UNIVERSITY SAAD DAHLAB of BLIDA

Faculty of Natural and Life Sciences

Department of Biotechnology

THESIS FOR THE DOCTORATE DEGREE

EFFECT OF PLANT DENSITY AND DOSE OF NITROGEN AND POTASSIUM ON PERFORMANCE OF GREEN BEAN

(*Phaseolus vulgaris* L.)

By

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Blida, May 2018

ABSTRACT

This experiment was executed in a split randomized complete block design arrangement with three replications and four plastic pots used as an experimental units. The treatments consisted of two plant densities (D), (D_1) one plant per pot and (D_2) two plants per pot used as main plot, and seven fertilizers doses (F), (N_0 K_0; N_1 K_0; N_1 K_1; N_2 K_0; N_2 K_2; N_0 K_1; and N_0 K_2) used as sub plot. N_0, N_1 and N_2 equal to 0, 0.46, and 0.92 g urea, while K_0, K_1 and K_2 equal to 0, 0.42 and 0.84 g potassium respectively. The results showed that the higher density (D_2) increased positively or significantly plant height. Contrary, number of leaves and branches (except in second season, at third and second reading respectively), days required to reach 10 and 50% flowering and plant dry matter were not affected. Even though the low density (D_1) significantly increased shoots dry weight, number of pods and pod yield per plant, pods yield per hectare decreased. High dose of nitrogen and potassium (N_2 K_2) significantly increased days to reach 10 and 50% flowering, plant dry weight, number of pods and pods yield per plant and yield ton per hectare in the first season, while in second season the higher values of these yield parameters obtained by a plant received lower dose of nitrogen without potassium (N_1 K_0). The interaction between them significantly affected the number of branches whereas; the higher means on dense planting (D_2) received no fertilizer (N_0 K_0). Low density (D_1) treated by higher dose of both nutrients (N_2 K_2) gave the heaviest plant dry weight. The number of pods and pod yield per plant significantly increased at low density (D_1) receiving nitrogen at low or high dose containing potassium or not (N_1 K_0; N_1 K_1; N_2 K_0 and N_2 K_2) and the difference between these treatments were positively. In the first and second season, dense planting (D_2) treated by higher dose of both fertilizers (N_2 K_2) and lower dose of nitrogen without potassium (N_1 K_0) gave the greatest yield per hectare, respectively.

Keywords: Bean Cv. Djadida; Nutrient Competition; Yield.

RESUME

Le dispositif expérimental adopté pour cette expérimentation est un split plot avec trois répétitions et quatre unités expérimentales. Les traitements sont constitués de deux densités de plants (D), avec (D_1) un plant par pot et (D_2) deux plants par pot respectivement et sept doses d'engrais selon les traitements suivants (F), (N_0 K_0 ; N_1 K_0 ; N_1 K_1; N_2 K_0 ; N_2 K_2; N_0 K_1; et N_0 K_2) utilisé comme sous-trame. N_0, N_1 et N_2 égales à 0, 0.46, et 0.92 g urées, tandis que K_0, K_1 et K_2 égales à 0, 0.42 et 0.84 g potassium respectivement. Les résultats ont montré que la densité la plus élevée (D_2) a un effet positif ou significatif sur la hauteur de la plante. Contrairement, le nombre des feuilles et des branches (à l'exception de la deuxième saison et ceci uniquement pendant la deuxième et troisième lecture, respectivement), le nombre jours requis pour atteindre 10 et 50% de la floraison et de la matière sèche des plantes n'ont pas été affectés. Bien que la faible densité (D_1) ait augmenté significativement le poids sec, le nombre de gousses et le rendement par plant. En revanche, le rendement par hectare a diminué. La dose élevée d'azote et de potassium (N_2 K_2) a significativement augmentée le nombre jours requis pour atteindre 10 et 50% de floraison, le poids sec de la plante, nombre de gousses et le rendement par plante, le rendement par hectare en première saison. Tandis qu'en deuxième saison, la valeur la plus élevée pour ces paramètres de rendement obtenus chez les plantes qui ont reçu la faible dose d'azote sans potassium (N_1 K_0). L'interaction entre eux a significativement affectée le nombre des branches tandis que les moyennes les plus élevés ont enregistrées chez la densité de plantation (D2) qui n'a pas reçu d'engrais (N_0 K_0). Une faible densité (D_1) combinée à des doses élevées en azote et potassium (N_2 K_2) a donné le poids sec le plus élevé. Le nombre de gousses et le rendement par plante augmente significativement à une faible densité (D_1) avec des apports faibles ou élevé en azote et en potassium (N_1 K_0; N_1 K_1; N_2 K_0 et N_2 K_2) et la différence entre ces traitements était positive. En première et deuxième saison, la densité de plantation (D_2) combinée à une dose élevée avec de (N_2 K_2) et une petite dose d'azote sans potassium (N_1 K_0) ont donné respectivement le rendement par hectare le plus élevé.

Mots clés: Haricot Cv. Djadida; concurrence nutritionnelle; rendement.

الخــلاصة

أجريت هذه التجربة بتصميم القطاعات العشوائية المنشقة بثلاث مكررات وأربعة اصص بلاستيكية استخدمه كوحدات تجريبية. إحتوت المعاملات على كثافتين نباتيتين (D)، نبات واحد بالأصيص (D_1) و نباتين بالأصيص (D_2) استخدمت كوحدات رئيسية، و سبع جرع سماد من النتروجين و البوتاسيوم (F)، $N_0 K_0$؛ $N_1 K_0$؛ N1 K_1؛ $N_2 K_0$؛ $N_2 K_2$؛ $N_0 K_1$ ؛ $N_0 K_2$ استخدمت كوحدات فرعية. N_0، N_1 و N_2 تساوي 0، 0.46 و 0.92 جرام يوريا، بينما K_0، K_1 و K_2 تساوي 0، 0.42 و 0.84 جرام سلفات البوتاسيوم، على التوالي. أظهرت النتائج أن الكثافة النباتية العالية (D_2) أعطت زيادة موجبة أو معنوية في طول النبات. على العكس، عدد الأوراق والفروع (عدا الموسم الثاني في القراءة الثالثة والثانية على التوالي)، والأيام المطلوبة للوصول إلى 10 و 50% إزهار ونسبة المادة الجافة بالنبات لم تتأثر. بالرغم من أن الكثافة المنخفضة (D_1) زادت معنوياً الوزن الجاف، وعدد وإنتاجية القرون بالنبات، إلا أنها أدت الى إخفاض الإنتاجية بالهكتار. الجرعة الزائدة من النيتروجين والبوتاسيوم ($N_2 K_2$) زادت معنويا عدد الأيام المطلوبة للوصول الى 10 و50٪ إزهار، وزن النبات الجاف، عدد القرون وإنتاج النبات والإنتاجية بالهكتار في الموسم الأول، بينما في الموسم الثاني القيم الأعلى لقياسات الإنتاجية هذه أعطيت بواسطة النباتات المعاملة بالجرعة الأقل من النيتروجين بدون بوتاسيوم ($N_1 K_0$). التفاعل بينهما أثر تأثيراً معنوياً على عدد الفروع حيث أن أعلى متوسط كان في الكثافة العالية (D_2) التي لم تعامل بأي سماد ($N_0 K_0$). الكثافة المنخفضة (D_1) المعاملة بالجرعة الأعلى من كل من السمادين ($N_2 K_2$) أعطت أثقل وزن جاف للنبات. عدد القرون وإنتاج القرون بالنبات ازداد معنوي في الكثافة المنخفضة (D_1) و المعاملة بالجرعة المنخفضة أو المرتفعة من النيتروجين و المحتوية أو غير محتوية على البوتاسيوم (N_1 K0؛ $N_1 K_1$؛ $N_2 K_0$ و $N_2 K_2$)حيث أن الفرق بين هذه المعاملات إيجابياً. في الموسمين الأول والثاني، أعطت الكثافة النباتية العالية (D_2) المعاملة بالجرعة الأعلى من كلى السمادين ($N_2 K_2$) والجرعة الأقل من النيتروجين بدون البوتاسيوم ($N_1 K_0$) أعلى عائد من الإنتاج بالهكتار، على التوالي.

كلمات المفتاح: الفاصولياء الصنف جديدة: المنافسة على الغذاء: الإنتاج.

ACKNOWLEDGMENTS

Merciful to Alla who Help me to present this Research. Also I Would Like to Thank my Supervisor Professor. Benmoussa, the Students of the Laboratory of Vegetable Biotechnology Production for their Support Intellectual and Handwork, The Ministry of Higher Education and Scientific Research (Republic of Sudan) and The Ministry of Higher Education and Scientific Research (Republic of Algeria) for The Scholarship.

With my Regards: Abdalla

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CHAPTER 1
INTRODUCTION

Green Beans are dicotyledonous plants and members of the family, Fabaceae (Leguminosae) forming part of the species (*Phaseolus vulgaris* L.). Growth habit can be bush or pole-type. Bush type, which does not have to be trellised, is the common type grown for commercial production, its short erect plants (determinate growth) that grow 0.3 to 0.6 m tall and have a somewhat uniform pod set. Acceptable snap bean quality includes well-formed and straight pods, bright in color with a fresh appearance, free of defects, tender (not tough or stringy) and firm [60]. Pod appearance, texture and curvature are the major physical qualities that directly influence pod quality for the fresh market. The diameter of the pod, rather than length, is a good indicator of quality. Buyers prefer pods with no or only slight bulges that indicate tender, young seeds. As the name implies, snap bean should break easily when the pod is bent, giving off a distinct audible snap [190]. Rich in nutrients containing a relatively high percentage of protein where consume freshly as green pods or as dry seeds [55]. Snap bean it is a valuable source of carbohydrates, calcium, iron, phosphorus and vitamins, particularly vitamin B. It is an important vegetable grown both for tender pods and dry seeds, which form a rich source of crude protein (21.25%), fat (1.7%) and carbohydrates (70%). Besides, it contains 0.16 mg iron, 1.76 mg calcium and 3.43 mg zinc per 100 g edible part. They require less energy to cook since they are consumed as vegetables and are rich in vitamins, minerals and dietary fiber, and source that can contribute to dietary calcium requirements in humans [139; 197]. Beans plant considered one of the important vegetable crops cultivated in many African countries for local markets, and one of the important vegetable crops used as a source of foreign currency [122]. More than 90% of snap bean produced in Africa is exported to within Africa or to other international markets such as Europe [70]. [262] indicated that compared to dry beans, snap beans have a high market value, mature much earlier and have longer harvest duration.

There is no denying that supplying sufficient food for the rapidly growing population of the world presents one of the greatest challenges facing mankind at the present time. Because there is so little reserve land suitable for cultivation, it is only possible to increase food production by increasing crop production per unit area. But, it is not only the quantity of food produced that should concern us, its nutritional quality is also important. Supplying the world's food is the business of both farmers and research scientists in developed and developing countries alike. Snap bean are legumes that can fix atmospheric nitrogen when the seed is properly inoculated with a suitable strain of bacteria, commercial snap bean growers do not inoculate their crop, choosing instead to rely on chemical fertilization [130]. Fertilizers offer the best means of increasing yield and of maintaining soil fertility at a level sufficiently high to ensure that good yields can be obtained consistently, year after year. Nitrogen is one of the most limiting nutrients to plant growth. Its supply to plants is mostly done through the application of mineral fertilizers [167]. The practice is not only expensive, but also unsustainable to small scale poor farmers such as those found in Africa who cannot afford to purchase them [21; 164; 265]. Low crop productivity is a general problem facing most farming systems in Africa. According to [183] estimate for the year 2006, world beans production was 1235 kg ha^{-1} while, that of Africa was 799 kg ha^{-1}. The average beans yield per annum in many African countries is always lower than that of the world. These low yields are pronounced in grain legumes and are often associated with declining soil fertility and reduced nitrogen fixation due to biological and environmental factors [178] while, potassium is improving fruit quality is an important element in legume nutrition [128]. Many studies explaining the utilization of fertilization, according to the area, taking no account of plant population applying in this area. Practically, a suitable combination of plant density, nitrogen and potassium level is very important to produce higher yields with unique of French bean. The objective of this study was to investigate the effect of plant density and dose of nitrogen and potassium on Green Bean Cv. Djadida.

CHAPTER 2

LITERATURE REVIEW

2. 1. General requirements of Green Bean

Bean plants are relatively sensitive to environmental stresses that may occur in the field compared to the other vegetable crops which negatively affect its growth, yield and even the quality of the pods [3]. Bean growth, pod quality and yield were greatly affected by variety, relative moisture, light, temperature (growing season), soil type, pH and salinity, drainage, plant population and other cultural practices [9]. Many of the different types of beans and varieties available will grow in high tunnels. Varieties should be selected to meet production goals and market demands. Some factors to consider when choosing varieties are: growing environment, available space, market requirements, and desired use. There are two common types of beans: bush and pole. Bush varieties do not require trellis systems and normally mature 50 to 60 days after planting. According to [77] Pole varieties require trellises to support their growth and extended production over many weeks. Beans require regular watering to prevent poor early vigor, inadequate leaf cover, and flower drop. Because beans are subject to soil crusting, pre irrigate the high tunnel before planting. As temperatures increase and plants grow, irrigation rates should be increased to meet plant needs. Overhead irrigation is not recommended as an increase in pathogens may result. It is important to prevent moisture stress during flowering, pod set, and pod growth. Water stress is known to influence the pod shape and quality. With dramatic temperature changes in the high tunnel on sunny days, monitoring temperatures closely will limit possible water stress to plants. Soil type greatly affects water holding capacity and will influence how often watering is required. Beans require well-drained, sandy loam soils, which warm rapidly in the spring. It’s grown on many soil types in a pH range of 5.5 to 7.5; the optimal pH for is 6 to 6.5. It is a warm season crop, are forest sensitive plant, the optimal temperature for plant growth is 18,3^{o} to 29.4°c [130]. [140] indicated that the nap bean is a heavy feeder and its production is best suited to friable, deep and well drained soils high in organic matter. Heavier soils can be productive, provided they have good drainage and proper irrigation management [77]. [42] found that the optimum yield of fresh pods is eight tons per hectare.

2. 2. Plant density

Plant density it means the total number of plants per unit area. From the definition density is a combination of two main factors; plant number and the area which receiving this plant. Plant population, it can be given by increasing seed rate per unit area. The selection of optimum seed rate is another important cultural practice and is mainly controlled by seed size, vigor, and germination percentage, sowing methods and required plant population of the crop. The interest in studies regarding the seed rates is further increased due to higher prices of good quality seed. Both higher and lower seed rates than the optimum is the principle cause of low yield [12]. Maximizing the yield of green beans requires a review of the current used plant population density in order to determine a population that could produce the highest yield of good quality maximize the use of the land and help solve problems on weed management, disease and pest incidence and low yield. Most farmers are not sure of the appropriate plant density to use. They either use very high plant density or very low plant density with no definite plant arrangement. This results in poor seed yield both in quality and quantity. This problem is critical because most of the agronomic studies are directed to dry beans, soybean and other pulses. As a result, green bean seed producers borrow some agronomic practices recommended in other countries and sometimes take packages developed for dry beans and soybeans. Plant spacing affects plant growth and yield due to increased competition with increased plant population. Moreover, the optimum plant population differs with the availability of soil moisture, relative humidity and nutrients [87]. Growth habit affected plant density, cultivars with upright growth forms have a higher plant population than vine or semi vine types, because the upright forms performs much better in narrow rows. Moreover, the environmental potential of the soil would help to determine the most favorable plant population required [72]. Green beans which can be grown as a cultivated row crop or as a non-cultivated narrow-row crop like small grains, respond favorably to narrow row spacing. It is best to grow 30 plants per m^2 [235]. When a seed size of 35 g /100 seeds with a germination of 80% is used, green beans are established at 130 kg of seed per hectare. In a study ranging from 80 to 300 kg the optimum seeding rate was 160 kg ha^{-1} [236].

2. 2. 1. Effect of plant density on growth parameters

Plant height increases with the increase of plant density because of competition of light [81]. Green beans can be planted at a rate of 250000 up to 350000 seeds per hectare. Row width, irrigation type, time of year etc, will determine the final decision. The average stand is usually between 250000 and 280000 seeds per hectare, depending on grade. According to [250] row spacing can however vary from 45 cm between rows to 90 cm or more between rows. Maximum plant height was obtained from the highest plant density (500 x 10^3 plants ha^{-1}) and the lowest from the lowest plant density (250 x 10^3 plants ha^{-1}) [184]. [199] investigated different plant spacing (30 x 10, 30 x 15 and 30 x 20 cm) on French bean. They found that tallest and the shortest plant presented at the large and narrow plant spacing respectively. In addition to they also, found the number of branch per plant significantly affected by plant densities, there was gradual increase in number of branch per plant with increasing spacing. They reported that the wide spacing produced vigorous plant with production of more leaves per plant. More availability of nutrient, moisture and spacing under wide spacing might be the cause of such higher number of leaves per plant, while close spacing produced the lowest number of leaves per plant. Longer time required to flowering was found in case of less plant density per unit area and shorter time was recorded in the case of closed plant density. [100] reported that growing bush beans at 91cm inter row spacing gave the highest leaf area index but the lowest light interception compared to 45.5 cm spacing. [273] reported that in cowpea, cultivar choice will affect plant population.

When the plant density per unit area was increased, the numbers of secondary branches per plant were decreased [47]. [256] used different plant densities of beans 30, 45 and 50 plants m^{-2} are reported that the maximum growth rate was obtained at the highest plant density. [187] examined several plant population densities 125000, 163265, 222222 and 320000 plants ha^{-1}. They found the lowest plant height was noted in the lower plant density and the tallest plants in plots with the highest plant density. There was significant influence of plant population to the number of branches per plant. There seemed to be a decreasing pattern in the parameter as plant density increased. The highest number of branches was recorded on the lowest population density and the lowest on the highest plant population. This implies a negligible role of plant population density treatments in influencing the number of days to 50% flowering. [142; 258] they indicated that the dense plant population increased the plant height due to competition among plants. The increase in plant height is due to inter-plant competition which, resulted to taller plants which were sparsely branched. Plant population density had a major effect on the number of branches per plant, at lower density, the interplant competition seemed to be less, and thus plants utilized the available resources with little competition [39]. [188] evaluated the effect of intra-row spacing of 10, 15, 20 and 30 cm. They found that intra-row spacing of 10 and 15 cm recorded the highest plant height but, were not significantly different from intra-row spacing of 20 cm. The shortest plant height was observed at intra-row spacing of 30 cm. Intra-row spacing of 20 cm produced the highest number of branches which, was statistically similar to that of 15 cm but significantly different from those of 10 and 30 cm. The widest intra-row spacing of 30 cm produced the least number of leaves while, the highest leaf number was observed at a spacing of 20 cm between plants. Plant dry weight increased significantly with increased intra-row spacing up to 20 cm beyond which it decreased. However, there were no significant differences between intra-row spacing of 15 and 20 cm. The spacing of 30 cm between plants produced the lowest dry weight followed by that of 10 cm. [87] conducted an experiment to evaluate the effect of plant population on the growth of bean cv. Star 2052. Six plant populations (10, 15, and 20 cm plant spacing x 2 and 3 plants hole^{-1}) to give 120000, 180000, 90000, 135000, 60000 and 90000 plants fed^{-1}, respectively. They found that the increase of both plant spacing and planting density up to 15 cm x 3 increased plant height. Increasing of either plant spacing up to 15 cm or planting density up to 3 plants/hole increased plant height. The same effect on plant height was obtained by their interaction, where the highest plants were obtained at 15 cm plant spacing and 3 plants/hole. However, the highest number of branches was obtained at the widest spacing (20 cm) and the lower number of plants per hole (2 plants/hole). Increasing plant spacing or number of plants per hole increased number of branches per plant. Increasing of planting density within the same spacing reduced number of branches and the same was reflected by increasing of space within the same density. The highest number of leaves was obtained at the middle plant spacing with the highest planting density. Both plant spacing and planting density showed no significant effect on the number of leaves. [206; 11] reported increases in plant height in densely planted French beans. [66] reported that the increase in branches number with increasing in intra-row spacing of French beans. In addition, [94] indicated that the increasing plant density in cowpea resulted in decreased branches and leaves number per plant. [186] attributed increased growth rate in sparsely populated plant to less competition for space, nutrients, moisture and light.

The population could be increased with benefit up to a point of complete light interception [276]. [144] reported a significant effect of seed rates on plant height of rice bean. [1] they reported a significant increase in plant height with increased rates of nitrogen. A significant increase in number of branches per plant by application of nitrogen [26; 287]. [51] observed inverse relationship between seed rate and the number of branches per plant. In beans the significance plant population [59] and plant arrangement [157] has been reported. The seeding density affects the plant growth due to its direct relation with plant population. The higher plant population increases competition among plants for nutrients, light and space while, lower population density causes inefficient use of natural resources and inputs [156]. [56] used different plant densities (63, 74, 88, 111, 148, 222, and 444 thousand plants ha^{-1} in 45 cm rows), reported that the plant density did not affect days to 50% flowering or maturity, plant height or show evidence of density-induced mortality, but slightly decreased the number of branches per plant. No significant effects on time to flowering were noticed due to increased plant spacing or planting density or their interactions [87]. The comparison of treatment means did not reveal any significant differences in the number of days from seedling emergence to flowering [187]. [7] found significant effects of plant population on time of flowering. Number of days for 50% of plants to be flowered was significantly affected by different planting densities.

Lower planting densities needed higher number of days for blooming. This could be related to the supportive effects of more available fertilizers to lower number of plants per unit area which permitted the building of more vigorous growth that resulted in a higher number of days for blooming of the bean plants.

Increasing plant spacing or reducing planting density increased both shoot fresh and dry weights. The interactions between plant spacing and planting density showed positive effects on both fresh and dry weights. However, the highest values of both were obtained at the middle plant spacing (15 cm) and the lower planting density (2 plants/hole) [87]. The total dry weight of leaves and crop growth rates relative crop growth rate were decreased with increasing plant densities [212]. There was fluctuating in growth of cluster bean at various seeding rates [24]. The early studies done by [230; 180] indicated that the dry matter was significantly increased with increase in seeding rates. The highest dry matter yield was obtained with seeding rates of 50 kg ha^{-1}. This increase can be attributed to more plant population at given seed rates. [199] found that the highest fresh weight obtained from lower density, while the lower weight obtained from higher density. [147] found that there was an increased dry weight in French beans with increase in row spacing. The low dry weight observed at the widest intra-row spacing of 30 cm [188]. [153] observed greater dry matter production in cowpea at higher plant density. [209] studied different plant densities of winter field beans under six target plant population densities ranging from 10 to 80 plants m^{-2}. They found that the total dry matter production increased to the maximum and then declined. However, growth rates slowed at pod set due to the change in the chemical composition of the newly synthesized biomass from carbohydrate to protein at that time. It was proposed that changes in plant population density affected the competition for assimilates within a plant rather than the competition for light between different plants.

2. 2. 2. Effect of plant density on yield parameters

Studies on the impact of various plant densities indicate that changing density through altering the radiation level, useable for plants, and competition between plants may affect both the yield and the yield components considerably; as the plant density is increased per unit area, the absorbed light as well as the efficiency of using total yield radiation will be increased, as well. When the plant density per unit area is increased, the single plant yield, number of secondary branches per plant, pods per plant are decreased, while plants yield per unit area is increased [47; 215]. Space inside the high tunnel is valuable and plants should be arranged to utilize all available space. As in row spacing increases, yield per plant and fruit size increases. However, total high tunnel yield decreases due to decreased plant numbers. With bush beans, planting rows can be arranged 12 to 15 inches apart with 2 to 3 inches between seeds [77]. [201] reported more nutrients available for fewer plants at lower plant density and higher competition at higher plant density. Green beans which can be grown as a cultivated row crop or as a non-cultivated narrow row crop like small grains, respond favorably to narrow row spacing. [187] estimated different plant population densities (125000, 163265, 222222 and 320000 plants ha^{-1}) Plant population density was found to have a significant depressive effect on number of pods per plant. The low population density had the highest number of pods per plant, while the lowest number of pods per plant was recorded in the highest population. Generally, there were fewer pods at the lower branches than at the upper part of the main shoot. Variation of plant population affects total bean yields [185]. [81; 186] attributed increased growth rate in sparsely populated plant to less competition for space, nutrients, moisture and light A markedly response of pods per plant to population density. [142; 39; 243] observed that there was an increase in pods with an increase in the row spacing because lower populations was more efficient in utilizing the resources of production than the higher plant densities. [20] concluded that the population density did not at all affect the number of seeds produced per pod. A general observation that yield increased up to an optimum plant population [185] attributed the increase in yield to the increased densities per unit area. [232] regarded that the higher population density contributes to higher yield. [17; 238] found that the number of plants per unit area seems to be more critical than the number of pods per planting influencing yield per unit area. For a given plant density, planting the green bean at more equidistant spacing results in higher yield as compared to the same population when plants are in the more rectangular arrangement. Yield of plants depends on both plant density and the spatial arrangement of these plants (plant rectangularity), that is, the ratio of the distance between plants within the row to the distance between the rows. This is primarily due to the increased of total solar radiation interceptions, which influence the number of seeds per pod. The decrease in seed yield with an increase in inter row spacing and decrease in intra row spacing indicate that it is possible to increase seed yield of green bean by adopting square arrangement pattern. This highlights shown the importance of equidistant spacing even at a high plant density as a way of optimizing production. The decreasing trend of the percent good seeds from low plant population to high plant population could be attributed to the amount of sunlight and nutrients absorbed by the plants per unit area of their growth and development. Although, higher rates of sowing and narrow rows tend to produce higher yields, seed cost is an important restriction to optimum seeding rate [237]. Despite good coverage of the crop, very limited work has been done on its agronomic management and varietal improvement. Constraints that contribute to low productivity of green beans include improper cultural practices and lack of good quality seeds leading to sub optimum plant stand resulting in poor yield [238]. When the plant density per unit area was increased, single plant yield and pods per plant are decreased, while plants yield per unit area increased [47]. Different varietal responses to plant density were observed in other growth measurements. Increased plant population decreases plant pod yield, but increases pod yield per unit area. However, after a certain range, depending on the crop and cultivar both will be decreased. [9] reported that high plant density (25 plants m^{-2}) gave the highest pod yield per unit area. There was no significant difference in pod size distribution between treatments. [272] studied the effects of the three planting designs; they found that higher planting densities (up to 116 plants m^{-2}) gave higher pod yields per unit area. [56] found that increasing plant density of cowpea increased the yield. However, the weight and numbers of pods per plant decreased as density increased. The number of pods per plant was the most yield components affected by the plant density. Pod size was reduced by density increments of 148 to 444 thousand plants per hectare. Pod moisture content was slightly reduced by plant densities of 222 and 444 thousand plants per hectare, but the grading quality of the pods and their fiber and protein contents were unaffected. The results indicated that high yields of good quality pods could be obtained from increased plant density up to

148 thousand plants per hectare. [220] studied different plant densities of beans (68, 109, 156 and 317 thousand plants ha^{-1}), they recorded that total and marketable yields were not linearly related to plant density. Doubling of plant density up to 317 thousand plants per hectare had no significant effect on beans yield. They recommended a plant density of 60 to 100 thousand plants per hectare for the highest economic yield of beans. [158] suggested that pod yield of bush bean could be increased by increasing plant density and reducing the rectangularity of the spatial arrangement of plants in the field. [256] tested several plant densities of beans (30, 45 and 50 plants m^{-1}) reported that the beans yield increased with increasing plant density in all tested cultivars. [260] reported that densities of at least sixty plants per m^2 were required to ensure that yield was not limited by sowing rate. Differences in yield in response to changes in density were reflected particularly in changes in number of pod-bearing nodes per plant, but also to a lesser extent in a number of pods per pod-bearing node. Differences in the number of beans per pod and number of pods per pod bearing node tended to equalize the yield of the two cultivars. [64] evaluated three plant densities of 44, 25 and 16 plants m^{-2}, established at spacing of 15 x 15, 20 x 20 and 25 x 25 cm in crates of size 60 x 55 x 20 cm. found that the yield per unit area increased from 354 to 581 g m^{-2} as plant density increased from 16 to 44 plants m^{-2} while, yield per plant decreased from 22.1 to 13 .1g, and when he worked at densities of 200, 139, 100 and 69 plants m^{-2}, established by at spacing of 10 x 5, 12 x 6, 10 x 10 and 12 x 12 cm in crates of size 60 x 55 x 20 cm. Reported that the yield per unit area increased from 462 to 822 g m^{-2} as plant density was increased from 69 to 139 plants m^{-2}, beyond which yield declined to 783 g m^{-2} yield per plant decreased from 66 to 3.9 g per plant as plant density increased from 69 to 200 plants m^{-2}. [138] tested different plant density (13, 16 and 22 plants m^{-2}). They showed that plant density had a significant effect on number of pods per plant, grain yield, biological yield and harvest index. The plant density of 13 plants m^{-2} had the highest number of pods per plant. The most stable component of yield throughout was number of beans per pod, and the least stability was the number of pod-bearing nodes per plant. The higher values of both pod length and diameter were observed at the widest plant spacing and the lowest planting density (plants/hole). Growing faba bean at six densities (13, 25, 38, 50, 63 and 75 plants m^{-2}). [104] reported a diminishing

yield response to density over that range of densities, where the optimum economic seeding density was 38 plants m^{-2}. Density had highly affected all yield components except seed weight. The primary yield component, pods per plant, exhibited the greatest sensitivity to changes in plant density. [52] tested the performance of different plant density on dry bean yield, founded that the greater yields of bean were attained by increasing density from 24 to 48 plants m^{-2}. Among the various factors that contribute towards the attainment to potential yield of French bean, optimum plant spacing or plant population is one of the important factors [206]. Higher plant populations increased yields of snap beans and black beans [88; 251]. However, fruit size or quality characteristics have generally been lower at high plant populations. Insects and pathogen population may be higher and more difficult to control at high plant densities. [207] reported that the choosing an optimum plant population for any crop is one of the major decisions a vegetable grower must make. Yield components viz., branches per plant, pod length, pod width, number of green pods per plant and green pod weight per plant recorded the highest values at lower plant density. However, it was not reflected in pod yield per ha, because higher (500×10^3 plants ha^{-1}) and medium plant density (333×10^3 plants ha^{-1}) out yielded the lower plant density. The maximum pod yield was recorded with the highest plant density and the lowest pod yield with the lowest plant density [184; 240]. Applying of plant spacing of (30 x 10, 30 x 15 and 30 x 20 cm) the maximum number of green pods per plant was obtained from wider spacing which was identically similar with middle spacing. The lowest number of green pods per plant presented at closer spacing [199]. [281] studied the response of field bean to plant population for fodder production and quality. Seeding rates of (125 and 150 kg ha^{-1}) had no significant influence on fodder yield of field bean. [186] obtained the highest yield of French bean from the plants spaced at 25 x 10 cm while, [81; 233] in their experiments observed the highest yield at the spacing of 30 x 10 and 30 x 15 cm, respectively. [29] assessed the performance three plant density, reported that the increase in plant density reduced plant dry weight and pods number per plant, but increased total pod yield per hectare. A highly significance difference was observed on total number of pods due to the different plant densities, expressed on a percentage basis. Plant population 200000 and 400000 plants per hectare being 32 and 60%

superior to 13333 plants per hectare. Plant density affects the yield considerably through influencing its capacity to take advantage of the growth inputs, particularly light and competition. Various studies show that the reaction of grains, including beans, two different levels of nitrogen fertilizer are different. In most studies, using nitrogen fertilizer, less than 100 kg ha^{-1}, will improve the yield; otherwise we will face a declined final yield [53]. [91] screened the effect of five levels of inter row spacing (50 x 7, 40 x 15, 40 x 10, 40 x 7 and 30 x 15 cm) reported, Plant spacing significantly affected on total marketable pod yield of green bean. The intra row spacing of 40 x 7 cm, gave the highest total marketable pod yield. Conversely, the lowest total marketable pod yield was obtained from green bean spaced at 50 x 7 cm. This value is a similar with that of marketable pod yield that was obtained from green bean spaced with 40 x 15 and 40 x 10 cm. spacing 40 x 7 cm resulted in the highest total unmarketable pod yield of green bean. Conversely, the lowest total unmarketable pod yield was obtained from a green bean spaced at 40 x 15 cm, and this value was a similar to the green bean sowed at 30 x 15 cm spacing. The probable reason for the higher unmarketable pod yield in the narrow spacing could be due to higher plant population at narrow spacing resulting in poor quality pods, that might have arisen from intra-plant competition and higher disease pressure. The largest total number of pods per plant was obtained from green bean sowed at the spacing of 40 x 15 and 30 x 15 cm, respectively. The highest dry weight of the pods was found for spacing of 40 x 15, 30 x 15 and 50 x 7 cm, according to the sowing date. This could probably be due to wider plant spacing that allowed plants get enough amount of moisture, with less competition between plants that resulted in better development of pods. [87] evaluated the effect of plant population (10, 15, and 20 cm plant spacing x 2 and 3 plants/hole), to give 120000, 180000, 90000, 135000, 60000 and 90000 plants fed^{-1}, respectively, on yield and quality of snap bean. They reported that the increase of plant spacing with the lower planting density (2 plants per hole) reflected the same significant increased number of pods per plant, yield per plant and yield per feddan, where the highest values were obtained at the middle plant spacing (15 cm) and the lower planting density (2 plants/hole). Increasing plant spacing increased number of pods per plant. The numbers of pods per plant were increased when the number of plants per hole was decreased up to two plants or when the plant spacing was increased up to 20 cm. The highest yield was obtained at 10 cm spacing and 3 plants per hole. The interaction between plant per hole and plant spacing gave the highest yield also at 10 cm spacing and 3 plants per hole. However, increasing plant density has a negative effect on yield as well as increasing plant spacing above 10 cm. There were no significant effects on pod quality, being significant on the pod diameter due to the interactions between plant spacing and planting density, where, the higher values of both quality attributes were obtained at the widest plant spacing (15 or 20 cm) and the lower planting density (2 plants per hole). Increasing plant spacing or planting density had a positive effect on pod length, but negative effect on pod diameter. Increasing both plant spacing and planting density had positive effects on pod length, but the reverse on pod diameter. There were positive effects due to increased plant spacing and planting density.

The significant of response for number of pods due to varying plant population reached 1% level, increasing in the pod dry matter was directly proportional to plant density. The treatment differences were significant on 50 and 57 days after planting. The pattern of dry matter accumulation was the same throughout except on 43 days after planting where the intermediate spacing happened to contain a higher amount of dry matter than the high density planting. However, this difference was no significant [114]. The study of soy bean by [73] indicated that the semi dwarf soybean produced greater yields at a very narrow spacing of 17 cm with little advantage over standard cultivars at 75 cm row spacing and low plant densities. The semi dwarf lines produced relatively higher yields at the narrowest row spacing. [50] noted that population density had a significant effect on cowpea pod and seed yields. Both pod and grain yields significantly increased with decrease in row width. Inter-row spacing of 60 cm resulted in 32 to 90% and 30 to 93% increase in cowpea pod and grain yields, respectively compared to 75 and 90 cm spacing. There were two obvious advantages in the closer spacing. First, there was early and better canopy formation, coupled with higher plant populations for enhanced weed suppression and crop productivity. For example, plant spaced at 60 cm had a population of 111111 plants ha^{-1} compared to 88888 and 74074 in the case of 75 and 90 cm inter-row spacing respectively [131]. [264; 19; 125] In their experiments conducted in semi-dwarf and standard height cowpea responses to inter-row spacing (15, 76 and 102 cm), they were observed that both the semi dwarf and standard height cowpea produced their greatest yields at the narrowest inter-row spacing of 51 cm. The increase in pod number and length in the wider spacing may be the result of the availability of better growth resources to the individual plants. Narrow spacing might cause mutual shading which may cause floral abscission and pod dropping in the lower canopy strata, however, the narrowest spacing gave the highest pod and grain yields probably due to higher plant population density. [22] noted that dry matter yield was increased with increase in seed rates. [213] studied impact effect of four plant spacing (40 x 10, 40 x 20, 40 x 30 and 40 x 40 cm) on yield and yield component of green beans the result of variance analysis indicated that the highest pods per plant which was achieved in a treatment known as 40 x 20 cm, while the least pods per plant was achieved in a treatment known as 40x30 cm. Number of pods per plant are the most variable feature among the yield components of the grains. The researcher [6], evaluates six planting densities (10 x 30, 20 x 30, 30 x 30, 40 x 30, 50 x 30, 60 x 30 cm) of bean righted the highest planting density (10 x 30 cm) gave the highest percent of early yield (93%) in comparison to the total yield it was among the lowest yielding ability and tended to give pods with lower nitrogen, phosphor, potassium and protein contents. The highest yields obtained by 20 x 30 and 30 x 30 cm planting densities with 73 and 71% respectively of early yield related to the total yield, moreover, total yields obtained from the two densities were statistically similar. Pod dry weight tended to be higher under the lower planting densities. The issue of this research seems to give clear perspectives to obtain a high early yield with good enough quality under 20 x 30 cm. The lowest yielding early and total yield was given from the lowest density (60 x 30 cm) treatment which produced. Mentioned constant significant superior yields of high plant populations over those of low a plant population of plastic house beans. [157; 245] worked on Bean crop under various planting densities. Found higher values of average pod fresh weight, pod dry weight by using lower planting densities; this could be due to lower number of plants per unit area, resulting in more water and soil nutrient pool per plant which consequently contributed to greater photosynthesis through larger stem diameter per single plant. Variation of plant population affects total bean yields. [185] inference that bean yield was increased as that densities increased.

On Faba bean, yield is closely correlated with number of pods per area [79]. Thus, increasing the number of plants per area in order to increase the number of pods might be a sustainable way of improving yield. There is a lot of available information about optimal population density on indeterminate forms of snap bean for green pod production. [10] recommend 10 to 16 plants per m^2; [78] 18 plants per m^2; [62] reported 40 plants per m^2. [224] compared three plant density (33, 17 and 11 plants m^{-2}) mean of immature green pod, yield showed three groups in which the means are significantly different from one to another (11.87, 7.46 and 5.27 kg ha^{-1}) respectively. The higher population density studied resulted in higher immature pod yield. Therefore, a significant advantage of narrow spacing has been obtained. [173] reported positive effect on narrow rows. Thus, as a practical result, they recommend for determinate growth habit cultivars when immature green pods (or "baby" seed) is sought, population densities higher than for standard culture.

2. 3. Fertilizer

Fertilizer, it's a substance used to improve soil characteristics and plant nutrition to increase yield quantity and quality [261]. Fertilizers are sources of mineral elements which plants required for growth and development [102]. Sixteen elements are essential for the growth of a great majority of plants and these are derived from the surrounding air and soil. In the soil the transport medium is the soil solution. The following elements are derived:

A) From the air: Carbon (C) as CO_2 (carbon dioxide).

B) From the water: hydrogen (H) and oxygen (O) as H_2O (water).

C) From the soil, fertilizer and animal manure: divided into:-

1) Macronutrients, divided into primary nutrients; Nitrogen (N), (leguminous plants obtain nitrogen from the air with the help of bacteria living in the root nodules) Phosphorus (P) and Potassium (K). Secondary nutrients; Magnesium (Ma), Calcium (Ca) and Sulphur(S).

2) Micronutrients or trace elements are: Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo) and Chlorine (Cl) [95].

For will growing elements nutrition should be sufficient in soil, in general the soil either poor in element nutrition or rich, but in unavailable form leading to add elements nutrition every year [67]. Chemical fertilizers are often considered as solutions to current nutrient deficiencies [134]. Fertilizer recommendations for selected crops, according to their needs, different crops need different amounts of nutrients. Furthermore, the quantity of nutrients needed depends largely on the crop yield obtained (or expected) [95]. To increase the efficiency with which fertilizers are used in crop production, it is important to understand the relationships between soil nutrient reserves, soil texture and root growth. For optimum growth of the plant, the concentration of nutrients in the soil solution should be maintained at the critical value below which the growth of the plant is decreased [174]. Balanced fertilization ensures that the plant has access to an adequate amount of each nutrient and is essential to optimize yields and, where appropriate, minimize environmental risk [128]. With fertilizers, crop yields can often be doubled or even tripled [95].

2. 3. 1. Effect of nitrogen fertilizer on growth parameters

Nitrogen is often the most important factor limiting plant growth even though the atmosphere contains 78% nitrogen. It is the nutrient required in the greatest quantity by most crops. It is also one of the most complex in behavior, occurring in soil, air and water in inorganic and organic forms [28]. The mineral nitrogen in the soil is mainly (NO^{-}_{3}) and to a lesser extent ammonium (NH^{+}_{4}). As nitrate is minimally adsorbed on to soil particles, it is very mobile resulting in leaching losses due to irrigation. Nitrogen is required by plants in comparatively larger amounts than other elements. One of the major biotic constraints to snap bean production is low soil fertility. Snap bean can fix atmospheric nitrogen when the seed is inoculated with a suitable strain of bacteria, commercial snap bean growers do not inoculate their crop, choosing instead to rely on chemical fertilization. Nitrogen is taken up by the roots principally in the form of nitrate (NO^{-}_{3}) and ammonium (NH^{+}_{4}), the most abundant nitrogen forms present in soil [165]. Taking into account uptake and assimilation costs, (NH^{+}_{4}) should be preferred to (NO^{-}_{3}) as a nitrogen source. However, (NH^{+}_{4}) nutrition usually has deleterious effects on plant growth and can result in toxicity symptoms in many plants [58]. Snap beans often receive 68 to 135 Kg ha^{-1} of nitrogen [8]. A large part of nitrogen in the plant is allocated two leaves and a large amount of leaf nitrogen is allocated to photosynthetic system. Photosynthetic activity is related to leaf nitrogen and the net photosynthetic rate increases with higher levels of leaf nitrogen. Generally, decreases leaf nitrogen content leading to a decrease in photosynthesis [193]. Nitrogen, as all plant nutrients, is absorbed in a dissolved form and therefore its absorption and utilization is dependent on the availability of water in the root zone. The nitrogen nutrient from the inorganic fertilizers is leached leaving the soils depleted of nitrogen [271]. Nitrogen is one of the major factors limiting plant growth. Worldwide food production doubled in the last four decades with a sevenfold increase in nitrogen fertilization [216; 115]. Nitrogen availability is the main constraint limiting yield in south the Mediterranean basin [205]. Increasing the fraction of NH^+ in the fertilizer dose increased pod yield and number per plant [89]. Several authors have reviewed that the concentration and the form of nitrogen sources have important influences on endogenous cytokinin (CK) synthesis [270]. Biological nitrogen fixation has often been reported insufficient in many studies [267]. Nitrogen is a plant nutrient required in comparatively larger amounts than other elements. Nitrogen is an essential component of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins [166]. Nitrogen being the motor of plant growth will usually show its efficiency soon after application: the plants develop a dark green color and grow more vigorously. Also a good supply of nitrogen for the plant is important for the uptake of the other nutrients. On the other hand, crops it will decrease in quality, particularly storage ability [95].

Nitrogen is the critical limiting element for growth of most plants due to its unavailability [105; 41] Beans need nitrogen more than any other nutrient [277]. Nitrogen is a building block of proteins and is highly needed for all enzymatic reactions in a plant [32]. It is a major part of the chlorophyll molecule and plays a necessary role in photosynthesis and also is a major component of several vitamins [254]. Concentration of chlorophyll dyes is a reliable index of physiological plant condition [253]. Bean nitrogen requirements are met in a complex manner, as this crop is capable of utilizing both soil nitrogen (mostly in the form of nitrate) and atmospheric nitrogen (through symbiotic nitrogen fixation) [266]. Nitrogen is currently the nutrient most widely used as fertilizer and demanded for growing agricultural crops [275].

Under normal conditions, a total nitrogen application of 100 to 120 kg ha^{-1} applied in various splits is seen as the norm. 60% of the total nitrogen can be applied prior to planting and the remainder needs to be applied by week four after planting [250]. Urea, with 46 percent nitrogen, is the world's major source of nitrogen due to its high concentration and its usually attractive price per unit of nitrogen. However, its application requires exceptionally good agricultural practices to avoid in particular, evaporation losses of ammonia to the air [95]. The biomass increased at high nitrogen treatment because the light within the canopy was distributed more than another treatment and then it caused a reduction of extinction coefficient in this treatment [194]. Snap beans lack nodulation genes, hence it does not have nodulation and this makes them poor in symbiotic nitrogen fixing [152]. Because of this poor nodulation in snap beans, nitrogen is greatly needed for good establishment of roots, nodulation and growth [249]. Nitrogen plays a dominant role in the physiological activity of growth and development in plant. Increases in plant size, which in turn assists utilization of nitrogen, increase in leaf area and retention of flowers are some of the more important functions of nitrogen. It is shown that with increased amounts of applied correspondingly larger amounts of dry matter are produced and maintained by leaves, stem, and pod throughout the life of the crop, which in turn would have contributed to increased yields [114]. Nitrogen is one of the fundamental compounds in nutrition of the plants. If there are enough water and food for the plant, then the light is the only factor that effects on qualitative and quantitative properties of the crop [286]. Nitrogen supply is a key limiting factor in determining plant growth and production, however, the form of nitrogen supply is still debatable Supply of nitrogen in the ammonium form has more positive effects compared to the nitrate form. However, the mixed forms, especially the treatment of 75% NH^{+}_{4} + 25% NO^{-}_{3} showed the highest positive effects on most of the measured parameters [155]. One of the objectives of agricultural management is maximum utilization of solar energy by the canopy. It was evidence that the application of nitrogen fertilizer affects chlorophyll content and then it cause an increase in radiation use efficiency [210]. The maximum energy from light absorption and radiation use efficiency cause the highest photosynthesis, and therefore biomass production and yield increase by penetrating light into different canopy layers [112]. Nitrogen requirement of leguminous crop is very low, but starting dose of nitrogen is indispensable for higher yield [200]. Non-significant effect on dry matter percentage was recorded [180]. Major nitrogen requirement of legumes is met by biological nitrogen fixing rhizobia but not in the soils that low in rhizobia due to low organic matter contents. The deficient soils require nitrogen as a starter dose for leguminous crop [200]. The nitrogen is major plant nutrient and plays an important role in the plant growth and development [255].

Nitrogen is a very important element for plant growth and is found in many compounds. These include chlorophyll (the green pigment in plants), amino acids, proteins, nucleic acids, and organic acids [116]. [226] treated Snap bean by six doses of nitrogen reported that N_3 presented the maximum production of foliar biomass, which was increased 43% over treatment N_6, the one that exhibited the lowest biomass value. It should be mentioned that the application of N_3 was the best treatment to increase the production of root and shoot biomass in green bean plants. Low nitrogen treatments (N_1 and N_2), can be considered as nitrogen deficient and were characterized by a relative increase in root biomass and a reduction in the growth of aerial biomass, hence an increase in the root to shoot ratio. Meanwhile, doses above optimum (N_4, N_5 and N_6), considered in this experiment as elevated to toxic, because of the decrease they caused in root and shoot growth, the latter being most affected. For an optimal yield, the nitrogen supply must be available according to the needs of the plant. Nitrogen deficiency generally results in stunted growth, chlorotic leaves because lack of nitrogen limits the synthesis of proteins and chlorophyll. This leads to poor assimilate formation and results in premature flowering and shortening of the growth cycle. The presence of nitrogen in excess promotes development of the above ground organs with relatively poor root growth. Synthesis of proteins and the formation of new tissues are stimulated, resulting in abundant dark green (high chlorophyll) tissues of soft consistency. This increases the risk of lodging and reduces the plants resistance to harsh climatic conditions and to foliar diseases [155]. The researcher [33] regarded that nitrogen application significantly affected plant height. Both the nitrogen levels (20 and 50 kg ha^{-1}) significantly increased the plant height over the control (no nitrogen). The highest plant was recorded when nitrogen was applied at the highest dose. [1] reviewed an increase in plant height with nitrogen application. The numbers of branches per plant were increased with increase in nitrogen rates [25; 141]. [126] reported that vegetative growth characters of pea plants, significantly, increased by increasing nitrogen fertilizer up to 90 Kg fed^{-1}. [231] indicated that increasing the nitrogen level from 0 to 40 Kg fed^{-1}, significantly, enhanced the vegetative growth characters of common bean plants as expressed by plant height , shoot fresh weight, number of leaves and leaf dry matter percentage. High application of nitrogen fertilizer increase nitrate accumulation in plant tissues [163]. [119] showed that the yield of wax bean was strongly influenced by the nitrogen applied. Plants accumulate nitrate in their tissues when Sulfur deficiency is suffering plants or available nitrogen increase. Nitrate accumulation in tissues of green bean occurs by absorption and transfer of this component. In the young plant, nitrate accumulates in stems and petioles [61]. [172] deduced that 22 kg N ha^{-1} would be more suitable for economical use of fertilizer and improvement of production of snap beans. This is calculated considering that most common plant population in bean monoculture is 22 thousand plants per hectare, thus the establishment of legumes may be delayed or retarded due to nitrogen stress and supply of starter nitrogen is desirable. While, [111] recommended that the application of 26 kg ha^{-1} as starter nitrogen for dry beans. Plant height and branches per plant increased with increasing level of nitrogen [184].

The presence of nitrogen in excess promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth. [57] consuming lives nitrogen rapid senility of this leaves so the availability of nitrogen increasing vegetative growth. Increasing nitrogen fertilizer increased number of leaves per plant and had no significant differ on the number of branches per plant among all treatments [283]. [204] regarded the deficit of nitrogen on soybean weaken the plants. Nitrogen is required for dry matter production in crops, result shown increases in vegetative growth of snap beans and dry beans in addition of nitrogen fertilizer [5]. Nitrogen consumption increasing in dry weight resulting in increased plant yield [109]. Plant height, number of leaves and plant fresh and dry weights responded positively and significantly with increased of the applied dose of nitrogen [89]. [166] examined nitrogen fertilizer management of the different levels (0, 25, 50 and 75 kg ha^{-1}) found that the increasing nitrogen levels up to 75 kg ha^{-1}, maximum plant height was obtained by 75 kg ha^{-1} nitrogen fertilizer management and hand the minimum plant height was recorded from control. [97] applied four nitrogen levels (0, 30, 60 and 90 kg fed^{-1}) on pea plants, in the form of ammonium sulphate (20.5% nitrogen). Recorded the application of nitrogen significantly, increased plant height, number of leaves and branches and plant fresh and dry weight over the control treatment. Also, whether the nitrogen applied level was at either 60 or 90 Kg fed^{-1}, all the studied vegetative growth characters showed the highest values. Additionally, the differences between two nitrogen levels appeared insignificant on all characters, such favorable effects of nitrogen application on vegetative growth could be expected, since nitrogen is known as an essential plant nutrient and plays a major role in nucleic acids and protein synthesis, cell division and elongation and protoplasm formation. The improving effects of nitrogen fertilizer on the leaves might be related to the vital role of nitrogen, for the formation of chlorophyll pigments and stimulation of photosynthesis process [177; 196] on common bean; [2] on cowpea; [246; 124] on the pea. Vigorous growth with the tallest plants was presented in highest nitrogen dose and decreased with nitrogen doses were decreased [172]. Research in addition of nitrogen fertilizer to Snap bean showed increasing plant growth with successive nitrogen fertilizer applications above 44.81 kg N ha^{-1} [80]. Nitrogen is a chlorophyll component, and it promotes vegetative growth and green coloration of foliage [129]. Meanwhile, [107] indicated that plant height decreased with increased urea. [93] reviewed that different doses of nitrogen fertilization increased the mean plant height .

[202] applied treatments consisted of three types of fertilizers: urea, NPK and compost as a control. The analysis of variance showed no significant difference on plant height between treatments in both seasons at 30, 45, 60, and 75 days, except in

the second season at 30 days. The highest mean of plant height was given by the urea treatment and control, in both first and second seasons, respectively. Number of leaves per plant was showed no significant difference between treatments in both seasons at 30, 45, 60, and 75 days. Control showed a slight increase in the number of leaves in the first season and NPK in the second season. [13; 242] reported no significant difference between nitrogen treatments in number of leaves. [289] showed that the difference in nitrogen levels had a slight influence on the mean number of leaves per plant. Plant height and branches per plant increased with increasing level of nitrogen [184]. The plant fresh weight varied significantly among different plant density. [199] investigated different levels of nitrogen (0, 30, 60, and 90 Kg ha^{-1}) on French bean. Regarded significant effect due to nitrogen application, the plant height was gradually increased with the increasing level of nitrogen. The tallest plant founded at high nitrogen dose, while the shortest plant found in control. The total number of leaves and branches per plant varied significantly with nitrogen application. The highest number of both obtained at the higher nitrogen rate while the lowest number obtained by control. The first flowering was about two days earlier in the control than the highest level of nitrogen. In case of plant received higher doses of nitrogen got long duration to complete vegetative growth which resulted in longer time of flowering, while in case of control and a plant had less supply of nitrogen had a shorter vegetative period. High rates of nitrogen promote vine growth and delay fruiting [130]. Nitrogen fertilization with 60 and 90 Kg fed^{-1}, significantly, delayed flowering compared with control (no nitrogen) and increased fruit set percentage. Such results might be attributed to the stimulating effects of nitrogen on the vegetative growth characters that, consequently, resulted in delaying the flowering and increasing fruit set percentage [97]. [40], on pea; [86] on lettuce and [98], on sweet pepper showed that the increased applied levels of nitrogen from 40 to 80 Kg fed^{-1}, significantly delayed the flowering, whereas, the application of 120 Kg N fed^{-1} increased significantly fruit set percentage. [283] used different levels of nitrogen (0, 50 and 100 Kg fed^{-1}) on soybean; they were reported that the increase in nitrogen fertilizer increased the number of days to present of 10% and 50% flowering but with no significant difference. Nitrogen application increased dry matter and green fodder yield of cluster bean cultivars [230; 141]. The effect of fertilizers on the number of days to the first 50 and 100% flowering presented no significant difference between treatments. Days to flowering decreases with the increasing urea fertilization [202; 68]. [289] reviewed that nitrogen fertilization can promote vegetative growth of soybean, and plants can be flowered around 33 days after sowing. Generally, high nitrogen levels of 60 and 120 kg ha^{-1} delayed flowering whereas, lower nitrogen levels had no influence on flowering. For an optimal yield, the nitrogen supply must be available according to the needs of the plant. Nitrogen deficiency generally results in stunted growth, chlorate leaves because lack of nitrogen limits the synthesis of proteins and chlorophyll. This leads to poor assimilate formation and results in premature flowering and shortening of the growth cycle. The presence of nitrogen in excess promotes development of the above ground organs with relatively poor root growth. Synthesis of proteins and the formation of new tissues are stimulated, resulting in abundant dark green (high chlorophyll) tissues of soft consistency [155]. Increasing doses of nitrogen increased total top dry matter of shoot system. Marked increase in total top dry matter was observed with the age of the crop [114]. Common bean has greater mineral nitrogen uptake was efficiency, this may indicate that early nitrogen demand could have been satisfied from the applied nitrogen, so early nitrogen supply would have contributed to the rapid growth of leaves and accumulation of dry matter [122]. Applied nitrogen in the range of 0 to 200 kg ha^{-1} was quadratic for plant dry weight and shoot dry matter production. The variation in shoot dry weight with the application of nitrogen fertilizer varied from 54 to 78%, depending on cultivars [123]. [85] showed there is an increase in plant growth and yield in dry beans in response to varying levels of nitrogen. The dry matter yield was increased significantly with an increase in nitrogen levels. The highest dry matter yield was recorded with high dose of nitrogen; the increase in dry matter yield can be attributed to production of more dry matter as a result of improved photosynthetic activity at higher levels of nitrogen [34]. [160] showed that plants produce dry matter by sunlight absorption and store it in themselves during their vegetative stages. [154] proved that there was a linear relationship between the total dry matter production and photosynthetic active radiation.

2. 3. 2. Effect of nitrogen fertilizer on yield parameters

In most low input systems where the majority of the bean is produced, the principal factors responsible for bean yield and quality losses are plant nutritional deficiencies [121]. Nitrogen treatment significantly affected pod number per plant; total pod yield and pod dry weight per plant of snap bean. Boston had the greatest number of pods; total pod yield and pod dry weight. The greatest number of those parameters was observed when 100 kg N ha^{-1} was applied. The least number was produced by control [122]. Nitrogen improved the yield of cluster bean cultivars by increasing their yield components [46]. The nitrogen not only improves the yield and yield components of legumes [35; 171] but also affects the biological nitrogen fixation [15]. Full recommended dose of fertilizer increased the grain and straw yield of cluster bean over control [150]). Therefore, selection of optimum nitrogen rates is essential for better performance of crop growth and yield. The greater pod number was obtained by 100 kg N ha^{-1}, a greater number of pods lead to higher yield [27]. Increased yield 42% due to application of inorganic nitrogen fertilizer [122]. Using of different doses of nitrogen (0, 30, 60, and 90) number of green pods per plant was increased gradually with nitrogen fertilizer was increased up to 90 Kg ha^{-1} [199]. [123] applied five nitrogen rates (0, 50, 100, 150, and 200 kg ha^{-1}) to evaluate grain yield production of Faba bean. Grain yield indicated significant quadratic relation with the increasing nitrogen rates. The variation in grain yield with nitrogen fertilization varied from 66 to 93% depending on genotypes. No significant yield increases were found with nitrogen fertilizer rates above 44.81 kg N ha^{-1} [80]. The effect of fertilizers on soy bean plant showed no significant difference except on the number of pods per plant [202]. Results of researchers [159; 134] showed that using of nitrogen improved pod quality of snap bean pods, such as texture, length and diameter and yield of snap Nitrogen application increased the quality of green bean. Appropriate nitrogen fertilizer improves yield and quality of snap bean [117; 118]. Total number of pods per plant presented highly significant differences due to nitrogen fertilizer [114]. The results of researches of [119] indicated that the wax bean yield is strongly affected by nitrogen nutrition. During the final harvest nitrogen had a positively significant influence on the yield components such as total number of pods per plant and total number of seeds per pod. Application of 60 Kg ha^{-1} nitrogen recorded 64% and 100% increase in yield as regard total pod and total seed respectively the zero nitrogen control [44; 59; 217]. [33] investigate the effect of different nitrogen levels (0, 25 and 50 kg ha^{-1}) on cluster bean (forage) yield and quality. The application of nitrogen significantly increased the cluster bean yield and maximum yield was recorded at 50 kg ha^{-1}. The increase in yield was mainly due to greater plant height, number of leaves and number of branches per plant. The quality parameters like dry matter increased significantly by nitrogen application over control. The increase in leaf dry weight was more pronounced, this indicates that applied nitrogen has a significant effect on the dry matter accumulation of leaves. The dry matter of the leaf is important as during reproductive growth there is retrains location of proteins and carbohydrates from the leaves to developing fruits [172; 54]. Nitrogen fertilizer use has played a significant role in increase of crop yield [181]. [89] examined the effect of two different nitrogen sources with three doses reported that the weight of crop yield recorded the highest significant value in plants grown in fertilized with 100% NH^{+}_{4} followed by 75% NH^{+}_{4} and 25% NO^{-}_{3} treatment Meanwhile, the lowest yield production was recorded in plants grown in 100% NO^{-}_{3}. The weight of pod yield was a reflection of pod number which also showed the same trend. Significant yield increases were not found with nitrogen fertilizer rates above 44.81 kg ha^{-1}. Increasing nitrogen fertilizer increased number of pods per plant significantly [283].

Data analysis of Cowpea showed that the effect of nitrogen fertilizer management on all measured traits was significant [162]. [166] tested nitrogen fertilizer management with four levels (0, 25, 50 and 75 kg ha^{-1} nitrogen from the source of urea 46%) found that the increasing nitrogen levels up to 75 kg ha^{-1}, growth was observed in all studied traits the highest seed yield, number of pods per plant, and plant height with was obtained by 75 kg ha^{-1} nitrogen fertilizer management. The minimum amounts of seed yield, number of pods per plant and plant height was recorded from the control treatment (without nitrogen fertilizer application) [101; 1]. Increasing the fraction of NH^{+}_{4} in the fertilizer dose increased pod yield and number of pods per plant [89]. [113] applied nitrogen fertilizer at 100 kg ha^{-1} to the vegetable green beans led to high marketable yield. Increasing nitrogen rates increased yield of green beans [5]. Higher values of plant height and number of branches per plant with the highest level of nitrogen resulted in better growth and development of plants, thus leading to the maximum pod size (pod length and width), more number of green pods per plant and green pod weight per plant [75; 81]. Pod length, pod width, number of green pods per plant and green pod weight per plant were found highest at 120 kg N ha^{-1}. Higher values of plant height and number of branches per plant with 120 kg N ha^{-1} resulted in better growth and development of plants, thus leading to the maximum pod size (pod length and width), more number of green pods per plant and green pod weight per plant. The maximum pod yield was obtained from the application of 120 kg N ha^{-1} and it was minimized in control. Higher yield for 120 kg N ha^{-1} fertilization was contributed by higher values for yield attributes compared to the lower dose (60 kg N ha^{-1}) [184]. [248] recorded that the maximum pod yield of French bean at 160 kg N ha^{-1} that was at par with 120 kg N ha^{-1}. [122] used three levels of nitrogen treatments: 0 and 100 kg N ha^{-1}, and rhizobium inoculation. Results obtained indicated that rhizobial inoculation and applied inorganic nitrogen increased on average the marketable pod yield of snap bean under rain fed conditions by 18 and 43%, respectively. Applied nitrogen fertilizer increased marketable yield by 33% compared with the control. [172] examined different levels of nitrogen (0 as control 1, 1.5, 2.0, and 2.5 gram nitrogen per plant) respectively. Recorded that the highest number of pod, pod fresh weight and pod dry weight was in 2.5, 2.0, 1.5 and 1 gram nitrogen per plant, respectively. Number of flower buds per plants were also highest performance average presented in the above doses, respectively and had 259, 231, 183 and 172% of the control, respectively. They concluded that the number of pods per plant, pod fresh and dry weight increased with the nitrogen was increased. Commercial snap bean production depends heavily on applied nitrogen fertilizer. Relatively high rates of nitrogen fertilizer are applied regardless of the cultivars and other factors such as residual soil nitrogen. Snap bean is a legume crop, but it requires some nitrogen fertilizer to maximize yield [244]. [222] reported that nitrogen fertilizer at a rate of 200 kg ha^{-1} in snap bean increased yield, biomass production, phosphorus and protein. The results also demonstrated that pod quality (pod length and weight) and nutritive value (N, P, K, total soluble solids, protein and carbohydrate contents) were gradually and significantly increased by increasing the level of nitrogen application up to 330 kg N ha^{-1} on snap bean [159]. The application of mineral nitrogen at the rates of 30, 60 and 90 Kg fed^{-1} to the growing pea plants, significantly, increased number of green pods per plant and yield of pods fed^{-1}, the highest regarded at two higher nitrogen levels. The results obtained by [97], clarified that increasing the application of nitrogen from 30 to 90 Kg N fed^{-1}, caused a significant increase in the number of pods per plant and yield per fed, over the control treatment. The higher two nitrogen doses (60 and 90 Kg fed^{-1}) were remarkable in this concern, but the difference between them did not appear to be significant. However, shelling percentage was not significantly responded to nitrogen application. The obtained increments of green pods yield fed^{-1} as a result of nitrogen application might be directly attributed to the increased pods number per plant. The enhancing effects of nitrogen may be related to the role of nitrogen in activating the vegetative growth. It is also possible that the sufficient quantity, and perhaps the efficient absorption of nitrogen coupled together promoted the production of more photosynthesis required for pea seed production. [30] regarded that the number and yield of the green pods per plant were significantly increased with increasing the applied nitrogen up to 80 Kg fed^{-1}. [126] indicated that the addition of 90 Kg N fed^{-1}, to the growing pea plants, was sufficient for the plants to express their best performance on green pods yield and its components. [36] carried out an experiment to study the response of French bean to applied nitrogen. Yield was increased with the increase of nitrogen and was higher with 120 Kg nitrogen per hectare. While, [252] stated that the application of nitrogen up to 100 Kg per hectare significantly increased the yield attributes. [65] reported the increased pod yield of bean with increasing nitrogen doses. The crop nutrition has a well-defined effect on yield and quality of cluster bean crops. The nitrogen has a key function in improving forage yield and crude protein [33]. [213] investigated four levels of nitrogen (0, 25, 50 and 75 kg ha^{-1}) found that the most pods per plant was achieved in a treatment known as 50 kg nitrogen, while the least pods per plant was achieved in a treatment known as 75 kg nitrogen. Results presented that the highest yield belongs to the treatment in which the nitrogen fertilizer (50 kg ha^{-1}) is used while the least green pod yield belongs to the treatment in which no fertilizer is used (control). They reported that nitrogen fertilizer plays a key role in the vegetative growth; hence, its impact on reproductive organs may bring about, to some extent, an additive effect beyond which we may face a new vegetative growth of plant and the decreased number of pods in the plant. Fertilizers increased the number of pods per plant [279; 13]. In contrast, [107; 68] observed that increasing the levels of nitrogen fertilization had no effect on the mean number of pods per plant.

Investigation of [122] showed the possibility of producing export quality snap bean under reduced inputs that minimizes the reliance of vegetable production on heavy nitrogen fertilizer rates, especially for resource limited farmers. [172] reported that very high dose (5, 10 and 15 gram nitrogen per plant) had unwanted effect. Using these doses the plant died off after a few days. The cause was established to be the scorching by the fertilizer.

2. 3. 3. Effect of potassium fertilizer on growth parameters

As a major constituent within all living cells, potassium is an essential nutrient and is required in large amounts by plants. Potassium ranks seventh in order of abundance in the earth's crust. As rocks slowly disintegrate, potassium is released, but the rate of release is frequently too slow to provide the larger amounts of this essential nutrient required by crops. Potassium has two roles in the functioning of plant cells. First, it has an irreplaceable part to play in the activation of enzymes, which are fundamental to metabolic processes, especially the production of proteins and sugars. Only small amounts of potassium are required for this biochemical function. Second, potassium is the plant preferred ion for maintaining the water content and hence the turgor (rigidity) of each cell, a biophysical role. A large concentration of potassium in the cell sap (i.e. the liquid inside the cell) creates the conditions that cause water to move into the cell (osmosis) through the porous cell wall. The benefit of soil potassium reserves depends on the ability of the soil to release potassium and on the crop being grown. For example, deep rooted winter wheat with a long growing season, gave the same grain yield on a potassium-releasing soil at both levels of potassium reserves and only a small response to potassium fertilizer. Field beans planted and sown in the spring have a short growing season and yielded much less on the soil with small potassium reserves than on the soil with adequate reserves [128]. Under normal conditions a potassium application of 50 - 95 kg ha^{-1} is adequate [250]. Applying potassium fertilizer to the soil with small reserves did not increase yield of either crop to equal that on the soil with adequate potassium reserves. The use of potassium fertilizers is not an issue giving rise to concern, for two main reasons. First, there are no known adverse environmental effects, direct or indirect, from applying potassium fertilizers to agricultural land. Second, there are such large reserves of potassium-bearing ores that there is no risk of shortage even in the far distant future [128]. Potassium, which makes up 1 to 4 percent of the dry matter of the plant, has many functions. It activates more than 60 enzymes (chemical substances which govern life). Thus, it plays a vital part in carbohydrate and protein synthesis. Potassium improves the water regime of the plant and increases its tolerance to drought, frost and salinity. Plants well supplied with potassium are also less affected by the disease [95]. High potassium concentrations enhance phloem loading of sucrose and also amino acids [37]. Several workers like [132; 189] etc. have reported that positive effect of potassium in vegetative and reproductive growth of several crops. For optimum growth of the plant, the concentration of nutrients in the soil solution should be maintained at the critical value below which the growth of the plant is decreased [174]. [135] reported that the plant height and number of branches per plant of the bean in were significantly increased by the increasing level of potassium up to 60 kg K_2O ha^{-1}.

A large amount of potassium is needed for proper growth and development. It acts as a coenzyme or an activator for many enzymes. These enzymes cannot act as an effective catalyst for necessary metabolic reactions in its absence. Protein synthesis is one process that requires a high amount of potassium because potassium deficient plants are usually low in protein content but high in amino acid, the building blocks of proteins. One of the enzymes activated by potassium is a respiratory enzyme called pyruvate kinase [223]. [228; 63] observed the increase in the weight of the broad bean leaves and stems when sulphur was applied. The positive effect on the growth and yield of leguminous plants results from improvement in the state of nourishment of the host plant and from the stimulation of nitrogen fixation [228]. [191] used potassium doses of (0, 50, 100 and 150 kg K_2O ha^{-1}) on pea at the time of seed bed preparation. They found potassium application had a significant effect on vine length; maximum vine length was recorded at the highest dose of potassium, followed by the medium dose. However, both treatments were statistically like. [136] found that the growth was increased significantly with increasing levels of potassium (0, 30, 60 or 90 kg ha^{-1}).

[45] studied the effect of different concentration of potassium (0.2, 0.4, 0.6, 0.8 and 1 kg K ha^{-1} and water was taken as control) as a foliar spray at the time of flowering on vegetative and yield characteristic, of Mung bean. The potassium concentration was observed that almost all the vegetative and reproductive characters increase with the increases of potassium concentration. The height of the plant increased with the foliar application of potassium and maximum increase was recorded in plants received a minimum dose of potassium (0.2 kg ha^{-1}). This increase was 33.19% over the control. Comparison of the effects of 673 kg K ha^{-1} applied annually as potassium sulphate or potassium chloride to Lucerne suggests that potassium fertilizer increases nodulation and nitrogen fixation. Potassium gave the greater increase in nodule mass while, potassium chloride gave the greater increase in shoot weight per plant [83]. Potassium fertilizers had a significant effect on the plant height of soybean [129]. [227] found that, high potassium supply had a positive effect on shoot and root growth. potassium may activate at least 60 different enzymes involved in plant growth [167] application of potassium also enhanced vegetative growth in French bean [135]. [83] studied the influence of potassium fertilizer rate and form on photosynthesis and nitrogen fixation of Alfalfa concluded that chlorophyll concentration increased linearly in response to the potassium application and net carbon exchange rate, it was increased by average of 28% over control. [82] confirmed that potassium deficiency in legumes is associated with low chlorophyll content. In particular, the ability of ATP as in membranes to maintain active transport is highly dependent on adequate potassium supply. Potassium influences the water economy and crop growth through its effects on water uptake, root growth, maintenance of turgor, transpiration and stomatal regulation [198]. Thus, efficient cell development and growth of plant tissues, translocation and storage of assimilating and other internal functions which are based upon many physiological,

biochemical and bio physical interaction requires adequate potassium in the cell sap [167]. The amount of potassium present in the cell determines how many of the enzymes can be activated and the rates at which chemical reactions can proceed. Thus, the Potassium influences the water economy and crop growth through its effects on water uptake, root growth [146; 241].

The effect of a single nutrient (like potassium) in a fertilizer may depend upon the way in which it is chemically combined with the fertilizer material and this affects both yield and crop quality. Because potassium fertilizers are obtained from natural products they may contain substances other than potassium, these substances may affect plant growth. Thus, choosing the right kind of potash fertilizer can be as important as applying the right amount of potash to a crop [284]. [108] studied the effect of 0, 80 and 160 kg ha^{-1} potassium oxide on growth and yield of soybean stated that potassium fertilizer increased plant dry weight. Studies have revealed that increasing the level of potassium fertilizer increased dry matter production and total nitrogen fixed in faba bean [282; 12]. [151] studied the effects of different rates of potassium fertilizer on dry matter production by chickpea and Faba bean. They found that plant species differed in their response to potassium fertilizer. The higher level of potassium fertilizer increased dry matter production in faba bean, but did not have any impact on chickpea. Generally, high potassium supply was required in the symbiotic system to ensure an optimal growth. They concluded that the higher level of potassium fertilizer increased both dry matter and production Faba Bean.

2. 3. 4. Effect of potassium fertilizer on yield parameters

Out of all the mineral nutrients, potassium plays a particularly critical role in plant growth and metabolism. The importance of potassium fertilizer for the formation of crop production and its quality is known [208]. Maintaining an optimum potassium nutritional status is essential for plant resistance to biotic and a biotic stresses. Balanced ion and efficient potassium usage in combination with other nutrients not only contribute to sustainable crop’s growth, yield and quality, but also influence plant health and reduce the environmental risks [179]. By maintaining the salt concentration in the cell sap, potassium helps plants combat the adverse effects of drought and frost damage; it also improves fruit quality [128]. [45] used different concentration of potassium sprayed on the leaves of Mong bean (0.2, 0.4, 0.6, 0.8 and 1 kg K ha^{-1}). Pod length and number of pods per plant increased with the application of potassium concentration was increased. A maximum increase was recorded in higher dose (1.0 kg K ha^{-1}) was applied. This increasing was 33.68 and 31.21% over the control (water without potassium) respectively. Potassium fertilizers, mined and refined from naturally occurring deposits, are available to supplement soil potassium supplies so that crops can produce economically viable yields and soil fertility can be maintained [128]. The shortage of Sulphur in the soil reduces the yield level and quality of leguminous plants [43; 106; 285]. Sulfur fertilization, moreover, improves the quality of yield [90; 221]. The effects of potassium deficiency can cause reduced yield potential and quality long before visible symptoms appear. This “hidden hunger” robs profits from the farmer who fails to keep soil potassium levels in the range high enough to supply adequate potassium at all times during the growing season. Even short periods of deficiency, especially during critical developmental stages, can cause serious losses [133]. Deficiency is potassium is on the increase and hence potassium management is of importance specifically because potassium influences the uptake of other major nutrients and influences crop quality [76]. [191] presented that the different levels of potassium and they’re significantly affected the length of the pods and pod number, regarding the effect of potassium levels, it is interesting that plants received 100 kg K_2O ha^{-1}, induced maximum pod length and stood at par with the plants received 150 kg K_2O ha^{-1}. Increasing potassium level beyond 100 kg K_2O ha^{-1} had no significant effect on pod length mean values for potassium revealed that maximum number of pods was obtained from the plants received K_2O 150 kg ha^{-1}. Minimum numbers of pods were recorded in those plants, which received no potassium. Application of potassium enhanced vegetative growth and increased pod yield in pea [136; 137], in cowpea [127] in French bean, with increasing K_2O rate up to 60 kg ha^{-1}. [269] recorded positive effect of applications potassium at all proportions on growth and yield of peas. Thus, plant nutrition is an important factor for obtaining higher yields of green pods. [96] conducted an experiment used potassium fertilizer at three levels (0, 90 and 180 kg ha^{-1}) their results showed that potassium fertilizer significantly affects all traits. The highest grain yield was obtained from treatment in the case of 180 kg ha^{-1} potassium. Use of potassium significantly increased numbers of fertile pods per plant, so that use of 180 kg ha^{-1} potassium, in comparison to control (no potassium) increased this trait by 16%. The results also, showed that potassium had significant impact on the number of grains per pod.

The number of grains per pod was observed at 180 kg potassium per hectare by 10.7, which were 13% greater than control treatment (no fertilizer potassium). Potassium consumption (180 kg ha^{-1}) increased grain weight by 5%, increasing grain weight can be resulted in increasing yield. The highest grain yield (2698.4 kg ha^{-1}) was observed in the case of higher potassium dose so that, compared to the control increased by 43%. The highest total dry weight obtained in the case of 180 kg ha^{-1} potassium increased by 18%, in comparison to control. Generally, the amount of fertilizer, potassium especially at 180 kg per hectare, cause to improve yield and yield components in mung bean. [92] reported that the amount of potassium sulfate had a significant effect on yield weight. [195] studied the effect of potassium on quantity and quality of bean and found that it has an important role in increasing grain yield through its effect on number of pods and number of grains per pods. [218] reported that for achieving the highest grain yield, in canola, getting enough potassium is important in the early flowering stage. [219] reported that adequate potassium is needed for the efficient use and metabolism of nitrogen. Generally, it has been established that potassium has an impact on the uptake of other cationic species and thus may affect the crop yield and crop quality [176]. Potassium plays significant roles in enhancing crop quality. High levels of available potassium improve the physical quality, disease resistance, and shelf-life of fruits and vegetables used for human consumption and the feeding value of grain and forage crops [227]. Quality can also be affected in the field before harvesting such as when potassium reduces lodging of grains or enhances winter hardiness of many crops [133]. [211] studied the content of potassium in the soil and current fertilization with this component (0, 25, 50 and 100%; where 100% equal to 133 kg K ha^{-1}), found that the highest yields were noted in treatments 133 kg K ha^{-1}

in first season and 66.5 kg K ha^{-1} in second season. In comparison with the yield from no potassium the difference ranged from 41 to 50%. In the first season, potassium was observed to have significant influence on the yield. In comparison with the yield from zero potassium there was a significant increase in the yield observed in 33.25 and 133 kg K ha^{-1}. The difference amounted to 61 and 66%, respectively. The high increase of yield in treatments 33.25 and 133 kg K ha^{-1} resulted from the long period of retention of green leaves on the plant and thus, from the assimilation of CO_2 nearly until the end of vegetation. Potassium fertilization significantly increased the number of pods on the plant, the number of pods per square meter and the weight of a thousand seeds, as compared with the control object. This factor, especially improved the values of the elements of yield structure in objects K 25% and K-100%. Potassium fertilization had a favorable influence on the number of seeds in pods and on the harvest index, but this reaction was a trend. In contrast to the potassium, sulphur fertilization significantly influenced only the number of pods per square meter. This factor also had a positive influence on the number of pods on the plant, the weight of one thousand seeds and the harvest index (except K-100%). As was proved in the research, the seeds yield was positively correlated with the weight of crop residues, the number of pods on the plant and the weight of one thousand seeds. However, the number of pods on the plant had the greatest direct influence on the yield of seeds. [14] studied the effect of various levels of potassium on the growth and green pod yield of pea concluded that mean values for potassium revealed that maximum number of pods was obtained from the plants received K_2O at 150 kg ha^{-1} Minimum number of pods was recorded in those plants, which received no potassium. [135] reported that when 0, 30, 60 or 90 kg K_2O ha^{-1} was applied to French bean, number of pods per plant increased with increasing K_2O rates up to 60 kg ha^{-1}. Pod length, pod girth, number of pods per plant and protein content of the bean in were significantly increased by the increasing level of potassium up to 60 kg K_2O ha^{-1} and consequently leading to greener pod yield. The increase in green pod yield with 30, 60, and 90 Kg K_2O ha^{-1} were 24.19, 42.69 and 33.41% respectively over control. Different levels of potassium (0, 50, 100 or 150 kg K_2O ha^{-1}) significantly affected the number of pods and pod length. Mean values for potassium revealed that maximum number of pods was obtained from the plants received 150 kg

K_2O ha^{-1}. Minimum number of pods was recorded in those plants, which received no potassium. Plants received 100 kg K_2O ha^{-1} induced maximum pod length and stood at par with the plants received 150 kg K_2O ha^{-1}. The effect of potassium revealed that 100 kg K_2O ha^{-1} resulted in maximum grains per pod, closely followed by 150 kg K_2O ha^{-1} and both the treatments behaved statistically alike. Green pods yield per hectare significance and presented the same picture as green pod yield per plant [191]. Snap bean often receives 0 to 112 Kg ha^{-1} of potassium, according to the soil [8]. Product quality is a complex matter and has various aspects, which are affected by many factors. Concerning plant nutrition, potassium plays an important role it plays an important role in yield and quality (storage quality or taste) [169]. Potassium is used as an activator in many enzymatic reactions in the plant. Another role for Potassium in plants occurs in special leaf cells called guard cells found around the stomata. Guard cell controls the degree of opening of the stomata and thus controls the level of gas and water vapor exchange through the stomata. Turgor is largely controlled by potassium movement in and out of the guard cells [116]. To promote quality, fertilization levels should be higher; therefore, the effects of potassium supply on yield may not be expected. The uptake of potassium by crops grown under conditions with low humidity was high. This was probably due to the result of the lower transpiration of the laminae and reduced potassium accumulation due to transport by mass flow [8; 38]. Crops absorb potassium in the highest quantities (by weight) and it is for several reasons that this element needs special attention in this intensive cropping systems. As these systems are capital intensive, maximum yield and quality are required, and potassium plays an essential role in both aspects. Moreover, the demand for potassium fluctuates strongly according to the stage of growth, which is particularly the case for fruit vegetables. A review is given on the significance of potassium for yield and quality of vegetable crops, especially fruity vegetables [268]. Potassium deficiency at the initial stage of plant development significantly disturbs the distribution of assimilates between the aboveground organs and roots [168]. As a result, potassium deficiency in the soil causes decreased yield of broad bean [182; 278]. As these systems are capital intensive, maximum yield and quality are required, and potassium play an essential role. There are several differences between field grown vegetables and crops grown under protection. Elevated temperatures and the exclusion of precipitation and other climatic influences allow higher growth rates with higher yields, which impose a high need for nutrients. It is evident that potassium fertilization is essential, for even in highly fertile alluvial soils, the natural potassium supply of soil minerals is insufficient. Especially long term vegetable absorbs such high quantities of minerals that it is impossible to supply those quantities as a base dressing with fertilizers, because the osmotic pressure in the soil solution would increase to detrimental levels [247]. According to [106] fertilization with sulphur at a dose of 30 kg ha^{-1} in K_2O increased the yield of broad beans by 21 to 40%. On the other hand, after the application of 60 kg ha^{-1}. [63] found that the seed yield increased by 19%. The use of fertilizer is considered to be one of the most important factors to increase crop yield. Potassium often limits production and needs to be included in a soil fertility program; potassium should be included as correcting nutrient. Increases in soybean yield were obtained in response to potassium fertilizer. The author [93] reported that potassium showed significant effect on yield and yield attributes of soybean in application of 40 kg ha^{-1}. Potassium is of great importance to increase nitrogen activity which results in high levels of uricides in pod walls and good seed partitioning increasing seed production [259]. As yields have increased, the total amount of nutrients removed with the harvested produce has increased. If the productive capacity of the soil, its fertility is not to decrease, then nutrients such as potassium removed from the field in the harvested crop must be replaced [128].

2. 4. Nitrogen and potassium fertilizers

2. 4. 1. Effect of nitrogen and potassium fertilizers on growth parameters

A significant interaction between the application of nitrogen and potassium was observed. The plants which were treated by nitrogen and potassium had more new leaves on the top of stem than other treatments. It caused an increase in plant height and light efficiency. Radiation absorption decreased when there were coating agents of nitrogen and potassium [194].The most important crop nutrients in agricultural systems are nitrogen and potassium [69]. Most compound fertilizers will contain these two elements essential for plant growth: nitrogen and potassium which stands for nitrogen (promotes leaf growth) and potassium (stem and root growth and protein analysis). The increased growth of soybean may be due to optimum nutrient supply and better soil condition for growth of root and shoot of the soybean crop [49]. Adequate amounts of potassium must be readily available in the soil for plant uptake to maintain cell turgid and efficient photosynthesis. If there is not sufficient potassium, nitrogen will be used inefficiently. Available potassium in the soil, it was only justified to apply 50 kg N ha^{-1} but with adequate potassium, 100 kg N ha^{-1} gave the optimum yield. When nitrogen does not increase yield because of lack of potassium, the excess nitrogen remains in the soil after harvest as nitrate, at risk of loss [128]. Significantly higher plant height, number of branches per plant, total dry matter production, was recorded in 80: 30 N: K_2O kg ha^{-1}. Increasing nitrogen and Potassium fertilizer increased some of growth parameters [5]. The changes in chlorophyll concentration are due to the ability of plants to maintain the source of power in environmental conditions; it was observed that Chlorophyll content is one of the key factors in determining the rate of photosynthesis and production of dry matter [103]. The application of plant nutrients, especially nitrogen and potassium affect the plants shoot characteristics such as leaf size, leaves direction and the ageing process of lower leaves that they cause an increase the light absorption by plants [274]. [194] reported that the, the application of nitrogen associated with potassium caused an increase in chlorophyll content. The main factors which affected chlorophyll content are nitrogen concentrations; chlorophyll content is being made in enough nitrogen concentration. The plant photosynthesis is increased by an increase in Chlorophyll content and it will lead to increase in yield. Potassium is often referred as the quality element for crop production due to its positive interaction with other nutrients (especially with nitrogen) and production practices [263]. Application of nitrogen and potassium to pea crop usually promotes vegetative growth and nodulation, and improves green pod yield [269]. Vine length tended to increase as the rate of all the both nutrients increased [74]. Sufficient potassium also ensures that other inputs required to achieve optimum economic yields are used efficiently. This applies especially to the use of nitrogen. With an adequate potassium supply, increased yields with nitrogen are accompanied by large amounts of nitrogen in the crops and thus smaller residues of nitrate in the soil at harvest at risk to loss [128]. Fertilizers are sources of mineral elements which plants required for growth and development. Nitrogen and potassium have great effects on plant growth and development; their deficiencies or excesses result in marked effects on growth and yield crops [102]. Significance increments on leaf nitrogen, potassium and chlorophyll contents due to increasing nitrogen fertilizer from 30 to 90 Kg N fed^{-1}, compared with the control treatment. The application of 60 Kg N fed^{-1} seemed to be sufficient and pronounced in this concern [97]. [175] reported that without applications of potassium the yield responses to nitrogen application were smaller.

2. 4. 2. Effect of nitrogen and potassium fertilizers on yield parameters

Applied nitrogen improved the potassium concentration of snap bean pods when compared to zero nitrogen [122]. Nitrogen and potassium have great effects on plant growth and development. Their deficiencies or excesses result in marked effects on the growth and yield of crops [129]. [102] investigate the effect of nitrogen and potassium with different fertilizers on beans crop yield. Results showed that means of green pods yielded by nitrogen and potassium fertilizer was significantly higher than other fertilizers. Nitrogen fertilizer promotes vegetative growth and green coloration of foliage; and Potassium is important in flower and fruit growth, a plant metabolism, protein synthesis and chlorophyll development [280]. [184] investigated three plant densities (250×10^3, 333×10^3, and 500×10^3 plants ha^{-1} as maintained by (20 x 10, 30 x 10, and 40 x 10 cm spacing, respectively) and three levels of nitrogen (0, 60, and 120 kg ha^{-1}). The lowest plant density (250×10^3 plants ha^{-1}) recorded significantly higher values of growth and yield attributes, except plant height which was the maximum with the highest plant density of 500×10^3 plants ha^{-1}. The highest plant density of (500×10^3 plants ha^{-1}) resulted in the highest pod yield in comparison with the lower and medium plant densities. Application of 120 kg N ha^{-1} coupled with the highest plant density ($500 \times l0^3$ plants ha^{-1}) gave the maximum pod yield. [234] worked on three levels of nitrogen (40, 80 and 120 N kg ha^{-1}), with two levels of potassium (30 and 60 K_2O kg ha^{-1}) with an absolute control (0: 0 N: K kg ha^{-1}). Significantly higher grain yield was recorded in 120: 60 kg N: K_2O ha^{-1}, which was on par with 80: 60 N: K_2O kg ha^{-1} and

80: 30 N: K_2O kg ha^{-1}. Significant number of pods per plant, seeds per pod, 100 seed weight and seed yield per plant were recorded in 80: 30 N: K_2O kg ha^{-1}. Increasing nitrogen and Potassium fertilizer increased yield of green beans [5]. [102] compared between nitrogen and potassium with other fertilizer found that the highest total green pod yields were obtained by applying the mix of nitrogen and potassium recorded while, K_2O fertilizer (alone) and untreated plants gave the lowest green pods. Statistical analysis demonstrated that means of green pods yielded by nitrogen and potassium fertilizer were significantly higher than other fertilizers. [31] conducted an experiment to investigate the effect of nitrogen and potassium on French bean. They used different doses of this element combination. It was concluded that nitrogen promoted growth and suggested that 25 and 50 Kilogram potassium per hectare was the best combination in terms of economics and seed yield. [99] reported that 120 Kg nitrogen and 45 Kg potassium per hectare gave a higher grain yield. The highest total green pod yields were obtained by applying the mix of nitrogen and potassium while, K_2O fertilizer and untreated plants gave the lowest green pods [102]. [194] worked in different doses of nitrogen and potassium found that the maximum and minimum fresh pod yield was observed in the lower nitrogen dose without potassium and in higher nitrogen dose with lower potassium treatments, respectively. High nitrogen treatments without potassium application had the lowest fresh pod yield because the number of flowers formed had significantly decreased therefore the process of flowering and pod was reduced in these treatments. Many scientists reported the effect of nitrogen in the reduction of nitrate accumulation in the plant [149; 120; 170]. Reduction of nitrate to nitrite and ultimately hydroxyl amine is affected nitrate and nitrite reeducates enzymes when these processes are activated effectively by micronutrients. The period of vegetative growth has become longer in higher nitrogen and lower potassium treatment application, and the plant has entered its reproductive phase later and thus its flowering and pod has coincided with hot season, function of enzymes was disrupted by environmental temperature and thus nitrate increased significantly [194].

2. 5. Plant density and dose of nitrogen and potassium fertilizers

2. 5. 1. Effect of plant density and dose of nitrogen and potassium fertilizers on growth parameters

There are many competing factors that play an extremely important role in the production of beans and their profitability to the producer. Such as fertilizer, row spacing and seeding rate are just a few vital factors that producers must consider when planting snap bean or any other production crop. It is important to plant the number of seeds that will achieve the desired number of plants per acre in a uniform stand of soybeans [71]. Plant density and soil fertility are the two important factors of crop production. Contrary to the general recommendation of reduced nitrogen application to legume crops because of their ability to fix atmospheric nitrogen, French bean readily responds to large doses of nitrogen. French bean possesses high yield potential, but unlike other leguminous crops, it does not nodulate with the native rhizobia and its response to applied nitrogen is as high as 120 kg ha^{-1} [248; 214]. A suitable combination of plant spacing and nitrogen level is very important in producing higher yields of French bean [184[. [23] reported that the close spacing of 20 cm x 10 cm coupled with the highest nitrogen produced maximum plant height. [34] directed a field experiment to evaluate the effect of different nitrogen levels (0, 30 and 45 kg ha^{-1}) and seeding rates (30, 40 and 50 kg ha^{-1}) on cluster bean. The plant height and branches capacity responded positively to applied nitrogen, and each increase in nitrogen levels significantly increased the both parameters, the tallest plants and higher number of branches were obtained from plots given nitrogen at 45 kg ha^{-1}. The plant height was not affected significantly by seed rates and maximum plant height was recorded at 40 kg seed ha^{-1}. Increasing the seed rates decreased the number of branches. The reason for having less number of branches at higher seed rates may be due to more competition among plants for light, space and nutrients at higher seed rates. The highest branches per plant were observed in seed rate of 30 kg ha^{-1}. The interactive effect of nitrogen and seed rates was not significant on all recorded parameters except green and dry matter yield. The lowest green forage and dry matter yield were obtained with lowest seed rate 30 kg ha^{-1} and without nitrogen application. The highest green forage and dry matter yield was obtained at seed rate of 50 kg ha^{-1} with nitrogen application at 45 kg ha^{-1}.

[184] tasted different plant densities with different nitrogen doses indicated that there was a significant difference in plant height, the maximum plant height was recorded with the highest plant density of 120 kg N ha^{-1} while, the minimum plant height was recorded at highest plant density without nitrogen. Average data indicate that 250 x 10^3 with 60 kg N ha^{-1} treatment gave the maximum plant height closely followed by 500 x 10^3 with 120 kg N ha^{-1}. [199] worked in different levels of nitrogen (0, 30, 60, and 90 kg ha^{-1}) and different plant spacing (30 x 10, 30 x 15 and 30 x 20 cm) found significances differences due to the interaction effect of nitrogen and plant density on some growth parameter. The highest plant found in wide plant spacing with high nitrogen dose, while the lowest plant height was found at narrow plant spacing with control. The combination of large spacing with higher nitrogen application gave the greatest number of leaves, while the lower number presented at combination of higher nitrogen application with no nitrogen fertilizer. Number of branches per plant was greater at large spacing with middle of nitrogen dose while, narrow plant spacing with no nitrogen gave the lower branches per plant. A plant treated by lower density with higher nitrogen dose required the longest time for first flowering, while the plant treated by higher density with no nitrogen application required the shortest time for first flowering. Lower density with higher nitrogen dose with gave the grand fresh weight of the plant while higher density with control (no nitrogen) gave the lower weight. [184] examined three plant population 500 x 10^3, 333 x 10^3 and 250 x 10^3 plants ha^{-1} maintained by adopting 20 x 10, 30 x 10, and 40 x 10 cm spacing, respectively, and three levels of nitrogen (0, 60, and 120 kg ha^{-1}), Concluded that French bean should be cultivated at the plant density of 500 x 10^3 plants ha^{-1} with application of 120 kg N ha^{-1} for obtaining higher yield. Plant population and fertilizes presented no significant effect on dry matter of shoot system [114].

2. 5. 2. Effect of plant density and dose of nitrogen and potassium fertilizers on yield parameters

Several authors have reported that pod yield of French bean increases with the increase of plant density [18; 81; 186; 233; 240]. [23] found the maximum number of green pods per plant and green pod weight per plant was recorded with the lower plant density at the highest nitrogen level (500 x 10^3 with 60 kg N) whereas, the highest plant density with 0 kg N ha^{-1} gave the lowest values. The maximum pod yield per hectare was recorded with the highest plant density at the highest dose of nitrogen (120 kg ha^{-1}) while, minimum pod yield per hectare was noticed in control with the highest plant density. Average performance indicated that the highest plant density accompanied by the high nitrogen levels gave the highest pod yield per hectare. [184] indicated that there was a significant difference in the number of green pods and green pod weight per plant and green pod yield due to plant density and nitrogen rate interaction due to the different plant densities and different nitrogen doses. Increased total top dry matter was observed significantly affected by plant density. Pod dry matter did not respond to interaction effect of nitrogen and spacing [114]. Protein and mineral concentration of snap bean pods were affected by cultural practices, including nitrogen fertilizer and planting densities [6]. Further, yield and quality of snap bean plant was significantly affected by macro and micro nutrients [257; 4]. [240] studied the effect of plant spacing and nitrogen level; they found that the net return was highest with up to 120 Kg nitrogen per hectare and 30 x 10 cm spacing. [148] reported that the plant density of 222222 and 333333 plants per hectare yielded 1.12 and 1.14 ton respectively, and the yield were decreased at the 444444 plants per hectare to the 1.05 ton. They observed that 60 Kg nitrogen per hectare gave the highest yield. [192] found that the closest spacing (30 x 5 cm) and the highest rate of nitrogen (75 kg) resulted in the higher yields in pea, but no appreciable response to (25 or 50 Kg K_2O ha^{-1}) was observed. [213] where used distance between row of four levels (10 × 40, 20 × 40, 30 × 40 and 40 × 40 cm) with four levels of nitrogen (0, 25, 50 and 75 kg ha^{-1}) regarded that the interaction between plant spacing and nitrogen fertilizer on green pod yield of bean per unit area was significant. The best yield belongs to the treatment in which the planting space is 40 x 20 cm and 50 kg ha^{-1} nitrogen fertilizers are used, while the lowest yield belongs to the treatment in which the planting space is 40 x 20 cm and 75 kg ha^{-1} nitrogen fertilizer is used. [145] reported that the interaction between planting space and nitrogen fertilizer on rice yield per unit area is significant. Likewise, [143] reported that the interaction between planting space and nitrogen fertilizer on seed is significant, as the density of Biomass: The intense competition between plants with short spaces is the main cause of low biomass production. In higher densities, the competition between plants belonged to a single species will result in decreasing of plant weight, at the same time in such densities we see that numerous plants will compensate the little weight which in turn enhances the biological yield per unit area. [48] observed that at spacing 22.5 x 15, 30 x 9 and 40 x 5 cm (296296, 370370 and 444444 plant ha^{-1}, respectively) gave a mean seed yield of 1.30, 1.36 and 1.34 ton per hectare, respectively. [225] stated that the row spacing had significantly influence on growth and pod yield of Snap bean. They reported that the yield was decreased with increasing row spacing (45 and 75 cm). [11] found that the plant density did not affect the yield and lower plant density of 222 thousand plants per hectare showed significant increase in yield per plant. [203] observed that an increase in within row spacing increased pod number and seed yield per plant. Pod number per unit area was more closely related to seed yield at higher plant density. [84] curried out an experiment to observe the response of Snap bean to the density and nitrogen levels. The crop was sown at inter row spacing of 30, 45 and 60 cm with an inter row spacing of 8 cm to give densities of (400, 286 and 200 thousand plant per hectare, respectively) and was given (40, 60, 80 and 100 Kg N ha^{-1}, respectively) reported that the yield was highest at a density of 400 thousand plant per hectare with a nitrogen level of 80 Kg ha^{-1}. [239] their results revealed that application of 62.5 Kg nitrogen and 100 Kg potassium per hectare and closer spacing of 35 x 25 cm produced significantly the maximum green pod yield. [199] worked in different levels of nitrogen (0, 30, 60, and 90 Kg) and different plant spacing (30 x 10, 30 x 15 and 30 x 20 cm) the highest number of pod green per plant presented in plants received higher dose of nitrogen with largest spacing, followed by the same dose of nitrogen with middle spacing while, zero nitrogen with narrow spacing gave the lowest number of green pods per plant. The seed rates and nitrogen application are vital factors for obtaining higher yield of crops, it has been recognized that the careful use of fertilizer can improve the yield of crops [229].

CHAPTER 3

MATERIALS AND METHODS

3. 1. Site of experiment

This study was carried out during winter seasons of the years 2015 and 2015/2016 (means of the minimum and maximum temperature were 16.86; 26.05°c and 14.40; 24.42°c in the first and second season, respectively), in the glasshouse of the laboratory of vegetables biotechnology production, faculty of Nature and Life Sciences, University of Blida 1, Algeria. The geographical coordinates are 36º 28 ’ 7 ’’ North, 2º 49’ 44’’ East, 260 m above the sea level.

3. 2. Experimental design

The experiment was executed in split trial in randomized complete block design with three replications. Four plastic pots 33 × 30 cm in dimensions contain 8.5 Kg soil were used as an experimental units.

2. 3. Treatments

The treatment consisted of two plant densities (D), D_1; one plant per pot (107145 plants per hectare) and D_2; two plants per pot (214290 plants per hectare) used as main plot, and seven fertilizers doses (F), (N_0 K_0; N_1 K_0; N_1 K_1; N_2 K_0; N_2 K_2; N_0 K_1; and N_0 K_2) used as sub plot. N_0, N_1 and N_2 equal to 0, 0.46 and 0.92 gram urea (46% nitrogen) per pot respectively, while K_0, K_1 and K_2 equal to 0, 0.42 and 0.84 gram potassium sulfate (50% potassium) per pot respectively. The fertilizer treatments applied as one dose, at four weeks from sowing.

3. 4. Soil characteristics

The soil is heavy clay with pH 7.75, and electric conductivity of 0.49 ds m^{-1}, contained 0.002 μeg g^{-1} potassium sulfate, 0.8 g Kg^{-1} azotes and 1.80% organic matter.

3. 5. Cultural practices

The cultural practices were made on similar phase at both seasons including the following:

3. 5. 1. Planting

The seeds were soaked in water for one day and pre-sown in a moist piece for four days, and then transplanted into plastic pots.

3. 5. 2. Irrigation

The plants were watered (normal water of Blida state) with the same equal quantities according to the plants need.

3. 5. 3. Weeds control

The weeds were uprooted handily to minimize it to the lower level as possible, in addition to soil dislocated after irrigation.

3. 5. 4. Plants protection

Used Menthomyle 25% (Pesticide) as solution 1.20 gram per liter water, sprayed uniformly on the plant when they required.

3. 6. Data collection

The data of both seasons was recorded to evaluate the effect of treatments on the following attributes;

3. 6. 1. Growth parameters

The vegetative growth from four plants was assessed (40, 55 and 70 days from sowing) during both seasons to evaluate the following parameters.

3. 6. 1. 1. Plant height (cm)

Plant height was measured from the base of the main stem to the apical bud for each plant and the average height was recorded.

3. 6. 1. 2. Number (No.) of leaves per plant

The total number of leaves of the same plants was registered and the mean of leaves number was noted.

3. 6. 1. 3. Number (No.) of branches per plant

The number of branches per plants was determined and the average number of branches per plant was calculated.

3. 6. 1. 4. Days to reach 10% and 50% flowering

The number of days required to reach 10% and 50% flowering were recorded by observing each experimental unit.

3. 6. 1. 5. Shoot fresh weights (g)

At the end of both experiments, shoots of four plants were separated from the roots and weighted to get shoot fresh weight.

3. 6. 1. 6. Shoot dry weights (g)

The separated shoots were dried approximately for five days under the shade and then in an oven, for two days at 78^{0}c till reaching the constant weight, and the dry weight of shoot was archived.

3. 6. 1. 7. Shoot dry matter (%)

The fresh and dry weight of the four plants were used to calculate the percentage of plant dry matter by the following formula;

$$\textbf{Shoot dry matter (\%)} = \frac{\textbf{Shoot dry weight (g)}}{\textbf{Shoot fresh weight (g)}} \times 100$$

3. 6. 2. Yield parameters

Each plant was harvested in a suitable period (3 days interval) until the end of the experiment to evaluate the following parameters.

3. 6. 2. 1. Number (No.) of pods per plant

The total number of pods from each four samples was determined and the average number of pods per plant was registered.

3. 6. 2. 2. Pod yield per plant (g)

The counted pods was weighted to calculate pods yield per plant using the following formula;

Pods yield per plant (g) = Number of pods per plant x pod fresh weight (g)

3. 6. 2. 3. Pod yield per hectare (t ha^{-1})

Pods yield per hectare was calculated from the yield per plant multiplying by the number of plants per hectare, as follows;

$$\text{Pods yield per hectare (t/ha)} = \frac{\text{Pods yield per plant (g)}}{1000000} \times \text{number of plant per hectare}$$

3. 6. 2. 4. Pod length (cm)

Twenty pods were randomly selected as a pattern during harvesting time (five pods in barter harvest) and measured to obtained mean of pod length.

3. 6. 2. 5. Pod diameter (mm)

The diameters of the same pods were measured using Vernier Caliper and mean pod diameter was listed.

3. 6. 2. 6. Pod fresh weight (g)

Fresh weights of the same twenty pods were weighted separately (five pods in four times) and the mean of the pod fresh weight was recorded.

3. 6. 2. 7. Pod dry weight (g)

The pods used for fresh weight (twenty pods) were dried under room condition until the end of the harvesting period and in an oven 78^{0}c till constant weight was reached, and the mean of pod dry weight was booked.

3. 6. 2. 8. Pod dry matter (%)

The fresh and dry weights of the twenty pods were used to calculate the percentage of pod dry matter using the following formula;

$$\text{Pod dry matter (\%)} = \frac{\text{Pod dry weight (g)}}{\text{Pod fresh weight (g)}} \times 100$$

3. 7. Statistical analysis

The data was statistically analyzed using computer software programme (MSTAT-C). Randomized Complete Block Design (R. C. B. D) was used for data analysis and Duncan multiple range test D. M. R. T, was used for mean separation at probability ≤ 0.05.

CHAPTER 4
RESULTS

4. 1. Effect of plant density and dose of nitrogen and potassium fertilizers on growth parameters

4. 1. 1. Plant height (cm)

The effect of plant density on plant height presenting significant difference in the early reading in both seasons and in the middle reading in the first season, whereas the greatest height shown at a high plant density (D_2). With no significant difference, increasing plant density (D_2) increased plant height, in the middle reading in the second season and in the late reading in the first season but in the second season low density (D_1) was mastery (Tables 1. 4; 2. 4; 3. 4; Figure 4. 1). As can be seen from the Table 1. 4, the data reflecting significant effect of fertilizers on plant height. In the first season, the tallest plant presenting by a plant received a half dose of nitrogen (N_1 K_0) and the shortest plant shown by a plant received low dose of potassium without nitrogen (N_0 K_1). In the second season, the longest and shortest plants presented by a plant received no fertilizer and with higher dose of nitrogen without potassium (N_0 K_0; N_2 K_0), respectively. The effect of higher fertilizer dose on plant height seems to gradually increase with increasing plant age, and it had positive effect compared with other lower treatments (Figure 4. 2). High dose of nitrogen and potassium (N_2 K_2) gave the tallest plant during the first season in the middle and late reading, while in the second season high potassium dose (N_0 K_2) had a longest plant (Table 2. 4; 3. 4). The interaction between density and fertilizers showing significant differences. In the first reading of both seasons, the tallest plant gave by a high density (D_2) received no fertilizer (N_0 K_0), while the shortest plant obtained by a low density (D_1) treated by high dose of nitrogen fertilizer (N_2 K_0). In the middle reading, high plant density (D_2) treated by a high dose of both nutrients (N_2 K_2) and high potassium dose (N_0 K_2) had a greatest height. In the both seasons the most surprising aspect of the data is in the third reading, whereas the lower density (D_1) received full dose of potassium without nitrogen (N_0 K_2) gave the shortest and longest plant. The shortest plants in generally obtained by a low plant density (D_1) but with different doses of fertilizer (Tables 1. 4; 2. 4, 3. 4; Figure 4. 3).

Table 1. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on plant height (cm) at the first reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	13.00^{e}	17.54^{a}	15.27^{ab}	14.70^{abcd}	16.18^{a}	15.44^{a}
N_1 K_0	15.96^{abc}	16.13^{ab}	16.04^{a}	13.33^{cd}	14.38^{abcd}	13.75^{bcd}
N_1 K_1	14.52^{cde}	16.63^{ab}	15.58^{ab}	13.38^{cd}	13.72^{ab}	13.55^{cd}
N_2 K_0	11.21^{f}	14.97^{bcd}	13.09^{c}	12.63^{d}	13.98^{bcd}	13.30^{d}
N_2 K_2	13.90^{de}	15.84^{abc}	14.87^{ab}	13.82^{bcd}	15.58^{ab}	14.70^{abc}
N_0 K_1	12.92^{e}	13.13^{e}	13.02^{c}	14.17^{abcd}	15.38^{ab}	14.78^{abc}
N_0 K_2	$13.\ 56^{de}$	15.25^{bcd}	14.40^{c}	14.39^{abcd}	15.71^{a}	15.05^{ab}
Mean	13.58^{b}	15.64^{a}		13.77^{b}	14.99^{a}	
LSD at 0.05	D 1.66	F 1.38	DF 1.64	D 1.08	F 1.28	DF 1.81
C V%	6.68			7.48		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 2. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on plant height (cm) at the second reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	21.78^{e}	24.67^{ab}	23.22^{ab}	30.22^{cde}	33.58^{ab}	31.90^{ab}
N_1 K_0	24.08^{abc}	25.54^{a}	24.81^{ab}	29.57^{cdef}	32.25^{abc}	30.91^{bcd}
N_1 K_1	22.08^{bc}	25.79^{a}	23.94^{ab}	29.45^{def}	32.17^{abcd}	30.81^{bcd}
N_2 K_0	21.50^{c}	24.58^{ab}	23.04^{b}	28.00^{ef}	31.00^{bcd}	29.50^{cd}
N_2 K_2	24.25^{abc}	25.83^{a}	25.04^{a}	27.22^{f}	31.00^{bcd}	29.11^{d}
N_0 K_1	22.33^{bc}	24.58^{ab}	23.46^{ab}	30.67^{cd}	31.00^{bcd}	31.38^{abc}
N_0 K_2	21.61^{c}	25.75^{a}	23.86^{ab}	31.29^{abcd}	34.50^{a}	33.21^{a}
Mean	22.52^{b}	25.25^{a}		29.58^{a}	32.37^{a}	
LSD at 0.05	D 2.73	F 1.73	DF 2.45	D 3.06	F 1.99	DF 2.38
C V%	6.09			4.56		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 3. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on plant height (cm) at the third reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	37.33^{bc}	40.08^{abc}	38.71^{ab}	40.94^{ab}	40.258^{ab}	40.60^{a}
N_1 K_0	37.22^{bc}	36.22^{c}	36.72^{b}	41.67^{ab}	38.42^{b}	40.04^{a}
N_1 K_1	36.44^{bc}	38.64^{abc}	37.54^{b}	42.08^{ab}	40.75^{ab}	41.42^{a}
N_2 K_0	38.22^{abc}	40.94^{ab}	39.58^{ab}	41.11^{ab}	37.94^{b}	39.53^{a}
N_2 K_2	39.92^{abc}	42.83^{a}	41.15^{a}	41.33^{ab}	40.56^{ab}	40.94^{a}
N_0 K_1	39.67^{abc}	37.78^{bc}	38.72^{ab}	41.04^{ab}	38.58^{b}	39.81^{a}
N_0 K_2	36.22^{c}	40.14^{abc}	38.18^{ab}	43.58^{a}	41.67^{ab}	42.63^{a}
Mean	37.86^{a}	39.45^{a}		41.68^{a}	39.74^{a}	
LSD at 0.05	D 9.69	F 3.30	DF 3.94	D 10.29	F 3.26	DF 3.88
C V%			6.04			5.66

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

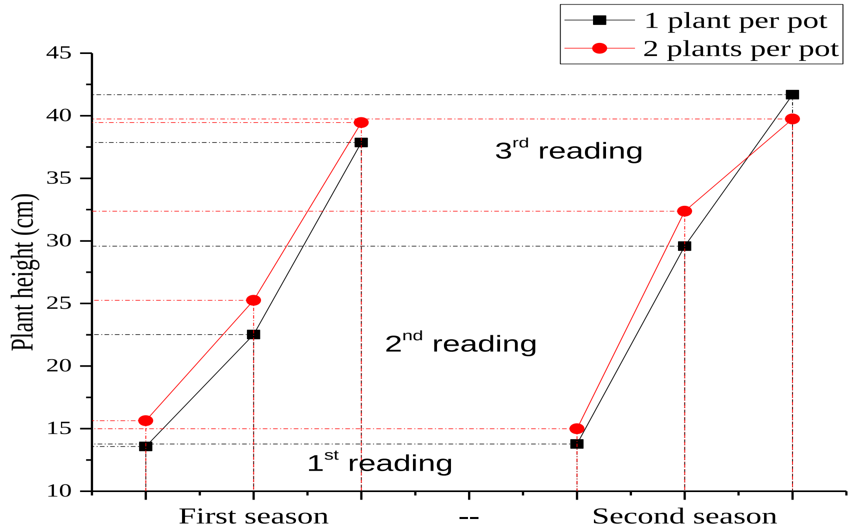


Figure 4. 1. Effect of plant density on plant height

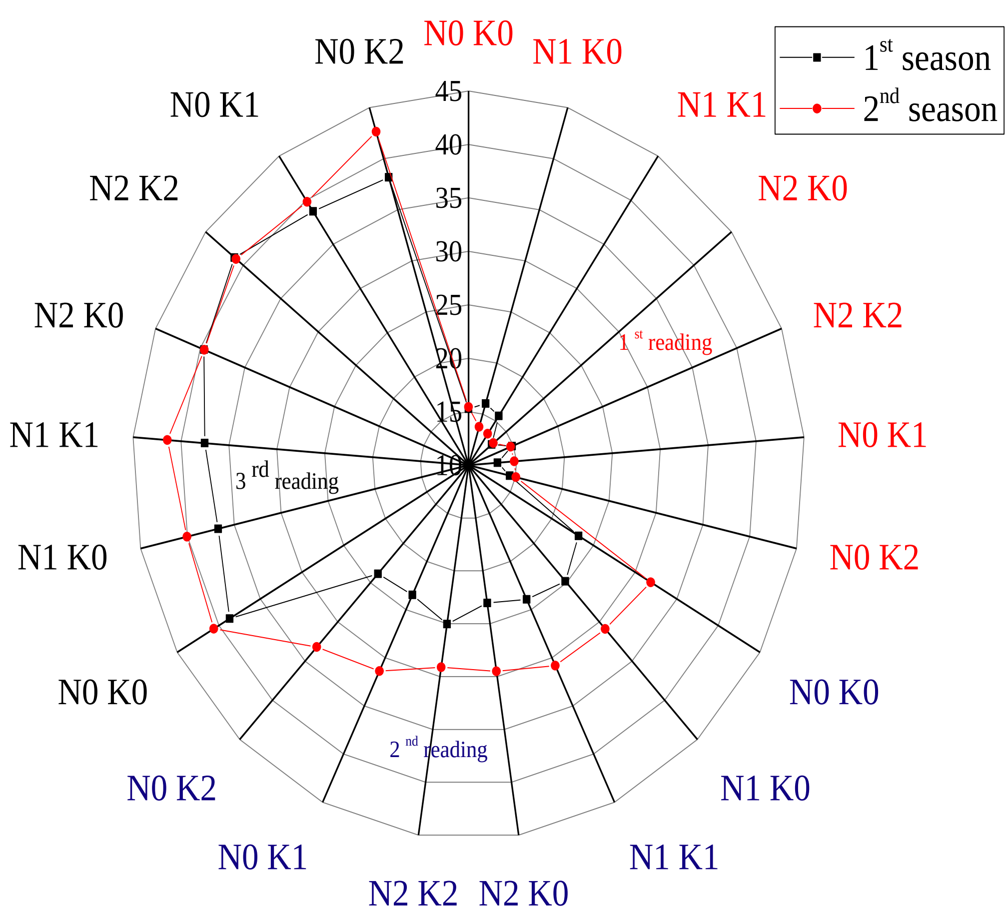


Figure 4. 2. Effect of nitrogen and potassium fertilizers on plant height

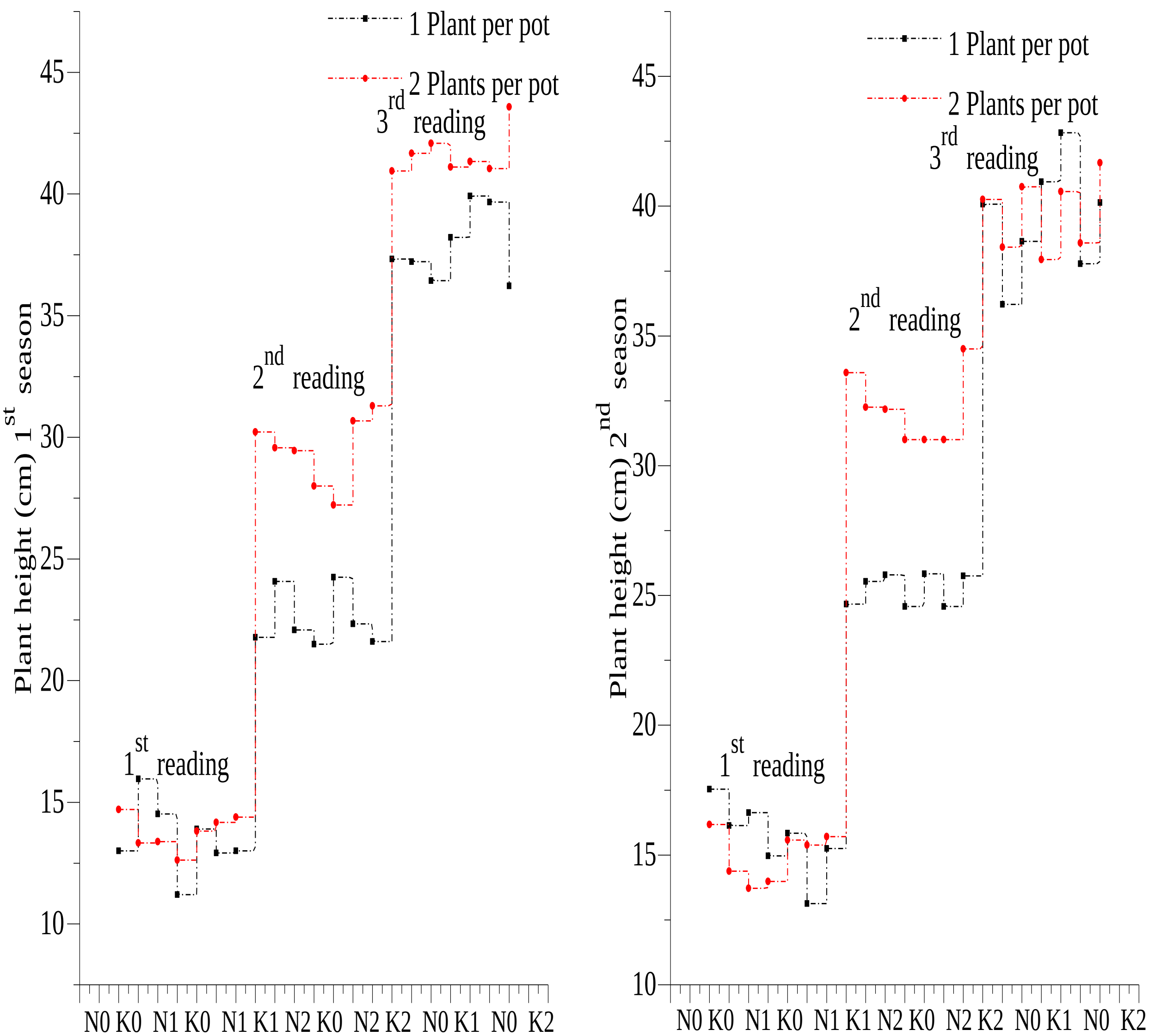


Figure 4. 3. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on plant height

4. 1. 2. Number (No.) of leaves per plant

As can be seen from the Tables 4. 4, 5. 4, 6. 4; Figure 4. 4 there is no significant difference on leaves number due to the plant density among early, middle and late reading, except in the second season at the third reading. Whereas, the highest number of leaves was obtained by the low plant density (D_1). The effect of nitrogen and potassium fertilizers as shown in Table 4. 4, reflect no significant effect on the number of leaves per plant in both seasons, in addition to the first season in the second reading Table 5. 4, and in the second season in the third reading (Table 6. 4). What stand out in the first and second season, increasing of both fertilizers (N_2 K_2) and potassium without nitrogen (N_0 K_2) increased significantly number of leaves per plant in late and middle reading respectively (Figure 4. 5; 4.6). In the middle reading of the second season, the lower dose of nitrogen and potassium separately (N_1 K_0; N_0 K_1) decreased leaves number. In the first season as in Table 6. 4, a plant received no fertilizer (N_0 K_0) and low dose of nitrogen and potassium (N_1 K_1) donates the smaller number of leaves per plant. The interaction between plant density and fertilizers dose significantly affects the number of leaves per plant except at the early reading in the second season. In the first season at two late readings, low density (D_1) remarkable effect with high dose of both fertilizers (N_2 K_2). This density (D_1) in the late reading of second season, as it was treated by the equal lower dose of both nutrients (N_1 K_1) gave a superior number of leaves. High density (D_2) with different doses of nitrogen and potassium fertilizers gave the lowest number of leaves per plant except at the early and middle reading of the first and second season respectively. During those reading, this density (D_2) received no fertilizer or received potassium in full dose increased leaves number (N_0 K_0; N_0 K_2) (Tables 4. 4, 5. 4, 6. 4; Figure 4. 6).

Table 4. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of leaves per plant at the first reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	5.92[ab]	6.83[a]	6.38[a]	4.72[a]	4.25[a]	4.58[a]
N_1 K_0	5.50[b]	6.17[ab]	5.83[a]	4.08[a]	4.42[a]	4.49[a]
N_1 K_1	6.00[ab]	6.50[ab]	6.25[a]	4.50[a]	4.19[a]	4.42[a]
N_2 K_0	5.56[ab]	6.25[ab]	5.90[a]	4.42[a]	4.17[a]	4.35[a]
N_2 K_2	6.25[ab]	6.44[ab]	6.35[a]	4.47[a]	4.50[a]	4.33[a]
N_0 K_1	5.92[ab]	6.50[ab]	6.21[a]	4.33[a]	4.50[a]	4.29[a]
N_0 K_2	5.83[ab]	6.17[ab]	6.00[a]	4.50[a]	4.67[a]	4.25[a]
Mean	5.85[a]	6.41[a]		4.39[a]	4.39[a]	
LSD at 0.05	D 0.69	F 0.91	DF 1.09	D 0.25	F 0.39	DF 0.56
C V%	10.52			7.59		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 5. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of leaves per plant at the second reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	11.89^{abcd}	11.97^{abcd}	11.93^{a}	9.17^{bc}	9.67^{ab}	9.42^{ab}
N_1 K_0	13.56^{ab}	12.17^{abcd}	12.86^{a}	8.64^{c}	9.33^{bc}	8.99^{b}
N_1 K_1	12.25^{abcd}	11.39^{bcd}	11.82^{a}	9.42^{bc}	9.67^{ab}	9.54^{ab}
N_2 K_0	13.50^{ab}	10.58^{d}	12.04^{a}	9.28^{bc}	9.86^{ab}	9.57^{ab}
N_2 K_2	13.64^{a}	11.56^{bcd}	12.60^{a}	9.56^{abc}	9.17^{bc}	9.36^{ab}
N_0 K_1	12.47^{abc}	11.08^{cd}	11.78^{ab}	9.00^{bc}	8.94^{bc}	8.97^{b}
N_0 K_2	12.69^{abc}	13.17^{abc}	12.93^{a}	9.42^{bc}	10.33^{a}	9.87^{a}
Mean	12.86^{a}	11.70^{a}		9.31^{a}	9.57^{a}	
LSD at 0.05	D 1.36	F 1.13	DF 1.60	D 1.54	F 0.66	DF 0.79
C V%			7.72			5.00

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 6. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of leaves per plant bean at the third reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	18.22^{bcde}	17.47^{cde}	17.85^{b}	18.07^{ab}	13.97^{ef}	16.02^{a}
N_1 K_0	19.83^{abc}	19.00^{bcde}	19.42^{ab}	16.50^{bcde}	14.89^{cdef}	15.69^{a}
N_1 K_1	19.00^{bcde}	17.25^{de}	18.13^{b}	19.03^{a}	14.37^{def}	16.70^{a}
N_2 K_0	19.67^{abcd}	17.44^{cde}	18.56^{ab}	16.92^{abcd}	15.72^{bcdef}	16.32^{a}
N_2 K_2	21.83^{a}	18.33^{bcde}	20.08^{a}	16.00^{bcde}	14.75^{cdef}	15.38^{a}
N_0 K_1	19.58^{abcd}	16.97^{e}	18.28^{ab}	16.89^{abcd}	13.33^{f}	15.11^{a}
N_0 K_2	20.33^{ab}	17.64^{cde}	18.99^{ab}	17.08^{abc}	14.00^{ef}	15.54^{a}
Mean	19.78^{a}	17.73^{a}		17.21^{a}	14.43^{b}	
LSD at 0.05	D 4.40	F 1.78	DF 2.12	D 1.49	F 1.88	DF 2.24
C V%	6.70			8.40		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

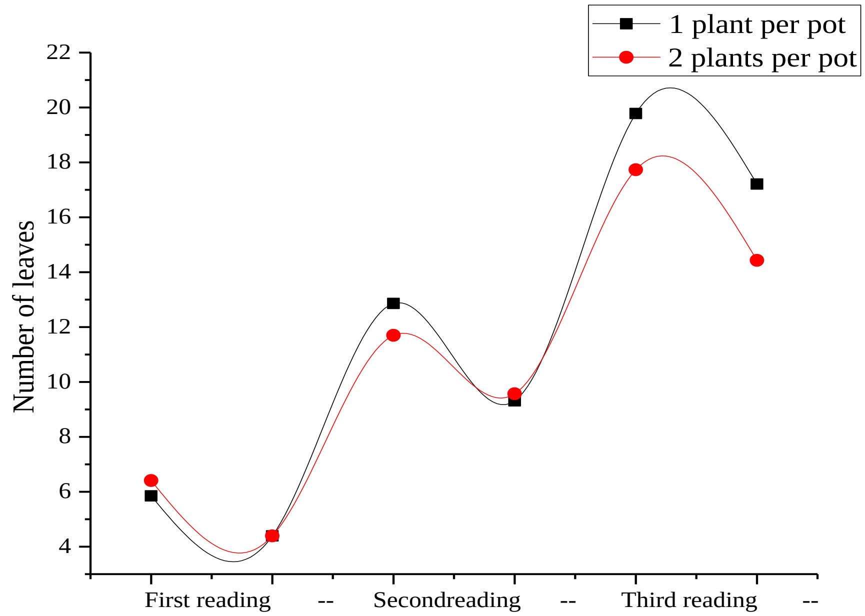


Figure 4. 4. Effect of plant density on number of leaves per plant

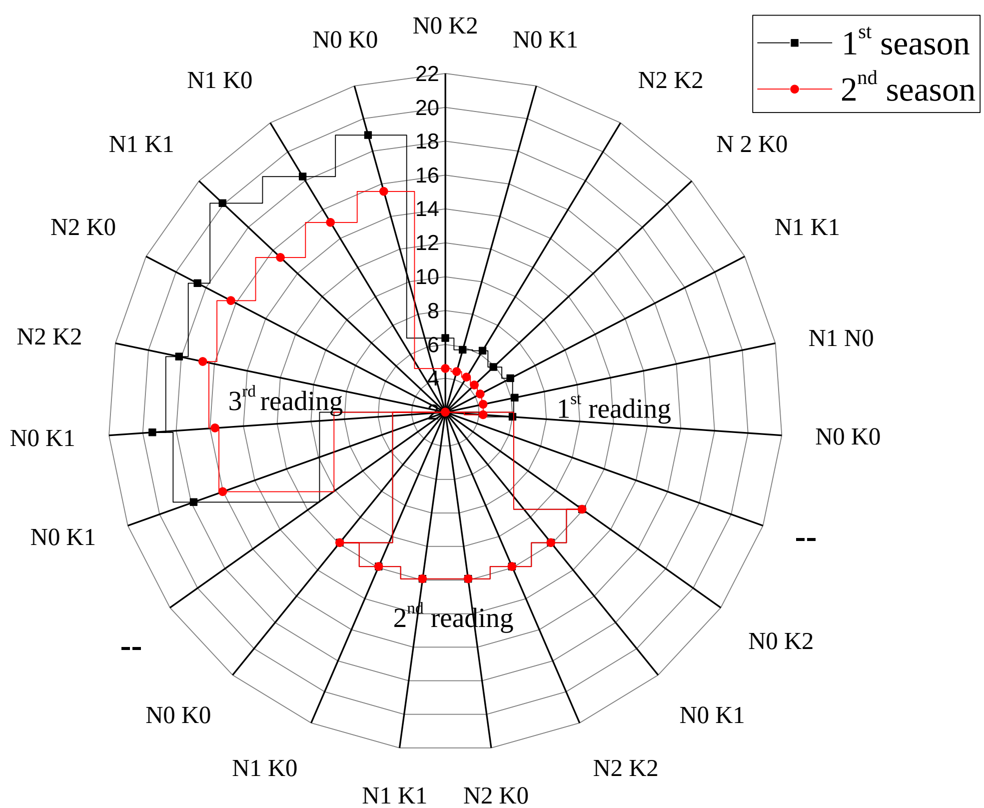


Figure 4. 5. Effect of nitrogen and potassium fertilizers on number of leaves per plant

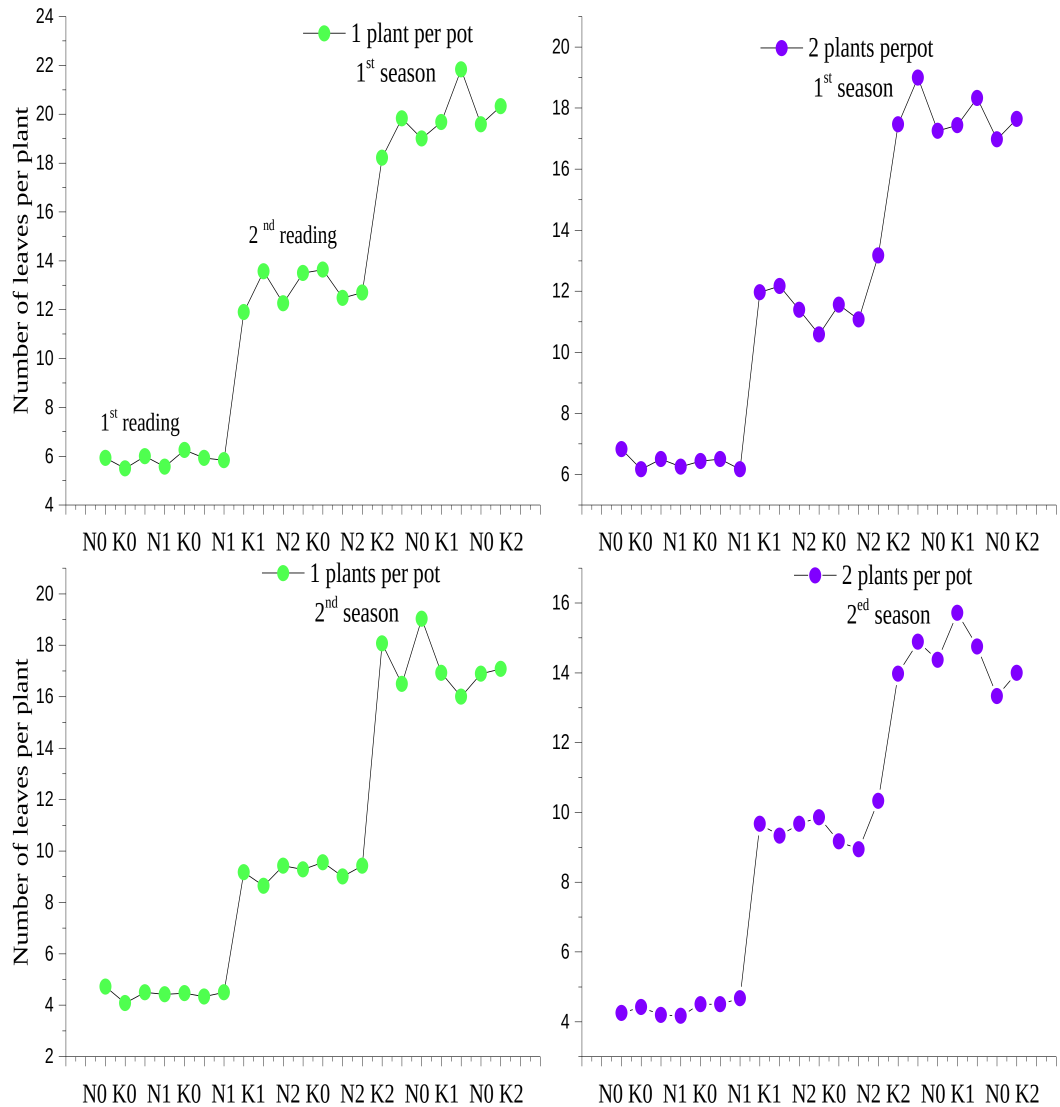


Figure 4. 6. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on number of leaves per plant

4. 1. 3. Number (No.) of branches per plant

No significant differences was noticed in both seasons and overall reading in the number of branches per plant due to the plant density except in the second season in the middle reading. Whereas, population density of two plants per pot (D_2) gave a higher number of branches per plant comparing with lower density (D_1) (Tables 7. 4, 8. 4, 9. 4). It can be seen from these Tables, that the fertilizer doses had no significant effect, except in the first and second season in the middle and first reading, respectively. In these both readings (Figure 4. 7) the highest values obtained by the higher and lower potassium dose without nitrogen (N_0 K_2; N_0 K_1). During the first season, the lower number of branches recorded by equal lower dose of both nutrients (N_1 K_1), while in the second season, recorded by a lower dose of nitrogen without potassium (N_1 K_0). The number of branches per plant significantly affected by the interaction. In both seasons and in the first reading, two plants and one plant per pot treated by equal half and higher dose of nitrogen and potassium fertilizers (N_1 K_1; N_2 K_2) respectively, had a biggest branches number. In both seasons these densities (D_2; D_1) minimized branches number when treated by lower dose of potassium (N_0 K_1) (Table 7. 4). In the middle reading, higher density (D_2) received lower and higher dose of potassium fertilizer without nitrogen (N_0 K_1; N_0 K_2) donate the greatest number of branches. In this reading, the both two densities treated by equal lower and higher dose of nitrogen and potassium fertilizers (N_1 K_1; N_2 K_2) gave lower number of branches (Table 8. 4). In spite of lowing density (D_1) treated by a half dose of nitrogen without potassium (N_1 K_0) screened a superior number of branches in the first season, decreased branches in the second season. In the second season, both densities of one and two plants per pot (D_1; D_2) received higher dose of both nutrients separately (N_2 K_0; N_0 K_2) showed the greatest number of branches per plant (Table 9. 4; figure 4. 8).

Table 7. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of branches per plant at the first reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 .plant/pot	2 plants/pot	
N_0 K_0	2.42[b]	2.83[ab]	2.63[a]	1.92[abc]	1.83[bcd]	1.88[abc]
N_1 K_0	2.58[ab]	2.58[ab]	2.58[a]	1.67[cd]	1.78[bcd]	1.72[c]
N_1 K_1	2.37[b]	3.13[a]	2.75[a]	1.94[abc]	1.92[abc]	1.93[abc]
N_2 K_0	2.50[ab]	2.67[ab]	2.58[a]	1.92[abc]	1.75[bcd]	1.83[bc]
N_2 K_2	2.81[ab]	2.58[ab]	2.69[a]	2.28[a]	1.75[bcd]	2.01[ab]
N_0 K_1	2.50[ab]	2.33[b]	2.42[a]	1.50[d]	2.08[ab]	1.79[bc]
N_0 K_2	2.67[ab]	2.83[ab]	2.75[a]	2.08[abc]	2.13[ab]	2.11[a]
Mean	2.55[a]	2.71[a]		1.90[a]	1.89[a]	
LSD at 0.05	D 0.19	F 0.49	DF 0.58	D 0.86	F 0.24	DF 0.34
C V%			13.14			10.55

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 8. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of branches at the second reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	3.89[ab]	4.33[ab]	4.11[ab]	4.19[ab]	4.00[ab]	4.10[a]
N_1 K_0	4.50[ab]	4.17[ab]	4.33[ab]	4.00[ab]	4.42[ab]	4.21[a]
N_1 K_1	3.86[ab]	3.16[b]	3.74[b]	4.08[ab]	4.67[a]	4.38[a]
N_2 K_0	4.17[ab]	3.97[ab]	4.07[ab]	3.94[ab]	4.50[ab]	4.22[a]
N_2 K_2	4.11[ab]	4.08[ab]	4.09[ab]	3.67[b]	4.17[ab]	3.92[a]
N_0 K_1	4.28[ab]	4.75[a]	4.51[a]	4.25[ab]	4.19[ab]	4.22[a]
N_0 K_2	4.56[ab]	4.42[ab]	4.49[a]	4.00[ab]	4.56[a]	4.28[a]
Mean	4.19[a]	4.19[a]		4.02[b]	4.36[a]	
LSD at 0.05	D 1.51	F 0.62	DF 0.88	D 0.16	F 0.59	DF 0.72
C V%	12.44			10.12		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 9. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of branches per plant at the third reading.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	6.00^{ab}	6.42^{ab}	6.21^{a}	5.75^{a}	6.17^{a}	5.96^{a}
N_1 K_0	6.72^{a}	6.33^{ab}	6.53^{a}	4.83^{b}	6.00^{ab}	5.42^{a}
N_1 K_1	6.17^{ab}	6.33^{ab}	6.25^{a}	5.53^{ab}	5.50^{ab}	5.51^{a}
N_2 K_0	6.67^{ab}	6.33^{ab}	6.50^{a}	6.19^{a}	5.61^{ab}	5.90^{a}
N_2 K_2	6.56^{ab}	5.50^{ab}	5.53^{a}	5.78^{ab}	5.53^{ab}	5.65^{a}
N_0 K_1	6.17ab	6.42^{ab}	6.29^{a}	5.83^{ab}	5.67^{ab}	5.75^{a}
N_0 K_2	6.25^{ab}	5.67^{b}	5.96^{a}	6.00^{ab}	6.25^{a}	6.13^{a}
Mean	6.36^{a}	6.29^{a}		5.70^{a}	5.82^{a}	
LSD at 0.05	D 0.94	F 0.75	DF 0.89	D 1.44	F 0.91	DF 1.09
C V%	8.39			11.22		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

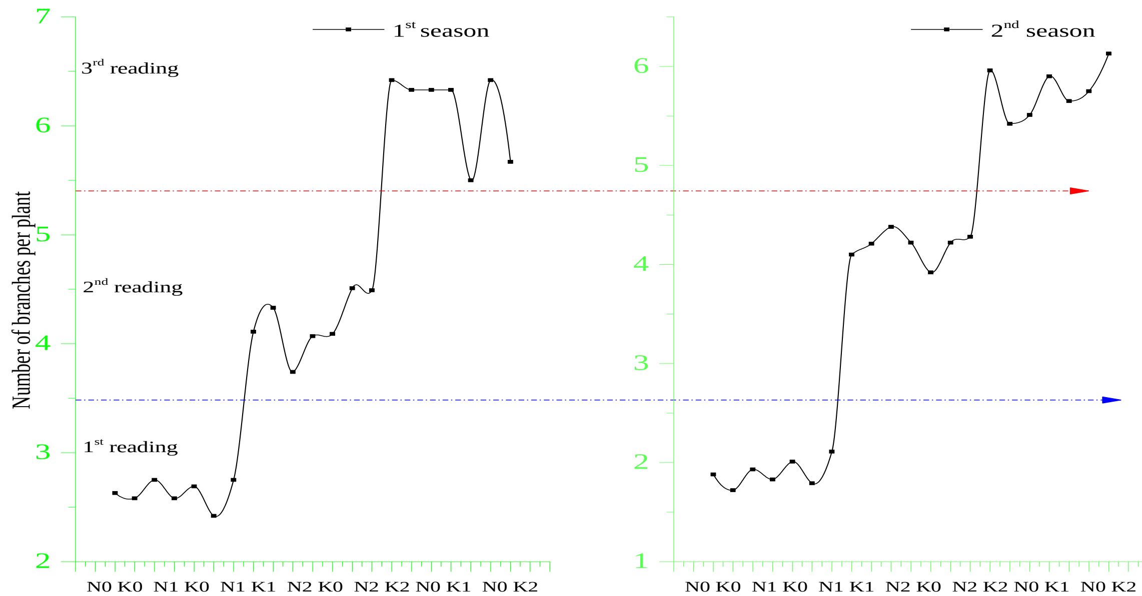


Figure 4. 7. Effect of nitrogen and potassium fertilizers on number of branches per plant

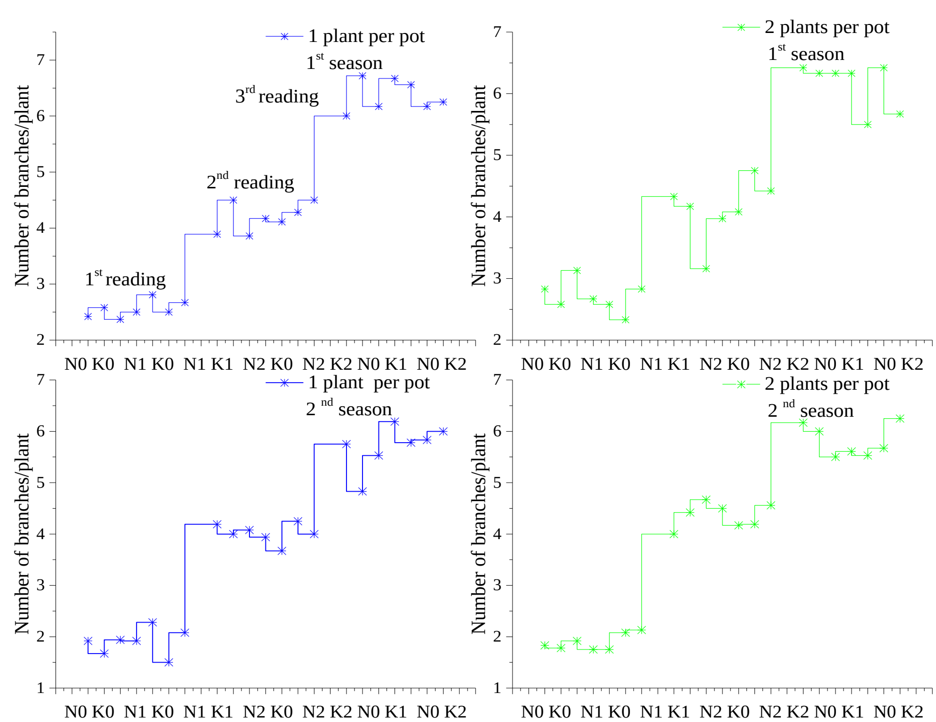


Figure 4. 8. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on number of branches per plant

4. 1. 4. Days to reach 10% flowering

No significant effect on days required to reach 10% flowering due to the plant density. In the first season dense planting (D_2) need relatively a short time comparing to low density (D_1) and vice versa in the second season. The effect of different nitrogen and potassium dose had a significant role in affecting the days of 10% flowering. In the first and second season, the plants treated by equal high and low dose of nitrogen and potassium (N_2 K_2; N_1 K_1) reached 10% flowering late, respectively. In both seasons, plant receiving no fertilizer (N_0 K_0) reached 10% flowering early, in addition to the plant treated by half dose of potassium only (N_0 K_1) in the first season which was statistically similar. The interaction between density and fertilizers dose significantly affected the days need to reaching 10 % flowering. In both season, dense planting (D_2) received no fertilizer (N_0 K_0) need short time. Low plant density (D_1) treated by double dose of nitrogen and potassium in the first season (N_2 K_2) and by half dose of them in the second season (N_1 K_1) delayed flowering. Different density (D_1 and D_2) and in cases of absent of nitrogen with or without potassium reached 10% flowering early (Table 10. 4; Figure 4. 9; 4. 10).

4.1. 5. Days to reach 50% flowering

Plant density had no significant effect on days needed to get 50% flowering. Over two seasons low plant density (D_1) relatively require long time to complete their flowering, while high plant density (D_2) reach flowering early. Increasing fertilizer dose of nitrogen and potassium (N_2 K_2) increased significantly the number of days to reach 50% flowering. The absence of either both fertilizers (N_0 K_0) or nitrogen only with the presence of potassium in small or high quantity (N_0 K_1 and N_0 K_2), the plant reach 50% flowering early. There is a significant difference in days to reach 50% flowering due to plant density and fertilizer interaction. In the first seasons, one plant per pot (D_1) treated by high dose of nitrogen and potassium (N_2 K_2) need long time, while in second season low and high plant densities (D_1; D_2) received equal low and high dose of both elements (N_1 K_1; N_2 K_2) late in flowering. In both seasons, the early flowering once upon the low and high planting (D_1; D_2) received no fertilizer (N_0 K_0), (Table 11. 4; Figure 4. 9; 4. 10).

Table 10. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on days to reach 10% flowering.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	47.00[c]	47.00[c]	47.00[d]	50.33[bc]	50.00[c]	50.17[c]
N_1 K_0	48.00[abc]	47.67[bc]	47.83[bc]	51.67[ab]	51.00[abc]	51.33[ab]
N_1 K_1	48.00[abc]	47.33[bc]	47.67[bcd]	52.33[a]	51.67[ab]	52.00[a]
N_2 K_0	48.33[ab]	48.33[ab]	48.33[ab]	51.00[abc]	51.00[abc]	51.00[abc]
N_2 K_2	49.00[a]	48.33[ab]	48.67[a]	51.33[abc]	51.67[ab]	51.50[ab]
N_0 K_1	47.00[c]	47.00[c]	47.00[d]	51.00[abc]	50.33[bc]	50.67[bc]
N_0 K_2	47.33[bc]	47.00[c]	47.17[cd]	50.67[bc]	50.33[bc]	50.50[bc]
Mean	47.81[a]	47.52[a]		50.19[a]	50.86[a]	
LSD at 0.05	D 0.35	F 0.64	DF 0.91	D 1.14	F 1.05	DF 1.26
C V%	1.13			1.46		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 11. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on days to reach 50% flowering.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	48.67[d]	48.67[d]	48.67[c]	52.33[bc]	52.00[c]	52.17[bc]
N_1 K_0	49.67[bcd]	49.33[bcd]	49.50[bc]	53.33[ab]	52.67[abc]	53.00[ab]
N_1 K_1	49.67[bcd]	49.33[bcd]	49.50[bc]	53.67[a]	52.67[abc]	53.67[a]
N_2 K_0	50.33[ab]	50.00[abc]	50.17[ab]	52.33[bc]	53.33[ab]	52.83[abc]
N_2 K_2	51.00[a]	50.00[abc]	50.50[a]	53.67[a]	53.67[a]	53.76[a]
N_0 K_1	49.00[cd]	48.67[d]	48.83[c]	52.67[abc]	52.33[bc]	52.50[bc]
N_0 K_2	49.33[bcd]	49.00[cd]	49.17[c]	52.33[bc]	51.67[c]	52.00[c]
Mean	49.67[a]	49.29[a]		52. 90[a]	52.66[a]	
LSD at 0.05	D 0.89	F 0.85	DF 1.02	D 1.07	F 0.84	DF 1.00
C V%			1.22			1.12

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

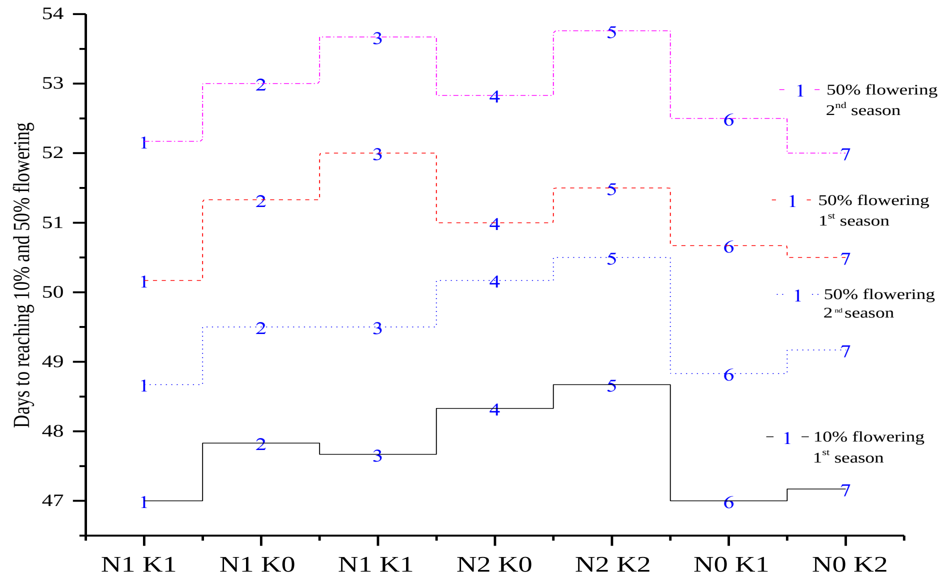


Figure 4. 9. Effect of nitrogen and potassium fertilizers on days to reach 10% and 50% flowering

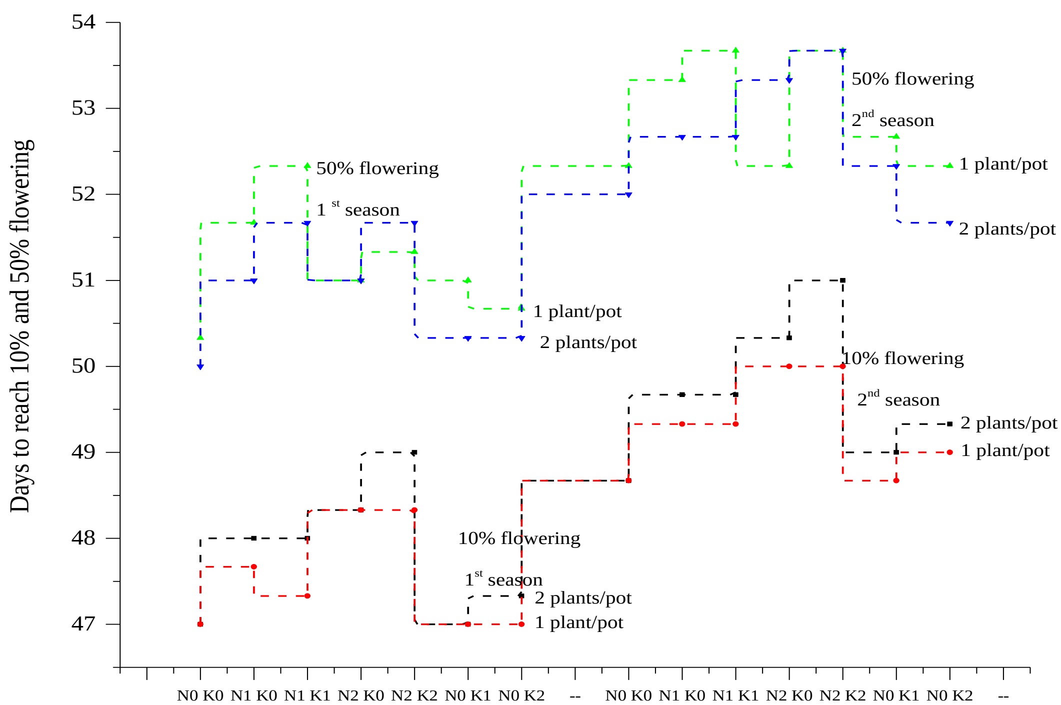


Figure 4. 10. Effect of population density and dose of nitrogen and potassium fertilizers on days to reach 10% and 50% flowering

4. 1. 6. Shoot fresh weight (g)

The population density, nitrogen and potassium fertilizers and their interactions showing significant different on shoot fresh weight (Table 12. 4; Figure 4. 11; 4. 12; 4. 13). In the both seasons, low plant density (D_1) gave the greatest shoot fresh weight. Plants received higher dose of nitrogen and potassium (N_2 K_2) in both seasons and high dose of nitrogen without potassium (N_2 K_0) in the second season had a heaviest fresh weight. The plants treated by nitrogen fertilizer are weighty, and statistically similar especially at the second season. In the first and second seasons the plant received lower and higher dose of potassium (N K_1; N_0 K_2) significantly decreased shoot fresh weight, respectively. The interaction between them showed that the low plant density (D_1) treated by higher dose of nitrogen and potassium (N_2 K_2) donate the weightiest plants over two seasons. High planting (D_2) spatially in the case of no nitrogen fertilizer decreased plant fresh weight even if treated by potassium or not.

4.1. 7. Shoot dry weight (g)

As in Table 13. 4 plant density, fertilizer doses and their interaction had a significant effect on plant dry weight. Increasing plant density up to two plants per pot (D_2) decreased significantly plant dry weight, compared with lower plant density (D_1) (Figure 4 14). The higher dose of nitrogen and potassium (N_2 K_2) in both seasons and lower dose of nitrogen without potassium in the second season (N_1 K_0) gave the greatest dry weights of the plant. Lower and higher dose of potassium without nitrogen (N_0 K_1 and N_0 K_2) and plant receiving no fertilizer (N_0 K_0) decreased plant dry weight (Figure 4.15). In both seasons, lower plant density (D_1) treated with higher doses of nitrogen and potassium (N_2 K_2) and lower dose of nitrogen (N_1 K_0) were significantly higher in dry weight. Higher plant density (D_2) receiving potassium without nitrogen of higher or lower dose (N_0 K_1; N_0 K_2) was mild in weight (Figure 4.16).

Table 12. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on shoot fresh weight (g).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	121.1^{bc}	88.80^{de}	104.9^{b}	118.9^{bc}	67.50^{f}	90.20^{bc}
N_1 K_0	140.2^{ab}	95.39^{cde}	117.8^{ab}	124.7^{bc}	85.94^{de}	105.3^{ab}
N_1 K_1	124.7^{b}	86.55^{de}	105.6^{b}	111.1^{c}	91.58^{d}	101.3^{abc}
N_2 K_0	140.5^{ab}	86.41^{de}	113.4^{ab}	129.1^{b}	85.17^{de}	107.2^{a}
N_2 K_2	156.3^{a}	111.3^{bcd}	133.8^{a}	146.8^{a}	82.90^{def}	114.8^{a}
N_0 K_1	129.6^{ab}	70.30^{e}	99.97^{b}	118.0^{bc}	66.84^{f}	92.34^{bc}
N_0 K_2	126.8^{b}	74.43^{e}	100.6^{b}	110.1^{c}	69.05^{ef}	89.56^{c}
Mean	134.2^{a}	87.60^{b}		122.7^{a}	78.00^{b}	
LSD at 0.05	D 13.96	F 21.89	DF 26.11	D 3.10	F 13.17	DF 15.71
C V%			13.97			9.27

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 13. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on shoot dry weight (g).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	22.04^{abc}	16.60^{def}	19.32^{abc}	26.26^{b}	14.59^{def}	20.42^{bc}
N_1 K_0	25.97^{a}	16.14^{ef}	21.06^{ab}	29.82^{a}	16.78^{de}	23.30^{a}
N_1 K_1	20.48^{bcd}	14.65^{fg}	17.57^{cd}	21.46^{c}	17.85^{d}	19.66^{bc}
N_2 K_0	23.71^{ab}	14.73^{fg}	19.22^{abcd}	26.60^{b}	16.94^{de}	21.77^{ab}
N_2 K_2	25.59^{a}	19.17^{cde}	22.38^{a}	30.35^{a}	17.85^{d}	24.12^{a}
N_0 K_1	21.01^{bc}	10.91^{g}	15.96^{d}	23.59^{bc}	14.13^{ef}	18.86^{c}
N_0 K_2	23.16^{abc}	12.78^{fg}	17.97^{bcd}	23.81^{bc}	12.97^{f}	18.39^{c}
Mean	23.14^{a}	15.00^{b}		26.00^{a}	15.86^{b}	
LSD at 0.05	D 4.94	F 3.11	DF 3.71	D 1.13	F 3.12	DF 2.61
C V%			11.54			8.84

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

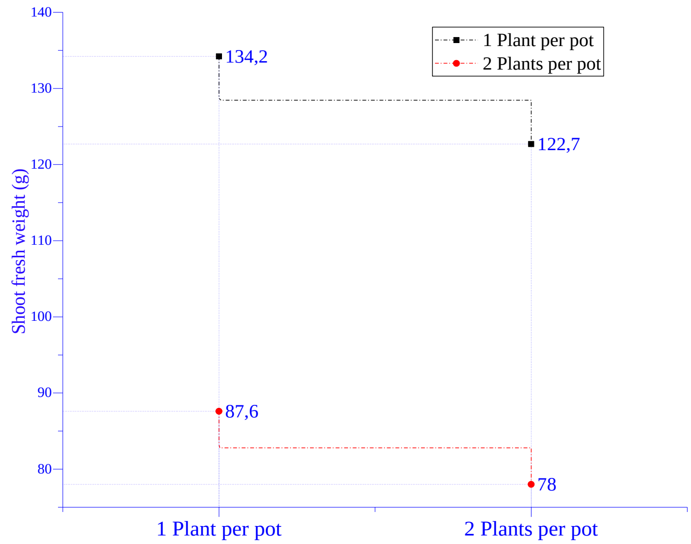


Figure 4. 11. Effect of plant density on shoot fresh weight

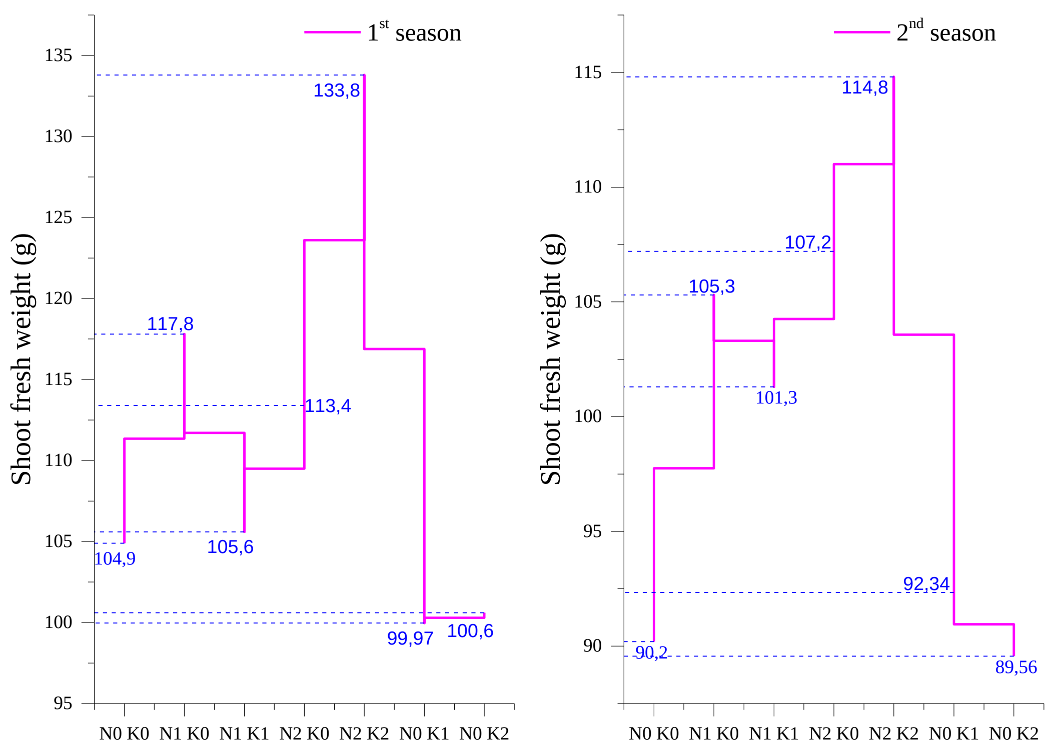


Figure 4. 11. Effect of nitrogen and potassium fertilizer on shoot fresh weight

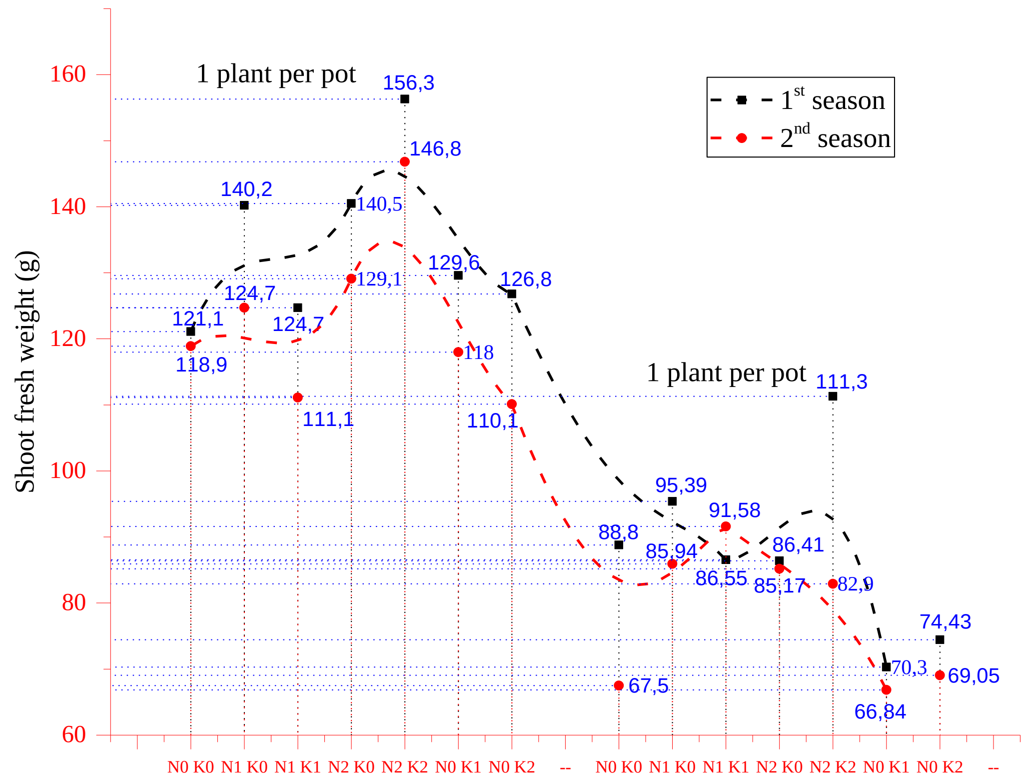
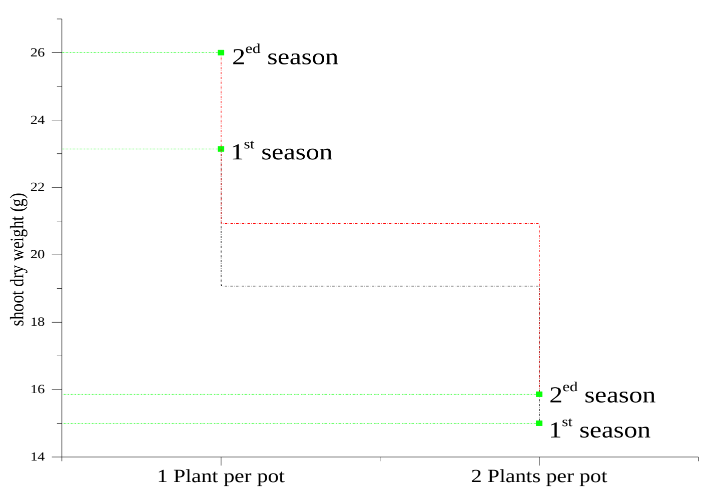


Figure 4. 13. Effect of interaction between plant density and dose of nitrogen and potassium fertilizer on shoot fresh weight



4. 14. Effect of plant density on shoot dry weight

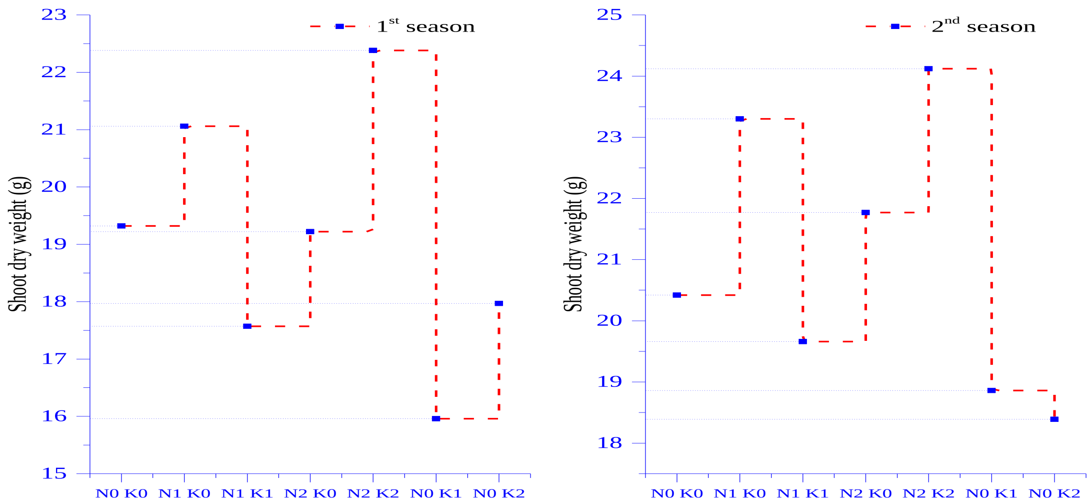


Figure 4. 15. Effect of nitrogen and potassium on shoot dry weight

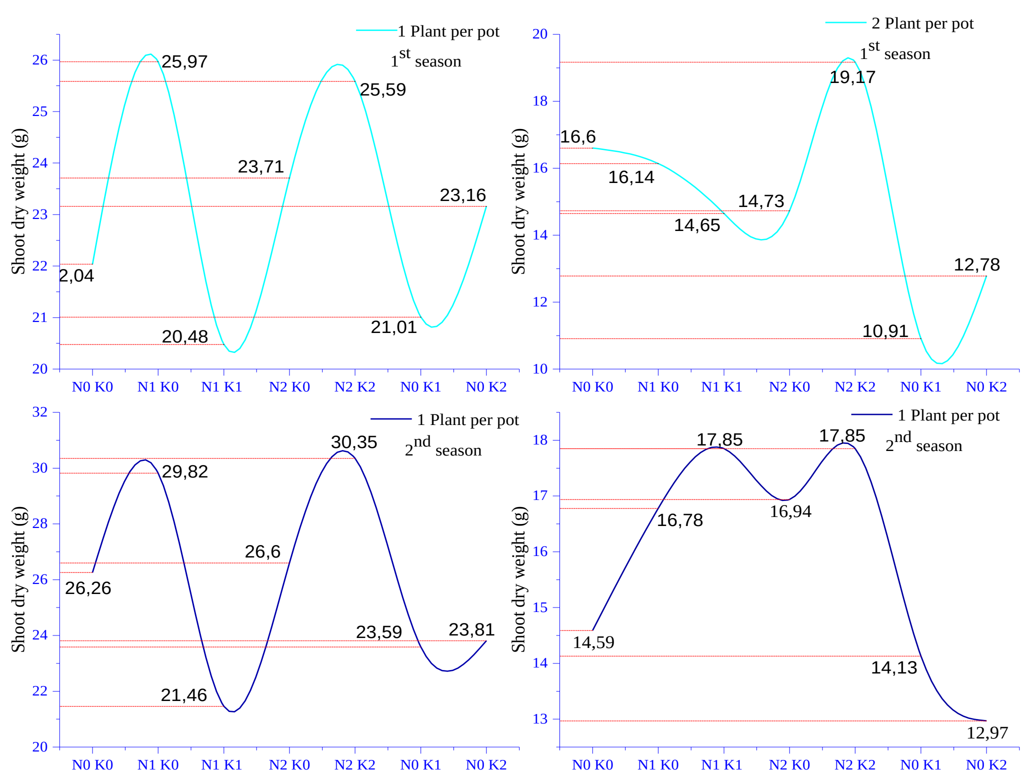


Figure 4.16. Effect of interaction between plant density and dose of notrogen and potassium fertilizers on shoot dry weight

4. 1. 8. Shoot dry matter (%)

Table 14. 4 presents that the plant density had no significance different on percentage of plant dry matter. Over two seasons, the highest value observed by a lower plant density (D_1). Fertilizer presented significance difference only in the second season. In spite of the increase of potassium fertilizer without nitrogen (N_0 K_2) increased the percentage of plant dry matter in the first season, the low dose of potassium without nitrogen (N_0 K_1) decreased it. The interaction effect of plant density and fertilizer indicated that the low plant density (D_1) treated by the low dose of nitrogen without potassium (N_1 K_0) in the first season, and high dose of potassium without nitrogen (N_0 K_2) in the second gave the greatest percentage of shoot dry matter (Figure 4. 17). In the both seasons, the least percentage of plant dry matter obtained by a high plant density (D_2) but by a different dose of fertilizer. In the first and second season, dense planting (D_2) treated by half and full dose of potassium without nitrogen (N_0 K_2; N_0 K_1) decreased significantly the percentage of plant dry matter, respectively.

Table 14. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on shoot dry matter (%).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	22.23^{ab}	21.55^{ab}	21.89^{a}	16.71^{bc}	16.34^{bc}	16.52^{ab}
N_1 K_0	23.69^{a}	19.59^{b}	21.77 ^{a}	18.92^{ab}	16.92^{abc}	17.92^{ab}
N_1 K_1	19.35^{b}	19.49^{b}	19.42 ^{a}	16.38^{bc}	16.96^{abc}	16.67^{ab}
N_2 K_0	20.63^{ab}	20.3^{0b}	20.47^{a}	16.89^{abc}	17.06^{abc}	16.98^{ab}
N_2 K_2	20.95^{ab}	21.67^{ab}	21.31^{a}	16.34^{bc}	17.21^{abc}	16.77^{ab}
N_0 K_1	19.94^{b}	21.21^{ab}	20.58^{a}	16.18^{bc}	15.92^{c}	16.05^{b}
N_0 K_2	21.60^{ab}	18.78^{b}	20.10^{a}	19.75^{a}	17.00^{abc}	18.37^{a}
Mean	21.24^{a}	20.37^{a}		17.31^{a}	16.77^{a}	
LSD at 0.05	D 1.19	F 2.61	DF 3.11	D 2.48	F 2.09	DF 2.49
C V%			8.87			8.69

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

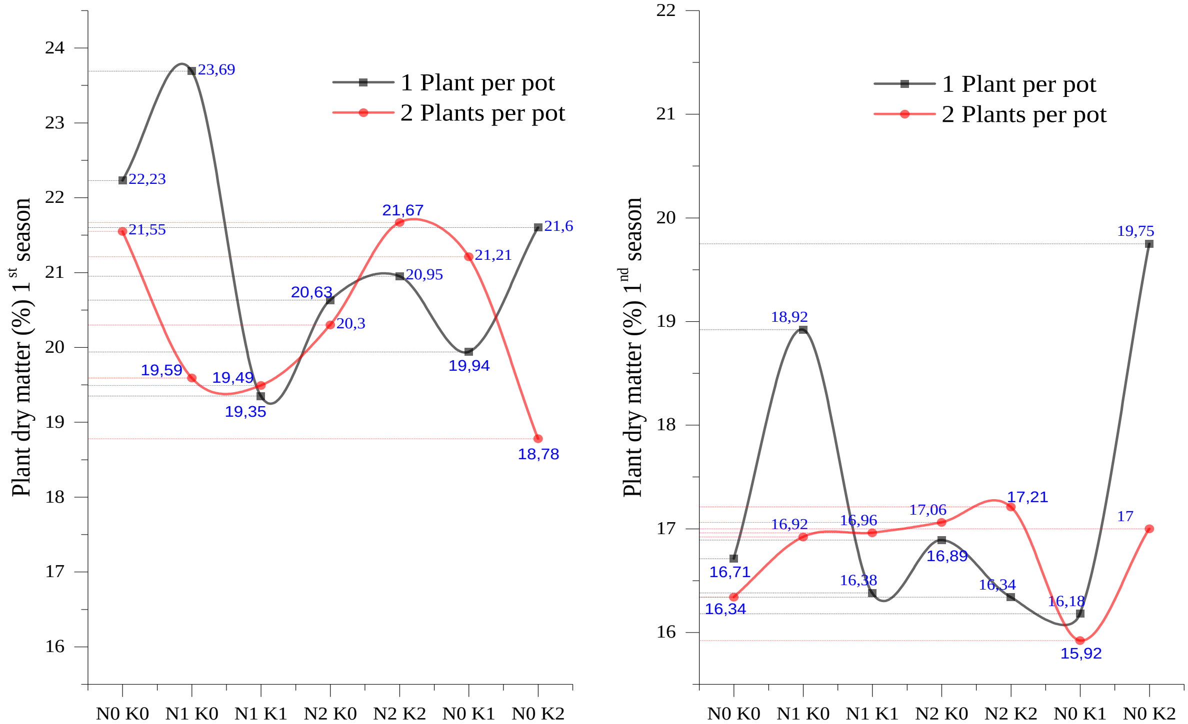


Figure 4. 17. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on shoot dry matter

4. 2. Effect of plant density and dose of nitrogen and potassium fertilizers on yield parameters

4. 2. 1. Number (No.) of pods per plant

There were significant differences on number of pods per plant due to plant density, fertilizer and their interaction (Table 15. 4). Lower plant density (D_1) gave the maximum number of pods per plant compared with the higher plant density (D_2) (Figure 4. 18). During the first season, the greatest number of pods per plant was obtained by plant treated with the highest dose of both elements (N_2 K_2) while, the lower dose of nitrogen with potassium or without potassium (N_1 K_1; N_1 K_0) gave the highest number of pods per plant in the second season, the pair doses were statistically similar (Figure 4. 19). A similar results in the both seasons were presented when lower plant density (D_1) treated with high doses of fertilizer (N_2 K_2) in the first season and (N_1 K_1; N_1 K_0) in the second season. Less number of pods per plant was a base phenomenon of higher plant density (D_2) overall fertilizer treatments compared with lower plant density (D_1) which received the same dose of fertilizer or other dose (Figure 4. 20).

Table 15. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on number of pods per plant.

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	31.84^{b}	21.92^{cd}	26.88^{b}	28.61^{bc}	19.14^{e}	23.88^{c}
N_1 K_0	34.72^{ab}	23.78^{cd}	29.25^{ab}	32.38^{a}	23.00^{d}	27.69^{a}
N_1 K_1	35.80^{ab}	24.11^{cd}	29.96^{ab}	32.38^{a}	22.88^{d}	27.62^{a}
N_2 K_0	35.89^{ab}	21.43^{cd}	28.66^{b}	32.25^{a}	20.92^{de}	26.58^{ab}
N_2 K_2	38.96^{a}	26.00^{c}	32.48^{a}	30.75^{ab}	21.75^{de}	26.25^{ab}
N_0 K_1	32.04^{b}	21.50^{cd}	26.77^{b}	30.25^{abc}	19.38^{e}	24.81^{bc}
N_0 K_2	32.92^{b}	21.25^{d}	27.08^{b}	27.74^{c}	19.50^{e}	23.62^{c}
Mean	34.59^{a}	22.86^{b}		30.62^{a}	20.94^{b}	
LSD at 0.05	D 3.57	F 3.50	DF 4.18	D 1.52	F 2.12	DF 2.53
C V%			8.63			5.81

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

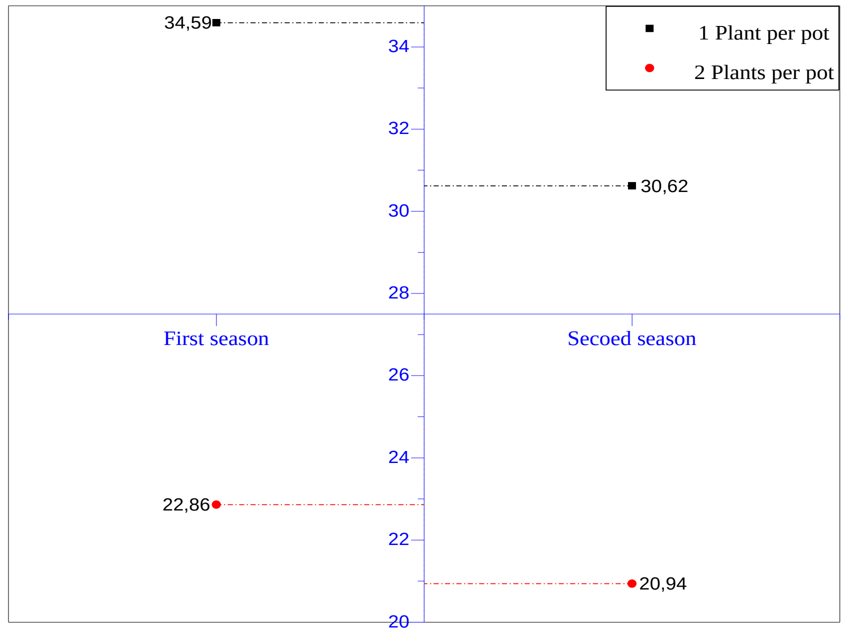


Figure 4. 18. Effect of plant density on number of pods per plant

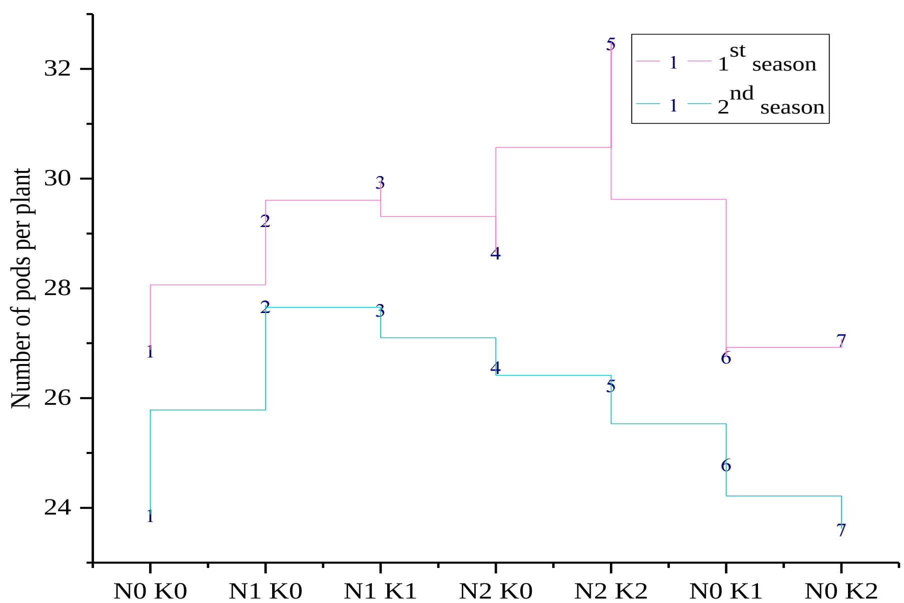


Figure 4. 19. Effect of nitrogen and potassium fertilizers on number of pods per plant.

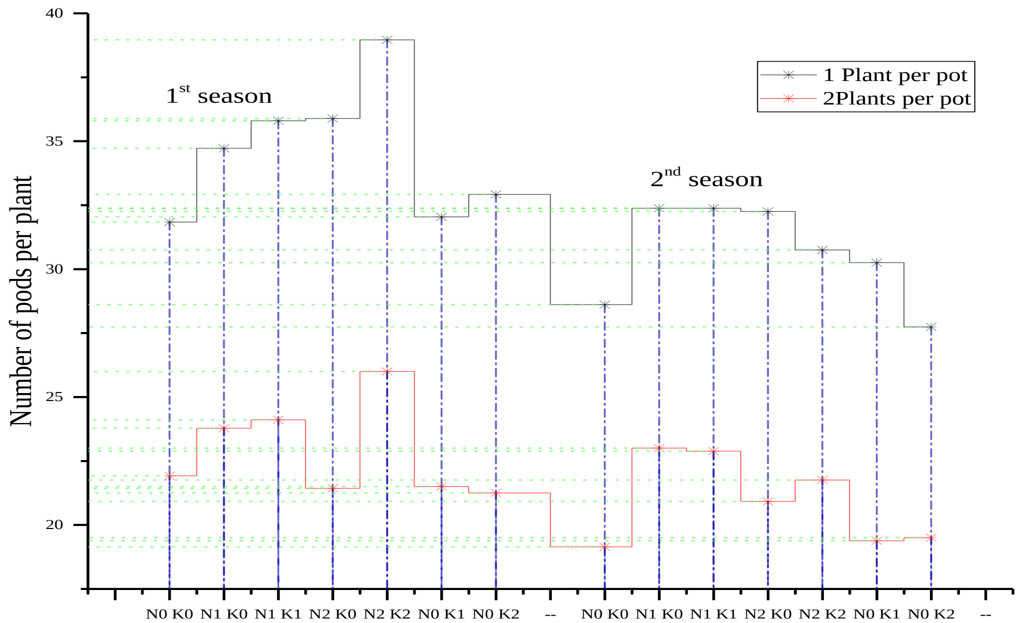


Figure 4. 20. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on number of pods per plant

4. 2. 2. Pods yield per plant (g)

The data pooled in Table 16. 4 indicated that the plant yield responded significantly to the plant density (D), different doses of nitrogen (N) and potassium (K) fertilizer and their interaction. Lower plant density (D_1) enhances pods yield per plant than the higher plant density (D_2) (Figure 4. 21). In the first season the higher dose of both fertilizers (N_2 K_2) increased pod yield per plant significantly, while in the second season the half dose of nitrogen without potassium (N_1 K_0) gave a superior yield of pods per plant followed by a plant which received a similar dose of nitrogen with a half dose of potassium (N_1 K_1) in both seasons. Pod yield declined when received no fertilizer (N_0 K_0) and when receiving potassium without nitrogen at higher dose (N_0 K_2) (Figure 4. 22). Interaction between plant density and fertilizer showed that the lower plant density (D_1) improved plant yield under all different fertilizer doses compared with the higher plant density, whereas the lower plant density (D_1) with a complete dose of nitrogen and potassium (N_2 K_2) in the first season and half dose of nitrogen without potassium (N_1 K_0) and half dose of both (N_1 K_1) in the second season increased plant yield. High plant population (D_2) treated with higher potassium dose (N_0 K_2) had a negative effect on pod yield followed by a similar density that received no fertilizer dose (N_0 K_0) (Figure 4. 23).

Table 16. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on pod yield per plant (g).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	166.6^{b}	110.2^{b}	138.4^{b}	146.7^{c}	101.5^{de}	124.1^{c}
N_1 K_0	187.1^{ab}	125.9^{cd}	156.5^{ab}	180.9^{a}	123.6^{cd}	152.3^{a}
N_1 K_1	194.1^{ab}	122.5^{cd}	$158.3a^{b}$	176.7^{a}	117.7^{de}	147.2^{ab}
N_2 K_0	178.4^{b}	112.1^{cd}	145.2^{b}	164.6^{ab}	106.7^{de}	135.6^{abc}
N_2 K_2	213.4^{a}	139.8^{c}	176.6^{a}	158.4^{ab}	118.7^{de}	138.8^{abc}
N_0 K_1	169.3^{b}	112.7^{cd}	141.0^{b}	165.4^{ab}	102.9^{de}	134.1^{abc}
N_0 K_2	179.3^{b}	118.3^{cd}	148.8^{b}	145.6^{bc}	98.43^{e}	122.0^{c}
Mean	184.0^{a}	120.2^{b}		162.7^{a}	108.6^{b}	
LSD at 0.05	D 12.04	F 21.59	DF 25.75	D 6.68	F 22.05	DF 18.48
C V%			10.05			9.46

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

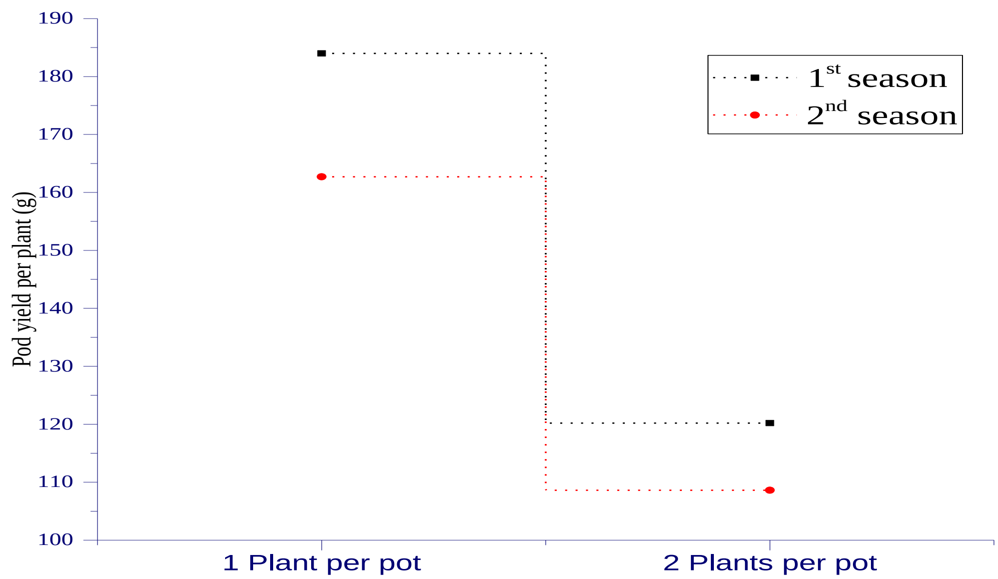


Figure 4. 21. Effect of plant density on pod yield per plant

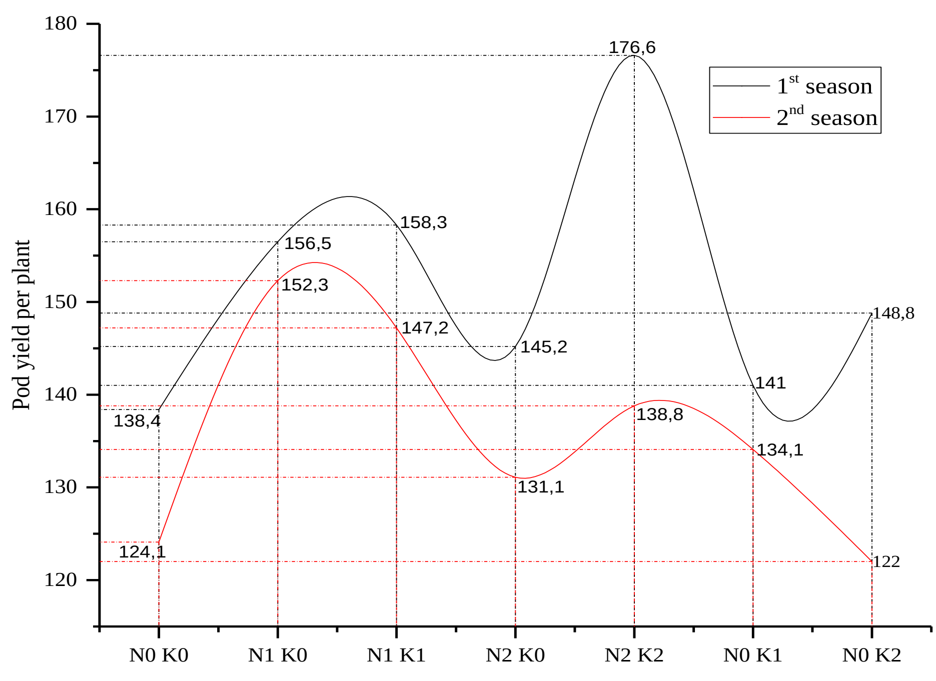


Figure 4. 22. Effect of nitrogen and potassium fertilizer on pods yield per plant

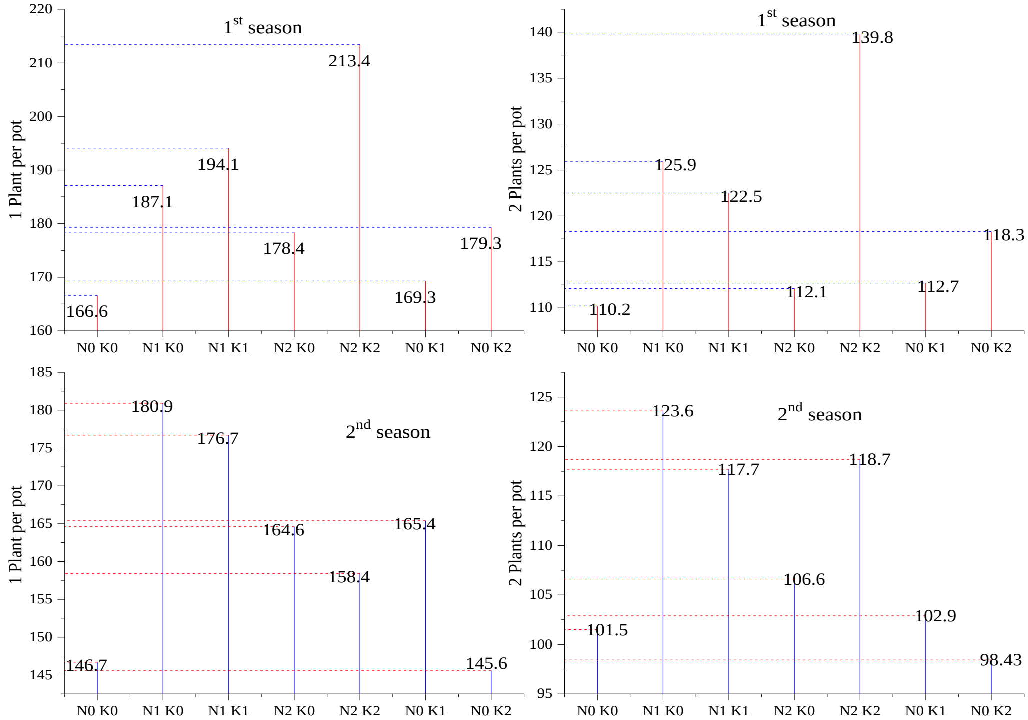


Figure 4. 23. Effect of interaction between plant density and dose of nitrogen and potassium on pod yield per plant (g)

4. 2. 3. Pod yield per hectare (t ha^{-1})

Pods yield per hectare was calculated from the yield per plant multiplying by a number of plants per hectare; therefore the results followed the same pattern of significance and presented a different picture as green pod yield per plant (Table 17. 4). Higher plant density (D_2) increased yield per unit area compared with lower density (D_1). A full dose of nitrogen and potassium fertilizer in the first season (N_2 K_2) and half dose of nitrogen in the second season (N_1 K_0) had superior means in term of plant yield per hectare, followed by a plant treated with lower doses of nitrogen and potassium (N_1 K_1) in both seasons, and plant receiving nitrogen without potassium (N_1 K_0), in the first season. Plant grown without fertilizer (N_0 K_0) or with potassium only (N_0 K_1; N_0 K_2) gave the lowest yield per hectare except the lower dose of potassium in the second season. Interaction between plant density and fertilizer had the same result due to doubling density. Higher density with all doses of fertilizers over yielded lower density. Dense plant (D_2) received a full dose of nitrogen and potassium (N_2 K_2) in the first season and the plant received a half dose of nitrogen only (N_1 K_0) in the second season, gave the greatest means. The lower density (D_1) receiving no fertilizer (N_0 K_0) in both seasons decreased yield.

Table 17. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on yield per hectare (t ha^{-1}).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	18.00^{e}	23.62^{bc}	20.81^{b}	15.62^{f}	21.75^{bc}	18.73^{c}
N_1 K_0	20.04^{cde}	26.64^{ab}	23.34^{ab}	19.38^{cdef}	26.50^{a}	22.94^{a}
N_1 K_1	20.80^{cde}	26.04^{ab}	23.42^{ab}	18.93^{cdef}	25.22^{ab}	22.08^{ab}
N_2 K_0	20.78^{cde}	24.01^{bc}	22.40^{b}	17.64^{def}	20.92^{cde}	19.28^{bc}
N_2 K_2	22.86^{bcd}	29.96^{a}	26.41^{a}	17.03^{ef}	25.42^{ab}	21.23^{abc}
N_0 K_1	18.13^{e}	24.15^{bc}	21.14^{b}	17.72^{def}	22.05^{bc}	19.89^{abc}
N_0 K_2	19.20^{de}	25.34^{b}	22.27^{b}	15.60^{f}	21.08^{cd}	18.34^{c}
Mean	19.97^{b}	25.68^{a}		17.43^{b}	23.28^{a}	
LSD at 0.05	D 2.35	F 3.15	DF 3.76	D 2.05	F 2.97	DF 3.54
C V%			9.78			10.32

Differences between means as indicated by the same letters for the different treatments are not statistically significant probability ≤ 0.05.

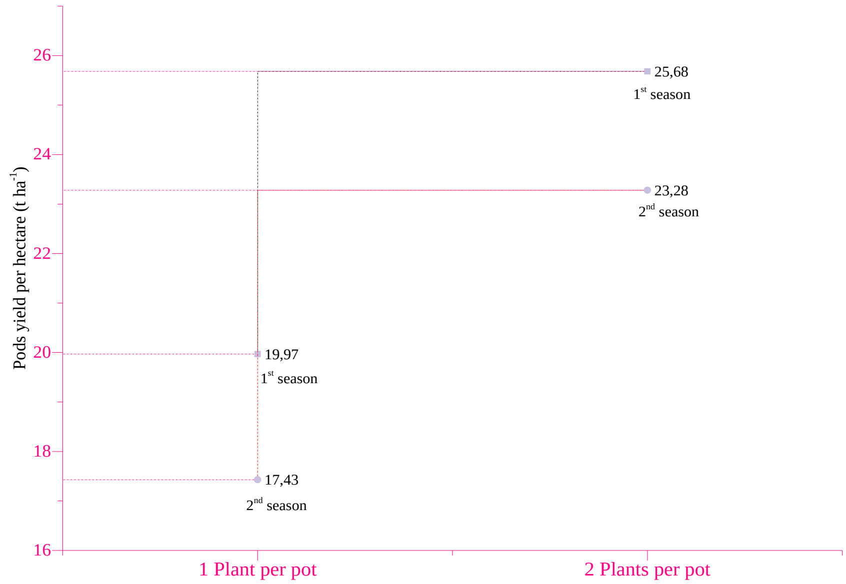


Figure 4. 24. Effect of plant density on pods yield per hectare

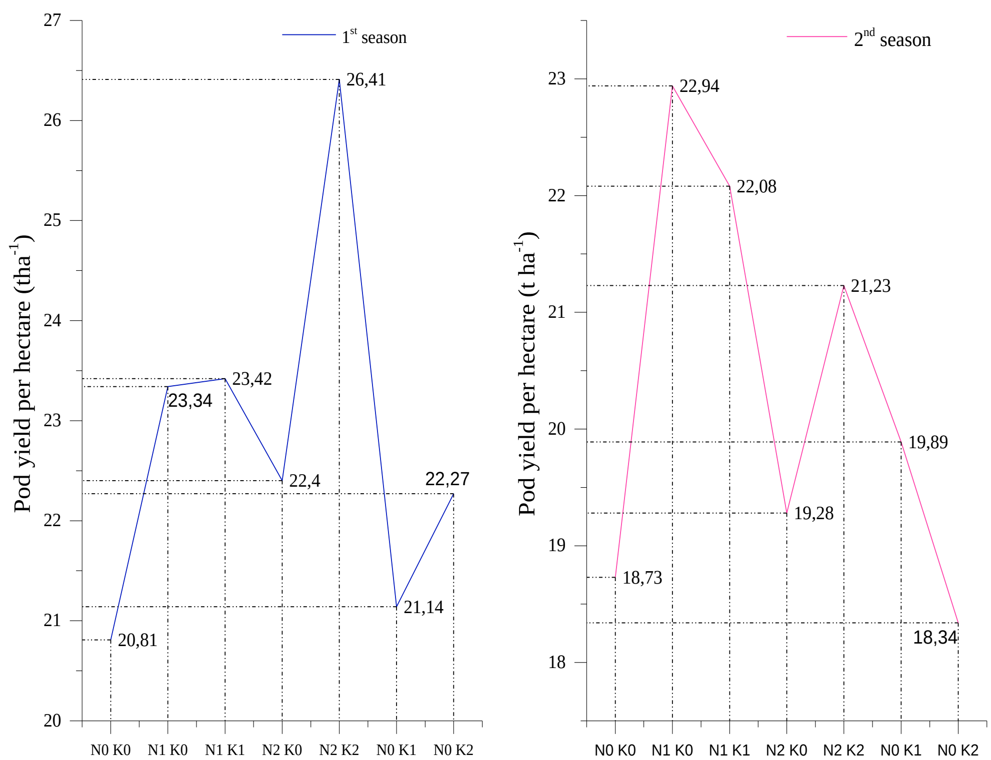


Figure 4. 25. Effect of nitrogen and potassium fertilizers on pods yield per hectare

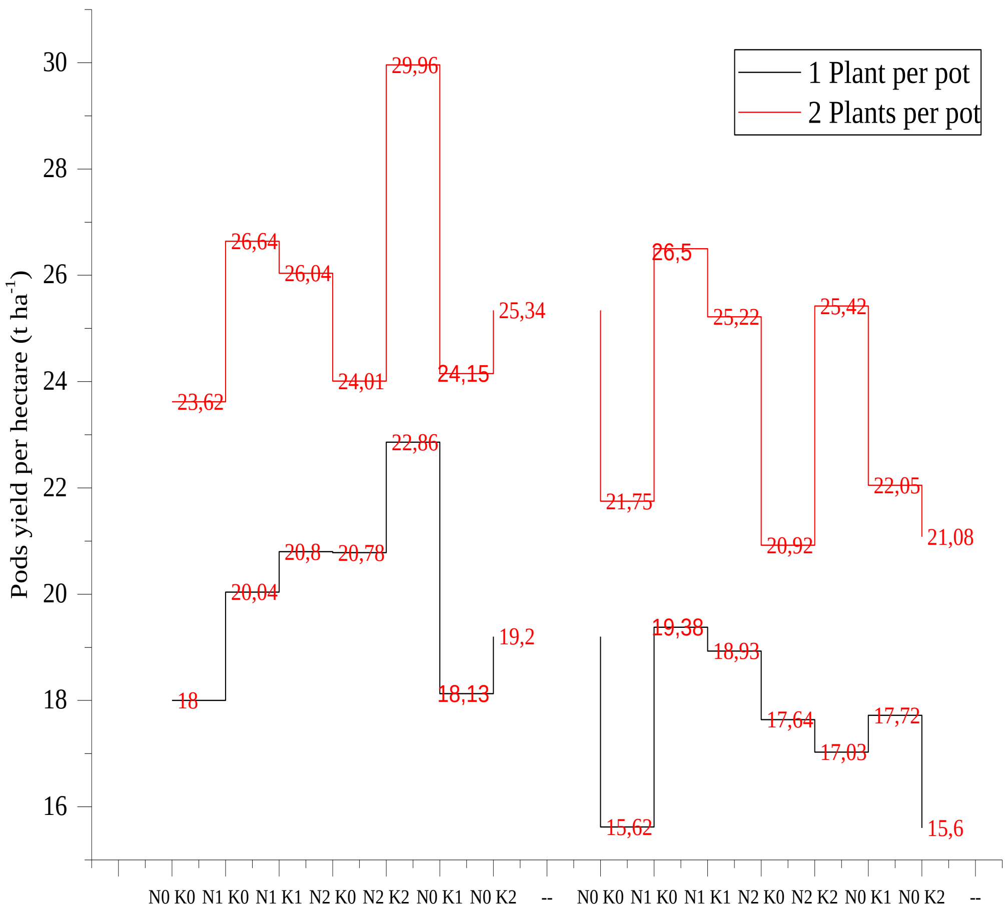


Figure 4. 26. Effect of interaction between plant density and dose of nitrogen and potassim fertilizers on pods yield per hectare

4. 2. 4. Pod length (cm)

The results of variance analysis and the comparison of means as in Table 18. 4 provides that different plant density had a negligible and significant increase in the first and second season, respectively. In both seasons, the longest pod observed in the plant treated by half dose of nitrogen without potassium (N_1 K_0). This dose of fertilizer (N_1 K_0) was statistically similar to the plant received a higher dose of potassium without nitrogen (N_0 K_2) in the first season, and the plant received no fertilizer (N_0 K_0) in the second season. In the first and next seasons, the plant received no fertilizer (N_0 K_0) and a plant treated by higher dose of nitrogen without potassium (N_2 K_0) gave the shortest pods, respectively. The combination effect of lower density (D_1) treated by a high dose of potassium (N_0 K_2) as in the first season, and the half dose of both nutrients (N_1 K_1) as in the second season, had remarkable increase in pod length. Contrary to these higher density (D_2) which appeared shortest pod over most fertilizer treatment especially in the second season.

4. 2. 5. Pod diameter (mm)

The results obtained from the pod diameter are set out in (Table 19. 4). Closer inspect of the table shows plant density had a significant effect only in the first season, whereas the widest pod noticed in dense planting (D_2). Different dose of both fertilizers were statistically similar in term of pod diameter during the first season, while it had significant effect in the second season. In the second season, half dose of nitrogen without potassium (N_1 K_0) increased pod diameter, while the high dose of both nutrients (N_2 K_2) decreased it. Interaction between plant density and fertilizer lacking the significant effect on the first season. In the second season, the maximum and minimum pod diameter recorded in the higher and low plant density (D_2; D_1) treated by low dose of nitrogen without potassium (N_1 K_0) and high dose of both fertilizers (N_2 K_2) respectively.

Table 18. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on pod length (cm).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	11.94[abc]	11.37[c]	11.66[b]	11.77[abc]	11.63[abcdef]	11.70[a]
N_1 K_0	12.31[ab]	12.26[ab]	12.28[a]	11.75[abcd]	11.68[abcde]	11.71[a]
N_1 K_1	12.16[ab]	11.73[bc]	11.94[ab]	11.92[a]	11.39[defg]	11.66[ab]
N_2 K_0	11.87[bc]	11.82[bc]	11.84[ab]	11.50[bcdefg]	11.28[fg]	11.39[b]
N_2 K_2	12.34[ab]	11.70[bc]	12.02[ab]	11.79[ab]	11.25[fg]	11.52[ab]
N_0 K_1	12.18[ab]	12.01[ab]	12.09[ab]	11.82[ab]	11.41[cdefg]	11.61[ab]
N_0 K_2	12.53[a]	11.90[abc]	12.22[a]	11.76[abcd]	11.34[efg]	11.55[ab]
Mean	12.19[a]	11.83[a]		11.76[a]	11.43[b]	
LSD at 0.05	D 0.43	F 0.46	DF 0.55	D 0.13	F 0.27	DF 0.32
C V%			2.73			1.65

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

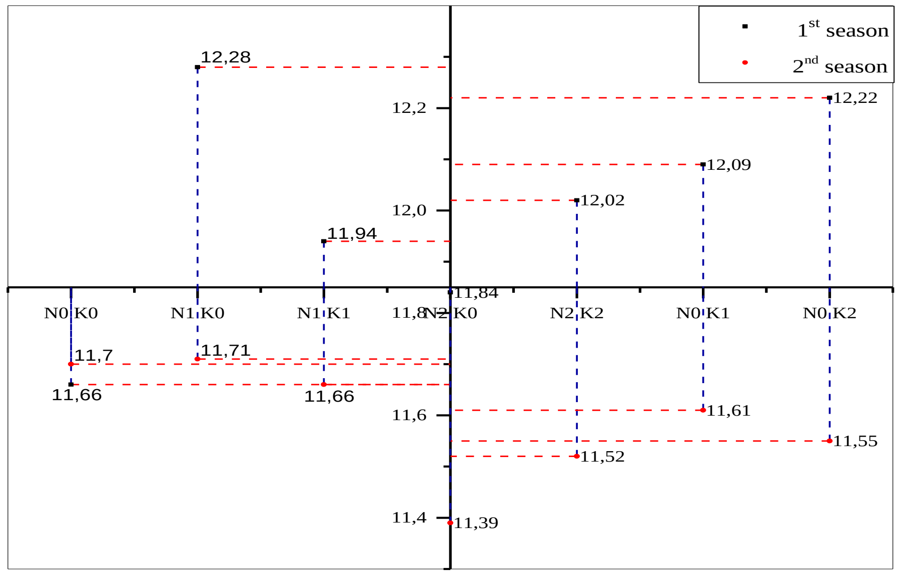


Figure 4. 27. Effect of nitrogen and potassium fertilizers on pod length (cm)

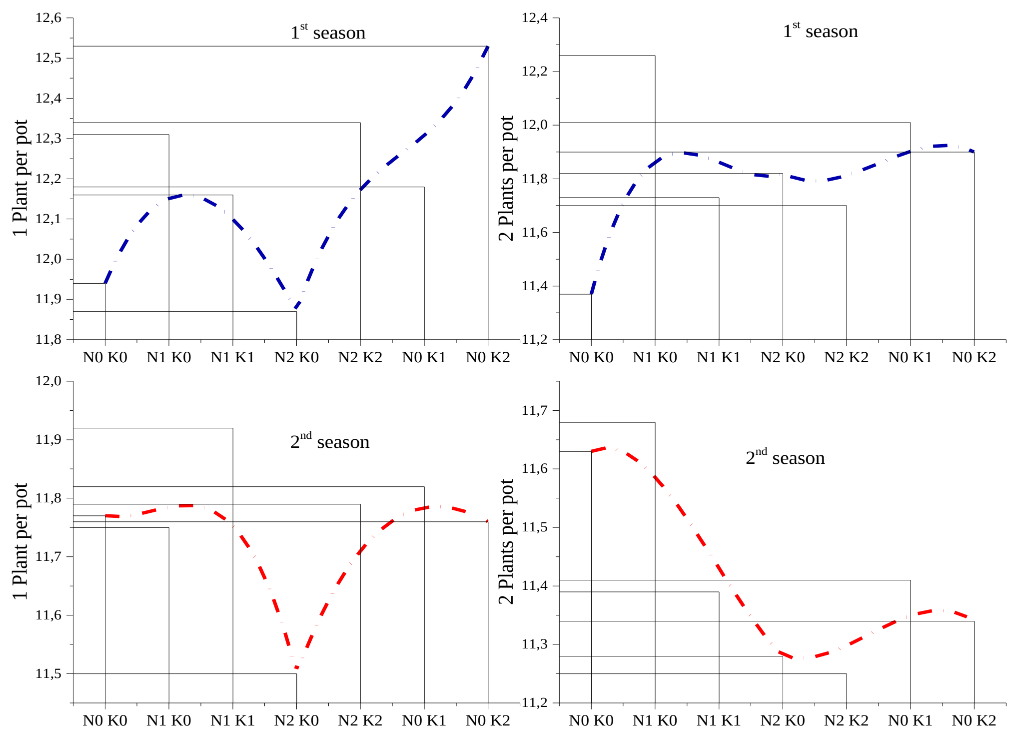


Figure 4. 28. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on pod length (cm)

Table 19. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on pod diameter (mm).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	7.87^{a}	7.85^{a}	7.80^{a}	7.46^{ab}	7.49^{bc}	7.56^{ab}
N_1 K_0	7.87^{a}	7.11^{a}	8.02^{a}	7.46^{ab}	7.76^{a}	7.70^{a}
N_1 K_1	7.87^{a}	7.92^{a}	7.89^{a}	7.61^{ab}	7.37^{bc}	7.49^{abc}
N_2 K_0	7.87^{a}	7.81^{a}	7.82^{a}	7.45^{ab}	7.39^{bc}	7.42^{bc}
N_2 K_2	7.87^{a}	7.88^{a}	7.91^{a}	7.31^{c}	7.38^{bc}	7.34^{c}
N_0 K_1	7.87^{a}	8.07^{a}	7.89^{a}	7.54^{abc}	7.54^{abc}	7.54^{abc}
N_0 K_2	7.87^{a}	8.06^{a}	8.04^{a}	7.38^{bc}	7.40^{bc}	7.39^{bc}
Mean	7.87^{a}	7.69^{a}		7.51^{a}	7.48^{a}	
LSD at 0.05	D 0.04	F 0.14	DF 0.38	D 0.35	F 0.19	DF 0.24
C V%			2.84			1.88

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

4. 2. 6. Pod fresh weight (g)

Table 20. 4 shows that pod fresh weight was not affected by different plant density nor with different doses of nitrogen and potassium fertilizers. The interaction between plant density and fertilizer doses varied significantly with a variation of plant density and fertilizer doses in the first season. In the first season, the individual plant per pot (D_1) with application of high rate of potassium without nitrogen (N_0 K_2) was superior to the other plants in term of pod fresh weight, especially with a dense planting (D_2) that received a higher doses of nitrogen and potassium (N_2 K_2).

4. 2. 7. Pod dry weight (g)

The recorded results as in Table 21. 4 clarified that the pod dry weight did not affect by different plant density. The application of full dose of potassium without nitrogen (N_0 K_2) in the first season and the separate half dose of both fertilizers (N_1 K_0; N_0 K_1) in the next season, had a weightiness dry pod. A mild weight of dry pods presenting by a plant received no fertilizer (N_0 K_0) and a plant received a full dose of both fertilizers (N_2 K_2) in the first and the second season, respectively. The interaction between density and fertilizers reflected significance different in pod dry weight. Generally, the heaviness pod dry weight distributed overall densities (D_1; D_2) with different doses of fertilizer. The less weight of dry pod presented in the dense planting (D_2) received no fertilizer (N_0 K_0) and high dose of both fertilizers (N_2 K_2) in the first and second season, respectively.

Table 20. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on pod fresh weight (g).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	5.23[ab]	5.04[ab]	5.13[a]	5.18[a]	5.30[a]	5.21[a]
N_1 K_0	5.32[ab]	5.29[ab]	5.31[a]	5.58[a]	5.37[a]	5.48[a]
N_1 K_1	5.41[ab]	5.12[ab]	5.26[a]	5.45[a]	5.21[a]	5.33[a]
N_2 K_0	4.97[ab]	5.23[ab]	5.10[a]	5.10[a]	5.10[a]	5.10[a]
N_2 K_2	5.48[ab]	4.95[b]	5.21[a]	5.18[a]	5.46[a]	5.32[a]
N_0 K_1	5.29[ab]	5.57[ab]	5.43[a]	5.47[a]	5.02[a]	5.25[a]
N_0 K_2	5.74[a]	5.21[ab]	5.47[a]	5.25[a]	5.04[a]	5.15[a]
Mean	5.35[a]	5.20[a]		5.30[a]	5.21[a]	
LSD at 0.05	D 0.17	F 0.55	DF 0.66	D 0.23	F 0.44	DF 0.53
C V%	7.39			5.98		

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

Table 21. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on pod dry weight (g).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	0.276[ab]	0.235[b]	0.256[b]	0.266[a]	0.228[a]	0.227[ab]
N_1 K_0	0.275[ab]	0.299 [a]	0.288[ab]	0.233[a]	0.227[a]	0.230[a]
N_1 K_1	0.271[ab]	0.261[ab]	0.266[ab]	0.233[a]	0.219[a]	0.226[ab]
N_2 K_0	0.267[ab]	0.302[a]	0.285[ab]	0.218[a]	0.212[a]	0.215[ab]
N_2 K_2	0.278[ab]	0.272[ab]	0.275[ab]	0.228[a]	0.194[b]	0.211[ab]
N_0 K_1	0.278[ab]	0.308[a]	0.294[ab]	0.233[a]	0.229[a]	0.231[a]
N_0 K_2	0.317[a]	0.293[ab]	0.306[a]	0.231[a]	0.209[a]	0.220[ab]
Mean	0.281[a]	0.282[a]		0.229[a]	0.217[a]	
LSD at 0.05	D 0.03	F 0.04	DF 0.05	D 0.02	F 0.02	DF 0.02
C V%			10.65			6.23

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

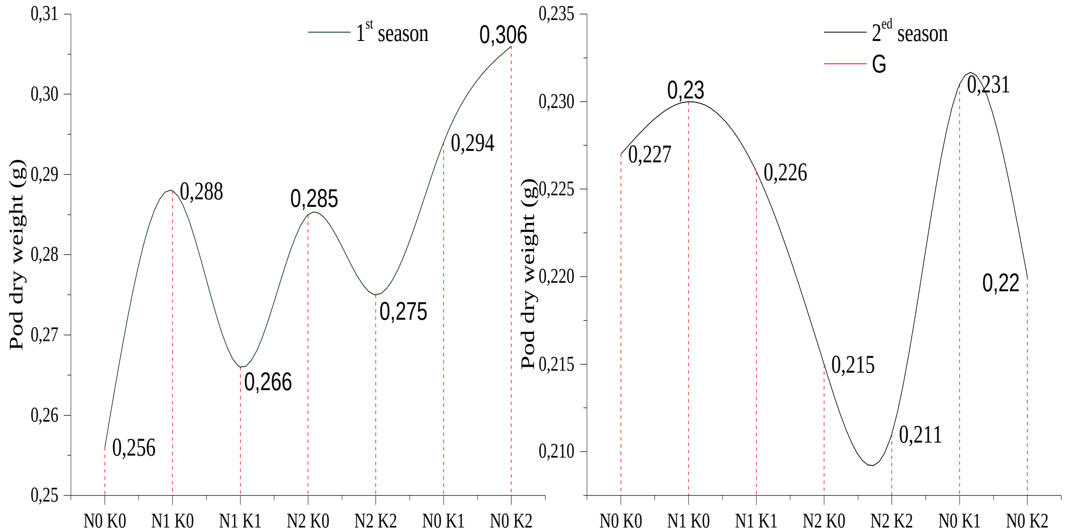


Figure 4. 29. Effect of nitrogen and potassium fertilizers on pod dry weight

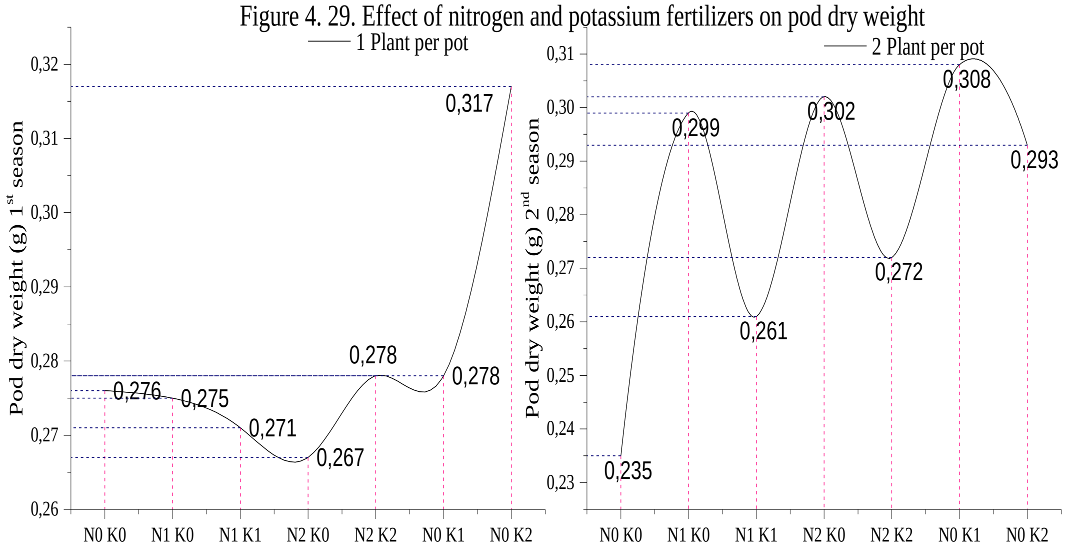


Figure 4. 30. Effect of interaction between plant density and dose of nitrogen and potassium fertilizers on pod dry weight (g)

4. 2. 8. Pod dry matter (%)

As in Table 22. 4 pods dry matter did not affect neither by plant density (D) and fertilizer (F) nor by their interaction (DF) except, in the second season. In the second season, dense planting (D_2) treated by the higher dose of nitrogen and potassium (N_2 K_2) significantly decreased the percentage of the pod dry matter against all other fertilizer treatments.

Table 22. 4. Effect of plant density and dose of nitrogen and potassium fertilizers on pod dry matter (%).

Fertilizer	First season		Mean	Second season		Mean
	1 plant/pot	2 plants/pot		1 plant/pot	2 plants/pot	
N_0 K_0	5.27[a]	4.80[a]	5.04[a]	4.44[a]	4.31[a]	4.37[a]
N_1 K_0	4.89[a]	5.67[a]	5.28[a]	4.18[a]	4.23[a]	4.21[a]
N_1 K_1	5.02[a]	5.11[a]	5.06[a]	4.29[a]	4.22[a]	4.26[a]
N_2 K_0	4.91[a]	5.72[a]	5.31[a]	4.30[a]	4.17[a]	4.23[a]
N_2 K_2	5.07[a]	5.07[a]	5.07[a]	4.45[a]	3.57[b]	4.01[a]
N_0 K_1	5.27[a]	5.87[a]	5.57[a]	4.27[a]	4.57[a]	4.42[a]
N_0 K_2	5.71[a]	5.28[a]	5.49[a]	4.57[a]	4.16[a]	4.37[a]
Mean	5.14[a]	5.47[a]		4.36[a]	4.18[a]	
LSD at 0.05	D 0.75	F 0.89	DF 1.06	D 0.34	F 0.47	DF 0.56
C V%			11.92			7.77

Differences between means as indicated by the same letters for the different treatments are not statistically significant at probability ≤ 0.05.

CHAPTER 5
DISCUSSION

Soils are frequently deficient of several nutrients so that two or more fertilizers have to be applied to crops, either separately or as a mixture. Ideally, each of the nutrients should be applied at an optimal rate, with due allowance for costs and returns in terms of yield maximization. This has been the major challenge facing the production of snap beans, as it is an important foreign exchange earner vegetable crop [161]. Contrary to the general recommendation of reduced nitrogen application to legume crops because of their ability to fix atmospheric nitrogen, French bean readily responds to large doses of nitrogen [184]. [146] reported that the potassium fertilizer has important roles in major plant processes such as growth and yield of plants, but does not enter into the composition of any product unlike nitrogen. Plant height was increased with increasing plant density and this may be due to competition of intensive planting to the sunlight. A similar results found by [184] who examined different plant densities, they reported that the maximum plant height was obtained from the higher plant density and the lowest from the lower plant density while, [199] investigated different plant populations, they regarded that the tallest and the shortest plant presented at the large and narrow plant spacing respectively. Moreover, [256] used low plant densities of beans (30, 45 and 50 plants m^{-2}), they reported that the maximum growth rate was obtained at the highest plant density. [144] reported significant effect on seed rates on plant height of rice bean. The results of this study were contradictory to those of [34] who noticed that the plant height was not affected significantly by seed rates. The contradictory results may be due to variation in soil fertility status, climatic conditions or species differences. The effect of plant density on plant height also explained by [81] who reflected that the highest plant presented by dense planting due to competition of light. Moreover, [167] documented that potassium activate at least 60 different enzymes involved in plant growth.

[45] applied different potassium concentration as a foliar spray at the time of flowering (0.2, 0.4, 0.6, 0.8 and 1 kg ha^{-1}). They observed that almost all vegetative characters increased with the increase of potassium concentration. The height of the plant increased with the foliar application of potassium and maximum increase was recorded in plants received 1 kg K ha^{-1}. The effect of nitrogen and potassium fertilizers in plant height takes place as the plant progresses in age since as, higher dose of fertilizer increased plant height. These results are in agreement with those of [34], who found that the plant height respond positively to applied nitrogen, and each increase in nitrogen levels increased significantly plant height and [1] who reported an increase in plant height with nitrogen application was increased.

The plant received a full dose of potassium fertilizer gave the tallest plant compared with a plant received a half dose of potassium, these results are in consonance with the findings of [45]. Several workers like [132; 189] etc. reported that potassium fertilizer had a positive effect in vegetative and reproductive growth.

Number of branches and leaves per plant did not affect by plant density or by different dose of nitrogen and potassium fertilizers. Different authors had a different results in term of branches and leaves per plant. [87] studded different combination densities (plant spacing and plant per hole), they regarded an increase in plant height with the plant density was increased and the reverse effect was noticed on the number of branches per plant while, the number of leaves was not affected. [56] applied different plant densities (63, 74, 88, 111, 148, 222, and 444 thousand plants ha^{-1}), they reported that the plant density slightly decreased the number of branches per plant. [232] studied different plant densities of beans (20, 40, 80 and 100 plants m^{-2}). They reported an increase in plant height at higher plant densities, but a decrease in the number of branches per plant. The researcher [184] noticed that the branches per plant had a highest values at lower plant density. [34] studied the effect of different seed rate, they regarded that the increase in seed rates decreased the number of branches per plant. Additionally, [50] observed negative relationship between seed rate and the number of branches per plant, while [33] noticed that the number of branches per plant was increased with increase in nitrogen rates. There were increase in the number of branches per plant with increase in nitrogen application [25; 141].

The results of this study supported the findings of [199] in case of the interaction effect of the plant spacing and fertilizer levels on the number of leaves and branches per plant. Who regard that the plant spacing and fertilizer play significant variations on the number of compound leaves and branches. They found that the highest number of compound leaves and branches was found in the treatment combination of large plant spacing and higher dose of fertilizer, and contradictory in the narrow plant spacing and lower dose of fertilizer, separately. They reported significant influence on the number of leaves and branches per plant due to plant spacing and due to fertilizer. It is also in agreement with the findings of [283] in the case of branches nevertheless, but contradictory in the number of leaves. This researcher found an Increasing nitrogen fertilizer increased number of leaves per plant but had no significant differ on the number of branches per plant among all treatments.

Number of days required to reaching 10% and 50% flowering did not affected by plant densities. Generally, low plant density required the higher number of days to blooming. This could be related with the supporting effects of more available nutrients to the lower number of plants per unit area which permitted the building of more vigorous vegetative growth, that resulted with the higher number of days need to the blooming. A similar results were found by [87] who reported that the plant density delayed flowering, but with no significant effect. Increasing fertilizer dose, delayed time to reach 10% and 50% flowering, Such results might be attributed to the availability of more nutrients to plant, especially with the lower plant density and it may cause longevity of vegetative growth. The higher rate of nitrogen promotes vine growth, delayed flowering and fruit maturity. The results of this work are in agreement with that of [194] who reported an increase in the period of vegetative growth had become longer in the higher nitrogen and potassium applications, and the plant had entered its reproductive phase late. Increasing productivity can sometimes be associated with late maturity period or an increase in pod size and decrease in quality [190]. Contrary to this, noticed by [56] who used different plant densities, they reported that the plant density did not affect days to reach 50% flowering or maturity. The research results of [97] in Pea plants concerning the effects of nitrogen levels on the studied flowering traits, their results indicated that nitrogen fertilization with 60 and 90 Kg N fed^{-1} significantly, delayed flowering and increased fruit set percentage. Such results might be attributed to the stimulating effects of nitrogen on the vegetative characteristics that, consequently, resulted in delaying the flowering and increasing fruit set percentage. Moreover, a similar results obtained by [40] on pea; [86] on lettuce and [98] on sweet pepper they showed that the increased applied levels of nitrogen from 40 to 80 Kg N fed^{-1}, significantly delayed the flowering, whereas, the application of 120 Kg N fed^{-1} increased significantly fruit set percentage.

The plant dry matter was slightly increased with decreasing plant density. The little increase in the plant dry matter in lower plant density (one plant per pot, D_1) as compared with the higher plant density (two plants per pot, D_2), it may be caused due to the higher competition between dense planting (D_2) in the term of water and sunlight etc. and vice versa in the lower plant density (D_1). The absence of competition in this low density (D_1) and more availability of nutrients make this differences in the plant dry matter. A memorandum of [95] who reflected the effect of potassium fertilizer on the plant dry matter. They reported that potassium makes up 1 to 4 percent of the plant dry matter. The current results generally, contrary to those results reported by many investigators such as [34] who found that the dry matter was significantly increased with increase in seeding rates. The highest dry matter yield was obtained with seeding rates of 50 kg ha^{-1}. They justified this increase can be attributed to more plant population at given seed rates. [22] reported that the dry matter yield was increased with increase in seed rates. [114] found that the increase in plant dry matter with the increasing plant density.

The dry matter percentage slightly increased with increasing the level of both nitrogen and potassium fertilizers and significantly with high dose of potassium without nitrogen. The lowest dry matter recorded in both seasons in an experimental unit received the lower dose of potassium without nitrogen and in the equal lower dose of both fertilizers. Many studies such as [33] who regarded that the nitrogen application significantly affected the dry matter percentage. They found that the plant dry matter was increased at each increased level of nitrogen. The higher dry matter was recorded in plots where nitrogen was applied 50 kg ha^{-1} and the lowest was recorded in plots given no nitrogen fertilizer. However, these results are contradictory to those of [230; 180] who reported that nitrogen application did not affect the dry matter percentage. These contradictory results can be attributed to differences in climate and soil fertility or may be due to differences in the genetic makeup of the cultivar. The work of [114] who examined different plant densities and fertilizer doses of nitrogen. They found an increase in the capsule dry matter was directly proportional to the plant density increasing dose of nitrogen increased plant dry matter, while the interaction between plant density and nitrogen fertilizer presented no significant difference.

The researches of [151; 244] who studied the effects of different rates of potassium fertilizer on dry matter production by chickpea and faba bean. They found that plant species differed in their response to potassium fertilizer as a means of enhancing growth. The higher level of potassium fertilizer increased dry matter production in faba bean, but had not any impact on chickpea.

In the current study shoot fresh and dry weight increased with decreasing plant density and with increasing levels of both nitrogen and potassium fertilizers. This results confirmed by [87] who showed that the increasing plant spacing or reducing the number of plants per hole increased shoot fresh and dry weight. The application of nitrogen significantly increased the green fodder yield at each nitrogen rate, which is attributed number of branches per plant [33]. Additionally, [180] reported a significant increase in green fodder yield by nitrogen application while, they found that the nitrogen nutrient had no significant effect on dry matter percentage.

Bean plant showed profound effects on reproductive growth with supplied fertilizers dose of nitrogen and potassium to the lower and higher plant density. This evident from the number of pods and yield per plant, whereas were increased with decreasing plant density and adverse in yield per hectare which was increased with increasing plant density. The higher dose of nitrogen and potassium as in the first season and the lower level of nitrogen with lower potassium or without potassium as in the second season showed remarkable increase on the number of capsules and capsules yield per plant in addition to the yield ton per hectare. The interaction between plant density and nutrients gave the same picture presented by this yield parameters, it can be clearly observed that plant density and fertilizers application play an important role on yield components.

There was an inverse relationship between the density of plants and the number of pods per plant and a positive correlation between density and productivity of pods per unit area. Higher plant density produced fewer number of pods per plant, but the highest yield per unit area, due to increase the total number of plants per unit area, while the pod fresh weight was not affected (Figure 1. 5).

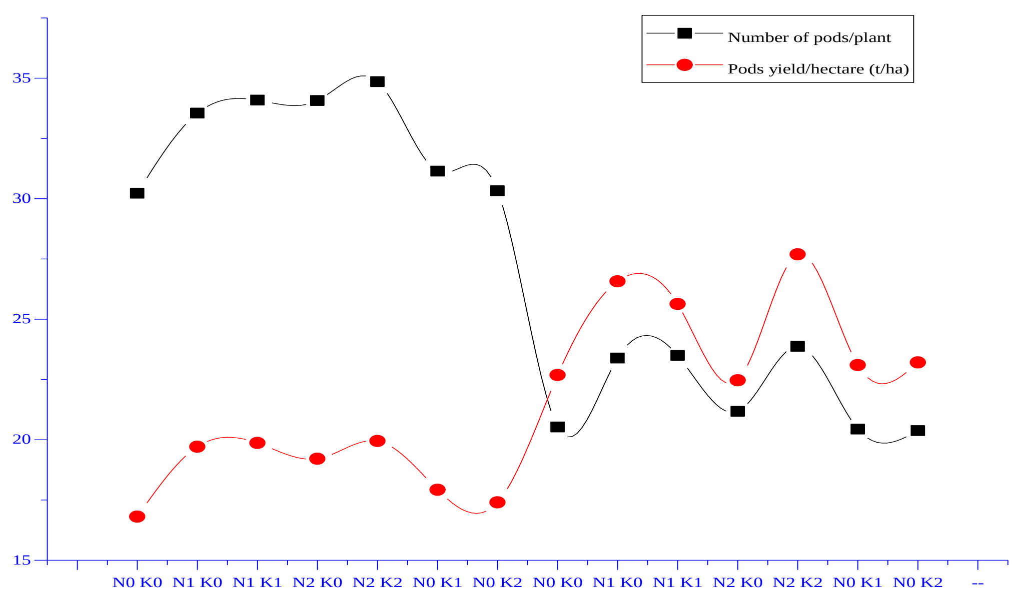


Figure 5. 1. Relationship between plant density and dose of nitrogen and potassium fertilizers on pods yield per plant and pods yield per hectare

Several authors were reported that pod yield of French bean increased with the increasing plant density. Higher plant population resulted in an increase yields of beans, however fruit size or quality characteristics were generally been lower at high plant population. Insects and pathogen population may be higher and more difficult to control at high plant densities. Increase plant spacing with lower planting density (No. of plant per hole) reflected the same significant increase of the number of pods per plant and yield per hectare [87]. The maximum number of green pods per plant and green pod weight per plant was recorded with the lower plant density at the highest nitrogen level, whereas the highest plant density with 0 kg N ha^{-1} gave the lowest values. The maximum pod yield per hectare was recorded with the highest plant density at the highest dose of nitrogen, while the minimum pod yield per hectare was noticed in control with the highest plant density [184]. The average performances of the data in this study, indicate that the highest plant density companied with the high nitrogen levels gave the highest pod yield per hectare. Number of pod, plant yield and yield ton per hectare in addition to the pod diameter and pod dry weight were increased with the increasing dose of nitrogen and potassium. The obtained increments of pods yield per hectare as the results of nitrogen and potassium application might be directly attributed with the increased pods number per plant. The enhanced effects of nitrogen and potassium may be related with the role of nitrogen in activating the vegetative growth and potassium in activating more than 60 enzymes, which were reflected in a significant increases in the different studied growth parameters (Tables 15, 16, 17). The sufficient quantities, and perhaps with efficient absorption, especially with the presence of nitrogen promote photosynthesis that required to the bean production. This results are in agreement with the results observed by [45], who noticed that the number of pods per plant, length of the pod and the pod diameter were increased with increasing the foliar application of potassium, and with [97] who found that the nitrogen levels affected yield components. They reported that the increase of nitrogen application from (30, 60 and 90 Kg N fed^{-1}) caused a significant increase in pods yield and number of pods per plant, over the control. They noticed that the higher two nitrogen doses were remarkable in this concern, but the difference between them did not appear to be significant. It’s also agree with results reported by [30] who regarded that the number and yield of pods per plant as well as the total yield per fed were significantly increased with increasing the applied nitrogen up to 80 Kg N fed^{-1}. The memorization of [126] indicated that the addition of 90 Kg N fed^{-1}, to the growing pea plants, was sufficient for the plants to express their best performance on pods yield and its components.

The results of the second season are in harmony with the finding of [194] who found that the maximum and minimum yield of fresh pods was observed in the lower and higher nitrogen with a similar dose of potassium treatments, respectively. The first condition for achieving a high yield per unit area is high dry matter production because about 90 percent of the dry weight of plants results from CO_2 assimilation during photosynthesis.

High dose of nitrogen without potassium decreased positively or significant number of pods, pod yield and yield per hectare, compared with the plant received higher or lower dose of both fertilizer. This maybe means that the balance of nitrogen and potassium is more preferable than the use of the higher or lower dose of potassium separately. The current results in agree with those results reported by [194] who showed that the nitrogen treatments had the lowest pod yield because the number of flowers formed in the treatments of high nitrogen and without potassium had significant decreases the process of flowering and pod formation was reduced. They warranted that treatment of the lower dose of both nitrogen and potassium fertilizers with suitable environmental conditions lead to increase fresh pod yield by sugar production, which resulted from photosynthesis and transferring them to the pod, although the treated plants by high dose of nitrogen with lower potassium fertilizer, had a suitable environmental conditions at flowering and graining stage. Therefore the produced assimilates was used for vegetative growth and thus the production of assimilation and fresh pod yield was reduced. The otheurs [75; 81] regarded that the maximum pod yield was obtained from the application of 120 kg N ha^{-1} and it was minimized in control. The higher yield for 120 kg N ha^{-1}, fertilization was contributed by higher values for yield attributes compared to the lower dose (60 kg N ha^{-1}). The researcher [248] recorded the maximum pod yield of bean at 160 kg N ha^{-1} that was at par with 120 kg N ha^{-1}.

The findings of [119] showed that the yield of wax bean was strongly influenced by the nitrogen applied.

Yield components viz., pod length and pod fresh weight recorded the highest values at lower plant density. However, it was not reflected in pod yield per hectare, the maximum pod yield was recorded with the higher plant density and the lowest pod yield with the lower plant density. These results are in agreement with the findings of [186; 240; 184]. While, pod dry matter did not respond to the plant density, nitrogen and potassium fertilizer and their interaction, except in the second season, whereas higher plant density treated with higher dose of both fertilizers were diluted in the weight and significance different. This results are in agreement with the findings of [114] who found that the pod dry matter did not respond to the interaction between density and nitrogen fertilizer. The study of [128] found that the applying of potassium fertilizer to the soil with small reserves did not increase yield of either crop to equal that on the soil with adequate potassium reserves. The use of potassium fertilizers is not an issue giving rise to concern, for two main reasons. First, there are no known adverse environmental effects, direct or indirect, from applying potassium fertilizers to agricultural land. Second, there are such large reserves of potassium-bearing ores that there is no risk of shortage even in the far distant future.

CONCLUSION

The yield component, total number of pods per plant, pod fresh weight, pods yield per plant and pods yield per hectare is the most important parameters, which were responded better to the plant density, nitrogen and potassium fertilizers as well as their interaction.

From the above results and discussion, it could be concluded that the bean plant should be cultivated in the soil of Blida state and the areas of the similar soils at the plant density of two plants per pot (D_2) (214290 plants per hectare) with application of fertilizer dose spatially nitrogen in lower or higher dose (0.46 or 0.92 gram urea per pot) (98.57 or 197.14 Kilogram urea per hectare). While, the individual application of potassium fertilizer (0.42 or 0.84 gram potassium sulfate per pot) had a limited unique effect on pod fresh weight in the first season and negative effect on some growth parameters such as shoot fresh and dry weight as in both seasons, which lead to decrease of some yield parameters such as, number of pods and pod yield per plant which was reflected negatively in the total yield of pods per hectare.

Furthermore, a chemical analysis to the soil of Blida state should be made in order to search and to understand the negative effects of potassium fertilizer in many vegetative growths.

Cultivar Djadida have unique characteristics with the strongest vegetative growth (the biggest and dark green triple leaves, suitable height and branchy plant etc.). In addition, the yield parameters (number of pods per plant, yield of pod per plant, yield of pods per hectare) and the yield qualities (weighty, longest, fleshy, uniform, and seed less pods of medium diameter etc.) are also superiors.

More consideration should be taken with nutrient researches especially with nitrogen fertilizer in different conditions of climate to search for the effect of time season on the behavior of the studied cultivar. The performance of this cultivar was clearly superior in both vegetative and yield parameters during the first season than the second season. This is mainly due to the temperature variation between both seasons. It is recommended to do further study with different beans genotypes in order to make the comparison and evaluate the performance of Djadida bean against the others.

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