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**Taminaw Zewdie**
Department of Plant Science, College of Agriculture, Mekdela Amba University, Ethiopia

**Eman Hassen**
Department of Plant Science, College of Agriculture, Mekdela Amba University, Ethiopia

**Correspondence**
**Taminaw Zewdie**
Department of Plant Science, College of Agriculture, Mekdela Amba University, Ethiopia

# Review on effects of phosphorus fertilizer rates on growth, yield components and yield of common bean (*Phaseolus vulgaris* L.)

**Taminaw Zewdie and Eman Hassen**

**Abstract**
Common bean (*Phaseolus vulgarise* L.) is one of the most important legumes worldwide because of its high commercial value, extensive production, consumer use and nutrient values. The objective of the Review is to review the effect of Phosphorus rate on growth, yield components and yield of common bean, the centre of origin of common bean is considered to be the central Andes, Central America, and Mexico. Common bean is adapted to a wide range of climatic conditions ranging from sea level to nearly 3000 meters above sea level. Common bean usually refers to food legumes which belong to genus-*Phaseolus,* species-vulgaris, family-Leguminosae, the establishment of research center's based on agro ecology of the country is also an excellent opportunity to advance the improvement of common bean in multi locations. About 23.9 million tons of dry bean, 20.7 million tons of green bean, and 1.9 million tons of string or common bean were produced worldwide. The crop provides vital nutrients such as high starch, protein and dietary fiber and is an excellent source of minerals and vitamins. The applied P fertilizer levels were reported a significant difference on leaf area, number of branch per plant, number of pods per plant, seeds per pod and dry matter yield. It is possible to conclude that phosphorus fertilizer rate of 20 kg ha$^{-1}$ was promising to enhance yield of common bean. In general, it recommended that investigating the same study in different localities to have a real recommendation for the optimum level of P fertilizer to produce common bean.

**Keywords:** Common bean, P-fertilizer, yield, productivity

## Introduction

### Back ground and Justification Common bean *(Phaseolus vulgarise* L.)

Common bean is one of the most important legumes worldwide because of its high commercial value, extensive production, consumer use and nutrient values (Povic *et al*., 2012) [44]. It is also an annual crop that belongs to the family Fabaceae and it grows best in warm climate at a temperature of 18 to 24 $^{\circ}$C (Teshale *et al*., 2010) [48]. Common bean (*Phaseolus vulgaris* L.) Common bean (*Phaseolus vulgaris* L.) is a major grain legume which is consumed worldwide for its edible seeds and pods (Heuze, 2013) [31]. It is one of the most important legume crops grown in all continents of the world with over 23 million metric tons (MT) of total production where 7 million MT were produced in Latin America and Africa (Arega, 2019) [4]. In Ethiopia common bean is the third most produced legume next to faba bean and field pea. It is one of the major grain legumes widely cultivated and grown as source of protein and cash by small holder farmers in eastern and southern Ethiopia (Fekadu, 2013) [23]. It performs best on deep, friable and well aerated soil with good drainage, height nutrient content and p$^{H}$ range of 5.8 to 6.5 (MOARD, 2010) [42]. It grows in most of the agro ecology zones of low and mid altitude areas of the country (Frehiwot, 2010) [26]. Common bean is used as one of the cheapest sources of protein apart from being the major source of cash income in Ethiopia and, its reasonable protein content (22%) made it the poor man's meat securing more than 16.7 million rural people against hidden hunger (CSA, 2014). Improved common bean production encompasses a proper use of different agronomic practices which include improved variety, seed rate, spacing, fertilizer rate and pesticide application as per recommendation (Mulugeta, 2011) [43]. Common bean production contributes both as food, fodder for livestock, export commodity and serves as a source of income and employment to a large supply chain and for risk aversion strategies to poor farmers' during drought due to early maturity and moderate degree of drought tolerance (Tumsa *et al*., 2015) [49]. Low yield is attributed to various biotic and biotic stresses like diseases, insect pests, drought, nutritional deficiencies and absence of improved high yielding varieties (Anju *et al.*, 2014) [3]. Common bean is highly polymorphic warm-season, herbaceous annual crop and which has two growth habit: erect herbaceous bushes (determinate), up to 20 to 60 cm high; and twining, climbing vines (indeterminate) up to 2 to 5 m long (Ecocrop, 2013). Common bean ranks third as an export commodity in Ethiopia, and contributing about 9.5% of total export value from agricultural income of the country (FAO STAT, 2015) [20]. The amount of export per annum from common bean is about $70.187million (Boere *et al*., 2015) [7]. Among pulses it takes the largest share of in terms of area coverage, with an increasing trend for the last ten years (CSA, 2016) [12]. According to (IFPRI, 2010). The yield of common bean increases with P application and its nodulation and atmospheric nitrogen fixation can also be improved with P application. When common bean economic importance is considered, it is used as source of foreign currency, food crop, means of employment, source of cash, and plays great role in diversifying the farming system (CSA, 2016) [12].

**Objectives of the Review**

- To review the effect of Phosphorus rates on growth, yield components and yield of common bean
- To identify the best phosphorus rate for common bean
- To advise farmers about the recommended phosphorus rate in order to produce common bean

## Literature Review

### Origin and Geographical Distribution of Common Bean

Common bean is believed to have two centers of origin, these are South America, Andean region (mainly Peru) and Middle America (Southern Mexico and High lands of Guatemala) (Kelly, 2010) [36]. The basis of the origin is based on DNA analysis that shows the simplest DNA structures exist in wild beans from these regions of Ecuador and Peru, those common bean accessions domesticated in the Andean regions from Ecuador south are considered as the Andean gene pool, whereas those domesticated from Colombia northwards belong to the Middle American gene pool (Kelly, 2010) [36]. However, according to Jones (1999) [34], the center of origin of common bean is considered to be the central Andes, Central America, and Mexico. Other archaeological evidence showed that common bean was domesticated 5000 BC in Peru and in 6000 BC in Southern Mexico (Freytag and Debouck, 2002) [27]. Then, from its center of origin common bean is introduced in to Brazil and East Africa in the 17 century by the Portuguese. Similarly, it is believed to be introduced in to Ethiopia in the same century by the Portugues (Jones, 1999) [34].

### Botany of Common bean

Common bean usually refers to food legumes which belong to genus- *Phaseolus*, species-vulgaris, family-Leguminosae, subfamily-Papilionoideae, tribe-Phaseoleae, sub tribe-Phaseolinae. The genus *Phaseolus* contains some 50 wild-growing species distributed only in the Americas. The Asian *Phaseolus* have been re-classified as Vegan (Gepts, 2001) [28]. According to (Lawrence, 2000) [37], like many other plants, common beans are hermaphroditic, containing both the stamen and pistil in the same flower. This makes common bean self-fertile, which means an individual plant is able to reproduce by itself which can have the effect of limiting genetic diversity. Common bean represents a wide range of life histories (annual to perennial), growth habits (bush to climbing), reproductive systems and adaptations (from cool to warm and dry to wet). The seeds of common bean are non-endospermic (for fabaceae the endosperm is not retained as storage tissue; it is used up to put storage chemical into the embryo itself) and they differ in seed size and color. The Andean lines have larger seeds in which 100 seed weight is above 30 grams while Mesoamerican lines have smaller seed size i.e., their 100 seed weight is less than 30 grams (Gonzales *et al.*, 2009) [30]. The seed size of common bean can be

i. i/small when randomly Measured 100 seed weight is below 25 grams,
ii. ii/ medium when 100 seed weight is between 25 and 40 grams and
iii. iii/ large when 100 seed weight is above 40 grams. Besides, the seed color of the crop varies from the small black wild type to the large white, brown, red, black or mottled seeds (Cobley and Steele, 2000) [11]. Common bean shows variation in growth habits that could be bushy determinate, bushy indeterminate, prostrate indeterminate and extreme climbing indeterminate types (Buruchara, 2007) [8].

### Adaptation and Agro Ecology of Common bean

Common bean is adapted to a wide range of climatic conditions ranging from sea level to Nearly 3000 meters above sea level (masl) depending on variety (Mekonen, 2007) [39]. However, it does not grow well below 600 meters due to poor pod set caused by high temperature (Dev and Eupta, 2005) [17]. It grows best in warm climate at temperature range of 18°C to 24°C (Abebe *et al*., 2005) [1]. Addition, Kay (2008) [35] reported that the crop is well adapted to areas that receive an annual average rainfall ranging from 500-1500 mm with optimum temperature range of 16°C-24°C, and a frost-free period of 105 to 120 days for maturity. Moreover, common bean performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 and the major common been producing areas of Ethiopia are central, eastern and southern parts of the country (CSA, 2016) [12].

### Challenges and Opportunities of Common Bean Improvement in Ethiopia

#### Opportunities

Common bean improvement in Ethiopia, has its own opportunities to achieve such impressive result. The common bean improvement program of the country is supported by budget, by International projects, national projects and government of the country. Currently, it is supported by CIAT (International Centre for Tropical Agriculture), PABRA (Pan Africa Bean Research Alliance), TL (Tropical Legume) and others (CIAT, 2013) [10]. The Ethiopian government has given due emphasis to the improvement of common bean due to its export value (EPPA, 2004) [19]. This support alleviates the budget challenges that would have been occurred in the improvement program. The existence of diversity between the Mesoamerica gene pool and Andean gene pool type of common bean helps for variety selection of different traits; like high yielding, disease resistance or tolerance and drought tolerance. In spite of the high level of brain erosion from the country, some of the country lovers work hard to bring this visible change in the improvement of common bean. The establishment of research center's based on agro ecology of the country is also an excellent opportunity to advance the improvement of common bean in multi locations; i.e., to exploit the genotype by environment response of selection

**Challenges**

Even though more than 50 common bean varieties are released by the NARS, due to less cooperation between agricultural extension and development offices and NARS of the country, few varieties (Red wolaita, Hawassa dume, Nasser etc.) dominate the production system; particularly, in the SNNPR regions of Ethiopia. It is clear that, in the crop improvement the target is making the farmers beneficial so that to recommend varieties according to their performance from the high yielding improved common bean varieties (Tumsa *et al*., 2015) [49]. Unless the improved common bean varieties reach to the producers, this may discourage the breeding system and make all the effort of the breeders futile (Anderson *et al*., 2017) [2].

According to the suggestion of (Tumsa *et al*., 2015) [49], the other challenge could be the dependency of breeding system only in conventional breeding and lack of basic molecular level research techniques and skill. The limitation of conventional breeding is that the time it takes to achieve desired result, it does not ensure the transfer of target gene, it is limited to only closely related species and also un-desirable gene may transfer along with desirable gene. These make the conventional breeding system less efficient in answering the question of the end users. These authors added the shortage of facilities such as screening houses; green houses and laboratory facilities weaken the breeding system. The source of resistance for some disease is also not known. According to (Anderson *et al*., 2017) [2], bio fortification is the process of breeding nutrients into food crops; it is feasible means of delivering micronutrients to populations that may have limited access to diverse diets, supplements, or commercially fortified foods. Breeding for bio fortified food crops is another challenge probably due to lack of expertise and molecular laboratories in Ethiopia (Tumsa *et al*., 2015) [49]. The other is the genetic base of most common bean cultivars with in marker class is narrow (Voysest *et al*., 1994) [51] because only a small portion wild common bean population was imported. The narrow genetic base of cultivars is attributed to the limited use of exotic germplasm (Miklas, 2000) [40]. In addition, the improvement of common bean is influenced by both a biotic and biotic factors. A biotic factors include climatic and soil factors; whereas biotic factors are diseases and insect pests. Beans are subjected to both field and storage insect pest attack. The Bean Stem Maggot (BSM) and bruchids significantly affects production and productivity. In Africa, due to BSM yield losses ranging from 30-100% have been reported (Demelash, 2018) [16]. Much of the bean crop is lost due to diseases as well as insect pests or drought, low soil-fertility and other a biotic stress (Bassett and Mc Clean, 2010) [5]. Bean rust (Uromyces appendiculatus) disease accounts for a yield loss of 85%, and Angular leaf spot (Phaeoisariopsis griseola) disease yield reductions is not quantified in Ethiopia but elsewhere range from 7 to 80%. The Anthracnose (Colletotrichum lindemuthianum) is another disease of common bean that causes yield reduction (Tusma, 2015).

**Production and Productivity of Common bean**

About 23.9 million tons of dry bean, 20.7million tons of green bean, and 1.9 million tons of string or common bean were produced worldwide in 2012 (FAO, 2016) [20, 21]. Common bean (*Phaseolus vulgaris* L.) is one of most important legume crops grown in all continents of the world with over 23 million metric tons (MT) of total production where 7 million MT were produced in Latin America and Africa (Arega, 2019) [4]. Ethiopia accounts 673,847.61-hectare (32.2%) production area and dry bean production of 845116.905 tons (25.7%) (CSA, 2016) [12]. It is also an important food and cash crop in Guji zone with an area of 15,850 ha and average productivity of 1.52 tons per hectare. Similarly, it contributed 39.49% for household consumption, 13.33% for seeds, 44.1% for sale, 0.58% for animal feed and 2.05% for other uses in the study zone (CSA, 2016) [12]. The total area allocated for common bean crop production and the yield obtained in Ethiopia is 357,299.89 ha and 540,238.94 tons respectively. The productivity of white and red common bean is 1.41 ton/ha and 1.59 ton/ha respectively in growing season. According to (CSA, 2016) [12], the area covered by common bean production in Ethiopia in 2016 was 113,249.95 ha and 244,049.94 ha for white and red common bean respectively with total area of 357,299.89 ha and total production of about 540,238.94 tons/ha. Generally, pulses covered 13.24% of the grain crop area; where common bean, faba bean and chickpea accounted for 2.86%, 3.56% and 2.07% respectively. The crop ranks second next to faba bean in the country in area of production (CSA, 2018). The major common bean producing regions are Oromia, Southern Nations Nationalities and Peoples Region (SNNPR) and Amhara. Their share to the national common bean production is 44.45% for Oromia, 31.01% for SNNPR and 21.67% for Amhara (CSA, 2018). Common bean is also one of the most important cash crops and source of protein for farmers in many lowlands and mid altitude zones. The crop ranks second next to faba bean in the country in area of production (CSA, 2018). The major common bean producing regions are Oromia, Southern Nations Nationalities and Peoples Region (SNNPR) and Amhara. Their share to the national common bean production is 44.45% for Oromia, 31.01% for SNNPR and 21.67% for Amhara (CSA, 2018). Common bean is also one of the most important cash crops and source of protein for farmers in many lowlands and mid-altitude zones. The country's export earnings are estimated to be over 85% of export earnings from pulses, exceeding that of other pulses such as lentils, faba bean and chickpea (Fissha and Yayis, 2015). National average yield of common bean in Ethiopia was 1.70 tons' $ha^{-1}$ and totally 520,979.33 tons yield was produced from 306,186.59 ha of land in 2017/18 cropping season (CSA, 2018) [14].

The national total area of common bean production is estimated at 290,202.43 ha of land and from which about 4, 839, 22.65 tons was produced per annum. According to this report, the current national average yield of common bean is 1.67 tons' ha-1. However, this yield is far less than the attainable yield (2.5-3.6 tons ha-1) under good management conditions (CSA, 2016/2017) [12, 13]. The average white and red common bean productivity is 1.41 tons/ha and 1.56 tons/ha respectively. It is predominantly produced in Oromia region, SNNPR and Amhara region with their area coverage of 146,452.41 ha (41%), 117,969.97 ha (33%) and 81,235.07 (22.74%) ha respectively. The rest 3.25% is produced in other regions of Ethiopia (CSA, 2016) [12]. (Girma *et al*., 2014) [29] Reported that in the southern part of the country, Sidama and Gamo gofa zones produce red and speckled types mainly for home consumption.

**Importance of Common bean**

The crop provides vital nutrients such as high starch, protein and dietary fiber and is an excellent source of minerals and vitamins and, as a legume, it provides nitrogen and other soil health benefits under cropping system to subsequently grown crops (Frank *et al.*, 2018) [25]. In addition to this; it is also important in providing fodder for feeding livestock and it contributes to soil fertility improvement through atmospheric nitrogen fixation during the cropping season (David, 2016) [15]. When common bean economic importance is considered, it is used as source of foreign currency, food crop, means of employment, source of cash, and plays great role in diversifying the farming system (CSA, 2016) [12]. (EPPA, 2004) [19], reported that in the year 2000, 2001 and 2002 Ethiopia exported 23,994.4, 32,932.7 and 42,127 tons of common bean obtaining 8.2, 9.8 and 13.2 million USD respectively. The main destination markets in 2002 were Pakistan, Germany, Yemen, UK, South Africa, India and Mexico having 12.9, 7.8, 6.9, 5.79, 4,4,4% respectively (Farid and Nvabi, 2015) [22].The country's export of common beans have increased over the last few years, from 58,126 MTs in the year 2005 to 78,271 MTs in the year 2007 and Ethiopia obtained 63 million dollar from common bean market in 2005 (Legese *et al*., 2006) [38]. The major storage and trading sites in Ethiopia is in the southern rift valley areas like in the towns of Wolaita sodo, Hawassa and Shashemene whereas the major collection centers for white beans is in Nazareth, before it is exported through Djibouti (Ferris and Kaganzi, 2008) [24]. The major processing companies, Ethiopia is a relatively new source of supply and recent investment site for a number of international companies like Italy, UK and Turkey. These countries are importing from Ethiopia and this indicates that market opportunities are boosting in the country even though the demand of the consumers in the country is not yet being fulfilled (CIAT, 2013) [10].

**Effect of Phosphorus Fertilizer on Growth, Yield Components and Yield of Common bean**

**Effect of different rates of phosphorus fertilizer on plant height, leaf area and number of branches per plant**

According to (Meseret and Amin, 2014) [41] the highest leaf area (119.8cm2) and (99.86 cm2) were reported at rate application of P 20 kg $ha^{-1}$and 30 kg $ha^{-1}$, respectively. In contrast, the lowest leaf area of (53.03 $cm^2$) was reported from the treatment with application of 40 kg P $ha^{-1}$. This result was in agreement with that the application of 75 kg $P_2O_5$ $ha^{-1}$ was significantly increased leaf area over rest level reported by (Shubhashree, 2012) [45]. Similarly, significant increase in leaf area was observed with increment in P application from 25 to 75 kg $ha^{-1}$(Veeresh, 2010) [50]. However, decrease in leaf area, even less than control at application rate of P 40 kg $ha^{-1}$ might be due to P response dependence on available P in study site and when it is above the optimum level it may interrupt other nutrients, which in turn can bring decrease in growth of bean. As indicated in Table 1, application of P fertilizer had no significant effect on plant height. The high plant height (125.5 $cm^2$) was reported on application rate of 20 kg P $ha^{-1}$. Moreover, from the application of 30 kg P $ha^{-1}$ showed high plant height (114.41$cm^2$) next to P 20 kg $ha^{-1}$. On the other hand, there was no significant difference between means of applied P fertilizer rates. This result is similar to the result reported by (Birhan Abdukadir, 2014) [6], a non- significant response of plant height to P application on common bean. The lowest plant height (82. 41$cm^2$) was reported at high application of P rate, this confirms with the lowest plant height was reported at application rate of P 40 kg $ha^{-1}$ (Eden, 2011) [18]. The highest rate of P application at the study site had no effect on plant height. This might be due to high dose of phosphorus fertilizer tends to form nutrient interaction and may affects the availability of other nutrients which are essential for growth of the bean.

**Table 1:** Effects of different rate of phosphorus fertilizer on growth, dry matter yield components and yield of common bean.

| Phosphorus rate kg/ha | Plant height | Leaf area | No of branches/plant | Pod/plant | Seed/pod |
|---|---|---|---|---|---|
| 0 | 91 | 57.673 | 2.33 | 24.83 | 3.14 |
| 10 | 96.83 | 79.07 | 4 | 31.16 | 5.67 |
| 20 | 125.5 | 119.8 | 5.67 | 48.16 | 5.85 |
| 30 | 114.41 | 99.86 | 5 | 39.67 | 5.81 |
| 40 | 82.41 | 53.03 | 3.58 | 30.33 | 4.20 |
| 20 | 19.55 | 19.766 | 24 | 21.4 | 13.19 |
| LSD (5percent) | NS | 31.45 | 1.84 | 14.04 | 1.2 |

**Source:** Meseret and Amin, (2014) [41]

The number of branch per plant increased with increasing phosphorus application rates up to optimum level. The highest number of branches per plant (5.67) was reported at rate of 20 kg P $ha^{-1}$. This is also similar to result reported by (Shubhashree, 2012) [45], significantly higher number of branches per plant was reported with 75 kg $P_2O_5$ $ha^{-1}$. The Mean of P fertilizer applied revealed significantly higher number of branches per plant over control. The lowest number of branches per plant (2.33) was explained at control. The increment in number of branches per plant might be importance of P for cell division activity, leading to the increase of plant height and number of branches and consequently increased the plant dry weight (Tesfaye *et al*., 2015) [47].

**Effect of different rates of phosphorus fertilizer on number of pods per plant and number of seeds per pod**

Application of P fertilizer had significantly increased the number of pod per plant (Table 1). Significantly higher number of pods per plant (48.16) was reported with P rates of 20 kg $ha^{-1}$ over rest of the levels. All applied P fertilizer rates significantly increased pods per plant over the control. The lowest pods per plant (24.83) were explained at control (no application of P fertilizer). The result is similar to (Shubhashree, 2012) [45], reported that applications of different rates of phosphorus fertilizer influence number of pod per plant. Similarly, (Veeresh, 2010) [50] observed significantly more number of pods per plant of common bean at application rate of 75 kg $P_2O_5$ $ha^{-1}$. Singh, (2016) [46] reported significant increase in number of pods per plant, due to increased P fertilization. Thus the increment of number of pods per plant due to application of P fertilizer confirms with Fertilizer promotes the formation of nodes and pods in legumes (Buttery, 2010) [9]. The highest number of seeds per pod (5.85) was reported at applied P rate of 20 kg ha$^{-1}$, whereas the lowest seed per pod (3.14) was recorded in the control treatment. The increment of seeds per pod with increasing P fertilizer application up to optimum level might be P fertilizer for nodule formation, protein synthesis, fruiting and seed formation. The applied rates of P fertilizer have significantly increased the dry matter yield of common bean at the probability level of 0.05 and 0.01. There was a significant difference among five levels P fertilizer rates. The maximum (75.5 gm plant$^{-1)}$ dry matter yield was reported at application of P 20 kg ha$^{-1}$, whereas the minimum (28.9 gm plant$^{-1}$) was reported on control. This result was similar to (Shubhashree, 2012) [45] who reported dry matter accumulation increase with application of phosphorus rates. Similarly, significant and linear increase in total dry matter production of common bean plant was observed due to increased phosphorus (Veeresh, 2010) [50]. This was in agreement with the study conducted on soybean indicated that increasing the phosphorus concentration in the soil increased the whole plant dry matter accumulation and total leaf area (Jennifer, 2017) [33]. This increment in dry matter yield with application of P fertilizer might be due to the adequate supply of P which attributed to an increase in number of branches per plant, and leaf area. This increased photosynthetic area and number of pods per plant, which demonstrates a strong correlation with dry matter accumulation and yield.

## Conclusion and Recommendation

Application of the correct level of fertilizer is necessary to achieve maximum yield of common bean crop, dry matter yield components and yield of common bean. The applied P fertilizer levels were reported a significant difference on leaf area, number of branch per plant, number of pods per plant, seeds per pod and dry matter yield. The application P 20 kg ha$^{-1}$ has significantly increased dry matter yield, yield components and all growth parameters, except plant height over the rest levels. While, application of 40 kg P ha$^{-1}$ was declined plant height and leaf area as compared to control. Thus, based on the report, it is possible to conclude that phosphorus fertilizer rate of 20 kg ha$^{-1}$ was promising to enhance yield of common bean. In general, it recommended that investigating the same study in different localities to have a real recommendation for the optimum level of P fertilizer to produce common beam. In addition, it is important to know the mineral content of the soil that hinders the uptake of phosphorus by the plant.

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