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Effects of Inorganic Phosphorus and Organic Fertilizer on Growth and Yield of Common Bean (*Phaseolus vulgaris* L.) under Kabul Conditions

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ABSTRACT

In Afghanistan, the main reasons for low crop yields are low soil fertility. Growing human populations has resulted in shrinking land areas and decreased soil fertility. Also, the overuse of chemical fertilizers is considered to be the main cause of soil characteristics deterioration, such as soil fertility, soil biology, and soil physical properties. On the other hand, no research has been done to find the ideal phosphorus and organic (ORGOFERT) fertilizer rate for improving common bean production in Afghanistan. Thus, it is pertinent to determine the optimum phosphorus and organic fertilizer dose for common bean cultivation in Afghanistan, where this crop is grown expensively. In 2020, a field trial took place at the agriculture faculty research farm of Kabul University during the growing season. The trial utilized a randomized complete block design (RCBD) with three replications. Each plot measured 200cm x 300cm, with plants spaced 40 cm apart in rows and 20 cm apart within rows. Different amounts of phosphorus and organic fertilizer were applied in the experiment. The results indicated that employing 50 kg of ORGOFERT and 80 kg of P2O5 fertilizers per hectare led to enhanced growth parameters such as plant height, number of branches per plant, and number of green leaves per plant, as well as improved yield attributes including the number of pods per plant, number of grains per pod, 100-grain weight, and total grain yield per hectare. The ideal amount of phosphorous and ORGOFERT fertilizer to improve the growth and production of common beans under field conditions might be the rate of 80kg P2O5 + 50 kg ORGOFERT fertilizer ha-1 under Kabul's agro-ecological conditions.

***Keywords**:* phosphorus, orgofert, growth, yield, common beans

INTRODUCTION

Pulses are necessary to meet essential human and animal needs like food, fodder, fiber, and energy. The common bean (*Phaseolus vulgaris* L.) originated in Central America, and it is currently widely grown as an important food crop in many tropical and subtropical parts of America, Asia, Africa, and Europe (Wortmann, 2006). The common bean was domesticated in America 8000 years ago, and it is now considered a main food that has been devoured throughout the world due to its tasty pods and seeds (Gudeta et al*.,* 2018). The Species vulgaris, Genus Phaseolus, Family Fabaceae, and Order Fabales make up its taxonomic hierarchy, and the terms Haricot bean, French bean, Salad bean, frijoles, and Snap bean are considered synonymous (Wortmann, 2006). Common beans are high in zinc, folic acid, vitamin B6, iron, potassium, selenium, molybdenum, and thiamine, 49% starch, 21.4% protein, and 22.9% dietary fiber (Ferris & Kaganzi, 2008; Buruchara et al., 2011). The world's top producers are the United States, Brazil, India, China, Mexico, and Myanmar (Martin et al., 1949).

However, nitrogen is necessary for all living organisms, but plants need it in greater quantities than any other living thing (Hawkesford et al., 2012). In the atmosphere, nitrogen is present as dinitrogen gas (N_2) that plants cannot use in this form. On the other hand, common beans and other legumes may fix nitrogen in a symbiotic relationship with Rhizobium bacteria. The process is called "biological nitrogen fixation, by which bacteria fix nitrogen to produce ammonia (NH_3) that plants can utilize biologically (Giller, 2001).

The three main nutrients are phosphorus, nitrogen, and potassium; particularly for legumes, phosphorus and nitrogen have the potential to enhance plant growth (Gizawy & Mehasen, 2009). One of the reasons why phosphorus is rarely sufficient for the best possible plant growth is due to its ability to combine with various soil components to create complexes that plants cannot absorb (Araujo et al., 2000; Liao et al., 2004). It is very important for the growth and development of legume roots and for the production of proteins, phytin, and phospholipids (Rahman et al., 2008).

Furthermore, the application of organic matter strongly impacts the physical, chemical, and biological properties of the soil (Liang et al., 2011). In order to improve soil fertility and subsequently crop productivity, it is necessary to apply both organic and inorganic resources in combination (Vanlauwe et al., 2000). In accordance with Alhrout et al., (2016), soil fertility depletion problems cannot be resolved by using neither mineral nor organic fertilizers. Thus, in order to overcome the limitations that both organic and mineral fertilizers have, it is advised to use them in combination. Especially in soils with low nutrient content, the practice increased microorganism activity, promoted the decomposition of organic wastes, and released essential nutrients, which led to a rise in the yield of grains (Rezig et al., 2013; Rezig et al., 2014; Issoufa et al., 2019). Furthermore, integrated nutrient management has contributed to a 50% reduction in mineral fertilizer costs (Kiani et al., 2005) or more (Wassie, 2012).

Afghanistan's main agricultural challenges are poor management, and inadequacy in scientific research. Thus, the key objectives of this study were to find and compare the effects of phosphorus, organic fertilizer levels, and the combination of them on yields, components of yield, and morphological and agronomical characteristics of common beans under Kabul climatic conditions.

MATERIALS AND METHODS

Area of study and properties of soil

This field experiment was conducted at Kabul University's agriculture faculty research farm in Kabul, Afghanistan (altitude of 1771 meters above sea level, longitude 69° 13' 93" E and latitude 34° 54' 44" N) during the summer cropping season from May to August 2020. The soil in the experimental field, specifically within the 0–15 cm depth, was classified as sandy loam. It had medium levels of available potassium but was characterized by low levels of organic matter, available phosphorus, and available nitrogen the pH and EC of the soil were 8.1 and 0.16 dSm-1, respectively. A moldboard plow was used to prepare the seedbed at each location, and a land leveler was then used to disk and smooth the area.

Experimental design

The experiment was conducted using a randomized complete block design (RCBD), where six treatments were tested. These treatments included different levels of phosphorus and organic (ORGOFERT) fertilizers (ORGOFERT is organic approved granular fertilizer for soil application with organic matter upto 80% and organic carbon more than 35%).The combinations of these treatments were randomized across three replications of the experiment.

A common beans local variety (Capsoly) was cultivated. Diammonium phosphate (DAP) and organic fertilizers at the respective treatment plots were applied as a bund application method 6 cm under from seed place at the final land preparation/harrowing before seed planting. Manually in each gap, two seeds were sown with a depth of 5cm according to the recommended planting geometry (40 cm x 20 cm). The direction of the line was north and south. Some agriculture practices (gap pilling, thinning, irrigation, and weeding) were done due to the need for common beans during the growing season. To accurately assess the effects of different treatments, plants were chosen systematically, arranged in a zigzag pattern, and labeled within each plot for data collection purposes. Throughout the current field experiment, data were gathered on various parameters including plant height (PH), number of branches per plant (NBP), number of green leaves per plant (NLP), number of pods per plant (NPP), number of grains per pod (NGP), 100-grain weight (HGW), and grain yield (GY).

Table1: Treatment detail

Treatment	Treatment description
T1	Control(no applied)
T2	120 kg P_2O_5 ha^{-1}
T3	80 kg P_2O_5+50kg organic fertilizer (ORGOFERT) ha^{-1}
T4	40 kg P_2O_5+50kg organic fertilizer (ORGOFERT) ha^{-1}
T5	60 kg organic fertilizer (ORGOFERT) ha^{-1}
T6	50 kg organic fertilizer (ORGOFERT) ha^{-1}

Statistical Analysis

The data were analyzed using the software of Statistical Tools for Agriculture Research (STAR) to distinguish significant differences in the treatment means. At a 0.01% probability level, the test of least significant difference (LSD) was used.

RESULTS AND DISCUSTION

Common bean growth

The common bean's plant height was shown to be significantly impacted by the application of phosphorus and organic fertilizer doses.

Data in Table 2 showed the height of common bean plants grew significantly with each treatment compared to the control treatments. The maximum value for plant height was measured on average for the T3 treatment (37.80 cm) and the lowest for the T1 treatment (24.47 cm). The increase in plant height may result from the slow release of important nutrients from ORGOFERT fertilizers and the P and N elements' availability during the growth season from DAP fertilizer. However, Plant metabolism and growth are greatly influenced by phosphorus, which is the most crucial nutrient (Tesfaye et al., 2007). Our findings similar those of Fouda et al. (2017), who found that the NPK 100%+ compost treatment resulted in the tallest plants, while the control treatment produced the shortest plants throughout the season. Similarly, our results are consistent with the conclusions drawn by Chavan et al. (2015), who observed that the application of compost and chemical fertilizers led to increased plant height in Leguminaceae compared to the control treatment. Also, DAP and ORGOFERT fertilizer applications in T3 produced the highest number of green leaves per plant (55.67) and the lowest number (39.20) for the control treatment (no applied). Similarly, the treatment of 75 kg P_2O_5+2 tons of chicken manure ha-1 resulted in a considerably increased number of green leaves per common bean plant (Veeresh, 2003). Also, Fletcher, et al. (2008) and Assuero, et al. (2004) reported that the decrease in leaf area in phosphorus-deficient common beans was due to a reduction in the number of cells formed early in leaf growth. The combination of phosphorus and organic fertilizer produced the most number of branches in a plant, followed by only organic fertilizer at the rate of 60kg ORGOFERT ha^{-1}, and the lesser number of branches was produced by no application (control treatment). Our results are similar to those of Elka Ermias and Fanuel Laekemariam (2020), who found that the application of NPS fertilizer and organic manure significantly influenced the number of branches per plant ($p < 0.01$). Additionally, Tesfaye et al. (2007) demonstrated that the number of branches per plant in haricot bean increased with higher rates of fertilizer application. This increase in branch number could be attributed to the crucial role of phosphorus in cell division activity, leading to greater plant height and branch development.

Table 2: Analysis of Variance (ANOVA) for the observed parameter of the common bean.

Source of Variance	df	Mean square						
		PH (cm)	*NLP*	*NBP*	*NPP*	*NGP*	*HGW*	*GY*
Replication	2	0.0156	0.6067	0.0467	0.3200	0.0089	1.348	581.837
Treatments	5	65.8742**	110.2013**	11.2000**	41.3173**	2.2156**	13.852**	69445.718**
Error	10	2.2609	2.6840	0.3267	1.9573	0.1769	1.095	637.095
CV%		4.86	3.54	10.46	9.67	10.91	2.56	0.3522

*Significant difference at 5%, **Significant difference at 1%, df: degree of freedom, and CV: coefficient of variation. GY is grain yield (kg ha-1); PH is plant height (cm); NLP is number of green leaves per plant; NBP is number of branches per plant; NPP is number of pods per plant; HGW is 100-grain weight (g); and NSP is number of grains per pod.

Table 3: Growth, yield, and yield components of common beans in response to phosphorus and ORGOFERT

Treatment	PH (cm)	*NLP*	*NBP*	*NPP*	*NSP*	*HGW*	*GY* (kg ha-1)
T1	24.47d	39.20d	2.27d	9.13d	2.33c	51.60d	1775.70d
T2	29.73c	44.00c	5.27bc	13.07c	3.87b	52.40cd	1854.27c
T3	37.80a	55.67a	8.20a	19.93a	5.00a	57.40a	2210.67a
T4	33.00b	48.80b	5.87bc	15.73b	4.07b	53.93bc	1925.87b
T5	32.93b	49.00b	6.20b	16.33b	4.00b	54.33b	1929.57b
T6	27.60c	41.13cd	5.00c	12.60c	3.87b	52.00d	1842.27c
LSD	2.735**	2.980**	1.039**	2.54**	0.7652**	1.9042**	45**

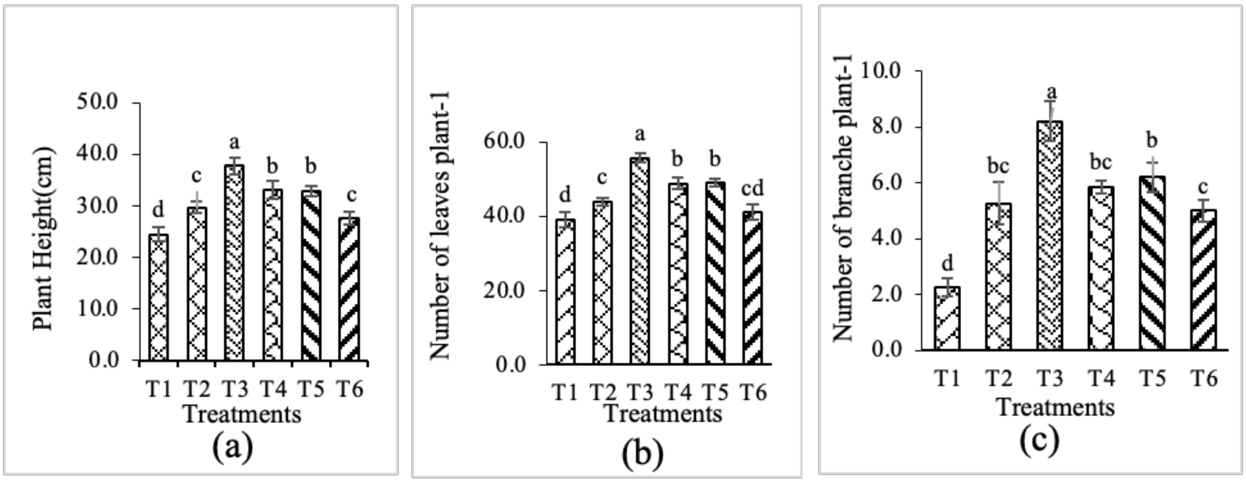

Fig 1: Effect of Phosphorus and organic fertilizers levels on (a) PH (cm), (b) NLP and (c) NBP of common bean. Significant differences ($P < 0.01$) are indicated by different letters, and the error bar indicates the standard deviation of three replicates.

Yield of Common Beans

The application of phosphorus and organic fertilizer resulted in a significant increase in the number of pods per plant (as shown in Table 3). Specifically, the T3 treatment yielded significantly more pods per plant (19.93), while the control treatment produced the lowest number (9.13). Across all levels of phosphorus and organic fertilizers, including their combinations, there was a significant increase in the number of pods per plant compared to the control treatment. Similarly, in Ethiopia, Fekadu et al. (2018) observed that the number of pods in faba bean plants increased from 3.4 to 9.2 when farmyard manure and phosphorus fertilizer were combined. Additionally, the use of organic fertilizer and phosphorus significantly enhanced the total number of grains per pod (as illustrated in Figure 2). The T3 treatment produced the highest average number of grains per pod (5.00), while the control treatment yielded the lowest (2.33). Moreover, there was a significant increase in grain numbers per pod at all levels of applied phosphorus and organic fertilizer compared to the control. Furthermore, our data demonstrated that the application rates of phosphorus and organic fertilizer significantly influenced the grain weight of common bean plants. Maximum 100-grain weight (57.40) g was obtained in the T3 treatment (80kg P_2O_5+ORGOFERT 50kg/ha) while the unfertilized (control) treatment produced a minimum 100-grain weight (52.40 g). The results are comparable to Fouda et al. (2017), who reported that the combined application of compost and NPK resulted in the highest values of 100-grain weight (49.73 g), while the control (no applied) treatment gave the lowest values (47.1 g) in bean plants. Also, our final results were similar with Kadam and Pathade (2014), who showed the combined application of chemical fertilizer with vermicomposting enhanced the common bean plant's 100-grain weight (g) compared to the control. Furthermore, Bildirici and Yilmaz (2005) reported that phosphorous raised the weight of common beans by 100 grains (g) and significantly influenced the grain yield. However, Arjumand, et al., (2013) reported that most nutrients are found in organic matter, leading to an increase in the weight of the seed due to the increased accumulation of protein and carbohydrates in the seed. Common bean grain production increased significantly with phosphorus and organic fertilizer application (Fig. 2). The maximum grain yield (2210.67 kg ha^{1}) of common bean was attained in plots fertilized with 80kg P_2O_5+ORGOFERT 50 kg/ha (T3). Maximum grain yield from T3 treatments was related to more pods per plant, more grains per pod, and a heavier 100-grain weight, which finally resulted in a higher grain yield. The result is similar to Duaja (2013), who reported that organic and inorganic fertilizers can improve green bean yields. Similarly, In India, Rana *et al.* (2014) found that soybean production increased when both organic and inorganic fertilizers were applied together. Similarly, Abdou et al. (2016) observed synergistic effects and improved synchronization of nutrient release and absorption by plants when a combination of inorganic and organic nutrient sources was used, resulting in higher yields. Sharif et al. (2011) also reported that combining organic and inorganic fertilizers shows promise in maintaining and restoring soil fertility and increasing crop production. Various studies, such as those by Agegnehu et al. (2005), have shown that both chemical fertilizers and manure treatments significantly increase faba bean production. Additionally, Manisha et al. (2007) demonstrated that the combined use of organic waste and chemical fertilizer substantially enhances peanut production and quality.

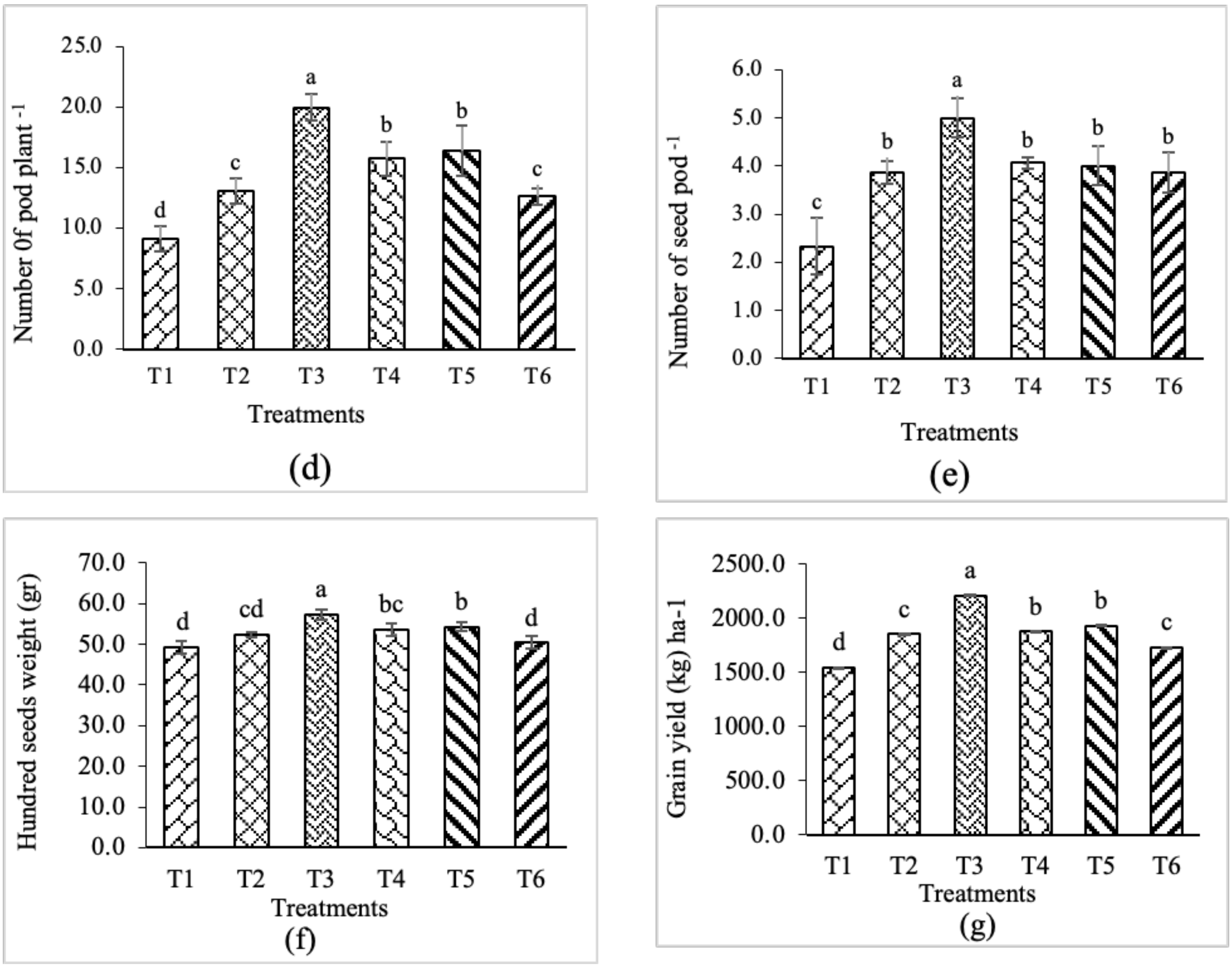

Fig 2: Effect of phosphorus and organic (ORGOFERT) fertilizers on (d) NPP, (e) NSP, (f) HGW (gr), and GY (kg) ha-1 of common bean. Significant differences ($P < 0.01$) are indicated by different letters, and the error bar indicates the standard deviation of three replicates.

CONCLUSION

To improve common bean yields, a sufficient quantity of organic and inorganic fertilizer must be applied. The results obtained from the experiment conducted integrated application of organic (ORGOFERT) and phosphorus (DAP) fertilizers had a significant influence on the common bean's growth, yield, and its components.

The application of phosphorus and organic fertilizers (120kg P2O5 ha-1, 80kg P2O5+50kg ORGOFERT ha-1, 40kg P2O5+50kg ORGOFERTha-1, 60 kg ORGOFERT ha-1, 50 kg ORGOFERT ha-1) indicated significant impacts of all treatments on common bean crop growth and production. All the growth and yield parameters were significantly higher with the application of 80 kg P2O5 and 50 kg ORGOFERT ha-1 compared to the other treatments. As a result of the findings, it was feasible to conclude that the rate of 80 kg P2O5+50kg ORGOFERT ha-1 was promising for increasing common bean yield.

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Conflict of Interest: In all aspects of this paper, the authors confirm that there are no conflicts of interest.

Contributions of the Authors: Aram provided a comprehensive literature review, synthesizing existing research on the topic, providing a solid foundation, and collecting and analyzing data to support the main subject of the manuscript. Inqilaabi played a role in structuring and organizing the manuscript. Ahmady and Hekmat edited and reviewed the manuscript critically, and Nikaml reviewed the final manuscript for proofreading. After reading the completed manuscript, each author gave their approval for it to be published.

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