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Effects of Organic Fertilizer on Growth and Yield of Common Bean (*Phaseolus vulgaris* L)

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Abstract: A field experiment was conducted in Zaqom Khail village, Baraki Barak district of Logar province, Afghanistan, during the summer cropping season in 2020 and 2021. The study focused on organic fertilizers at rates of 300 kg/ha, 450 kg/ha, and 600 kg/ha. The NPK (100:100:50) and zero treatment were served as positive and negative controls, respectively. A dosage (100 and 50%) of organic fertilizer was applied during sowing time, at the last harrowing. The experiment followed a randomized completely block design with three replications and five treatments. Each plot had a size of 2m x 1.5m, resulting in an area of 3m², and the gaps between adjacent plots and blocks were maintained at 0.50 meters and 1 meter, respectively. Bean seeds were sown with a spacing of 0.40 m (row-row) x 0.20 m (plant-plant) and at a depth of 6 cm. The plant lines were arranged in a north-south direction, with a population of 60 plants per plot. Each plot consisted of four lines, with 15 plants in each line. The total experimental area was approximately 110 m^2. The results showed that the growth parameters (number of plant branches and plant height) and yield attributes (number of plant pods, number of seeds per pod, dry matter weight per plot, and grain yield per hectare) were highest with the application of 600 kg of organic fertilizer per hectare in both 2020 and 2021. This treatment resulted in a maximum plant height of 51.0 and 49.4 cm, a higher number of plant branches (6.0 and 5.93), the maximum number of pods per plant (8.20 and 8.08), a number of seeds per pod (5.60 and 5.53), dry matter weight (30.77 and 29.30 grams), and grain yield per hectare (2.563 and 2.535 metric tons), respectively, compared to the control group. These findings indicate that the optimal dose of organic fertilizers for promoting the growth and improving the yield of common beans in the field may be a rate of 600 kg of organic fertilizer per hectare under the agro-ecological conditions of Logar.

Keywords: Common bean, phosphorus, organic fertilizer, yield, seeds

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most important legume crops in worldwide. Common bean, locally known as Boleqe. It also a major staple food crop in Africa. In a continent where over 30% of the households live below the poverty line (Alemu, 2017). This short-season crop takes approximately 65-110 days from planting to reach physiological maturity (Buruchara, 2007). This bean type has been cultivated for more than 7,000 years in two primary regions of origin: Mesoamerica (Central America and Mexico) and the Andean region. Among the genus *Phaseolus* L., Runner bean (*Phaseolus continuous* L.), Tapary bean (*Phaseolus acutifolius* L.), Year bean (*Phaseolus polyanthus* L.), Lima bean (*Phaseolus unatus* L.), and Common bean (*Phaseolus vulgaris* L.) are most cultivated worldwide (Delgado-Salinas et al., 2006).

Common bean is grown as an affordable source of protein for the majority of Sub-Saharan African people. The crop is originated in tropical America (Mexico, Guatemala, and Peru) and domesticated to Central-America. In the16th century common bean is introduced to Ethiopia by the Portuguese. Common bean adapted to mid to high-altitude areas

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of Ethiopia but the suitable production areas have been indicated (1200 – 2200 m.a.s.l), with rainfall of 350-500 mm well distributed over 70-100 days. The crop is grown by subsistence farmers either as a sole crop and/or intercropped with either cereal or tree crops. In Ethiopia, common bean is used us rotational crop to improve soil fertility and it is one of the most important cash crops and an emergency crop to reduce hunger since it is source of protein, starch, dietary fiber and is an excellent source of potassium, selenium, molybdenum, thiamine, vitamin B6 and folic acid. It also consumed as Nifro, Shirowet, soup and samosa. In a plant breeding context, adaptation is the ability of the material to be high-yielding with respect to a given environment or given conditions to which it is adapted. Moreover, adaptability is the ability to show good adoptedness in a wide range of environments (Achenef et al., 2021).

Organic fertilizers comprise a variety of plant-derived materials that range from fresh or dried plant material to animal manures and litters to agricultural by-products (Green, 2022; Das and Jana, 2023). The nutrient content of organic fertilizers varies greatly among the material sources. Usually, biodegradable materials produce good nutrient sources. However, nitrogen and phosphorus content are lower compared to chemical fertilizer. Moisture content is another factor that reduces or dilutes the nitrogen and phosphorus concentrations in organic fertilizers. Thus, it can be cost ineffective to transport high-moisture organic fertilizer long distances. However, use of locally available sources is perfectly reasonable if its use is consistent with the production strategy. Nutrient value of animal manures is more variable than that of agricultural by-products.

The organic carbon content of organic fertilizer can be of equal or greater importance than its nitrogen and phosphorus contents. Application of organic fertilizer promotes increases in heterotrophic bacterial biomass, which stimulates other secondary productivity and mineralizes nutrients to stimulate primary productivity (Barkoh et al., 2005). An organic fertilizer is a fertilizer that is derived from organic sources, including organic compost, cattle manures, poultry droppings and domestic sewage. Organic fertilizers have been widely used in tilapia ponds, especially in Asia ((Behera et al., 2022). A wide variety of organic fertilizers, including poultry manure, cattle manure, domestic sewage (sludge), green manure and composted agricultural wastes, are currently in use in tilapia pond fertilization.

Organic manures enhance secondary production in fish ponds more than inorganic fertilizers. This is mainly because the organic matters stimulate heterotrophic bacteria, and, in turn, enhance the decomposition of organic matters in the pond (Sivojiene et al., 2022). Animal manures can be as the basic productivity, while nitrogen or phosphorus can be added as needed to gain nutrient balance in the pond. This approach is very appropriate due to its ecological efficiency and cost-effectiveness. However, this scenario may not be easily applied in some countries. For example, current certification rules and best practices consider animal manures as potential problems to human health.

According to Qadiri et al. (2023), single and combination applications of NPK, chicken manure, and the combine of NPK and chicken manure (NPK + Ch. M) with different rates affected the growth, yield, and their components of common bean during summer (June to September). They discovered NPK (15:15:15) at 150 kg per ha produced the highest plant in terms of height (54 cm), number of leaves per plant (63), and branch count per plant (7). The optimum performance of common bean with regard to 25 g pod number/plant (PNP) ha^{-1} and 253 g pod weight/plant was achieved with the combination of NPK (15:15:15) at a rate of 150 kg/ha and chicken manure at a rate of 20t/ha above control. Mohamad et al. (2022) stated various organic amendments, such as vermicompost, biochar, and microbial compost, exhibit distinct impacts on plant growth performance due to the ability of beneficial bacteria to enhance soil structure and nutrient uptake. Due to various effects of organic fertilizer on the plant growth and yield, thus, this study was conducted to determine the effect of organic fertilizer on growth and yield of common bean.

2. Materials and Method

2.1. Experimental Site and Climate Information

The experiment was conducted at Zaqom Khail village, Baraki Barak district of Logar province, Afghanistan during the summer cropping season, in both 2022 and 2021. The research was conducted in a field experiment and the experimental field was located at 33° 57'22.8" N latitude and 68° 55'07.9" E longitude, with a height of 1925 m beyond the ocean level. Based on MAIL (Ministry of Agriculture, Irrigation and Livestock) data the Baraki Barak District of Logar province is classified under the cold climate. January and February are the coldest months of the year and the maximum temperature reach to the peak in July. The monthly maximum and minimum temperatures, which are practiced by the crop, and the amount of rainwater obtained during the crop, period is shown in (Figure 1). At, the planting time the temperature, was various 8-20°C, and during the growing season the extreme temperature, was different between 20.6 °C to 34.2°C, and the lowest temperature, was 8.1°C to 22.8°C. With increasing the, crops growth, the both maximum and minimum temperature was raising. The maximum amount of rainfall (36.97 mm) occurred in April at the sowing to emergence time and the rainfall was less later in the growing season.

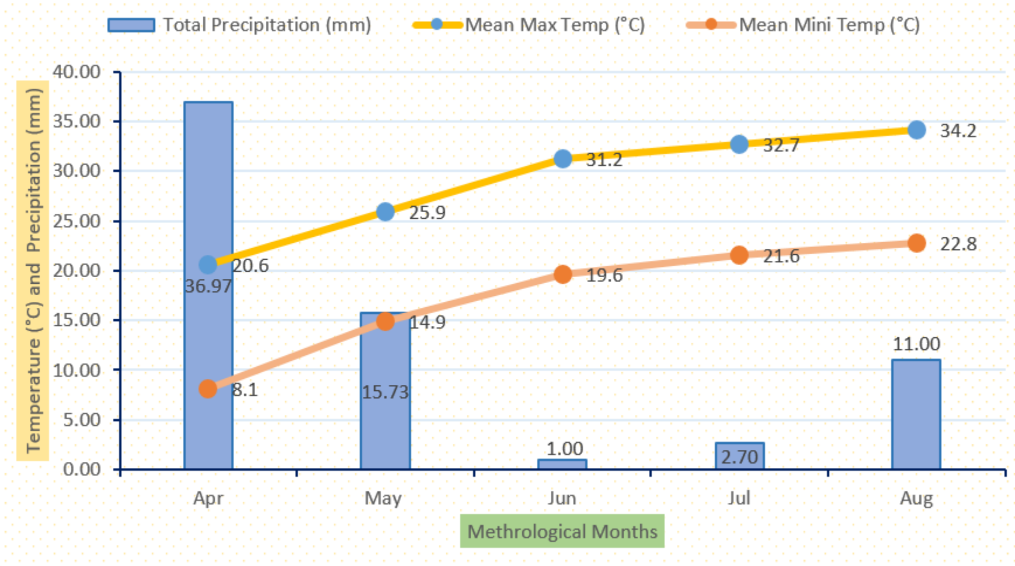

Fig.1:Temperature and precipitation data of Logar province during summer cropping seasons (2020-2021). Source: (Ministry of Agriculture, Irrigation and Livestock - Islamic Republic of Afghanistan, *n.d.)*

2.2. Physical and Chemical Properties of Soil at Experimental Site

An auger was used for soil sampling in experimental site. The samples were taken from 25 cm deep, from each experiment field 10 samples taken and mixed, the compound both site samples of soil tested for chemical and physical possessions in MAIL soil Lab in Badambagh Kabul, the properties of soil are presented in Table 1.

Table 1: Physical and chemical properties of soil at experimental site

Experimental site	Soil Analysis											
	pH	EC ms/cm	Elements						Soil Texture			Remarks
			T-N %	P2O5 ppm	K ppm	Na Ppm	$CaCO_3$ %	OM %	Sand %	Silt %	Clay %	
Baraki Barak District of Logar province	8.3	0.175	0.168	9.50	24.00	14.00	12.50	1.00	50.96	38	11.04	Loam

2.3. Field Preparation and Fertilizer Application

The field was harrowed twice followed by one plugging with cultivated and planking to get well pulverized seed bed for sowing, stubbles and weeds were removed from the ground on June 01, 2020. The field was leveled by hand and was arranged for channels, bunds, and field borders. The experiment field was subdivided into unit plots in accordance with the design of the experiment (Figure 2 and 3).

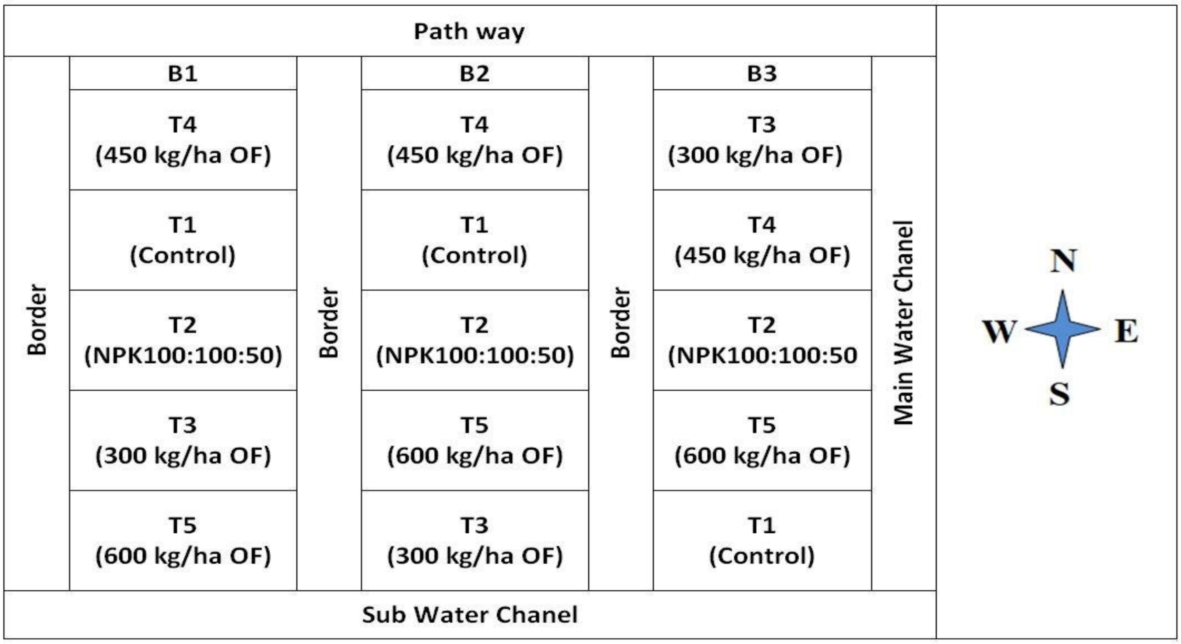

Fig. 2: Experimental Layout, 2020

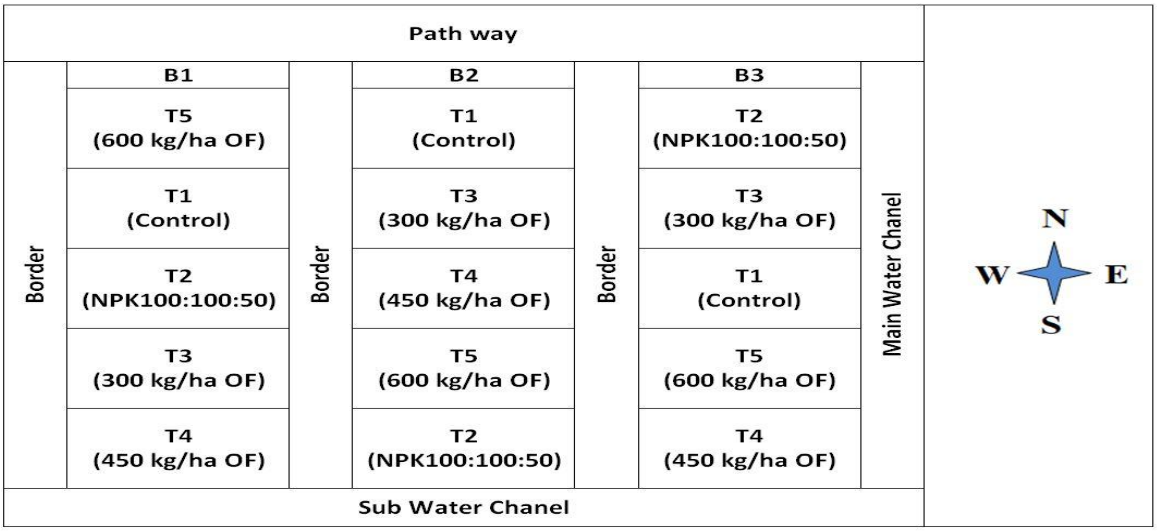

Fig. 3: Experimental Layout, 2021

The full dose (100 and 50 %) of phosphorus was applied during sowing time, specifically at the last harrowing stage. The experiment followed a complete randomized block design, with three replications and five treatments as tabulated in Table 2. Each plot had dimensions of 2 m x 1.5 m, resulting in an area of 3 m^2. The gaps between adjacent plots and blocks were maintained at 0.50m and 1m, respectively. Bean seeds were sown with a spacing of 0.40 m (row-row) x 0.20 m (plant-plant) and at a depth of 6 cm (Tesfaye & Balcha, 2015). The plant lines were arranged in a north-south direction, and there were 60 plants maintained in each plot. Each plot consisted of four lines, with 15 plants in each line. The total area of the experiment covered approximately 110 m^2.

Table 2: Treatments description

No.	Treatment code	Description
1	T1	Control (0) No Applied
2	T2	NPK (100:100:50)
3	T3	Organic Fertilizer 300 kg/ha
4	T4	Organic Fertilizer 450 kg/ha
5	T5	Organic Fertilizer 600 kg/ha

2.4. Planting Material, Agronomic Practices

A high-yielding common bean (Red woliata) variety was selected for this study. The Red Woliata has greater adaptability to the wider agro ecological area and grows and adapted well at altitudes ranging from 1200 to 2200 mm Sea level and annual precipitation of 150 to 1500 mm. It is one of the most successful hybrid varieties released in 2014. The color of the seeds is Red. It needs about 100 to 120 days for maturity in the summer season and good soil condition. The good quality high yielding, seed was sourced from Badam Bagh, Kabul province, and used for this study. The seed germination was 99%. Common bean seeds were sown in well prepared raised bed field on 09 July, 2020. Two seeds were placed manually at 20 cm distance along the rows. The seedling of the common bean emerged out within 7- 9 Day after sowing. Necessary gap filling was done at 15 DAS in both growing seasons. The optimum common bean plant population per unit area was maintained by thinning at 28 days after sowing. Thinning is very essential for getting high seed productivity. One healthy plant was retained per hills and the other plants were removed.

In the experimental field, the first irrigation was applied before sowing time; the second irrigation was after the emergence stage and the others were 7-9 days until one week before the maturity of the common bean crop. About 13 times common bean was irrigated in its growth season irrigations were applied to common bean crop. Weeding was performed manually just after emergence. Late emergent weeds were detached by the hoeing in order to avoid interfering with the bean crop. Weeding was done two times, at 35 and 50 days after sowing. Weeds in the rows of common bean crops were removed with hand hoeing.

2.5. Growth Measurements

Plant growth is the pre-requisite for knowing the effect of any factor on seed productivity. Therefore, the plant growth parameters such as plant height and number of branches average was taken. The plant height from the soil surface to the apical branch were measured according to the method described by Tesfaye & Balcha (2015). Nine randomly plants from tow central plant height rows of net plot were measured using measuring tape. Meanwhile the number of branches per plant was recorded by counting number of branches from nine pre tagged plants.

2.6. Yield

The experimental crop was reaped plot-wise at full maturity on 25 August 2020. The trial plants were reaped separately for recording yield attributes and yield. The data of yield were recorded from harvested plants of each net plot after removing the border area. The harvested plants from each plot were bundled separately and properly dried for threshing. The grains were cleaned and dried in an oven at 130 ºC for one hour properly (Dida, 2019). Seed and yield were recorded after proper threshing and cleaning of the seed (Figure 5).

Fig. 5: Threshing and seed cleaning

The number of seeds per pod was counted from nine selected per tagged plants in the field experiment. The yield was taken from the common bean pods harvested from the net plot. The seed yields were adjusted to 12.5% moisture and converted to hectare basis.

3. Results

3.1. Plant height

The analysis of statistical data concerning plant height demonstrated a significant influence of fertilizer on the common bean plants' growth. Among the different treatments, the plot treated with 600 kg/ha of organic fertilizer exhibited the tallest plant height, reaching 51 cm in the first year of 2020 under the T5 treatment. In contrast, the control treatment resulted in the lowest plant height, measuring 43.47 cm in the same year. Similarly, in the second year of 2021, the plot treated with 600 kg/ha of showed the tallest plant height, reaching 49.4 cm under the T5 treatment, while the control treatment yielded the shortest plants at 41.13 cm, as shown in Figure 6.

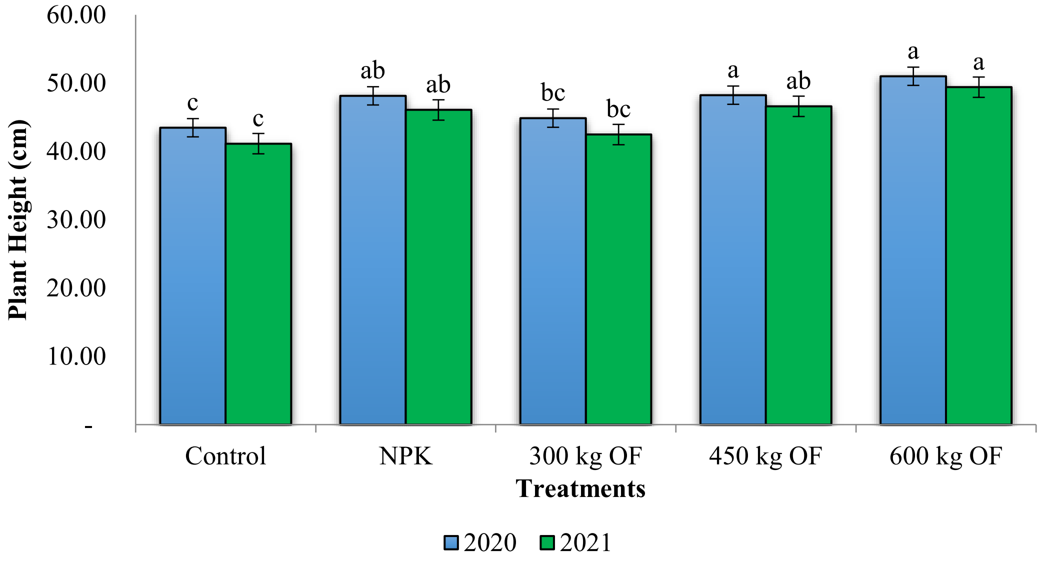

Fig. 6: Effect of organic fertilizer on plant height of common bean (cm)

3.2. Number of branches per plant

The quantitative analysis of the data recorded for the number of branches on each plant revealed a significant impact of the organic fertilizer on the common bean's branch development. The plot treated with 600 kg/ha of displayed the highest number of branches, reaching 6.0 under the T5 treatment, surpassing all other treatments in the first year of 2020. Conversely, the control treatment exhibited the lowest number of branches, with only 3.4 branches per plant during the same year. Similarly, in the second year of 2021, the plot treated with 600 kg/ha of showed the maximum number of branches, measuring 5.93 under the T5 treatment, while the control treatment resulted in the fewest branches, with 3.27 branches per plant, as depicted in Figure 7.

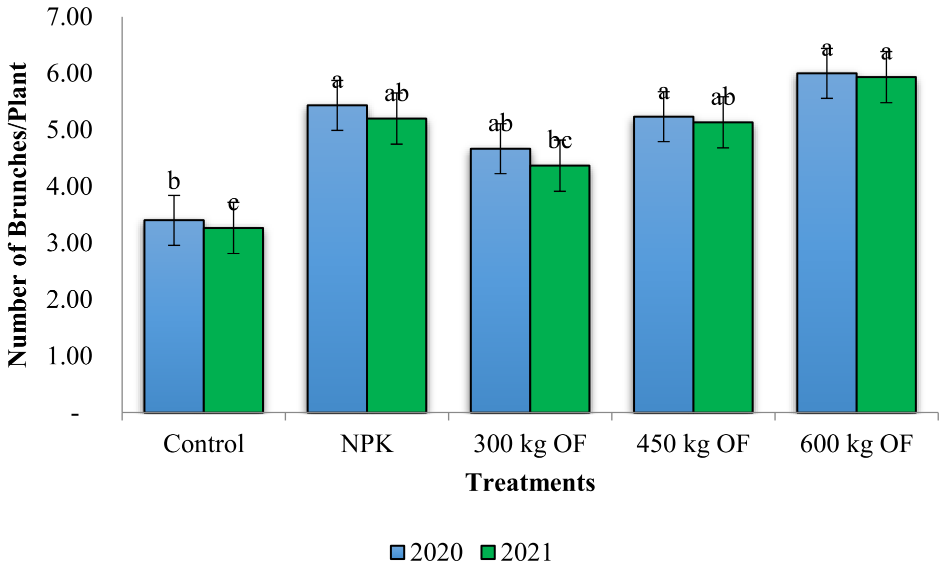

Fig. 7: Effect of organic fertilizer on the number of branches per plant of Common bean

3.3. Number of pods per plant

The statistical analysis of the data recorded for the number of pods on each plant demonstrated a significant influence of Organic Fertilizer on the common bean's pod production. The plot treated with 600 kg/ha of yielded the highest number of pods, reaching 8.2 under the T5 treatment, outperforming all other treatments in the first year of 2020. Conversely, the control treatment resulted in the lowest number of pods, with only 4.53 pods per plant during the same year. Similarly, in the second year of 2021, the plot treated with 600 kg/ha of displayed the maximum number of pods, measuring 8.07 under the T5 treatment, while the control treatment produced the fewest pods, with 4.37 pods per plant, as illustrated in Figure 8.

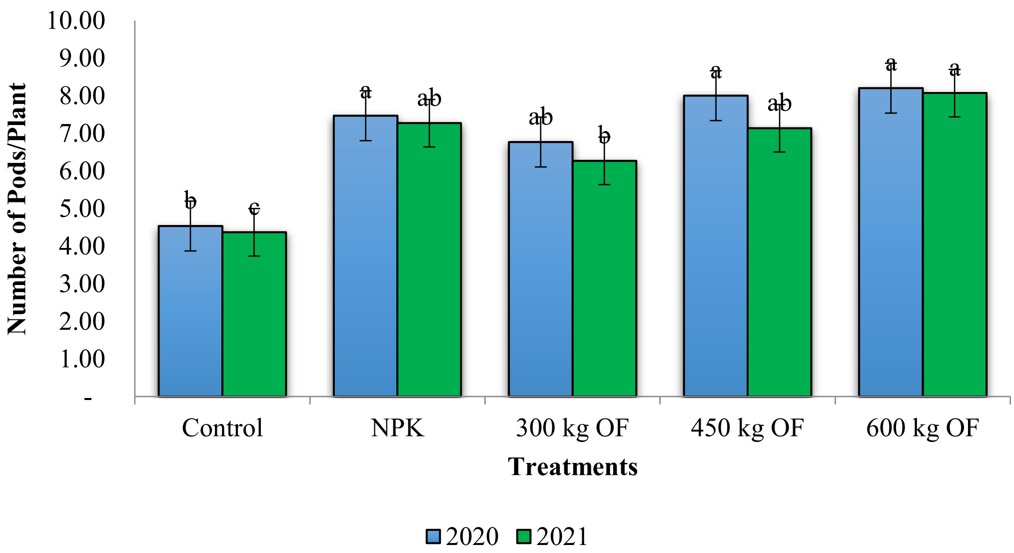

Fig. 8: Effect of organic fertilizer on the number of pods per plant of common bean

3.4. Number of seeds per pod

The statistical examination of the data recorded for the number of seeds per pod indicated a significant influence of Organic Fertilizer on the number of seeds in common beans. The plot treated with 600 kg/ha of exhibited the highest number of seeds, reaching 5.6 under the T5 treatment, surpassing all other treatments in the first year of 2020. Conversely, the control treatment resulted in the lowest number of seeds, with only 4.23 seeds per pod during the same year. Similarly, in the second year of 2021, the plot treated with 600 kg/ha of. displayed the maximum number of seeds, measuring 5.53 under the T5 treatment, while the control treatment produced the fewest seeds, with 3.9 seeds per pod, as depicted in Figure 9.

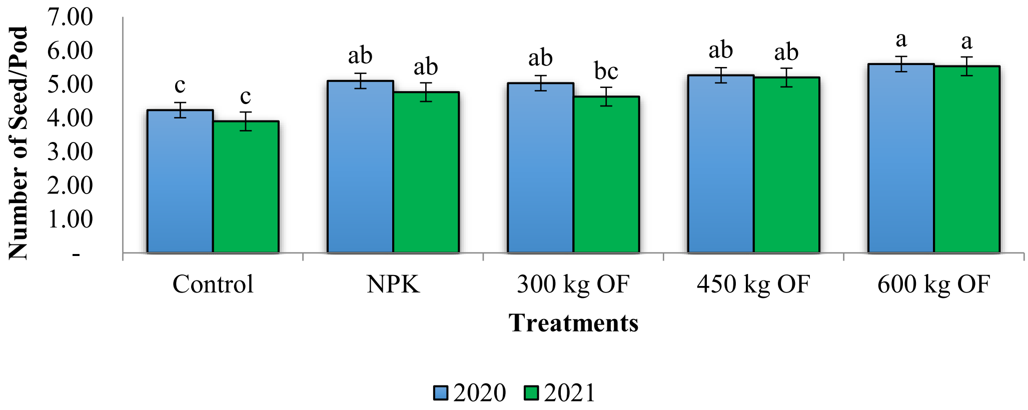

Fig. 9: Effect of organic fertilizer on the number of seeds per pod of common bean

3.5. Dry matter weight per plant

The analysis of statistical data concerning dry matter weight revealed a significant impact of phosphorus on the dry matter weight per plant of common beans. The plot treated with 600 kg/ha of organic fertilizer exhibited the highest dry matter weight, reaching 530.77 grams under the T5 treatment, outperforming all other treatments in the first year of 2020. In contrast, the control treatment resulted in the lowest dry matter weight, with only 22.80 grams per plant during the same year. Similarly, in the second year of 2021, the plot treated with 600 kg/ha of organic fertilizer showed the maximum dry matter weight, measuring 29.30 grams under the T5 treatment, while the control treatment yielded the minimum dry matter weight of 21.03 grams per plant, as shown in Figure 10.

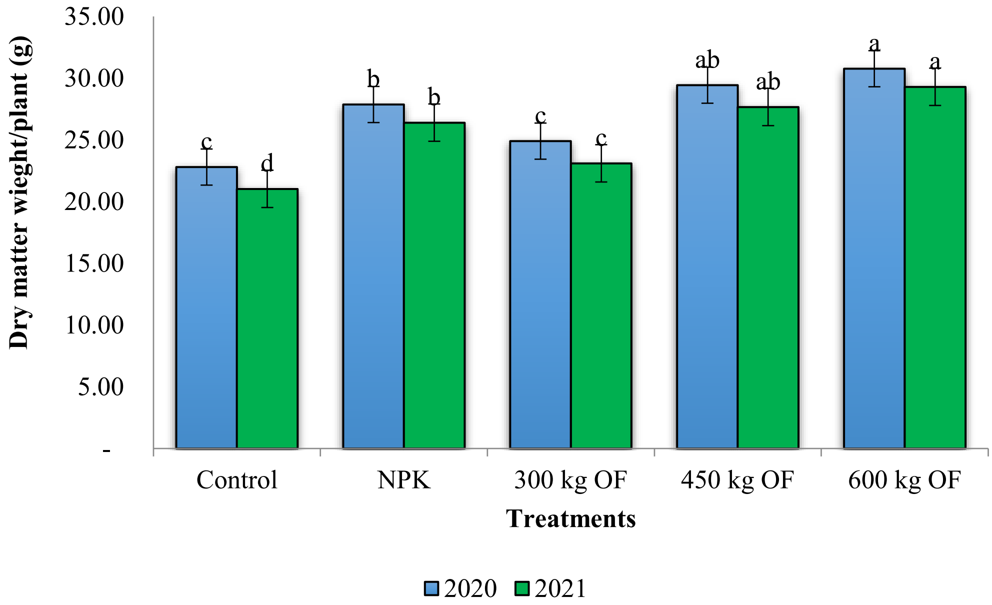

Fig. 10: Effect of organic fertilizer on dry matter weight per plant of common bean

3.6. Total yield

The statistical examination of the data recorded for the total yield per hectare demonstrated a significant influence of organic fertilizer on the common bean yield. The plot treated with 600 kg/ha of displayed the highest yield, producing 2.563 metric tons per hectare under the T5 treatment, surpassing all other treatments in the first year of 2020. On the contrary, the control treatment resulted in the lowest yield, with only 1.668 metric tons per hectare during the same year. Similarly, in the second year of 2021, the plot treated with 600 kg/ha of showed the maximum yield, reaching 2.535 metric tons per hectare under the T5 treatment, while the control treatment yielded the minimum yield of 1.639 metric tons per hectare, as depicted in Figure 11.

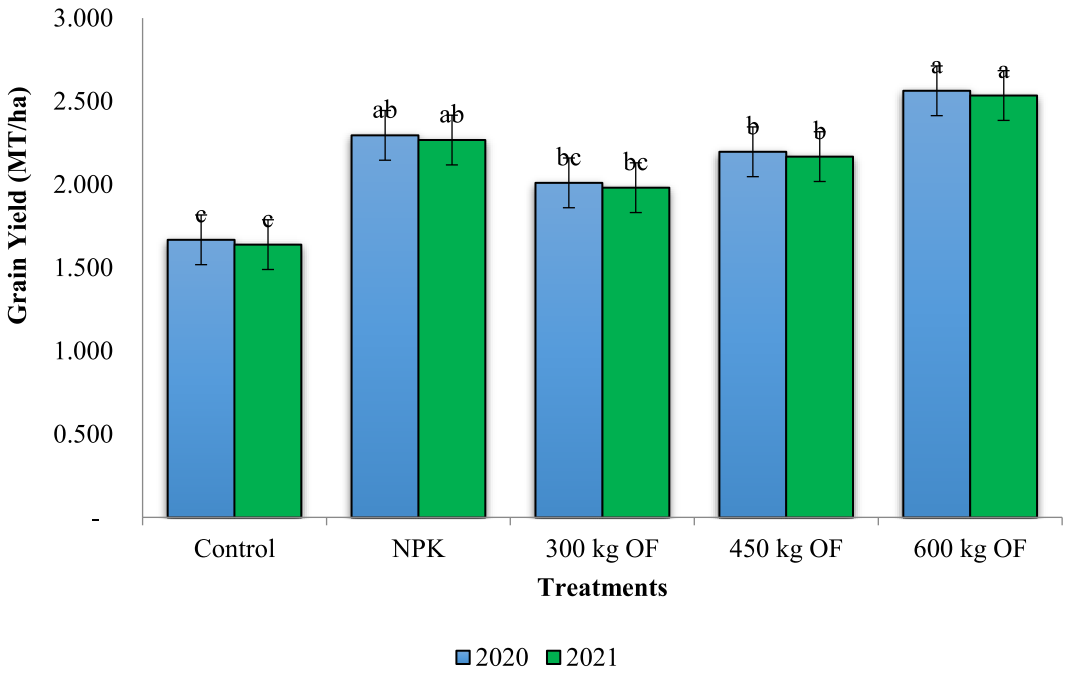

Fig. 11: Effect of organic fertilizer on total yield per hectare of common bean

4. Discussions

The utilization of organic fertilizer had a significant impact on the growth and yield parameters of common beans. The addition of organic fertilizer positively influenced plant height, leaf number, total plant biomass, and other relevant parameters by providing crucial macro and micronutrients such as iron, boron, and zinc, which are often deficient in Afghan soils. Treatment T5, with an application rate of 600 kg/ha of organic fertilizer, resulted in the tallest plant height, and it also positively influenced the number of leaves, total pod count, and overall plant biomass. However, excessive doses of organic fertilizer had negative effects on certain yield parameters, including pod weight per plant, seed yield per plant, and grain yield per hectare, as noted by Fekadu et al. (2018).

To achieve a good yield, common beans require a substantial amount of phosphorus from organic fertilizer, especially in alkaline soil conditions (Smith et al., 2001). The application of 600 kg/ha of organic fertilizer significantly increased the number of pods per plant compared to the control treatment, accompanied by higher seed yield per plant. Combining organic and chemical fertilizers provides an optimal balance of macro and micronutrients, enhancing the yield and yield components in common beans (Baghdadi, 2018).

The grain yield per plant was also significantly affected by the application of organic fertilizer, as reported by Mehdi et al. (2011). Organic manure helps mitigate the reliance on chemical fertilizers and addresses micronutrient deficiencies in the soil, resulting in improved grain yield (Geng et al., 2019). Overall, the use of organic fertilizer had a significant influence on the yield and yield components of common beans.

Regarding growth parameters, the application of organic compost notably affected plant height and the number of pods per plant. The control treatment exhibited lower values for plant height due to insufficient soil nutrients, and the 300 kg/ha organic fertilizer treatment also showed lower values compared to the control. Treatment T5, with an application rate of 600 kg/ha of organic fertilizer, consistently yielded higher plant height. It should be noted that organic manure tends to have higher acidity compared to chemical fertilizers, which generally have an alkaline pH (Smith et al., 2001).

Regarding the number of pods, all treatments with increasing levels of organic fertilizer resulted in a higher number of pods per plant compared to the control treatment. The total number of pods per plant, number of seeds per pod, dry matter weight per plant, and total seed yield were significantly influenced by the application of organic fertilizer. Treatment T5, with an application rate of 600 kg/ha of organic fertilizer, consistently yielded the highest values for yield and yield components compared to the control treatment. The increase in shoot, root, and total dry weight can be attributed to the availability of nutrients from the applied organic fertilizer, which enhances physiological functioning and metabolism in plants and positively influences biomass production (Letaa et al., 2015).

The integrated nutrient management approach, which combines organic and chemical sources, is recognized as a sustainable way to improve crop productivity, particularly when dealing with reduced soil fertility caused by continuous cropping without adequate addition of manure and mineral fertilizers (Joseph et al., 2014a).

5. Conclusion

In present study a comprehensive investigation was carried out within the Baraki Barak district of Logar province over two consecutive summer seasons in 2020 and 2021. The attainment of optimal common bean crop yields hinges on the accurate application of fertilizer levels. The results derived from the conducted experiment, encompassing the cultivation of common bean crops subjected to varying organic fertilizer quantities (600 kg/ha, 450 kg/ha, and 300 kg/ha) as well as NPK (100:100:50) chemical fertilizer, underscore the substantial impact of all treatments on crop growth and yield. The application of different organic fertilizer levels unequivocally demonstrated noteworthy differentials in critical metrics such as plant height, branch count per plant, pod count per plant, seed count per pod, dry matter weight per plant (measured in grams), and seed yield (quantified in kilograms per hectare). Particularly, the implementation of the 600 kg/ha organic fertilizer rate emerged as profoundly influential, leading to a significant enhancement across all growth and yield parameters in comparison to the alternative treatments. Based on these compelling findings, it is reasonable to deduce that the adoption of the 600 kg/ha organic fertilizer rate holds substantial promise for amplifying the yield potential of common bean crops.

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Conflict of Interest

The authors declare no conflicts of interest.

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