day temperature was not constrained by flower production since 27 °C at night promoted branching and flower bud appearance. Under 27 °C day/night temperatures the large reduction in pod set was due to enhanced abscission of flower buds, flowers and young pods. He further reported that the onset of anthesis and of pod development were the plant stages most sensitive to night temperature.
Yoldas and Esiyok (2009) mentioned that if the reproductive period of bean coincides with high temperatures then due to abscission of buds and flowers, there is a significant decrease of productivity.

Balasubramanian, Vandenbeng and Hucl (2004) stated that planting date and suboptimal seedbed temperature affects bean establishment, phenology and yield.

Greven et al. (2004) stated that seed quality of dwarf French beans (Phaseolus vulgaris L.) was reduced because of rain during harvest, especially for seeds with <25 % seed moisture content. They further mentioned that seed quality can be reduced by rewetting before harvest maturity is reached.

Duke (1983) mentioned that rain is undesirable when dry seeds are harvested. Excessive water will injure plants in a few hours. He further reported that common beans can tolerate annual precipitation of 0.9 - 42.9 dm, annual mean temperature of 5.7° to 28.5°C and pH of 4.2-8.7.

As reported by Tibig (2008) climate change negative impact on crop yield and productivity will vary; positive effect-more carbon dioxide in the atmosphere will boost productivity (increased photosynthesis) (carbon fertilization effect). Negative effect in areas where temperatures are already high, yields could be further reduced due to; added heat stress, shifting monsoons causing rainfall, shorter rainy seasons, late arrival of the rainy season and early termination of rainy season. Higher temperature will influence production pattern; higher temperature plus water shortages damage the crops and eventually reduce yield. As a consequence, prices will be higher and production costlier.

As cited by Zwane and Rhykerd (2006) soil temperature has been reported to influence physiological processes including seed dormancy and germination (Relf, 1997), seedling emergence and growth noting that soil temperatures above the annual soil temperature range could cause flower blast. Among the possible reasons for increased soil temperature are greater solar radiation impacts in the soil nearer the soil surface.

Heat stress particularly affects the development of reproductive organs (Hall, 1992). High air temperature exceeding 20 °C, 8 to 11 days before flowering of snap beans, more than 80 % of the pollen produced was sterile. A high negative coefficient of correlation between temperature (15 °C-350°C) and the percentage of pods set was estimated (Bouwkamp et. al., 1982). Pod yield of snap
beans is severely depressed under a high temperature condition. It is determined by the number of pods which is a product of the number of flowers and pod-set-ratio.

As cited by Sotiriou et al., (2008) large differences in days to maturity are found in cultivated common bean. These differences are associated with differences in growth habit, degree to sensitivity to photoperiod and temperatures, and growing environments. Genetic control of earliness vs. lateness depends on prevailing day and night temperatures, photoperiods and genotypes utilized in the study (Singh, 1991).

According to Nilsen and Orcutt (1996), limited water availability for the bean crop can be caused by soil-precipitation relationship amongst other physical and climatic factors of the environment. It is clear that the water holding capacity of the soil in conjunction with the amount of precipitation in time scale influences the moisture supply to plant roots, especially the light textured soils as this one, amongst other factors which interplay notably ambient temperature and the soil-plant relationship.

As noted by Tihanum et al. (2004), drought which includes moisture and heat stress, acts in conjunction with biotic stress, especially diseases and pests.

Day length and other environmental factors may contribute to the phenotypic plasticity and diversity of seed germination in many plant species. The germinability of seeds of many species is affected by day length during seed development and maturation. In some plant species, short days result to higher germinability. Alternating diurnal temperatures (22/12°C) during seed development also resulted to higher germination than in seeds developed under constant temperatures (Karssen, 1970).
MATERIALS AND METHODS

This chapter presents the research design and methodology. It includes the general description of the study site and varieties used in the study, experimental design, establishment and cultural management practices and data gathering procedure.

General Description of the Study Site

The experimental site has Type 1 climate with two seasons. Wet season from July to November, sometimes extends to January and dry season from February to June. However, due to climate change that the country and the whole world is experiencing, climatic condition varies from time to time. The experimental farm of the Ifugao State University is situated in a valley enclosed by two mountains and a small river near the farm.

The soil type of the experimental site is clay loam with good drainage and previously planted with organic vegetables and legumes.

Varieties Used

The following are the two varieties of pole snap beans used in the study:

<table>
<thead>
<tr>
<th>Pole Snap Beans</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burik</td>
<td>It matures in 59 days after emergence and can be harvested 9 times. Seeds are elliptical, brown color with strips of brown lines. The pods are dull green, rough, with strings and cross section is elliptical. It has a pod length of 13.29 cm with pod width of 0.98 cm. Seeds are light brown with dark brown mottle. The average yield is 18.48 t/ha as recorded by IPB.</td>
</tr>
<tr>
<td>2. Alno</td>
<td>This variety matures in 63 days after seed emergence. The pods are reddish green with red cross section. Pods are straight, fibrous with an average pod length of 14.5 cm. Seeds are elliptical and</td>
</tr>
</tbody>
</table>
black in color. Seed coats are waxy. The average yield is 18.68 t/ha as recorded by IPB.

Experimental Design

The experiment was laid out in a 3 x 3 x 2 factorial experiment arranged in a split-split-plot design with three replications. The different treatments are the following:

Factor A – Main Plot (Date of planting- D)

D₁- October
D₂- November
D₃- December

Factor B – Subplot (Population Density- P)

P₁ – 1 plant per hill
P₂ - 2 plants per hill (Farmer’s Practice)
P₃ - 3 plants per hill

Factor C- Sub-sub- plot (Variety- V)

V₁- Burik
V₂- Alno (Black Valentine)

Every block was subdivided into three main plots representing the date of planting. The main plot was further subdivided into six plots representing population density and variety totaling to 18 plots per block measuring 1 x 10 m each.

Establishment and Cultural Management Practices

Land preparation

A total area of 540 square meters was used. The experimental area was cleared from weeds prior to plot formation. Plots were constructed with the use of grab hoe. One week after digging, the plots were dug in order to pulverize the soil then plots were raised to about 25 cm above the ground level to ensure good drainage and aeration of the root zone during heavy rains.

Soil sampling and analysis
Soil samples were collected one month before the land preparation. Ten (10) sampling sites were identified for the collection of soil samples. Soil samples were collected at random in the experimental site for organic matter content, nitrogen, available phosphorus, exchangeable potassium analysis and soil pH determination. A composite soil sample of 1 kilo was taken to represent the unit area. The samples were air dried inside the laboratory, pulverized and cleaned from roots and other foreign matters. Samples were analyzed by the Cagayan Valley Integrated Agricultural Research Center, Integrated Laboratory Services, Ilagan, Isabela. The result was used as basis for the application of fertilizers. The results of the soil sample analyzed are as follow:

- pH: 7.1
- OM, %: 1.99
- P, ppm: 12
- K, ppm: 162

**Fertilizer and fertilizer application**

The fertilizer recommendation based from the result of soil analysis for pole snap beans is 45 kg N, 30 kg P₂O₅. Two (2) kilograms of IFSU Bio Organic Fertilizer (4-9-2) was drilled in prepared furrows one week before planting in order to improve the soil structure and enhance biological activities in the soil. The IFSU Bio Organic Fertilizer was mixed with the soil in the prepared furrows one week before sowing the seeds. One hundred fifty (150) grams of 16-20-0 mixed with 100 g of 46-0-0 was applied between furrows per plot as sidedress 8 days after seedling emergence. Plants were hilled up immediately after sidedressing to cover the fertilizers applied.

**Planting**

One week after the application of the IFSU Bio Organic fertilizer, seeds were sown per hill at a distance of 25 cm between hills and 30 cm between rows at a depth of 2 centimeter. A distance of 40 cm between plots and 50 cm between blocks was observed in the experiment. The number of seeds sown range from 1, 2, 3 seeds per hill following the plant density specified in the treatments. First planting was on the 4th week of October, second planting was on the 4th week of November and third planting was scheduled on the 4th week of December.
Watering

Watering was done two days after sowing the seeds for October planting since there was no rain for one week. No watering was done thereafter because there was sufficient rainfall that watered the plants.

Trellising

“Rono” trellis were installed in each plot in crisscross fashion in between the adjacent rows at 25 to 30 pieces per 10 linear meters before the vines appeared to avoid intertwining of vines.

Weeding, pests and disease control

Hand weeding, hoeing and hilling-up were carried out to manage weeds from competing with the crops for nutrients, sunlight, water and space. Weeding was done as often as necessary.

Insect pests and diseases observed infecting the plants were controlled with the use of Lannate and extracts from Makabuhay combined with Madre de cacao. Lannate was sprayed to control pod borer once a week following recommended dosage of 3 tbsp/16 liters of water. Makabuhay stem and Madre de Cacao leaves were prepared using the decoction method at a proportion of 1:3. One kilogram of Makabuhay and 1 kg of Madre de Cacao were collected, washed and chopped. Three liters of water was boiled for 5 minutes in stainless pot, after which the chopped botanicals were added to the boiled water and allowed to boil for another 5 minutes under a very slow fire. The decoction was strained after 24 hours and was sprayed at the rate of 2 tbsp/liter of water. Spraying of these botanicals was done once a week alternate with Lannate insecticide.

Pruning

Pruning was done by removing old and infected leaves in all the treatments. This was done in order to reduce bean pod borer infestation and to induce more flowers and pods to be formed.

Harvesting
Matured pods were harvested when 50 percent of the seeds reached maturity. Pods were harvested by snapping the pedicel of the pods with the finger to avoid damaging other pods that are not yet physiologically matured.

**Post harvest practices**

Immediately after harvesting, pods were dried under the sun for 6 days until pods turned brittle and seeds are firmed and hard. Dried pods were shelled separately by treatments and blocks. Seeds were further dried under the sun for 2 days until moisture content (MC) reached 14 percent. Moisture content was taken using the Digital Grain Moisture Meter, Model No. Mc-7821.

All yield and seed quality parameters were measured and recorded accordingly.

**Climatic conditions**

Rainfall data was taken from the Department of Agriculture at Lamut, Ifugao, 10 kilometers away from the research area. The data on temperature was taken from the IFSU PAGASA weather station.

**Data Gathering Procedure**

**Growth parameters**

*Days to flowering.* Number of days was counted from seedling emergence until approximately 90% of the plants produced flower buds. This was done by visual observation of the plants that produced flower buds.

*Days to maturity.* Number of days from flowering to seed maturity was determined when approximately 50% of the pods were turned brown in color. The average days per treatment were computed.

*Number of lateral branches per plants.* The number of lateral branches was counted when pods were almost matured. Ten randomly selected plants per treatment were given tag as sample plants. The lateral branches per plant were counted and the average computed.

**Yield and yield components**
**Number of pods per plant.** The counting of the number of pods was done when pods were almost matured. Ten (10) sample pods were selected per plot as representative plants. The number of pods per plant was counted and recorded.

**Number of seeds per pod.** The number of seeds per pod was counted after drying the pods under the sun for 6 consecutive days. Ten (10) pods were selected randomly per treatment as sample pods. All seeds in the pods regardless of the size, whether damaged or not were counted and the average computed.

**Weight of 1000 seeds per plot.** Seeds classified as good seeds were selected randomly from each treatment or plot. One thousand (1000) seeds were counted and weighed. Weight of the seeds was compared to the standard weight for 1000 seeds.

**Seed yield per plot.** The seed yield was computed after drying and shelling, all dried seeds regardless of the size, shape, damaged or not were summed up to get the seed yield per plot of 0.6 m x 10 m.

**Computed seed yield (t) per hectare.** The computed seed yield per hectare was measured using ratio and proportion.

**Seed quality parameters**

**Percent germination.** 100 seeds were randomly selected from the 1000 seeds from each treatment as sample seeds. Percent germination was tested using the ragdoll method. The laboratory test using the ragdoll method was done inside the room at an average temperature of 28.35 °C. Number of seeds that germinated was counted and the percent germination computed. A seed was considered to be germinated as seed coat ruptured, plumule and radicle came out and were >2mm long. The germination percentage was calculated using the following formula;

\[
\text{Germination} \, (\%) = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds set for test}} \times 100
\]

**Germination speed.** 100 seeds from the 1000 seeds from each treatment were randomly selected for germination speed measurement. The germination speed was computed using the following formula (Krishnaswamy and Seshu, 1990).
Germination Speed = \[
\frac{\text{Number of germinants (first count)}}{\text{Days to first count}} + \frac{\text{Number of germinants (2nd count)}}{\text{Days to second count}}
\]

\[
\frac{\text{Number of Germinants (3rd count)}}{\text{Days to 3rd count}} + \frac{\text{Number of Germinants (final count)}}{\text{Days to final count}}
\]

Percent good seeds per plot. Only good seeds that have the characteristics of plumpness or fullness, free from damage, uniform seed size, shape and color were weighed and computed. Good seeds were selected after sun drying when moisture content is 14%. Abnormal seeds that were damaged, deformed or diseased, discolored as shown by the presence of spots on the seeds were discarded. Percent good seeds were computed using the following formula:

\[
\% \text{ Good seeds} = \frac{\text{Weight (g) of good seeds}}{\text{Total weight (g) of seeds}} \times 100
\]
RESULTS AND DISCUSSION

Crop Environment

Rainfall data was obtained from the Department of Agriculture, Lamut, Ifugao approximately 5 kilometers away from the research site (Figure 1). Temperature was taken from IFSU PAGASA Weather Station (Table 1). Monthly average rainfall and weekly average temperature is presented in figures 1 and 2.

Variation in temperature was observed from October to the third week of March ranging from 18.52°C to 29.88°C from planting to harvesting. Higher temperature was observed during the seedling stage of October and November planting ranging from an average weekly temperature of 25.83 °C to 29.88 °C. The highest temperature was noted during the second week of November with an average of 29.88 °C and lowest temperature was noted during the 1st week of February with an average of 18.92 °C.

Uneven distribution of rainfall during the entire growth and development of the snap bean plants was observed. Snap beans planted during the 4th week of December received the highest amount of rainfall of 610 mm during the vegetative stage. The lowest rainfall was noted during the month of February with a mean of 85 mm during pod formation of December planting.
Table 1. Average weekly temperature (°C) for the whole duration of the study.

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>28.07</td>
<td>27.58</td>
<td>29.17</td>
<td>29.15</td>
<td>28.49</td>
</tr>
<tr>
<td>November</td>
<td>26.96</td>
<td>29.88</td>
<td>26.12</td>
<td>25.83</td>
<td>27.19</td>
</tr>
<tr>
<td>December</td>
<td>25.47</td>
<td>26.54</td>
<td>25.96</td>
<td>24.52</td>
<td>25.62</td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>20.16</td>
<td>19.25</td>
<td>20.16</td>
<td>19.74</td>
<td>19.82</td>
</tr>
<tr>
<td>February</td>
<td>18.92</td>
<td>20.17</td>
<td>20.74</td>
<td>19.58</td>
<td>19.85</td>
</tr>
<tr>
<td>March</td>
<td>21.18</td>
<td>21.03</td>
<td>20.4</td>
<td>-</td>
<td>20.87</td>
</tr>
</tbody>
</table>

| Room day | 1   | 2   | 3   | 4   |         |
|          | 29.91 | 27.61 | 28.35 | 27.72 |

| temperature | 27.92 | 28.29 | 28.26 | 28.58 | 28.35 |

Table 2. Average weekly rainfall (mm) from October 2011 to March 2012

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>204.0</td>
<td>96.0</td>
<td>117.0</td>
<td>87.0</td>
<td>28.49</td>
</tr>
<tr>
<td>November</td>
<td>26.96</td>
<td>29.88</td>
<td>26.12</td>
<td>25.83</td>
<td>27.19</td>
</tr>
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<tr>
<td>2012</td>
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<td>21.18</td>
<td>21.03</td>
<td>20.4</td>
<td>-</td>
<td>20.87</td>
</tr>
</tbody>
</table>
Figure 1. Weekly sum of temperature from October 1, 2011 to March 21, 2012

Figure 2. Weekly sum of rainfall from October 1, 2011 to March 21, 2012 (DA, Lamut, Ifugao, 2012)
Insect Pests and Diseases

The plants were attacked by insect pests and diseases during the vegetative and reproductive stages. Bean flies were present one week after seed germination and they made holes on the leaves. Pod borers bored the young pods, and grasshoppers were also present but were controlled with the use of Lannate and botanical insecticides that were used alternately once a week to control these pests.

Alternaria leaf spot disease caused by fungus Alternaria sp, angular leaf spot caused by fungus Isiaropsis griseola and anthracnose caused by fungus Colletotricum lindemuthianum were observed on the pole snap beans towards maturity. Leaves attacked with alternaria leaf spot disease have brown irregular-shaped lesions that were large, gray-brown oval with concentric rings. Leaves attacked with angular leaf spot disease were characterized by angular-shaped spots on the leaves. Infected pods showed circular-shaped spots with reddish brown centers. All the plants planted in October, November and December were attacked with alternaria leaf spot, angular leaf spot and anthracnose.

Growth Parameters

The data on the growth parameters which are days to flowering, days to maturity and number of lateral branches as affected by date of planting, population density and variety is shown in Table 3.

Effect of variety

**Days to flowering.** A highly significant effect on the number of days to flowering between the two varieties was observed (Appendix Table 1e). Flower buds of the Burik variety significantly formed earlier (33 DAE) than Alno variety (34 DAE). The presence of highly significant variation between the two varieties would imply that the variety exerted strong influence on the length of days from seedling emergence to flower bud formation. The significant difference that exists between the two varieties on the number of days from seed emergence to flowering can be attributed to the length of maturity of the variety. Burik variety generally matures in 59 days while Alno variety
matures in 63 days. The result of the study confirm the observation of Singh (1987) and Ahlawat and Sharma (1989) that there is a large variation in the growth, adaptation and seed yield of pole snap bean varieties. The result further confirms the observation of Comaad (1993) that there was a highly significant difference shown on the number of days to flower bud formation of variety Burik, Blue Lake and BSU Selection no. 1.

**Days to maturity.** Days to maturity varies with variety of pole snap beans. A highly significant variation between varieties on the number of days to seed maturity was noted (Appendix Table 2e). The highly significant effect is indicative of the different character traits of the Burik and Alno varieties. The Burik variety matured two (2) and a half days earlier ((30 days) than the Alno variety that matured 32 days after flower bud formation. The result may be due to the shorter maturity (59 days) of the Burk variety and longer maturity (63 days) of the Alno variety.

**Number of lateral branches.** Comparison of the treatment means between the Burik and Alno varieties showed no significant difference on the average number of lateral branches developed (Appendix Table 3e). The insignificant variation implied that both varieties have similar capacity to produce the same number of lateral branches that can be attributed to their identical genetic trait.

The result seems to confirm the observation of Comaad (1993) that between the Burik and BSU selection # 1 varieties, the number of lateral branches developed was not significant indicating that both varieties responded similarly to the numeral development of lateral branches. Further the observation of Moniruzzaman et al., (2009) that varieties of snap beans tested did not significantly influence the number of branches developed. Result is presented in Table 3.

**Effect of population density**

**Days to flowering.** Population density of two (2) plants per hill had the longest number of days to flowering followed by three (3) plants per hill and shortest was in one (1) plant per hill (Table 3). The comparison of treatment means however, did not reveal any significant differences in the number of days from seedling emergence to flowering implying a negligible role of population density treatments in influencing the number of days from seedling emergence to flowering. The result
confirmed the study of Abubaker (2008) that found no significant effect of population density on the number of days to flowering and the observation of Lucas and Milbourne (1976) that there was no significant effect of population density on the days to flowering and number of nodes per plant in pole snap beans. This further confirms the observation of Comaad (1993) that seeding rate did not influence the number of days to flower bud formation.

**Days to maturity.** The number of days from flowering to seed maturity as affected by the population density per hill is shown also in Table 3. Result showed that there was no significant variation on the number of days to seed maturity as influenced by population densities (Appendix Table 2e). The result confirmed the observation of Abubaker (2008) that found no significant effects of plant population on the days, time of flowering and stem diameter. The result could be associated with the character traits of the plant. As mentioned earlier, the response of pole snap beans to plant density is greatly dependent on the cultivar and its growth habit.

The results however showed that the number of days from flower bud formation to seed maturity decreased with increasing population density. Three (3) plants per hill obtained the shortest average of 31.11 days followed two (2) plants with 31.17 days and the longest of 31.28 days was observed in one (1) plant per hill (Table 3). The presence of non-significant effects implied that population density did not have strong influence on the length of days from flower bud formation to seed maturity.

**Number of lateral branches.** Population density did not significantly influence the number of lateral branches produced per plant (Appendix Table 3e). However, the number of lateral branches seems to decrease with increasing plant population density. Lateral branches per plant was highest in plant population of three (3) plants per hill followed by two (2) plants per hill and lowest was noted in one (1) plant per hill (Table 3). The result of the study confirmed the observation of Khalil et al., (1993) that increasing plant density negatively influences number of branches and pods per plant of two varieties of faba beans. Lucas and Milbourn (1976) also observed that there was no significant effect of density on the number of nodes and lateral branches of pole snap beans which was verified by the data of Scarisbrick et al., (1977). Related to
this, Moniruzzaman et al. (2009) observed that the effect of population density on the number of lateral branches and pod yield did not differ significantly between the two varieties of snap beans.

The result implied that the number of lateral branches could be attributed to the genetic trait of the variety’s capacity to produce lateral branches. For economic benefit, the result of the study indicates that one (1) plant planted per hill can produce statistically the same number of lateral branches in two (2) and three (3) plants per hill.

**Effect of date of planting**

*Days to flowering.* A highly significant influence by date of planting on the days to flowering was observed (Appendix Table 1e). December planting appeared to have influenced the earliest flower formation having the shortest number of days from seedling emergence to flower bud formation as shown in Table 3. October planting was found to have the longest number of days while November planting was intermediate with 33 days. The result could be due to the effect of temperature and photoperiodism which shortened the vegetative stage of the plants for floral primordial differentiation leading to earlier pod formation (Devlin and Witham, 1983). December had the shortest daylength of 11.25 hours while November and October has 11.43 and 11.79 hrs. respectively (Comaad, 1993). The result of the study confirms the observation of Comaad (1993) that there was a highly significant effect of the date of planting on the days to flower bud formation.

*Days to maturity.* Planting dates markedly influenced the days to seed maturity. Sowing seeds on December significantly matured the earliest with a mean of 29.11 days but no significant variation was noted with November planting. Bean plants planted in October registered the longest number of 35 days from flowering to seed maturity (Table 3). This confirms the study of Comaad (1993) that snap beans planted on December matured the earliest and plants planted in October matured the longest. The result may be attributed to the photoperiod, temperature and rainfall during those months. Snap beans require an optimum temperature of 15.6 -21.1 °C for better growth, pod set and maturity (Rangaswamy, 1975). The result also confirmed the study of Garner and Allard (1980) that beans have a short day requirement for flowering implying that photoperiod-sensitive
cultivar will flower only under days with a dark period longer than at a critical length. It also means that the number of days from planting to flowering decreases as the day length is shortened until a minimum number of days to flowering are obtained (Masaya and White, 1991).

For October planting, flower formation to seed maturity period was during the month of December with average temperature of 25.5 °C and rainfall was 212 mm. For November planting flower formation to seed maturity period was during the months of January until the first week of February with an average temperature of 19.83 °C and average rainfall of 67 mm. Flower formation to seed maturity period for December planting was during the month of February until the 2nd week of March with an average temperature of 20.6 °C and an average rainfall of 106 mm. November and December planting was within the optimum temperature for better growth and maturity of pods and seeds.

**Number of lateral branches.** The highest average number of lateral branches was obtained by plants sown in October followed by plants sown in December and November planting in that order (Table 3e). Comparison of treatment means showed no significant effect on the average number of lateral branches developed by the Burik and Alno variety. The absence of any significant variation implied that plants can be planted on October, November or December without any significant effect on the numerical development of the lateral branches. The result of the study confirms the observation of Comaad (1993) that there were no significant differences on the number of lateral branches as affected by the date of planting of the three varieties of pole snap beans studied. The result may be attributed to the genetic trait of these varieties to produce lateral branches. Lateral branches have been found to be correlated with the genetic makeup of the plant. Liebenberg (1989) indicated that the number of lateral branches was believed to be genetically independent and that under stress situations, negative correlation arise as induced relationship.
Table 3. Days to flowering, days to maturity and number of lateral branches per plant as influenced by date of planting, population density and variety.

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>DAYS TO FLOWERING</th>
<th>DAYS TO MATURITY</th>
<th>NUMBER OF LATERAL BRANCHES/PLANT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main plot (A)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Date of planting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D₁ - October</td>
<td>36.72a</td>
<td>35.22a</td>
<td>10.33</td>
</tr>
<tr>
<td>D₂ - November</td>
<td>33.22b</td>
<td>29.22b</td>
<td>9.33</td>
</tr>
<tr>
<td>D₃ - December</td>
<td>31.06c</td>
<td>29.11b</td>
<td>9.72</td>
</tr>
<tr>
<td>(Fc = 105.96^{**})</td>
<td>(Fc = 106.11^{**})</td>
<td>(Fc = 1.0^{ns})</td>
<td></td>
</tr>
<tr>
<td>(LSD .05 = 1.09)</td>
<td>(LSD .05 = 1.33)</td>
<td>(LSD .05 = 2.10)</td>
<td></td>
</tr>
<tr>
<td>(cv = 3.05 %)</td>
<td>(cv = 4.62 %)</td>
<td>(cv = 23.08 %)</td>
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</tr>
<tr>
<td><strong>Sub-plot (B)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pop. density</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P₁ - 1 plant/hill</td>
<td>33.33</td>
<td>31.28</td>
<td>9.44</td>
</tr>
<tr>
<td>P₂ - 2 plants/hill</td>
<td>34.11</td>
<td>31.17</td>
<td>9.89</td>
</tr>
<tr>
<td>P₃ - 3 plants/hill</td>
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<td>10.11</td>
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<tr>
<td>(cv = 2.62 %)</td>
<td>(cv = 2.78 %)</td>
<td>(cv = 9.20 %)</td>
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<tr>
<td><strong>Sub-sub-plot © Variety</strong></td>
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<td></td>
</tr>
<tr>
<td>V₁ - Burik</td>
<td>33.26b</td>
<td>30.33b</td>
<td>9.89</td>
</tr>
<tr>
<td>V₂ - Alno</td>
<td>34.07a</td>
<td>32.04a</td>
<td>9.74</td>
</tr>
<tr>
<td>(Fc = 8.96^{**})</td>
<td>(Fc = 62.24^{**})</td>
<td>(Fc = 0.35^{ns})</td>
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<tr>
<td>(LSD .05 = 0.5)</td>
<td>(LSD .05 = 0.45)</td>
<td>(LSD .05 = 0.53)</td>
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<tr>
<td>(cv = 2.97 %)</td>
<td>(cv = 2.54 %)</td>
<td>(cv = 9.40 %)</td>
<td></td>
</tr>
</tbody>
</table>

Means with a common letter within a column in each factor are not significantly different (0.05) according to Least of Significant Difference (LSD) Test.

**Interaction Effects**

The results of the interaction effects of the date of planting, population density and variety on the days to flower formation, days to seeds maturity and number of lateral branches per plant is presented in Table 3.
Days to flowering

**Interaction effect of date of planting and plant population density.** Statistical analysis of variance showed that there was no interaction effect between the date of planting and plant population density on the days to flowering (Appendix Table 1e).

The result implies that the treatment combinations of date of planting and population density did not affect the number of days to flowering. As observed by Craighton (1981), the key factors influencing legume growth and yield components are cultivar growth habits and genotypic response to population density.

**Interaction effect of date of planting and variety.** Statistical analysis (Appendix Table 1e) showed no significant interaction effect by the date of planting and variety on the days to flowering. The result is in contrast with the observation of Comaad (1993) that the date of planting and variety showed a highly significant interaction effect on the days to flower bud formation.

The absence of significant interaction would mean that there was no interacting capacity of planting date and variety to affect the length of days to flowering of the two varieties of pole snap beans.

**Interaction effect of population density and variety.** The interaction effect by population density and variety did not show significant influence on the days to flowering. The non-significant interaction effect shows that there was no interacting capacity of planting date and variety to affect the length of days to flowering of the two varieties of pole snap beans.

**Interaction effect of date of planting, population density and variety.** Result showed no significant changes in the days to flowering indicating that date of planting, plant population density and variety did not have a significant interaction influence on the number of days to flowering (Appendix table 1e). The result could be attributed to the genetic trait of the varieties to respond to the days to flower formation.
Days to maturity

Interaction effect of date of planting and population density.  By expressing the combined effect of date of planting and population density on the days to seed maturity, the effect was quantified. Statistical analysis of the interaction effect of date of planting and population density on the number of days to seed maturity was significant (Appendix Table 2e). The result indicates that the days to seed maturity was affected by planting date and population density combinations applied.

The days to seed maturity remain relatively stable as plant density increases in December planting however in October and November planting, variation was noted in population density of two (2) plants per hill with slightly longer days than population densities of one (1) and three (3) plants per hill in November and December planting (Figure 3). The significant interaction effects of the date of planting and population density indicates the importance of the date of planting in seed maturity.

![Bar chart showing interaction effect of date of planting and population density on days to maturity.](chart.png)

Figure 3. Interaction effect of date of planting and population density on the days to maturity.

Interaction effect of date of planting and variety. Date of planting and variety did not have a significant interaction influence on the number of days to seed maturity of the Burik and Alno
varieties (Appendix Table 2e). Data on the interaction effect shows that variety Alno matured longer than Burik in all the planting dates implying that the date of planting and variety did not strongly influence the days to seed maturity. The absence of any significant variation points to the genetic trait of the variety to respond to the days to seed maturity.

**Interaction effect of population density and variety.** Result shows that variety Alno consistently has slightly longer days to seed maturity in all population densities than variety Burik. As there were no significant variations in the days to seed maturity as influenced by population density and variety is an indication that there was no significant interaction influence on the days to seed maturity (Appendix Table 2e).

**Interaction effect of date of planting, population density and variety.** The interaction effect of date of planting, population density and variety did not show any significant effect on the days to seed maturity of Burik and Alno varieties (Appendix Table 2e). Longer days were obtained by variety Alno than variety Burik in all levels of plant density treatments and different planting dates. The insignificant interaction effect implied that these factors did not have the capacity to effect change in the number of days to seed maturity of the two varieties.

**Number of lateral branches**

**Interaction effect of date of planting and population density.** No significant interaction effect between the date of planting and population density to the number of lateral branches developed was noted (Appendix Table 3e). The result is an indication that date of planting and population density did not strongly interact to influence on the number of lateral branches that were developed.

**Interaction effect of date of planting and variety.** There was also no significant interaction effect of date of planting and variety on the number of lateral branches developed in both varieties (Appendix Table 3e). The result of the study implied that the date of planting and variety did
not strongly affect the number of lateral branches that were developed. The result could be due to the genetic trait of the varieties.

**Interaction effect of plant population density and variety.** There was no significant interaction between the population density and variety to influence the number of lateral branches that developed in varieties Burik and Alno (Appendix Table 5e). The result confirms the observation of Thomas (1965) that there was no variety population interaction effect as indicated in the seed yield of pole snaps beans.

**Interaction effect of date of planting, population density and variety.** There were no significant combined effect of planting date, population density and variety to cause change in the number of lateral branches that were developed by the varieties Burik and Alno (Appendix Table 3e). The results indicate that there is a possibility of increasing density in both varieties in October, November and December planting without significantly changing the number of lateral branches that developed.

**Yield and Yield Components**

The data on the seed yield and seed yield components which are the number of pods per plant, number of seeds per pod, total seed yield per plot, computed seed yield per hectare and weight of 1000 seeds per plot as influenced by date of planting, population density and variety is shown in Table 4.

**Effect of variety**

**Number of pods per plant.** The effect of variety on the number of pods per plant showed no significant variation between Burik and Alno variety (Appendix Table 4e). Burik variety however gave a slightly higher number of pods with an average of 11.48 while the Alno variety produced 11.11 pods (Table 4). The findings confirmed the observation of Comaad (1993) that the number of pods that developed among the three varieties of snap beans that were tested was the same. The result implied that both varieties responded similarly to the numeral pods that developed per plant.
**Number of seeds per pod.** The data on the effect of variety on the average number of seeds per pod is presented in Table 4. Result showed that variety Alno significantly outnumbered the number of seeds produced per pod by variety Burik (Appendix Table 5e). The highly significant effect between the two varieties is the indication that the two varieties responded differently to the number of seeds developed per pod. The result could be attributed to the longer average pod length of 14.5 cm of variety Alno compared with the shorter average pod length of 13.29 centimeter of the Burik variety. The result confirms the observation of Singh and Singh (1987) and Ahlawat and Sharma (1989) that there were variations of varietal differences in terms of yield components of pole snap beans. Similarly the result of the study confirm the observation of Dahmardeh et al., (2010) that cultivars of faba beans were greatly different in the number of their seeds per pod.

**Total seed yield per plot.** Seed yield per plot between the two varieties did not differ significantly (Appendix Table 7e). The result seems to confirm the observation of Bennet et al. (1977) that seed yield per plant did not differ significantly between the two varieties of pole snap beans studied. On the average, Burik however gave a better weight of 1092 g of dried seeds per plot compared to the lower weight of 1033.26 g dried seeds per plot of the Alno variety. The higher weight of variety Burik could be associated with the higher number of branches and pods produced by variety Burik. Though the result is insignificant, economically it reflects the importance of number of pods per plant and branches as yield contributors.

**Weight of 1000 seeds per plot.** Statistical analysis revealed highly significant varietal differences on the weight of 1,000 seeds per plot. Means comparison between the two varieties showed that Burik significantly outweighed the Alno variety in terms of One Thousand (1,000) seed weight per plot (Appendix Table 6e).

The result of the study confirms the observation of Ngueguim et al., (2011) that the weight of 1000 seeds of dry beans (*Phaseolus vulgaris* L.) gave significant differences among the genotypes studied. Further the observation of Chandhla (2001) confirms the result of the study stating that a high degree of variation was recorded on the 1000 seed weight of cultivar Kranskop and cultivar
Teebus but remain relatively stable as plant density increased. Specifically, Burik weighs an average of 272.67 g compared to the average of 251.28 g 1,000 seed weight of the Alno variety (Table 4). The result could be attributed to the larger size of the Burik seeds compared to the smaller size of the Alno seeds.

**Computed seed yield per hectare.** No significant effect on the computed seed yield per hectare was observed between variety Burik and variety Alno as reflected in Appendix Table 8e. The same trend of result was observed in variety Burik that produced higher computed weight of dried seeds per hectare of 17.99 tons while variety Alno produced an average seed yield of 19.59 tons per hectare.

The result seems to confirm the observation of Chandhla (2001) that there was no significant difference in mean seed yield between two cultivars of snap beans. The absence of significant effect points to the varietal similarities in their response to weight of seed yield produced per hectare. The result further confirms the observation of Liebenberg (1989) that the yield components of beans are believed to be genetically independent and that under stress conditions, negative correlations arise as induced relationship.

**Effect of plant population density**

**Number of pods per plant.** The response of plants to the number of pods per plants as influenced by plant population density is shown in Table 4. Statistical analysis showed no significant difference among the population densities in their influence on the number of pods developed (Appendix Table 6e). The finding confirms the observation of Dahmardeh et al., (2010) that the number of pods of faba beans was not affected by plant density. Furthermore, the observation of Crothers and Westermann (1976) that plant density did not affect the number of pods per plant for either of the cultivars of beans that were utilized. Similar result was also observed by Bennet et. al (1976), Scarisbrick et. al (1977) and Comaad (1993) that there was no significant effect of plant density on the number of pods per plant of Navy beans, Burik, Blue Lake and BSU Selection # 1.
The result could be attributed to the genetic trait of the Burik and Aino varieties to respond to pod development.

**Number of seeds per pod.** The values obtained in Appendix Table 5e shows that the population density did not at all affect the number of seeds produced per pod as shown by the insignificant differences among the treatment means. The findings appear to confirm the observation of Crafton et al., (1988) that the number of seeds per pod in dry beans did not show any significant variation in their response to increased plant density. In relation to this, the finding also seems to confirm the observation of Craighton (1981) that plant population had no significant effect on the number of pods per plant, number of seeds per pod and seed yield of snap beans. Further the result of the study confirms the observation of Dahmardeh et. al., (2010) that the number of seed per pod was not affected by plant density and cultivar.

It was observed that the number of seeds per pod decreased with increasing population densities. The highest average number of seeds per pod was observed at the lowest population density while the lowest was observed in the highest population density. The absence of any significant effect result would imply that population density did not exert strong influence on the number of seeds developed between the two varieties of pole snap beans.

**Total seed yield per plot.** Weight differences of dried seeds per plot as influence by population density were highly significant (Appendix Table 6e). It was observed that increasing the number of plants from one (1), two (2), and three (3) per hill had a corresponding significant seed yield per plot. Table 7 shows that population of three (3) plants per hill had the highest weight of dried seeds (924.33 g) followed by two (2) plants per hill (804.00), the least was registered by plant population of one (1) plant per hill.

The result indicated that population density showed distinct influence on the weight of dried seeds per plot. This confirms the study of Shirliffe & Johnston (2002) that high population density led to higher seed yield. Related to this, the result of the study also confirm the observation of Dwivedi et al. (1994) that higher population density of French beans significantly produced higher seed yield over lower plant populations. Dahmardeh et al. (2012) also observed that the effect of
plant density on seed yield of pole snap beans had significant differences. The result could be attributed to the higher number of plants per unit area as confirmed by the observation of Lucas and Melbourne (1976) that the number of plants per unit area increased the seed weight of dried bean seeds of *Phaseolus vulgaris* varieties.

**Weight of 1000 seeds per plot.** Population density did not significantly influence the weight of 1,000 seeds per plot (Appendix Table 7e). Nonetheless, it was noted that the weight of 1000 seeds decreased with increasing plant population densities. One (1) plant per hill had the highest 1,000 seed weight per plot of 267.67 g followed by two (2) plants in descending pattern with three (3) plants per hill producing the least weight of 1,000 seeds per plot. The result seems to confirm the observation of Chandhla (2001) that the main effects of population density on thousand seed mass (g) of two cultivars of Pole snap beans was not significant. The absence of any significant effect among the population densities indicate that plant population of one (1), two (2) and three (3) plants were not strong to influence the weight of 1000 seeds for each variety. The result of the study may be attributed to the genetic traits of the Burik and Alno varieties to produce weight of 1000 seeds.

**Computed seed yield per hectare.** A highly significant effect of population density on the computed seed yield per hectare was noted as reflected in Appendix Table 8e. Population density of three (3) plants per hill out-yielded significantly population densities of one (1) and two (2) plants per hill but there was no significant difference between one (1) plant and two (2) plants per hill. The highly significant interaction effects indicate that computed seed yield responded differently to the different population density treatments applied. The trend that was observed was an increase in computed seed yield with increasing population density treatments. As seen in Table 4, population density of three (3) plants per hill gave the highest weight of 19.55 tons of dried seeds per hectare followed by two (2) plants per hill producing 17.62 tons per hectare while the lowest was noted in one (1) plant per hill with 16.21 tons. The result is in agreement with the observation of Moniruzzaman et al., (2009) that the maximum yield of French bean per hectare was highest with the highest plant density and lowest with the lowest plant density.
In line with the increasing productivity of the Burik and Alno varieties, population density should be taken into consideration to take advantage of the benefits of producing high seed yield per hectare.

**Effect of date of planting**

*Number of pods per plant.* The number of pods per plant is the yield component with the predominant influence on the yield of beans since it incorporates the other components (Chung & Goulden, 1971). The comparison of the treatment means, however, did not reveal any significant effect on the date of planting in the number of pods produced per plant (Appendix Table 4e). The number of pods per plant in the different planting date was comparable. However, October planting produced the highest mean number of 11.89 pods per plant followed by plants planted in November and December planting with means of 11.72 and 10.28 pods per plant respectively. The absence of significant effect confirmed the observation of Comaad (1993) that the date of planting did not significantly affect the number of pods developed in the three varieties of pole snap beans. He further stressed that October planting registered the highest mean number of pods developed per plot followed by December and November planting in that order.

The result could be attributed to the character traits of the varieties to produce pods which was not affected by the date of planting. The result is an indication that both varieties can be planted in October, November and December with no significant difference on the number of pods that were developed.

*Number of seeds per pod.* The data on the number of seeds per pod as affected by date of planting is presented in Table 4.

The number of seeds developed per pod in November significantly outnumbered the seeds developed per pod in December planting but no significantly difference with October planting as shown in Appendix Table 5e. The lowest number, 6.94 seeds per pod observed in December planting could be due to the insufficient rainfall during the months of January to March that have affected the vegetative and reproductive performance of the two varieties. The result seems to
confirm the observation of Craighton (1981) that snap beans are very sensitive to water stress during the period of flowering, as well as the stages of pod and seed development.

November planting was done on the 4th week and consequently the vegetative and reproductive stages were affected by the prevailing temperature and rainfall on the months of December to the first week of February. The average temperature in December and January were 25.62 °C and 19.82 °C respectively. The temperature in January (19.82 °C) was within the optimum temperature required for better growth, pod set and crop maturity. The mean rainfall of 212 mm during the month of December was sufficient for proper vegetative growth of the snap bean plants that contributed to higher seed development. The non-significant differences between October and November and between October and December planting may be attributed also to the similar temperature and rainfall during those periods.

Variation in soil moisture and plant water content can have quite an impact during specific phases of plant development leading to marked effects on several growth parameters and subsequent yield.

**Total seed yield (g) per plot.** Data shows that November planting had the highest weight of dried seeds per plot with a mean of 1,307 g significantly out-yielding October and December planting with a mean weight of 902 g and 979 g respectively (Table 6). October and December planting did not show any significant differences on the weight of dried seeds per plot. The highest seed yield obtained in November planting could be attributed to the high number of seeds developed per pod in November planting.

The result of the study seems to confirm the observation of Sardana et al. (2000) that the different sowing dates of pole snap bean varieties showed significant differences on the number of pods per plant, seeds/pod and seed yield. Further observation of Comaad (1993), states that a significant difference was noted among the different varieties of pole snap beans on the total seed yield per plot.
The effect of photoperiodism, temperature and rainfall on the vegetative and reproductive development of the pods and seeds could be the determining factor that might have influenced pod and seed weight.

**Weight of 1000 seeds per plot.** The 1,000 seed weight in grams is a measure of seed size. It is an index of the size and plumpness of air-dried seeds expressed in grams. By using the 1,000 seed weight, a producer can account for seed size variations when calculating seeding rates, calibrating seed drills and estimating shattering and combine losses. Determining a 1000 seed weight help farmer determine the ideal seeding rate in order to get the most out of the seed. Weight of 1,000 seeds per plot was not significantly influenced by the three planting dates. The result on the effect of planting dates on 1000-seed weight in the two pole snap bean varieties is shown in Table 4. On the average, October planting had the highest 1000-seed weight of 267.67 g while December planting gave the lowest average of 252.67 grams. November planting registered an intermediate mean of 266.19 grams.

Vladimir et al. (2012) in their studies on sunflower plants observed that there was no significant difference in 1000-seed weight between adjacent dates of planting in several occasions.

As shown by the result of the study, planting date did not have the potential to influence the weight of 1000 seeds of the two varieties of pole snap beans. In this regard, these two varieties can be planted from October to December without significant variation on their 1000-seed weight.

**Computed seed yield (t) per hectare.** On the average, plants planted in November produced significantly higher weight of dried seeds than those planted in October and December (Appendix Table 8e). Following similar trends of production of dried seeds, planting in November of the two varieties produced remarkably higher yield of 21.78 tons per hectare (Table 4). This was significantly higher than those planted in October and December. October planting produced the lowest computed seed yield of 15.04 tons per hectare while December planting produced intermediate seed yield of 16.55 tons per hectare. This implies that these two varieties could be planted in November.
Table 4. Yield and yield components as influenced by date of planting, population density and variety.

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<thead>
<tr>
<th>TREATMENTS</th>
<th>NUMBER OF PODS/PLANT</th>
<th>NUMBER OF SEEDS/POD</th>
<th>TOTAL SEED YIELD (G)/PLOT</th>
<th>WT. 1000 SEEDS/G/ PLOT</th>
<th>COMPUTED SEED YIELD (T)/HA.</th>
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<tr>
<td><strong>Main plot- Date of planting (A)</strong></td>
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<td></td>
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<tr>
<td>D1 - October</td>
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<td>902b</td>
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<td>D2 - November</td>
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<td>P2 - 2 plants/hill</td>
<td>11.17</td>
<td>7.28</td>
<td>1064b</td>
<td>261.61</td>
<td>17.62cb</td>
</tr>
<tr>
<td>P3 - 3 plants/hill</td>
<td>11.29</td>
<td>7.11</td>
<td>1185a</td>
<td>260.28</td>
<td>19.55a</td>
</tr>
<tr>
<td><strong>Sub-sub-plot (C)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V1 - Burik</td>
<td>11.48</td>
<td>6.89b</td>
<td>1092</td>
<td>272.67a</td>
<td>17.99</td>
</tr>
<tr>
<td>V2 - Alno</td>
<td>11.11</td>
<td>7.59a</td>
<td>1033.26</td>
<td>251.67b</td>
<td>17.59</td>
</tr>
</tbody>
</table>

Interaction effects

A x B | 1.45ns | 0.918ns | 2.013 | 0.468ns | 0.836ns |
A x C | 0.125ns | 2.88ns | 6.72** | 1.70ns | 2.50ns |
B x C | 0.338ns | 1.33ns | 0.43 | 0.609ns | 0.83ns |
A x B x C | 1.25ns | 0.722ns | 0.208 | 1.60ns | 0.21ns |

Means followed by the same letter within each factor are not significantly different at 0.05 % level of significance by LSD Test.

Interaction Effects

The interaction effects of the date of planting, population density and variety on the number of pods per plant, number of seeds per pod, total seed yield per plot, weight of 1000 seed per plot and computed seed yield per hectare is presented in Table 4.
**Number of pods per plant**

*Date of planting and population density.* No significant interaction effect of the date of planting and population density on the number of pods developed by Burik and Alno was noted (Appendix Table 4e). The insignificant interaction effect is an indication that the date of planting and population density acted independently in affecting the number of pods that were developed by the two varieties of pole snap beans.

*Interaction effect of date of planting and variety.* There was no significant interaction effect obtained between the date of planting and variety in the number of pods developed by the Burik and Alno varieties (Appendix Table 4e).

The insignificant interaction effect shows that date of planting and variety treatment combinations did not have the capacity to affect the number of pods that developed indicating the possibility of planting either of the varieties on October to December without any effect on the number of pods developed.

*Interaction effect of population density and variety.* The interaction effect by population density and variety on the number of pods developed was not also significant (Appendix Table 4e).

The result confirms the observation of Chandhla (2001) that the interaction effect of variety and population density on the number of pods produced per plant for dry bean seed production was not significant. The result could be attributed to variation in variety’s response at different population levels and is characteristically cultivar dependent.

*Interaction effect of date of planting, population density and variety.* Statistical analysis showed no significant interaction effect of the date of planting, population density and variety on the number of pods developed (Appendix Table 4e).

The result is an indication that the date of planting, population density and variety did not have the interacting capacity to influence the number of pods produced by each variety. As mentioned earlier, the benefits of this finding is to ascertain that it is possible to plant any of the two
varieties from October to December at plant density of one, two or three plants per hill without significant reduction on the number of pods produced.

**Number of seeds per pod**

*Interaction effect of date of planting and population density.* For date of planting and population density interaction effect, statistical analysis showed no significant interaction effect on the number of seeds per pod (Appendix Table 5e). The result confirms the observation of Comaad (1993) that there was no significant interaction of the date of planting and population density on the number of seeds per pod by the three varieties of pole snap beans.

*Interaction effect of date of planting and variety.* Statistical analysis also revealed no significant interaction effect of the date of planting and variety on the number of seeds per pod (Appendix Table 5e). The result confirms the observation of Dahmardeh et al., (2010) that the seed per pod of faba beans was not affected by the interaction effect of plant density and cultivar. The result is an indication that planting dates and variety did not interact to influence the average number of seeds produced in varieties Burik and Alno. However, in the main effects, both date of planting and variety gave a significant effect on the number of seeds developed per pod in both varieties.

*Interaction effect of population density and variety.* The same result is obtained from population density and variety interaction effect. The result showed the same trend in the number of seeds per pod for both varieties in the three levels of population density, indicating the absence of significant interaction effect as shown in Appendix Table 5e.

The result implied that population density and variety did not interact strongly to influence the number of seeds produced by each variety.

*Interaction effect of date of planting, population density and variety.* Statistical analysis shows that the interaction effect of date of planting, population density and variety to influence the number of seeds developed per pod is insignificant (Appendix Table 5e). The result could be attributed to the genetic trait of the variety to respond to the number of seeds produced per pod.
Total seed yield (g) per plot

*Interaction effect of date of planting and population density.* Analysis of variance showed that the date of planting and population density did not interact significantly to affect the total seed yield of the two varieties (Appendix Table 6e).

The insignificant interaction indicates that the different parameters affected seed yield independent from each other in all treatment combinations applied. However, the highest seed yield per plot was produced by population density of three (3) plants per hill followed by population density of two (2) plants per hill and the lowest was noted in population density of one (1) plant per hill across the different planting dates.

*Interaction effect of date of planting and variety.* Statistical analysis showed a highly significant interaction effect between the date of planting and variety (Appendix Table 6e). The highly significant interaction indicates that seed yield was affected by the different dates of planting and variety combinations applied.

Burik produced the highest weight of 1,346.77 g of dried seeds in November planting followed by 1076.66 g in December planting and lowest was 852.88 g in October planting. On the other hand, variety Alno produced the highest seed yield (1266.66 g) followed by 952 g per plot in October and lowest with 881.11 in December planting. The result of the study confirm the observation of Comaad (1993) that the interaction effects of date of planting and variety on the seed yield of three (3) varieties of pole snap beans were significant.

The highly significant interaction effect implied that the date of planting and variety strongly influenced the seed yield of the two (2) varieties tested. The result reflects the importance of date of planting on seed yield in pole snap bean production.
Interaction effect of date of planting and variety on the weight (g) of total seed yield per plot

Interaction effect of population density and variety. As reflected in Appendix Table 6e, the interaction effect by population density and variety on the total seed yield per plot was not significant at 0.05 % level of significance by LSD test. The insignificant interaction indicates that population density and variety affected seed yield independently from each other in all treatment combinations. The result confirm the observation of Chandhla (2001) that the interaction influence of cultivars and plant density on the seed yield per plot of cultivar Kranskop and Teebus was not significant.

Interaction effect of date of planting, population density and variety. By expressing the combined effects of date of planting, population density and variety in terms of their effects on seed yield per plot, the effects were quantified. Analysis of variance in Appendix Table 6e showed that these three (3) parameters did not significantly influence the weight of seed yield.
Although the interaction effects of the three (3) parameters were not significant, seed yield decreased as the population density decreased from three (3) plants to one (1) plant per hill for variety Alno. For Burik variety, a slight variation in the trend is observed in November planting where population density of two (2) plants per hill was slightly higher than the population density of three (3) plants per hill.

**Weight of 1,000 seeds per plot**

*Interaction effect of date of planting and population density.* The date of planting and population density did not interact significantly to affect the number of 1000 seed weight of the Burik and Alno varieties (Appendix Table 7e).

Result of the study implied that the population density and date of planting did not have the interacting capacity to influence the weight of 1000 seeds of both varieties which is an indication of the possibility of planting these varieties during the months of October, November and December with increasing plant population density without significant effect on the weight of 1000 seeds.

*Interaction effect of date of planting and variety.* Date of planting and variety did not show also any significant interaction effect on the weight of 1000 seeds of both varieties (Appendix Table 7e). The non-significant interaction effect indicates that both factors did not exert strong influence on the weight of 1000 seeds produced by the two varieties. The result could be attributed to the genetic characteristics of the two varieties that influenced the weight of 1000 seeds produced.

*Interaction effect of population density and variety.* The interaction effect of population density and variety on the weight of 1000 seeds per plot was not significant as shown in Appendix Table 7e. The presence of insignificant interaction effect shows that the two factors were independent from each other in influencing 1000 seed weight per plot.

The result confirms the observation of Chandhla (2001) that two cultivars of pole snap beans interaction with plant density was not significant. This may be due to the genetic characteristics of the two varieties that influenced the weight of 1000 seeds produced.
**Interaction effect of date of planting, population density and variety.** Statistical analysis of the interaction effect of the three parameters did not reveal any significant influence on the weight of 1000 seeds of variety Burik and Alno. The two varieties did not respond differently to the different population densities and planting dates. Burik variety, however, produced the highest weight of 1000 seeds (283.67 g) per plot at population density of three (3) plants per hill in October planting and the lowest was at population density of three (3) plants per hill in December planting. For Alno variety, the highest weight of 1000 seeds (263.67 g) per plot was at one (1) plant per hill in October planting and lowest was at two (2) plants per hill in December planting.

Again, the result may be attributed to varietal genetic characteristics of the plants that influenced the weight of 1000 seeds produced.

**Computed seed yield (t) per hectare**

**Interaction effect of date of planting and population density.** In spite of the interaction of the date of planting and population density not being significant, interesting trends in performance among the treatment combinations were observed. Computed seed yield at population density of three (3) plants per hill produced the highest weight (22.61 tons) of seed yield per hectare in all the planting dates followed by computed seed yield at population density of two (2) plants per hill (22.35 tons) in October and November planting but December planting gave the same result with population density of one (1) plant per hill with 15.37 tons/ha.). Computed seed yield produced at population density of one (1) plant gave the lowest weight (12.89 tons/ha) in October planting.

As there was no significant interaction effect is an indication that the weight of seed yield per hectare was not affected by the date of planting and population density combinations (Appendix Table 8e).

**Interaction effect of date of planting and variety.** Interaction effect by date of planting and variety is not significant as reflected in Appendix Table 10e. The non-significant interaction
indicates that the date of planting and variety affected computed seed yield are independent from each other in all treatment combinations applied.

**Interaction effect of population density and variety.** No significant interaction effect between population density and variety on the computed seed yield (t) per hectare was also observed (Appendix Table 8e). However, for variety Burik, the highest computed seed yield of 19.72 tons per hectare was obtained at population density of three (3) plants per hill and the lowest was 15.91 tons at population density of one (1) plant per hill. For variety Alno the highest weight of 19.57 tons seed yield per hectare was obtained at population density of three (3) plants per hill and the lowest was 16.51 tons at population density of one (1) plant per hill.

The result showed that the weight of computed seed yield per hectare increased as the population density increased in both varieties.

**Interaction effect of date of planting, population density and variety.** Date of planting, population density and variety did not interact significantly to influence the computed seed yield per hectare as reflected in Appendix Table 8e. The non-significant interaction effect shows that the three parameters were independent from each other in influencing computed seed yield per hectare.

**Seed Quality**

The data on seed quality which are the percent good seeds per plot, percent germination and percent germination speed as influenced by date of planting, population density and variety is shown in Table 5e.

**Effect of variety**

**Percent good seeds per plot.** The percent good seeds develop was not affected by variety. No significant difference was observed between variety Burik and Alno on the percent good seeds developed (Appendix Table 9e). However, on the average variety Burik gave a slightly higher (95.59) percent good seeds developed than variety Alno as shown in Table 5. The result appears to be
associated with the percent seed germination with Burik variety producing slightly higher percent seed germination than Alno variety.

The result implied that both varieties responded similarly to the percent of good seeds developed.

**Percent seed germination per plot.** Percent seed germination was not significant at 0.05% level of significance by LSD Test (Appendix Table 10e). Numerical differences however were observed between the two varieties. Burik variety gave a higher seed germination rate of 95.59% than variety Alno with a lower seed germination rate of 94.37%. The result may be attributed to the similar quality of seeds produced by the two varieties tested.

**Percent germination speed per plot.** A highly significant variation between the two varieties on the seed germination speed was observed (Appendix Table 10e). Seeds of the Burik variety significantly gave higher seed germination speed of 73.76 percent while the Alno variety registered a lower seed germination rate of 60.76%. The highly striking difference between the two varieties could be attributed to variations in their genetic and morphological characteristics. It was observed that seeds of the Burik variety are bigger and heavier than seeds of the Alno variety. As observed by Griffen (1972), Sorensen and Campbell (1993) relatively heavier seed weight is often correlated with rapid germination and good seedling establishment. Further observation of Sadeghi et al., (2011) stated that large seed size produced the highest germination rate among the cultivars of safflower.

**Effect of population density**

**Percent good seeds per plot.** A highly significant effect of population density on the percent developed good seed was noted in Appendix Table 9e. The result showed that population density strongly influenced the percent of good seeds developed. Population density of one (1) plant per hill significantly produced the highest percent (96.07) of good seeds. However, no
difference between population density of two (2) plants and three (3) plants per hill was observed. It was observed that percent good seeds developed decreased with increasing population density.

The decreasing trend of the percent good seeds from one plant per hill to three (3) plants per hill as shown in Table 5 could be attributed to the amount of sunlight and nutrients absorbed by the plants per hill for their growth and development. In one plant per hill, more light is intercepted and more nutrients are absorbed. In contrast, two (2) or three (3) plants per hill is crowded, thus, competition for nutrients existed with minimal interception of sunlight to shading resulting to lesser carbohydrates accumulated by the seeds.

**Percent germination per plot.** The effect of population density on percent seed germination was insignificant (Appendix Table 10e). Nevertheless, the highest seed germination was 96.22 % at population density of one (1) plant per hill followed by 94.67 % at 2 plants per hill and the lowest was 94.06 % at one (1) plant per hill. The trend noted was a reduction in percent germination with increasing plant density (Table 5).

Ellis (1992) and IRRI (2000) underscored the importance of the effect of population density in the production of quality seeds stating that increased population density may increase yield but may affect quality of seeds developed.

In this study, population density did not have the potential to influence the percent germination of the two varieties tested. The result could be attributed to the percent of good seeds produced at different population density levels with the same trend.

**Percent germination speed per plot.** The population density effect on the seed germination speed per plot is presented in Table 5. Result showed that population density did not significantly influenced the percent seed germination speed as shown in Appendix Table 10e. Nevertheless, the highest germination speed was noted in population density of one plant per hill followed closely by three (3) plants per hill while the lowest was registered by plant population of two (2) plants per hill.
Under the conditions of this study, it appears that regardless of the number of plants per hill, the quality of seeds produced is similar in their respond to germination speed. Again the result may be attributed to the quality of seeds produced.

Effect of date of planting

**Percent good seeds per plot.** A highly significant difference was observed among the different dates of planting as shown in Appendix Table 9e. The highly significant interaction effect indicates that the percentage of good seeds produced responded differently to different dates of planting. December planting significantly produced the highest percent (97.23) of developed good seeds followed by 93.94 % in November planting and the lowest 91.27 % was observed in October planting (Table 5). There seem to be a relationship between the percent developed good seeds and percent germination in the different planting dates. In percent seed germination the highest was noted in November planting followed by December planting and the lowest was in October planting with no significant differences.

The result may be attributed to the climate particularly rainfall and temperature during those months. Generally snap beans require between 200 to 400 mm of rainfall as comparable residual soil moisture during growth and development (Broughton et al., 2003). The temperature requirements for snap beans range from 18 to 29 °C with optimum ranging from 21- 24 °C (PCARRD, 2009). In December planting which has the highest percent of good seeds per plot, the average temperature during the vegetative and reproductive growth from January to March was 19.82, 19.85 and 20.87 respectively. These temperature ranges were within the optimum temperature for snap beans compared with the higher temperature from October to December.

**Percent germination per plot.** The percent seed germination as influenced by date of planting did not differ significantly (Appendix Table 10e). Nevertheless, November planting registered the highest percent seed germination of 96.56 %. However, it was comparable to the percent germination of seeds produced in December and October planting. The result implies that seed germination percentage was not influenced by the date of planting and could be attributed to
the similar climatic conditions favoring seed development and maturation that contributes to high seed germination percentage. The observation of Gutterman (2000) that in many plant species, the fate of the next generations as far as germination of seeds is concerned, is dependent, at least to a certain degree, on the maturation conditions of the seeds when they were still on the mother plant. He further stated that climatic factors operating during the development and maturation of seeds influence seed germinability. A similar observation is applicable in onions (Ellis, 1992) where germination percentage was negatively associated with time of sowing to emergence but rather differences in seed quality influences the percent seed germination.

**Percent germination speed per plot.** Date of planting did not affect the seed germination speed for either of the cultivars as noted in Appendix table 11e. Nevertheless, November planting had the highest germination speed of 72.31 % while October planting had the lowest germination speed of 61.99 %. Germination speed of seeds followed a similar trend with the percent seed germination with November planting having the highest percent germination and October having the lowest while November planting was intermediate.

The result points that date of planting did not influence the seed germination speed of the two varieties of pole snap beans. The result could be attributed to the favorable climatic conditions influencing seed quality. IRRI (2001) reported that seed quality is determined by several factors, one of which is the growing conditions during seed development.
Table 5. Seed quality parameters as influenced by date of planting, population density and variety.

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>% GOOD SEEDS/PLOT</th>
<th>% GERMINATION/PLOT</th>
<th>% GERMINATION SPEED/PLOT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main plot- Date of planting (A)</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>D1- October</td>
<td>91.27c</td>
<td>92.00</td>
<td>61.99</td>
</tr>
<tr>
<td>D2- November</td>
<td>93.94b</td>
<td>96.25</td>
<td>72.31</td>
</tr>
<tr>
<td>D3- December</td>
<td>97.53a</td>
<td>96.30</td>
<td>67.75</td>
</tr>
<tr>
<td>Fc = 22.05**</td>
<td>Fc = 2.11ns</td>
<td>Fc = 1.15ns</td>
<td></td>
</tr>
<tr>
<td>LSD .05 =2.62</td>
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<td></td>
</tr>
<tr>
<td>cv = 3.0%</td>
<td>cv = 7.95%</td>
<td>30.37%</td>
<td></td>
</tr>
<tr>
<td><strong>Sub-plot- Pop. Density(B)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>P1- 1 plant/hill</td>
<td>96.07a</td>
<td>96.22</td>
<td>67.83</td>
</tr>
<tr>
<td>P2- 2 plants/hill</td>
<td>93.50b</td>
<td>94.67</td>
<td>66.67</td>
</tr>
<tr>
<td>P3- 3 plants/hill</td>
<td>93.18b</td>
<td>94.06</td>
<td>67.55</td>
</tr>
<tr>
<td>Fc = 14.44**</td>
<td>Fc = 1.07ns</td>
<td>Fc = 0.063ns</td>
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<tr>
<td>LSD .05 =1.28</td>
<td>LSD .05 =3.33</td>
<td>LSD .05 =7.45</td>
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<td>cv = 1.88%</td>
<td>cv = 4.83%</td>
<td>cv = 15.24%</td>
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</tr>
<tr>
<td><strong>Sub-sub-plot- Variety(C)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>V1- Burik</td>
<td>94.25</td>
<td>95.59</td>
<td>73.94a</td>
</tr>
<tr>
<td>V2- Alno</td>
<td>94.24</td>
<td>94.37</td>
<td>60.76b</td>
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<td>Fc = .003n</td>
<td>Fc = 1.28ns</td>
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<td>cv = 1.96%</td>
<td>cv = 4.18%</td>
<td>cv = 16.21%</td>
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</tbody>
</table>

Means with a common letter within a column in each factor are not significantly different at 5 % level by LSD Test.

**Interaction Effect**

The result of the interaction effects of the date of planting, population density and variety on the percent good seeds per plot, percent seed germination per plot and percent germination speed per plot is presented in Table 5.

**Percent good seeds**

**Interaction effect of date of planting and population density.** A highly significant interaction effect of both factors on the percent good seeds was noted. Varied percentages of
developed good seeds were attributed to the combined influence of date of planting and population density. The highest percent (97.64) good seeds was obtained by population density of three (3) plants per hill followed by one (1) plant per hill in December planting while the lowest of 88.8 % was noted in population density of three (3) plants per hill in October planting.

The highly significant interaction effect indicates that percent good seeds were affected differently by the different population density and date of planting treatment combinations. The significant interaction was due to the fact that percent good seed developed by bean plants in October planting at population density of one (1) plant per hill produced significantly higher percent of good seed than population density of two (2) and three (3) plants per hill. December planting produced the highest percent of good seeds in all the population densities while October planting produced the lowest amount of good seeds in all the population densities applied. Result is presented in Figure 4.

Figure 4. Interaction effect of date of planting and plant population density on the percent good seeds developed.
Interaction effect of date of planting and variety. Interaction effect by date of planting and variety was not significant as shown in Appendix Table 9e. The non-significant interaction indicates that the two parameters affected percent of good seeds to be independent from each other in all treatment combinations applied. However, the highest percent (97.84) of good seeds per plot was obtained by variety Burik in December planting. Alno variety, on the other hand, produced also the highest percent (97.21) of good seeds in December planting.

Although the interaction effects were not significant the trend was that both varieties produced the highest amount of good seeds all in December, intermediate in November and lowest in October planting.

Interaction effect of population density and variety. The population density and variety interaction effect on the percent good seeds per plot was not significant. Nevertheless, the highest percent (96.51) of good seeds was produced by variety Alno at population density of one (1) plant per hill. Variety Burik produced the highest percent (95.62) of good seeds also at population density of one (1) plant per hill. Both varieties produced the lowest percent of good seeds at population density of three (3) plants per hill while population density of two (2) plants per hill was intermediate.

The result implied that population density and variety combined did not have the capacity to influence the percent good seeds developed. The result could be attributed to genetic traits of the varieties, climate, insect pests and diseases.

Interaction effect of date of planting, population density and variety. The interaction effect of the date of planting, population density and variety on the percent good seeds per plot was not significant (Appendix Table 9e).

The insignificant interaction effect indicates that the three parameters affected percent good seeds independently in all treatment combination applied. The result could be attributed to other factors that may have influenced the performance of the two varieties tested.
Percent seed germination

**Interaction effect of date of planting and population density.** The interaction effect of the date of planting and population density is not significant (Appendix Table 10e).

The absence of significant interaction effect is an indication that the date of planting and population density treatment combinations affected seed percent germination independently from each other. The result implied that percent germination may be attributed to the genetic make-up of the seed lot to germinate.

**Interaction effect of date of planting and variety.** The interaction effect of the date of planting and variety on the percent seed germination per plot is presented in Figure 5. The result reveals significant interaction effect of the date of planting and variety on percent seed germination (Appendix Table 10e). The highest percent germination of 98.78 % per plot was obtained by variety Burik in December planting followed by 97.67 % germination November planting. The lowest of 90.33 % was observed in October planting. For variety Alno, highest germination of 95.44 % was obtained in November planting followed by 94 % in December planting and lowest was 9.67 % in October planting (Figure 5).

The significant interaction effect could be attributed to the fact that the percent germination of the two varieties were affected similarly by November and December plantings except in October planting where variety Alno significantly produced higher percent seed germination than Burik.
Interaction effect of population density and variety. Interaction effect of population density and variety on the percent seed germination was not significant as reflected in Appendix Table 10e. The insignificant interaction effect points that population density and variety affected percent seed germination as independent from each other even with all treatment combinations applied. The result could again be attributed to the germinative energy of the seed lot of the two varieties studied. The result indicates that there is a possibility of increasing plant population density of pole snap beans without any effect on the germination percentage of the seeds produced.

Interaction effect of date of planting, population density and variety. Appendix Table 10e revealed no significant interaction effect of the date of planting, population density and variety on percent seed germination per plot. The insignificant interaction result shows that the three parameters were independent from each other in influencing seed germination percentage per plot.

Percent germination speed

Interaction effect of date of planting and population density. According to the results of variance analysis, the interaction effect by the date of planting and population density was not significant (Appendix Table 11e).
The result could be attributed to the genetic characteristics of the seeds and favorable factors during the growth and seed development that influenced seed quality which were not affected by the combined effects of population density and date of planting treatments.

**Interaction effect of date of planting and variety.** Highly significant interactions were observed between the date of planting and variety on seed germination speed as shown in Appendix Table 11e. A highly significant difference was noted between Burik and Alno sown in December. Burik variety registered the highest germination speed of 86.34 % followed by same variety sown in November. Alno sown in December gave the lowest germination speed of 49.16 %. While variety Burik showed higher percent germination speed in November and December planting than the Alno variety, there was a slight increase in the case of variety Alno in October planting (Figure 6).

\[ F_c = 16.93^{**} \quad \text{LSD}_{.05} = 12.12 \quad \text{cv (D)} = 30.37 \% \quad \text{cv (V)} = 16.21 \% \]

Figure 6. Interaction effect of date of planting and variety on the germination speed per plot.
**Interaction effect of population density and variety.** The percent germination speed was not affected by the combined population density and variety treatments as shown in Appendix table 11e. Nevertheless, variety Burik consistently produced higher germination speed than variety Alno across the population density treatment combinations applied.

As there was no significant interaction effect on germination speed, population density and variety did not interact strongly to affect it, indicating the possibility of increasing density without effect on germination speed of the two varieties.

**Interaction effect of date of planting, population density and variety.** The three parameters did not interact significantly to influence the germination speed of the two varieties of pole snap beans (Appendix Table 11e). Higher germination speed for variety Burik remain relatively stable in November and December planting but tend to decrease in October planting across population density treatments. On the other hand, lower germination speed in Alno variety was also stable in November and December planting but producing a somewhat higher speed in October planting across all population density treatment combinations.

The non-significant interaction among the three parameters is an indication that the seed germination speed was not affected significantly by the different treatment combinations applied.
SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The effect of planting date, population density and variety on the growth, yield and yield components and seed quality of pole snap beans of the Burik and Alno varieties were studied in the field to develop a component technology for high seed yield and seed quality of pole snap beans in Ifugao. A total of 11 variables were measured and compared, three (3) of which are growth parameters, five (5) are yield parameters and three (3) are seed quality parameters. Growth parameters included were the days to flowering, days to seed maturity and number of lateral branches. Yield parameters included were number of pods per plant, number of seeds per pod, weight of 1000 seeds, total weight of seed yield per plot and computed seed yield per hectare. Seed quality parameters included were percent good seeds produced, percent germination and germination speed.

The Analysis of Variance (ANOVA) was used to determine the significant differences between and among treatments and the Least Significant Difference Test was used in comparing treatment means.

Growth parameters

The study revealed variations in response to planting date, population density and variety. Plant maturity was advanced 12 days earlier in December planting than November and October planting. Conversely population density did not affect the length of maturity of the snap beans. For variety, Burik significantly matured 2 and half days earlier than variety Alno. The number of lateral branches of Burik and Alno were not affected by the date of planting, population density and variety as there were no observed significant interaction effects obtained. The result indicates the importance of identifying the best date of planting pole snap beans.
Yield and Yield Components

Similarly, yield components showed variations in response to date of planting, population density and variety treatment combinations applied. The data can be summarized as follows:

1. The number of pods produced per plant was not influenced by date of planting, population density and variety. There were also no significant interaction effects of the date of planting, population density and variety on the number of pods per pod.

2. The number of seeds per pod was significantly influenced by the date of planting but not influenced by population density. November planting gave the highest number of seeds per pod. December planting gave the lowest number of seeds per pod while October planting gave slightly higher number of seeds than December planting. Variety Alno produced higher number of seeds per pod than variety Burik. There were no significant interaction effects obtained on the date of planting, population density and variety on the number of seeds per pod.

3. The weight of 1000 seeds is significantly higher in variety Burik than variety Alno. The variation is attributed to the genetic trait of the variety. The weight of 1000 seeds was not influenced by the date of planting and population density levels. There were no interaction effects obtained between and among the different treatments on the weight of 1000 seeds per plot.

4. The total weight of seed yield per plot was highest in November planting and lowest in October planting. The highest yield was associated with the favorable temperature and rainfall during those periods. The total weight of seed yield per plot increase as population density level increase also. The increase was associated with the increase number of pods per plant though there were no significant variations among the population density level. Total weight of seed yield per plot in both varieties was similar. There was a highly significant interaction effect by date of planting and variety while the other independent parameters did not show significant interaction effects.
5. Computed seed yield per hectare was highest in November planting and lowest in October planting. Computed seed yield per hectare increases as the population density increases also. There were no significant interaction effects on the date of planting, population density and variety on the computed seed yield per hectare.

The result is indicative of the importance of determining the best planting date and appropriate population density in increasing the productivity of pole snap beans. Further, the limited land resource cultivated for pole snap beans will be optimized in its use in pole snap bean seed production.

**Seed Quality**

Seed quality is measured in terms of percent good seeds produced per pod, percent germination rate and percent germination speed showed variations in their response to date of planting, population density and variety. Data on seed quality can be summarized as follows:

1. On the percent of good seeds produced per plot, date of planting gave a highly significant effect while population density and variety did not show any significant effect on the percent good seeds developed. November planting gave the highest percent of good seed produced and lowest was in October planting. The highest percent of good seeds produced per plot could be attributed to the favorable climate during those months. Population density and variety did not influence the percent of good seeds produced but a highly significant interaction effect of the date of planting and variety on the percent of good seeds produced was observed.

2. Percent seed germination per plot was highest in November planting but with no significant difference with the November and October planting. Population density of one (1) plant per hill gave the highest percent germination but there was no significant variation with population density of two (2) and three (3) plants per hill. Both varieties gave almost the same percent seed germination rate. There was a highly significant interaction effect by the
date of planting and variety on the percent seed germination rate. Other parameters did not interact significantly to affect the seed germination rate.

3. Percent seed germination speed was higher in variety Burik than variety Alno. The higher germination speed could be attributed to genetic trait of the variety and other factors like climate. Germination speed was not influenced by the date of planting and population density but a highly significant interaction effect by date of planting and variety was detected which shows that germination speed was influenced by the combined effect of date of planting and variety.

The technology generated on seed quality has particular relevance on the production of good quality seeds for higher productivity in pole snap bean production.

Conclusion

Based on the above findings, date of planting, population density and variety influenced the growth, yield and yield components and seed quality of pole snap bean seed production in Ifugao. Increasing yield and producing quality seeds of pole snap beans for planting is dependent on the variety, population density and date of planting. Variety Burik demonstrated better performance than variety Alno in the length of maturity, seed yield weight of 1000 seeds, germination percentage and germination speed. Germination percentage and speed are varietal genetic trait. Population density of three (3) plants per hill produced higher seed yield, higher weight of 1000 seeds and computed seed yield per hectare, a potential for increasing seed yield per unit area. Weather conditions in November and December are conducive for snap bean seed production for earlier maturity, higher seed yield, higher weight of 1000 seeds and higher percent of good seeds.

Recommendations

In view of the above-mentioned findings, the following recommendations were made;

1. Burik can be used for seed production for earlier maturity, higher seed yield, good seed quality, germination and rapid germination speed.
2. Population density of three (3) seeds per hill for higher seed yield and computed seed yield per hectare.

3. November to first week of December planting for earlier seed maturity, higher seed yield, computed total seed yield per hectare and higher percent good seeds.

4. Further studies on other parameters for growth, seed yield and seed quality be conducted to come up with complete information along this practice and at improving snap bean seed production in the farmer's field.

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APPENDIX

Pictorial Representation

The Alno Seeds

The Burik Seeds

Field layout and land preparation
With Dr. Delfin Ordonio, Dr. Edwin Ramos and Dr. Jimmy Carreon inspecting the field layout
Dr. Edwin Ramos checking the field layout
Sowing seeds for December planting

The research site at the IFSU Model Farm, Nayon, Lamut, Ifugao
Observing flower bud formation
Burik variety  
Alno variety  

Flower formation stage

Counting the number of lateral branches and pods per plant

Observing leaves and pods damaged by insect and disease
Alno variety at two (2) plants per hill

Burik variety at two (2) plants per hill

Monitoring the research by Dr. Edwin Ramos and Dr. Delfin Ordonio
Harvesting matured pods

Pods already harvested for October planting

Sun drying of harvested bean pods

Selecting good seeds

Normal Seeds  Abnormal Seeds

Normal Seeds  Abnormal Seeds
Weighing and recording seed yield, 1000 seed weight in the laboratory
Germinating seeds through ragdoll method

Counting and recording germinated seedlings

Germinated seedlings of the Burik variety
Germinated seedlings of the Alno variety